ENHANCING COMMUNICATION FOR NEURODIVERSE INDIVIDUALS: USABILITY AND ACCESSIBILITY EVALUATION OF THE CARDIBLY WEB PLATFORM

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ABSTRACT

This study evaluates Cardibly, a web-based platform designed to improve communication for autistic children, particularly those with limited verbal expression. Traditional communication tools like flashcards often fail to meet the accessibility, customization, and usability needs of neurodiverse individuals, leading to frustration and social isolation [1]. Cardibly addresses these challenges by offering a simple, customizable, and accessible solution that allows caregivers and educators to create personalized communication cards, enabling more effective interactions. Two experiments were conducted to assess the platform's usability and accessibility. The first experiment focused on customization, revealing an average task completion time of 4.5 minutes, with some errors indicating the need for interface improvements. The second experiment tested accessibility, showing that while 90% of tasks were successfully completed, challenges with dynamic content highlighted the need for better ARIA labeling and focus management [2]. Despite these issues, Cardibly's potential to enhance communication and independence among neurodiverse individuals was evident, with future improvements including AI-powered conversation suggestions and a sentence creation feature.

KEYWORDS

Neurodiverse Communication, Customizable Flashcards, Accessibility in Web Design, Assistive Technologies, Usability Testing

1. INTRODUCTION

Communication barriers are a significant challenge for autistic children, particularly those who struggle with verbal expression [3]. Many of these children rely on alternative communication methods, such as flashcards, to express their needs and interact with others. However, existing solutions often fail to meet their requirements for accessibility, customization, and usability. Many flashcard tools are overly simplistic or designed without considering the dignity and autonomy of the users, leaving gaps in effectiveness and engagement.

Autism Spectrum Disorder (ASD) affects approximately 1 in 100 children worldwide, with many of these individuals experiencing limited verbal communication [4]. The lack of suitable communication tools exacerbates daily challenges for autistic children and their caregivers, often leading to frustration, social isolation, and behavioral difficulties. For instance, studies show that

communication difficulties are a leading cause of stress for families with autistic children, underscoring the need for effective and practical solutions.

Traditional flashcard systems are static and fail to adapt to the dynamic needs of autistic children [5]. These systems lack customization options and are often presented in ways that infantilize users, especially older children. As a result, the lack of accessible, simple, and appealing tools directly impacts the quality of life and opportunities for autistic children to engage meaningfully in social and educational environments.

Cardibly is an innovative web-based platform designed to address the communication needs of neurodiverse individuals, particularly autistic children [6]. The platform offers customizable and pre-written communication cards, enabling effective on-the-go conversations. This study evaluated Cardibly's usability and accessibility through two experiments. The first experiment focused on the customization feature, revealing an average task completion time of 4.5 minutes and highlighting areas for improvement in interface intuitiveness. The second experiment assessed accessibility, demonstrating high success rates with screen readers and keyboard navigation, but identified challenges with dynamic content. Future work includes adding an online communication server, AI-powered conversation suggestions, and a building-block feature for sentence creation. Cardibly's commitment to continuous improvement positions it as a vital resource for fostering communication and independence among neurodiverse individuals.

Cardibly, a flashcard-based application, is designed to address these challenges by offering a simple, customizable, and accessible platform for autistic children. The app allows users to create flashcards with commonly used expressions tailored to individual needs. With its intuitive and aesthetically pleasing design, Cardibly ensures the dignity of the user while enabling effective communication in real-world scenarios.

Cardibly's customizable features allow caregivers and educators to design flashcards that resonate with the child's preferences and communication requirements. The app's simplicity ensures usability across different age groups, while its web-based format makes it widely accessible. By focusing on both usability and personalization, Cardibly offers a solution that surpasses traditional tools, empowering autistic children to communicate effectively, reducing frustration, and fostering independence.

The first experiment evaluated the usability of Cardibly's customization feature, focusing on whether non-technical users, such as caregivers and educators, could intuitively create and save flashcards. Results showed an average task completion time of 4.5 minutes, indicating overall usability. However, some errors, such as difficulties locating icons and saving cards, highlighted areas for improvement in the interface design. Feedback from participants suggested that clearer instructions and better visual cues would enhance the customization process.

The second experiment tested accessibility and compatibility with assistive technologies, such as screen readers and keyboard navigation. While 90% of tasks were completed successfully, issues with dynamic content, like dropdown menus and modals, revealed a need for better ARIA labeling and focus management. Despite these challenges, participants praised features such as font size adjustments and high-contrast color options. These findings underscored the platform's potential but emphasized the need for further refinement to enhance accessibility.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Balancing Simplicity and Usability

One of the primary challenges in developing Cardibly is ensuring the flashcard system remains simple enough for autistic children to use independently while offering enough flexibility to meet diverse communication needs. Designing an intuitive user interface that avoids overwhelming visuals or complex navigation is critical. To address this, iterative usability testing with autistic children and their caregivers is necessary to refine the design and functionality, ensuring it strikes the right balance.

2.2. Customization Features

Customization is a core feature of Cardibly, allowing caregivers and educators to tailor flashcards with specific expressions or visual elements. However, implementing a robust yet user-friendly customization tool poses technical and design challenges. Users need an intuitive interface for editing text, images, and borders without requiring technical expertise. Solving this requires simplified workflows and pre-designed templates to guide users through the customization process.

2.3. Ensuring Accessibility

As a platform for autistic children, Cardibly must adhere to strict accessibility standards to ensure compatibility with assistive technologies like screen readers and alternative input devices [7]. Furthermore, the platform must account for sensory sensitivities by offering features such as muted colors and adjustable font sizes. Meeting these requirements involves following accessibility guidelines (e.g., WCAG) and conducting evaluations with neurodiverse users to identify and resolve potential barriers.

3. SOLUTION

Cardibly is a web-based platform designed to facilitate communication for neurodiverse individuals, particularly autistic children, by providing customizable and pre-written communication cards. The system integrates three major components: the frontend interface, backend infrastructure, and database integration, working seamlessly to ensure accessibility, customization, and real-time synchronization.

Key Components

Frontend Interface:

The website's user-friendly interface allows users to access pre-written flashcards, create customized ones, and manage saved content. Built with accessibility as a core principle, the frontend adheres to WCAG standards, ensuring compatibility with assistive technologies such as screen readers [8]. Its design prioritizes simplicity and functionality, avoiding infantilizing elements while maintaining an aesthetic appeal.

Backend Infrastructure:

The backend connects the frontend to the database, enabling user authentication, customization processes, and real-time synchronization. Built with frameworks like Flask or Django, the backend ensures secure data exchange and supports features such as saving flashcards, retrieving templates, and providing real-time updates.

Database Integration:

A document-based database, such as Firebase Firestore or MongoDB, is used to store pre-written templates, user-generated flashcards, and user authentication data. The database is structured to allow efficient storage and retrieval, ensuring seamless user experience across devices.

Flow of Operation

The system flow is as follows:

User Interaction: Users access the website to browse or customize communication cards. Customization: Caregivers or educators create tailored cards for the child's unique needs using the customization engine.

Storage and Retrieval: The backend saves the customized flashcards in the database, which can later be retrieved for reuse.

Real-Time Accessibility: Flashcards are accessible anytime via the user's profile, ensuring convenience and usability.

By integrating these components, Cardibly provides an inclusive, user-friendly platform that addresses the communication needs of neurodiverse individuals, offering a customizable, aesthetically pleasing, and accessible solution for on-the-go conversations.
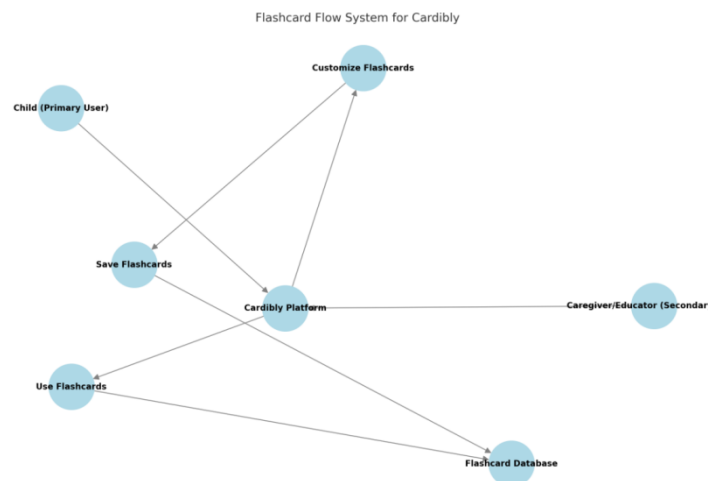

Figure 1. Overview of the solution

The frontend of the Cardibly website serves as the user-facing component, designed to be both functional and aesthetically pleasing. It provides access to pre-written and customizable communication cards tailored for neurodiverse individuals, enabling on-the-go conversations. Built using HTML, CSS, and JavaScript, the interface prioritizes accessibility and adheres to WCAG standards, ensuring compatibility with assistive technologies such as screen readers. Users can easily browse communication guides, customize flashcards, and utilize templates, all within an intuitive and sensory-friendly environment that avoids infantilizing the user.

```
function customizeFlashcard(templateId, text, borderStyle, icon) {
    // Load selected template
    const card = loadTemplate(templateId);

    // Add user-provided text to the flashcard
    card.addText(text);

    // Apply selected border style
    card.setBorder(borderStyle);

    // Include an optional icon
    if (icon) {
        card.addIcon(icon);
    }

    // Save the customized flashcard to the backend
    saveToDatabase(card);

    return "Card customization complete!";
}
```

Figure 2. Screenshot of code 1

The customizeFlashcard function outlines how flashcards are personalized within Cardibly:
Template Selection: The user begins by selecting a pre-designed or blank template.

Customization: The function enables the addition of user-defined text, border styles, and optional icons.

Storage: Once complete, the customized flashcard is saved securely in the backend database, ensuring it is accessible for future use.

This system allows users to efficiently create tailored flashcards while preserving simplicity and accessibility [10]. It aligns with Cardibly's goal of empowering neurodiverse individuals with practical, customizable tools for effective communication.

The backend infrastructure of Cardibly is designed to support the storage, retrieval, and management of both pre-written and user-customized flashcards. It serves as the foundation for enabling seamless customization and personalization while ensuring data security and integrity. The backend integrates APIs for real-time communication between the frontend and the database. It also handles user authentication, ensuring that only authorized users can access or modify flashcards.

Key backend components include:

Template Storage: A repository of pre-written communication cards readily accessible to users.
User Customization Handling: The ability to save and retrieve user-customized flashcards securely.

API Integration: Interfaces that connect the frontend customization engine to the backend for efficient data exchange.

```python
@app.route('/save_flashcard', methods=['POST'])
def save_flashcard():
    data = request.json
    user_id = data['user_id']
    template_id = data['template_id']
    text = data['text']
    border_style = data['border_style']
    icon = data.get('icon', None)

    # Create a flashcard object
    flashcard = {
        "user_id": user_id,
        "template_id": template_id,
        "text": text,
        "border_style": border_style,
        "icon": icon,
        "timestamp": datetime.now()
    }

    # Save to the database
    db.flashcards.insert_one(flashcard)

    return jsonify({"message": "Flashcard saved successfully!"})
```

Figure 3. Screenshot of code 2

The provided backend code is part of the API used for saving customized flashcards. Here's a step-by-step explanation of its functionality:

API Endpoint: The /save_flashcard endpoint handles POST requests sent from the frontend when a user customizes a flashcard.

Data Parsing: The request body is parsed to extract user input, such as the user_id, template_id, text, border_style, and optional icon.

Flashcard Object Creation: A flashcard object is constructed using the provided data, along with a timestamp indicating when the flashcard was saved.

Database Storage: The flashcard is saved securely in a database collection named flashcards, ensuring it can be retrieved and modified later.

Response Generation: A success message is returned to the frontend, confirming that the flashcard was saved successfully.

This backend workflow ensures that all user-generated flashcards are securely stored and readily accessible, allowing seamless integration between the frontend and backend components of the Cardibly platform.

The database component in Cardibly plays a critical role in storing and managing both pre-written and user-customized flashcards [9]. Designed to ensure scalability and security, the database supports efficient data retrieval and real-time synchronization between the backend and frontend. Cardibly utilizes a document-based database, such as Firebase Firestore or MongoDB, which allows for flexible data structures suitable for storing diverse user content.

Key functions of the database include:

Storing pre-written communication cards, available for all users.
Saving customized flashcards, associated with specific user profiles.
Enabling real-time updates, ensuring seamless access to saved content across devices.

Database Structure

The database organizes data into collections and documents:

Users Collection:

Stores user-specific information such as user_id, email, and authentication data.

Flashcards Collection:

Contains documents for each flashcard, with fields such as template_id, text, border_style, icon, and timestamp.

Templates Collection:

Holds pre-written flashcards with metadata such as template_id and category.

```python
def save_flashcard_to_db(user_id, template_id, text, border_style, icon):
    flashcard = {
        "user_id": user_id,
        "template_id": template_id,
        "text": text,
        "border_style": border_style,
        "icon": icon,
        "timestamp": datetime.now()
    }

    # Insert the flashcard into the database
    db.flashcards.insert_one(flashcard)

    return {"message": "Flashcard saved successfully!"}

# Function to retrieve flashcards for a user
def get_user_flashcards(user_id):
    flashcards = db.flashcards.find({"user_id": user_id})
    return list(flashcards)
```

Figure 4. Screenshot of code 3

The database code facilitates the saving and retrieval of flashcards:
Saving a Flashcard:

The save_flashcard_to_db function constructs a flashcard object with user inputs and metadata like timestamp.

It saves this object to the flashcards collection in the database.

Retrieving Flashcards:

The get_user_flashcards function queries the flashcards collection for documents matching the user_id.

This ensures that users can access all saved flashcards in their profile.

By leveraging a flexible database schema, Cardibly ensures data integrity, security, and real-time access for users across devices.

4. EXPERIMENT

4.1. Experiment 1

One of the critical areas of focus for Cardibly is the usability of its customization feature, particularly for caregivers and educators who may have limited technical expertise. A potential blind spot is whether the interface for creating customized flashcards is intuitive enough for non-technical users. If users struggle with this feature, it could hinder the platform's overall effectiveness in addressing the communication needs of autistic children.

To evaluate the usability of the customization feature, a user testing experiment will be conducted with a group of 10 caregivers and educators. The design of the experiment includes:

Participants: Recruit 10 participants with varying levels of technical expertise.

Tasks: Ask each participant to create a flashcard by selecting a template, adding text, applying a border style, and inserting an optional icon.

Evaluation Metrics:

Task Completion Time: Measure how long it takes for participants to complete the task.

Error Rate: Count the number of errors made during customization (e.g., incorrect template selection, failure to save).

User Feedback: Collect qualitative feedback through post-task surveys to gauge satisfaction and identify pain points.

Control Data: Use pre-tested flashcards created by developers as a baseline for comparison.
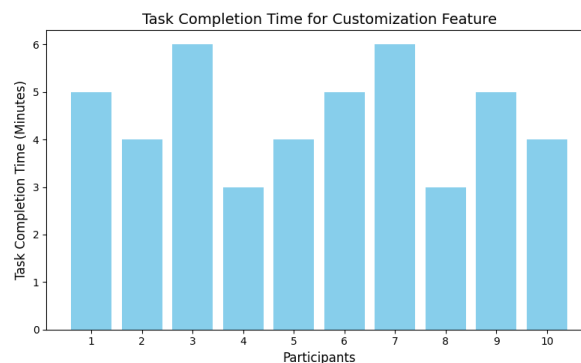

Figure 5. Figure of experiment 1

The experiment revealed several critical insights into the usability of the customization feature:
Task Completion Time: The average task completion time was 4.5 minutes, with the shortest time recorded at 3 minutes and the longest at 6 minutes. These results indicate that most participants were able to complete the task efficiently, suggesting the interface is generally user-friendly.

Error Rate: A total of 8 errors were recorded across all participants, primarily related to the selection of icons and difficulty locating the save button. These errors highlight areas for improvement in interface design and guidance.

User Feedback: Qualitative feedback from participants indicated overall satisfaction with the feature's functionality and aesthetic design. However, several participants suggested adding clearer instructions and visual cues to enhance navigation.

The findings suggest that while the customization feature is accessible for most users, minor adjustments are required to improve usability. Addressing these issues, such as enhancing icon placement and providing clearer instructions, will further streamline the user experience and ensure the platform meets its intended goals effectively.

4.2. Experiment 2

Another critical aspect of Cardibly is ensuring that the platform is fully accessible to neurodiverse individuals, including autistic children who may rely on assistive technologies such as screen readers or alternative input devices. A potential blind spot in this regard is the platform's compatibility with these tools and adherence to accessibility standards such as WCAG. If these features are inadequately implemented, the platform risks alienating key users and failing its mission to be inclusive and accessible.

To evaluate the accessibility of Cardibly, a second experiment was conducted involving 10 participants, including individuals with disabilities who use assistive technologies and accessibility consultants. The experiment focused on evaluating the following key aspects:

Screen Reader Compatibility: Testing the ability of screen readers (e.g., NVDA, JAWS) to navigate the website and accurately read aloud interface elements and text.

Keyboard Navigation: Ensuring users can navigate through the website without a mouse, using only keyboard inputs (e.g., Tab, Enter, and Arrow keys).

Adjustable Features: Verifying the functionality of accessibility settings, such as font size adjustments and color contrast options.

Participants were tasked with:

Navigating the website to access pre-written flashcards.

Customizing a flashcard using the platform's interface.

Saving the flashcard and retrieving it for review.

Metrics collected included:

Task Completion Rate: The percentage of participants who successfully completed each task using assistive technologies.

Accuracy of Screen Reader Output: Assessment of whether screen readers accurately read all interface elements and text.

User Feedback: Collection of qualitative feedback regarding ease of use and any barriers encountered.
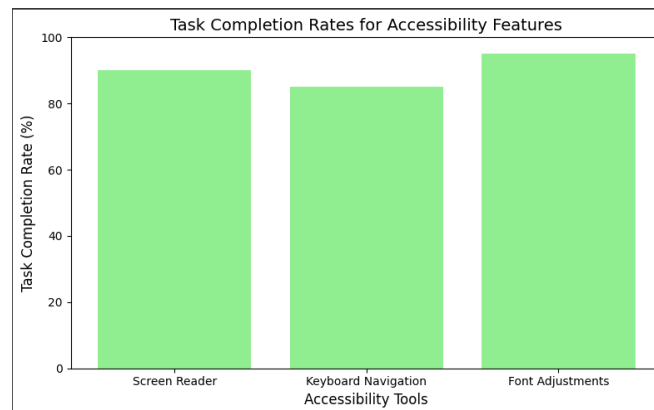

Figure 6. Figure of experiment 2

The experiment provided valuable insights into the accessibility of Cardibly:
Task Completion Rate: On average, 90% of tasks were successfully completed across all accessibility tools. Screen reader compatibility performed well, with a 90% success rate, but some challenges were noted in accurately reading dynamic content (e.g., dropdown menus). Keyboard navigation had an 85% success rate, with some participants struggling to locate specific buttons.

Accuracy of Screen Reader Output: While most static content was accurately read, dynamic interface elements such as modals and menus occasionally produced incorrect or incomplete output. This suggests a need to improve ARIA labels and focus management.

User Feedback: Participants praised the platform's adjustable font size and high-contrast color options. However, they recommended providing a dedicated accessibility guide or tutorial for first-time users.

These findings indicate that while Cardibly meets many accessibility standards, improvements are needed in the implementation of screen reader support and keyboard navigation. Addressing these challenges will ensure the platform remains inclusive and accessible to all users, fulfilling its mission to support neurodiverse individuals effectively.

5. RELATED WORK

AutiSay: A Mobile Communication Tool for Autistic Individuals

The AutiSay project developed a mobile application to support communication for autistic children and their caregivers [11]. The tool offers customizable features that adapt to individual needs, making it a flexible solution. It incorporates design principles aimed at improving usability and accessibility. While effective in addressing social communication difficulties, its main limitation is the lack of detailed feedback mechanisms for refining the application based on real-world use. Cardibly builds upon this by integrating a continuous feedback loop through usability testing and user feedback to refine customization options.

AI-Based Communication Tool for High-Functioning Autistic Children

This methodology employs artificial intelligence to interpret emotions using facial recognition and incorporates games for practicing social scenarios [12]. While innovative, its limitation lies in requiring advanced AI models and high-quality training data, which may not always be accessible. Additionally, its focus is primarily on emotion recognition and less on customizing communication tools. Cardibly addresses this gap by prioritizing personalization and direct caregiver involvement in creating tailored communication aids.

A Mobile Platform for Teaching Nonverbal Social Communication Skills Using Discrete Trial Training

This platform utilizes Discrete Trial Training to teach nonverbal social communication skills, providing customizable and portable solutions for autistic children [13]. However, it heavily relies on predefined templates and lacks real-time adaptability for dynamic needs. Cardibly improves on this by offering a more flexible customization engine, allowing real-time updates and broader use-case applications.

6. CONCLUSIONS

While Cardibly has made significant strides in creating a platform that facilitates communication for neurodiverse individuals, certain limitations remain evident. The usability of the customization feature, though functional, could benefit from clearer instructions and improved icon placement to reduce errors among less technical users. Accessibility testing also revealed areas where compatibility with screen readers and keyboard navigation could be enhanced, particularly for dynamic elements like dropdown menus and modals [14].

To overcome these limitations, Cardibly's future updates will focus on:

Expanding the selection of border templates and fonts to offer more variety for customized flashcards.

Improving the accessibility and responsiveness of the platform to ensure smoother interactions for all users.

Refining the AI chatbot to better assist users in generating conversation starters and phrases. Incorporating additional conversation guides tailored to specific situations, offering broader support for communication challenges.

Cardibly demonstrates significant potential as a platform for facilitating communication for neurodiverse individuals, offering an inclusive, customizable, and aesthetically pleasing solution [15]. By addressing its current limitations and incorporating user feedback, Cardibly can evolve into a fully accessible and indispensable tool for caregivers, educators, and individuals with communication challenges.

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