Design of a Digital Application to Aid Hindi Alphabet Recognition/Formation for Children With Learning Disability

Abhishek Bose, Gojek, India
Jyotsana, Publicis Sapient, India

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Abstract
Dyslexia is the most common learning disability that majorly affects language development and reading. In India, dyslexic children despite being moderately intelligent and good with English alphabetic knowledge perform poorly in Hindi. These children find it very difficult to recognize and remember the shapes of the Hindi alphabets because of its complex features such as the curves, matras (dependent-forms), halants (half-form), etc. The importance of learning Hindi cannot be ignored especially in India where all the major day to day activities are carried out in the Hindi language. After knowing the problem, the authors revisit the Hindi Alphabets (Varnmala) and tries to find out how the complex features of the Hindi alphabets can be taught efficiently. The data and insights were gathered through observation sessions, video recordings and behavioral studies of 5 dyslexic children aged 8-12 years. Open-ended interviews with teachers and parents helped to understand the problem better. A deeper analysis of the Hindi language led the authors to reconstruct all the 48 alphabets of the script (36 Consonants and 12 Vowels) using combinations of just 10 basic shapes. Findings from these sessions helped authors to design and develop an interactive touch-based digital application that helps these children to recognize and form Hindi alphabets efficiently and also provides audio-visual feedback to the children which makes learning fun. Testing the application with 12 dyslexic children revealed that the average time to learn a new Hindi alphabet got reduced from 2-3 weeks to one week.

Keywords: Dyslexia, Learning Disability, Mobile Application, Hindi, Drag and drop

Introduction

Academics is one of the most vital part of any child's life but not all children excel in it. There is a significant number of children facing difficulties in various areas of academics like counting, reading, memorizing, learning, writing, etc. in spite of being really good at other things. A person who has difficulty learning in a typical manner, usually caused by an unknown factor or factors are classified as having a "learning difference"[1]. Physicians like Hinshelwood and Orton were the first ones to observe and document about the children who have specific problems in learning to read. These children go through many problems such as very slow reading speed, skipping lines while reading aloud, making spelling mistakes repeatedly, inability to solve simple mathematical problems, very illegible handwriting which leads to very poor grades in academics[2][3][4]. Besides academic problems, these children have problems with non-academics as well like visuomotor issues, memory problems, perceptual problems, language difficulty and problem in phonological processing. According to Wong(1996)[5], 60 percent of the children who are diagnosed with a learning disability have some or the other form of reading disability.

In India, 5-15% [6] of the school-going children are affected by specific learning disability(SpLD) such as dyslexia, dysgraphia, dyscalculia[4]. SpLD can be defined as a combination of neurodevelopmental disorders in which a person despite being intelligent find it difficult to learn reading, writing or performing mathematical calculations. SpLD is believed to be caused due to functional disruption in neural systems rather than an anatomic problem and is generally inherited[2][6][7]. 80% of the SpLD inflicted children suffer from dyslexia[3]. Dyslexic children suffer from "phonological awareness" and "poor visual perceptual skills". As per the "phonologic-deficit hypothesis," dyslexic children find difficulty in connecting the sound of the language with the written letters. Visuo-perceptual deficiencies have been linked with dyslexia for many decades which suggests that visual system impairment is one of the major causes [8].

Significance

Dyslexia is the most common learning disability and nearly 70% - 80% of students diagnosed with a learning disability have reading problems. The worldwide incidence of dyslexia is 5-20% whereas in India the incidence is believed to be around 15%. The number of dyslexic children in India is nearly 35 million and the count is continuously increasing[9].

In India, Hindi is the most spoken language and is one of the 22 official languages of India. Hindi is also the official language of 10 Indian states including Union Territory state Delhi. Hindi is also the prime medium of teaching in these 10 states along with English[10]. Under Sarva Shiksha Abhiyan, all the government primary schools have Hindi as the only medium of teaching. So, learning to read and write in Hindi is an essential part of these children's life. Hindi is a direct descendant of Sanskrit and is written using Devanagari script which is very logical and straightforward hence easy to learn. Unlike English, this script has no capital letters and also the pronunciation is done in the exact way as it is written[11]. Learning Hindi becomes even more important as language and culture are inseparably connected from the very beginning.

Any clear demarcation of language and culture is not possible as they both compliment each other to a significant extent[12].

This research is focused on helping the children with special learning needs aged between 7-12 years to learn Hindi letter formation/recognition. Hindi is the major language for communication in this part of India, the significance of having knowledge in Hindi can never be ignored.

Learning Disability and Learning Hindi

The level of children in reading Hindi is very low in these below states, and since Hindi is the only medium of teaching in the government primary schools the children find difficulty in learning other subjects as well. The below chart shows statistics of children who are only able to read letters and not words. Madhya Pradesh has the highest percentage 25.9% of students being able to read letters and Himachal Pradesh has the lowest percentage 11.2% of students being able to read letters[13].

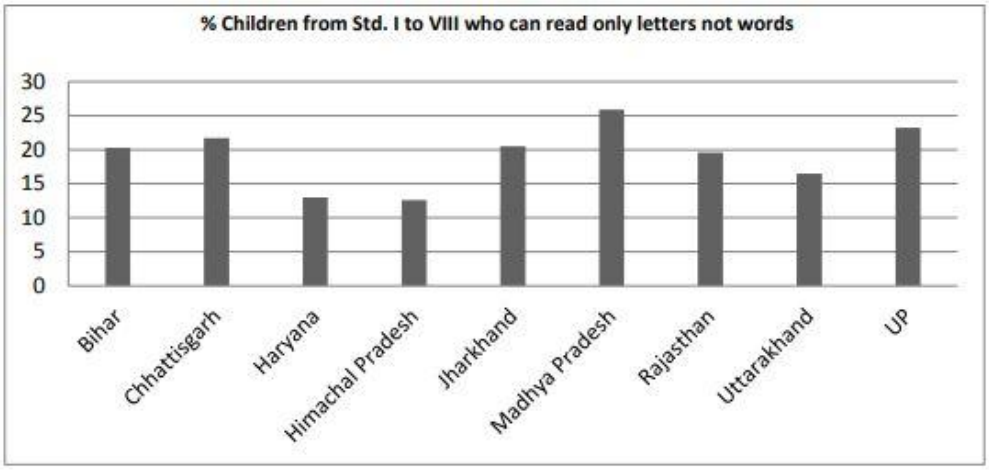

Figure 1: ASER 2013 Data - State-wise percentage of children who can read only letters

On one side we see that the status of Hindi learning is very poor, but studies show that Hindi is a very logical language and is easy to learn. Hindi is a direct descendant of Sanskrit and is written using the Devanagari script which is extremely logical. In Hindi pronunciation is comparatively easier as compared to English because Hindi letters are pronounced in exactly the same way as they are written. As there are no capital letters in the script it's easier to remember the rules for writing in Hindi [11]. It is important to know if alphabetic orthographic transparency has an effect on the way children learn to read. Studies have revealed that acquiring reading knowledge depends heavily on the nature of orthography[14]. According to Wimmer and Goswami[15], orthographic transparency and reading development are directly related. So, it can be concluded that letter to sound mapping in more consistent in transparent orthographic system i.e. letter to sound mapping of Hindi is more consistent than that of English.

Further studies revealed that though Hindi is a very transparent language where the mapping from grapheme to phoneme is consistent, readers find Hindi difficult to learn due to its complex graphemic features. Hindi alphabet arrangement is strictly phonetic

and letters are categorized by place of articulation: first, come vowels and diphthongs, and then comes the consonants with intrinsic schwa vowel, where the independent graphemic form is absent[16]. The cluster of consonants is generally written one above the other or by introducing a special sign to indicate that the schwa is absent. Vowels can appear in either of the two ways, at initial position in a full form word or as diacritical signs (as matras) in the middle-word or word-final position[17]. In order to learn Hindi, a child has to remember the specific features of the script. For example, the odds of occurrence of consonant clusters at the word-initial or word-medial position is not fixed. A Gupta in her studies shows that dyslexic Hindi readers face trouble in achieving high-quality phonological representations of words. It has also been observed that word blending skills of dyslexic Hindi readers are poor.

So, we can say that although Hindi is easy to learn as a language, most dyslexic Hindi readers find it difficult to learn due to the complex geometry of Hindi alphabets such as the curves, matras, halants, etc.

Process of learning Hindi

Frith [18] postulated three main stages of reading any alphabetic systems as Logographic, Alphabetic and Orthographic.

1. Logographic Stage: In this stage, a child sees words as visual objects or symbols. For example, a child learns the basic units of the Hindi alphabet by memorizing, repeating and writing.
2. Alphabetic Stage: In this stage, a child represents letters in ordered sequences. For example, in Hindi there is a concept of vowel(matra). This is a very challenging stage for learning Hindi. Without understanding the concept of matra learning word formation is not possible.
3. Orthographic Stage: In this stage, a child learns to remember the whole-word grapheme sequence on repeated exposure. The child learns to combine alphabets and form words. This is also a time taking process.

According to Ehri [19], there are four phases in the development of word recognition. Similar to Frith's model is the first three phases of Ehri's model. Those phases are pre-alphabetic, partial alphabetic and full alphabetic. The fourth phase or the consolidated alphabetic phase suggests that a reader consolidates their knowledge by memorizing the recurring pattern of multi-letter sequences such as -ight sequence in bright, light, flight or -ock in clock, dock, rock.

Field Research

Figure 2: Spastics Centre Kanpur

The Spastic Center is a non-governmental organization for children which is working in the field of rehabilitation for over 20 years. The spastic center provides special education to children aged between 6-12 years.

Behavior study of dyslexic children

For a better understanding of the target audience's needs, the authors conducted observation sessions in the classroom. Each child was observed for 20 minutes. The authors used the initial few sessions in building rapport with the children so that they become comfortable with their presence during the classes. Pictures and videos were also taken for future references.

Participant 1, Age: 11 years


Figure 3: Participant 1

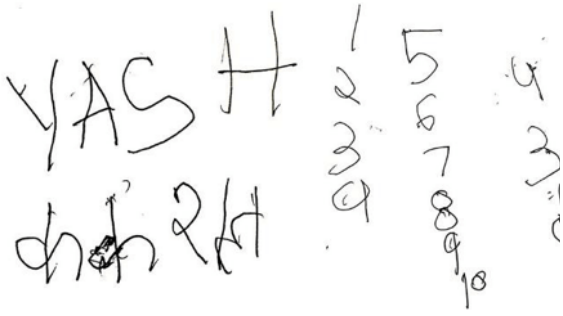
Figure 4: Handwriting sample of participant 1

Participant 1 is a very interactive child. He has fairly good fine-motor skills and hand-eye coordination. His attention span is very good and he can concentrate on things that he is doing for more than 5 minutes. He has poor handwriting. When he was asked to write some simple words in Hindi, he performed very poorly. He needs some

reference to write in Hindi, as he finds Hindi letters very difficult to remember. He is very good at handling smartphones.

Participant 2, Age: 12 years

Figure 5: Participant 2

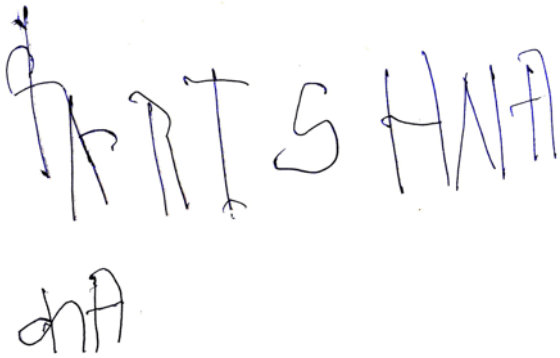

Figure 6: Handwriting sample of participant 2

Participant 2 actively performs all the activities like studies, sports, and music. He has a habit of repeating words continuously. For example, if he greets someone saying ‘namaste’ he will continue repeating ‘namaste’ for a minute. His attention span is fair but he gets easily distracted. He is very good in English and mathematics and can solve simple mathematical problems. He is not able to recall the shapes of the Hindi alphabets and has a tendency to mix up Hindi and English alphabets. He enjoys learning from a smartphone. He is delighted by the audio-visual feedback of the device.

1. Participant 3, Age: 8 years

Figure 7: Participant 3

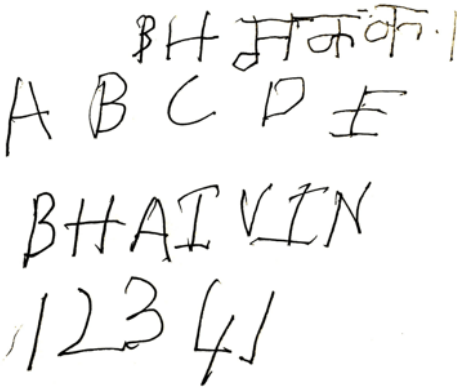

Figure 8: Handwriting sample of participant 3

Participant 3 is a very interactive and fun-loving girl. She has very good communication skills. Although she has severe speech problems she can explain anything by gestures. She loves to interact with her peers. She can read and write English. She can write Hindi alphabets very slowly but she cannot read Hindi. She can use a smartphone with ease and enjoys listening to music on smartphones. She doesn’t hesitate to explore new applications on the smartphone.

Participant 4, Age: 11 years

Figure 9: Participant 4

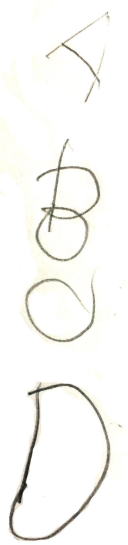

Figure 10: Handwriting sample of participant 4

Participant 4 is a very calm and composed boy. He speaks very less and his pronunciation is not clear. He has a very good attention span and his connection with the subject of matter is very strong. He can write simple words in English but finds difficulty in writing Hindi. He knows how to operate smartphones, but he cannot use the device efficiently as he always touches the screen at multiple points due to his poor fine-motor skills.

Participant 5, Age: 10 years

Figure 11: Participant 5

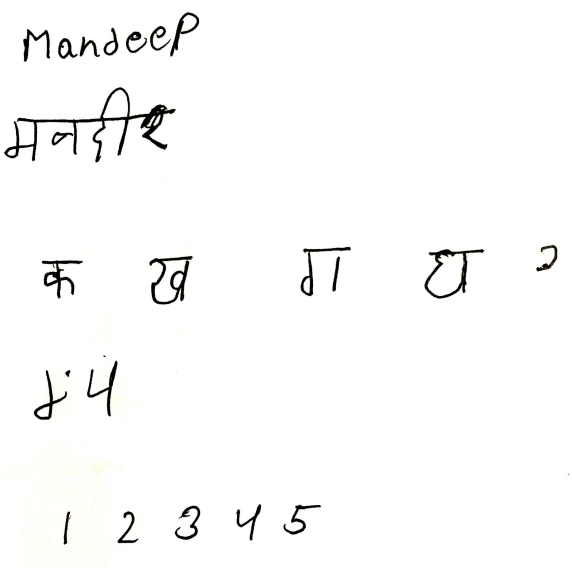

Figure 12: Handwriting sample of participant 5

Participant 5 is a very intelligent boy. He has severe speech complication and he cannot speak. But his fine motor skills are fairly developed. He is good at English and mathematics. He has fairly good handwriting. However, he writes at a slow speed. He finds difficulty in recalling the names of the Hindi alphabets. Sitting in one place is difficult for him, and he likes to move around the classroom all the time. He is very confident in using digital devices. He can play games on a mobile interface with ease. He is very responsive to the audio-visual feedback from the smartphone.

Insights

1. They are fairly good at English in comparison to Hindi. Almost all the children were able to write English letters properly and but failed miserably when asked to write anything in Hindi.
2. Most of the children are unable to remember the shape of Hindi letters due to their complex features such as curves, matras, halant, etc.
3. Most of the children are not able to write Hindi alphabets on their own, they always need a reference.
4. Due to poorly developed fine-motor skills, they find it very difficult to hold pencils, erasers, notebooks, etc.
5. They are very much interested in digital devices such as smartphones, tablets, etc.
6. Using smartphones is easier for them as they just had to use their fingers.
7. The children were responding well to the audio-visual feedback of the digital devices.
8. Their attention span is higher (4-5 minutes) when they are playing games on smartphones and tablets.
9. It's easier for the children to read and learn when the text and images are larger.

Design criteria for developing applications for Dyslexic users

When we are designing something for dyslexic users we have to keep in mind that there is no single solution that works for all. Every dyslexic user is different and their severity of problems is also unique. The following things should be kept in mind:

1. Typography
    a. Usage of Sans-serif font is recommended. The issue with serif fonts is that the projections of serif font distorts the shape of the letters and makes it difficult for the dyslexic reader to read.
    b. Italics should be strictly avoided.
    c. Usage of the under-lined font is not recommended.
    d. It is suggested to reduce the letter spacing while increasing the word spacing.

2. The digital layout of a screen
    a. Dyslexic readers find it difficult to read wider text spans, so its recommended to keep the column width narrow.
    b. There should be a limit of 80 characters per line for adults and for children the limit is 45 characters per line.

c. Leading between lines should be 18pt for dyslexic readers.
d. All the columns should be left-justified.
e. Asking the user to type should be avoided wherever possible.
f. All caps letters should be avoided, as it makes dyslexic readers slower.
g. Too many movements on the screen should be avoided as it can distract the users.
h. Clear and simplified graphics should be used.
i. Auto-fill features should be provided wherever possible in order to avoid typing.
j. Consistency of white space is expected because uneven spacing disrupts pattern recognition and slows down dyslexic readers.
k. Justified text alignment should be avoided.
l. High contrasting colors should be avoided for background and foreground.
m. Black text on a white background creates a blurred effect so it should be strictly avoided.

3. Utility Tools
    a. Features to change font size and font type should be provided. Sometimes it's difficult for them to read smaller text.
    b. Certain fonts like OpenDyslexic, Lexia Readable, Dyslexie are specially designed to help dyslexic people in reading. An option to use these fonts can be provided.
    c. A masking tool can be provided so that the reader can mask unwanted areas of the screen and concentrate only on what he/she is reading.
    d. Text to audio conversion and vice-versa feature is very handy for dyslexic users as typing is a very difficult task for them. It takes a lot of effort for them to type on the small screen of smartphones.
    e. Features like auto-suggest words and spell checkers help dyslexic readers in many ways.

The Concept

The concept of the solution came when it was observed that most of the children faced difficulty in recognizing the Hindi alphabets. Although the children were intelligent enough to read and write in English but they were unable to remember the shapes of the Hindi alphabets. So, the author deduced that these children cannot be taught Hindi in the same way they are being taught English. The author dug deeper and finally came to understand that these children find the Hindi alphabets to be very complex due to its features like curves, matras, etc. So, the author focused on how Hindi can be taught efficiently to these children.

The author did a very detailed study of the Hindi fonts. The author focused mainly on the formation of the Hindi fonts and its features such as curves, lines, and dots. It was found that most of the Hindi alphabets have a common 'T' shaped structure. The 'T' shape was very much defined in 33 out of 48 alphabets and all these 33 alphabets were constructed around the 'T' shape. And the remaining 15 alphabets could be formed with a similar 'T' shape but with a reduced stem as shown in the below figure.

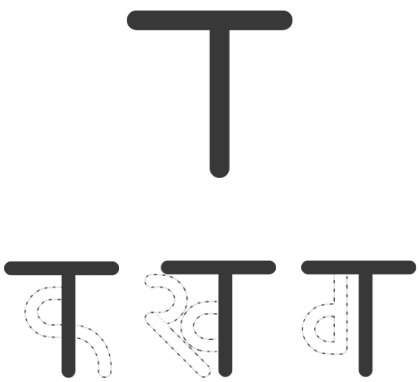

Figure 13: Alphabets constructed around 'T' shape

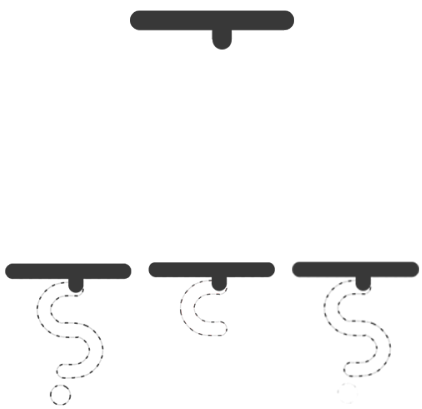

Figure 14: Alphabets constructed around 'T with reduced stem' shape

Next, the author also observed the repeating patterns of curves, for example, the curve on the left side in ‘क’ is similar to the curve in ‘व’. Also, the same curve is present in ‘ख’ although it is a little smaller as compared to ‘क’ and ‘व’. Based on the idea of similarity the author grouped all the shapes which repeat itself in some or the other way across the Hindi Varnmala.

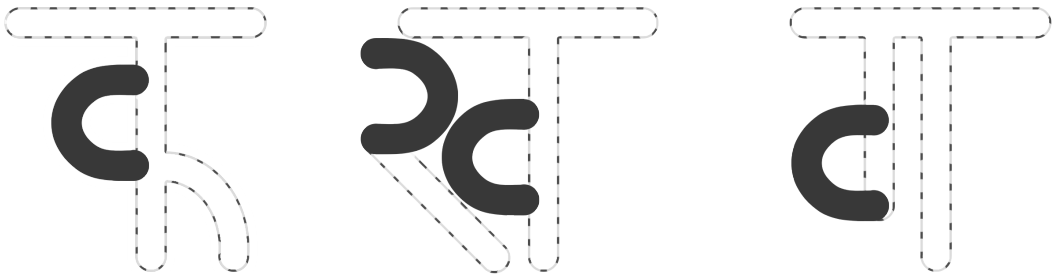

Figure 15: Alphabets that consists of the same curve

In the same way, the author split all the alphabets of Hindi Varnmala into parts constituting only simple lines, curves and dots. In Hindi, there are 36 Vyanjan(consonants) and 12 Swar(vowels). The author recreated the whole Hindi Varnmala by just using 10 simple shapes. Below are the 10 shapes which can be combined in different ways to create the alphabets of Hindi Varnmala.

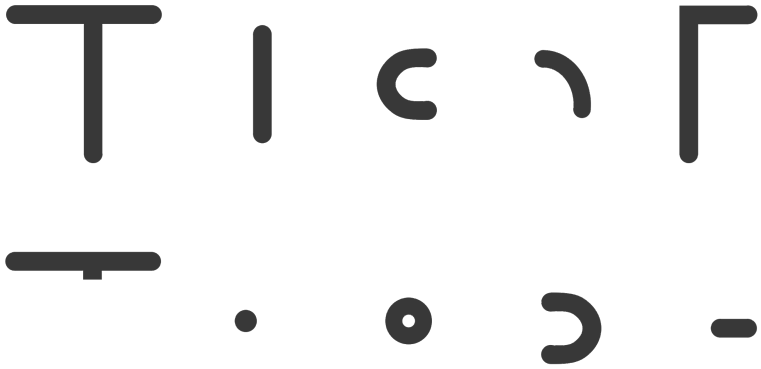

Figure 16: The 10 simple shapes for Hindi alphabet formation

For example, the first alphabet of Hindi Varnmala ‘क’ can be formed in this way.

Figure 17: Formation of 'क'

Using the combinations of the shapes in Figure 21, all the 48 Hindi alphabets can be formed. Hence, the child has to remember these basic shapes in the first place and then they need to select the appropriate combination of the pieces to construct the alphabet. Figures 23 and 24 show the vyanjans and swars as formed by the combination of the shapes.

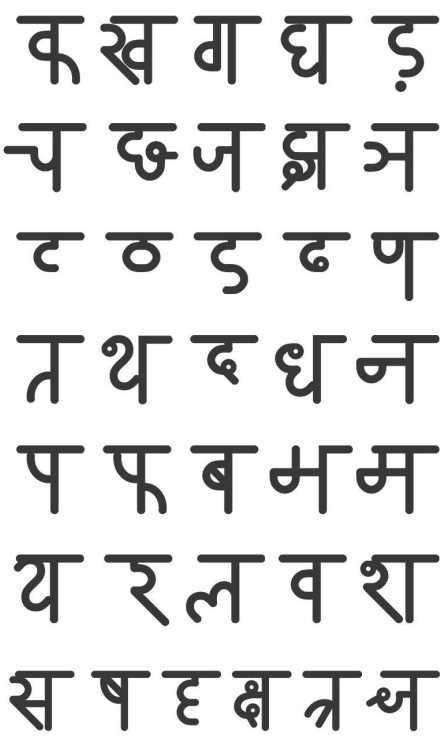

Figure 18: List of Vyanjans as formed by the shape combinations

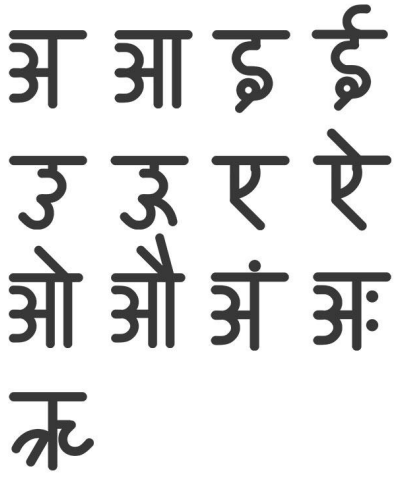

Figure 19: List of Swars as formed by the shape combinations

Low fidelity prototypes

1. Cardboard prototype: The cardboard prototype consisted of sheets and shapes (lines, curves, dots). The outline of the Hindi alphabets was printed in a dotted format on the sheets, which can also be referred to as the alphabet puzzle. One sheet contained only one alphabet puzzle. There was also a set of shapes like lines, curves, and dots.

Next, the child was given this sheet of paper which had an alphabet puzzle and the child was asked to complete the puzzle with the shapes he had. The child's task was to select the appropriate shape from the set of shapes and complete the puzzle.

The children were able to relate that the given Hindi alphabet was made out of these few shapes. This prototype was tangible and it was made out of cardboard cutouts. Small magnets were inserted into the cardboard shapes and the puzzle part of the sheets was also magnetic. As a result, when the correct shape was placed accurately over the puzzle the shape would stick to the paper.

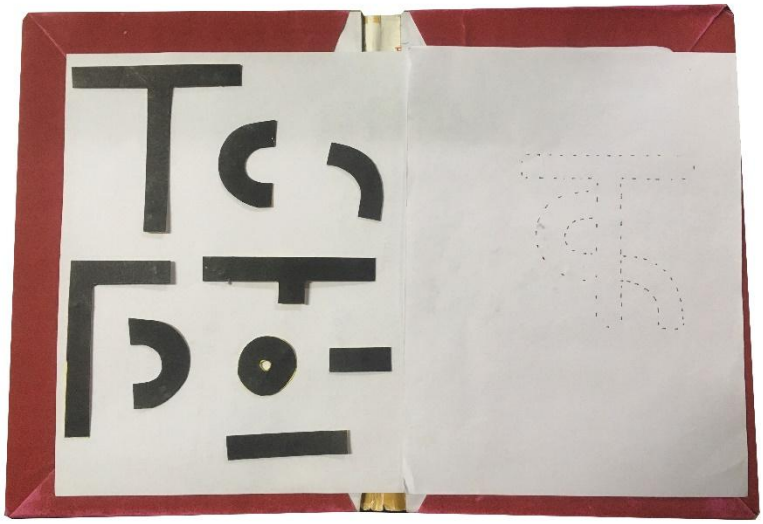

Figure 20: The cardboard prototype

2. Digital prototype: The author also used a digital prototype in the form of a smartphone application to accomplish the task of teaching Hindi alphabets to these children. The application contains an alphabet puzzle in the form of a dotted outline of the Hindi alphabets at the center of the screen and the parts of the alphabets were on the top of the screen. The task for the child was to drag and drop the parts of the alphabets at the correct position over the dotted puzzle. Once the child drops the alphabet part at the correct position the application greets the child with a success sound. This feedback encourages the child to accomplish the task correctly and, in the process, learn Hindi alphabet formation and recognition. If the child drops the alphabet part at the wrong position of the puzzle the application gives proper feedback to the child and dropped alphabet part goes back to its original position.

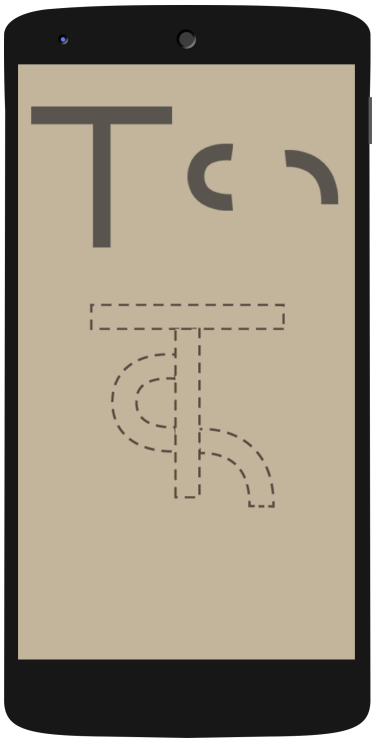

Figure 21: The digital prototype

Insights from testing

- Cardboard prototype:
  1. The concept of completing the alphabet puzzle was understood by the child and it was considered in the form of a game.
  2. The shapes were not sticking properly at the desired place on the page and were easily removed if touched by mistake.
  3. As the motor skills of the children are very poor the shapes should stick properly at the place otherwise they might be easily removed by touch.
  4. As the shapes are made out of cardboard and chances of getting folded was high.
  5. This prototype lacked in providing proper feedback to the child which should be one of the main features any games designed especially for children.

Figure 22: The cardboard prototype being tested 1

Figure 23: The cardboard prototype being tested 2

- Digital prototype

1. The child was able to drag and drop the alphabet parts at the desired location.
2. When the shapes were dropped at the appropriate location they would just stick. This was an important feature of the digital medium that the shapes could not be dislocated once placed in the correct position.
3. On a successful drop the application would provide a music feedback hence encouraging the child.
4. If the shapes were not dropped at appropriate position then they would go back to the original position on their own.
5. On an unsuccessful drop, the application would provide feedback in the form of music.
6. As the children were poor in motor skills they had poor control of their fingers. So in the app, it was desired that only one item would be responsive to touch at a time.
7. The next shape should become responsive to touch only when the first shape was dropped successfully.
8. The children had a habit of resting their palms on the screen on the smartphone, hence it was decided that the application would run only in landscape format to avoid the unnecessary touch.

Figure 24: The digital prototype being tested 1

Figure 25: The digital prototype being tested 2

Final prototype

The application has been designed to be very simple and self-sufficient so that the child does not need any assistance in operating the app. Proper care has been taken while deciding the color palette of the app and it is custom made to suit the requirements of children with various learning disabilities. To aid better concentration of the children, a rhythmic music is being played at the background which can be switched on or off very easily from the home page using the sound icon. For better visibility and accessibility, all the app icons have been designed to be larger than usual. This app is very interactive and always aims to keep the child focused through various audio-visual feedback. Below are the wireframes of the smartphone application:

Figure 26: Home screen of the application

This is the landing screen of the application. The vyanjans are arranged in form of blocks and in sets of 5 just the way they appear in the Hindi Varnmala. This screen is scrollable and the affordance of scrolling is justified by partial visibility of the top part of the blocks that are below the page fold. The various icons on this screen are the home icon, trophy icon, idea icon and the sound icon. In this page the home icon is highlighted which denotes that the user is in the current page. The trophy icon takes the user to the awards and achievement page where all the badges and awards unlocked by the user are stored. The idea icon is the module where the user can take

quizzes and puzzle tests. On successful completion of each test, points or badges are awarded to the user to motivate them. The sound icon is used to control the rhythmic background music that plays when the app is started. Using this icon, the user can choose to enable or disable the background music. Tapping on any of the vyanjan block will take the user to that specific activity page.

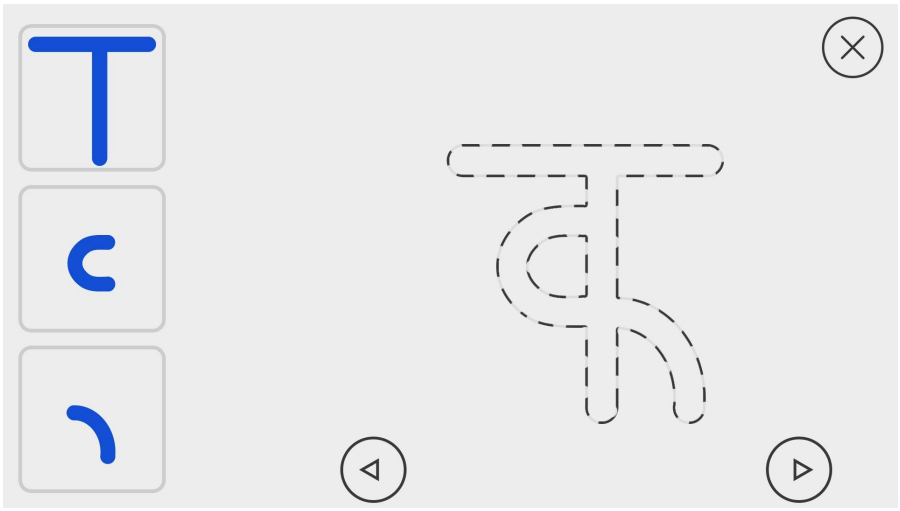

Figure 27: Activity page

This is the activity page. When a user comes to this page the first piece of the alphabet flickers and tries to catch the attention of the user. In this page the aim of the user should be to successfully drag and drop the pieces of the alphabets over the appropriate part of the center alphabet. If the user successfully drops the piece over the appropriate area then the application congratulates the user with music. On completion of the whole alphabet, the application appreciates the users and plays an interesting animation. In this screen, only a single piece of the alphabet is active at a time. The next piece becomes active only when the first piece is dropped successfully. If the user fails to drop the alphabet piece at the appropriate position then the piece goes back to its original position inside the block. The user can use the next and previous buttons to linearly traverse to the next and previous pages.

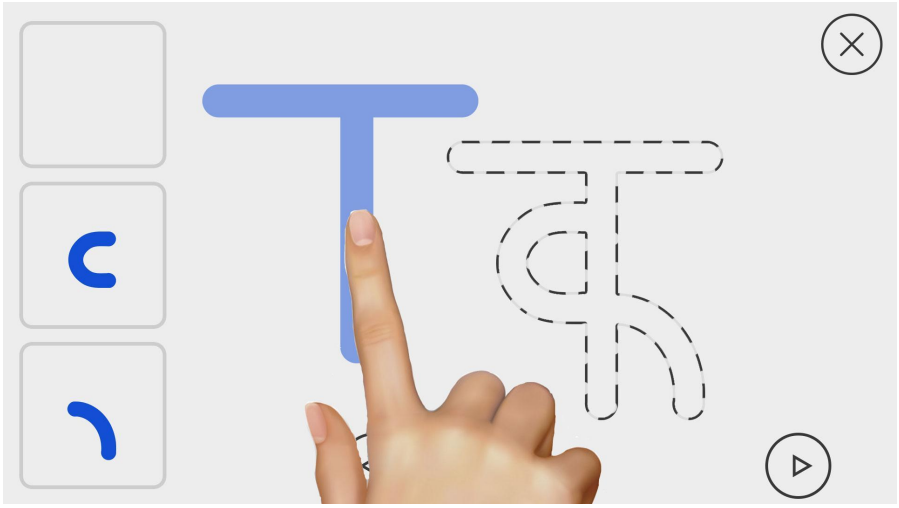

Figure 28: Shape being dragged to solve the alphabet puzzle

This figure shows the user dragging the first piece of the alphabet over the center alphabet.

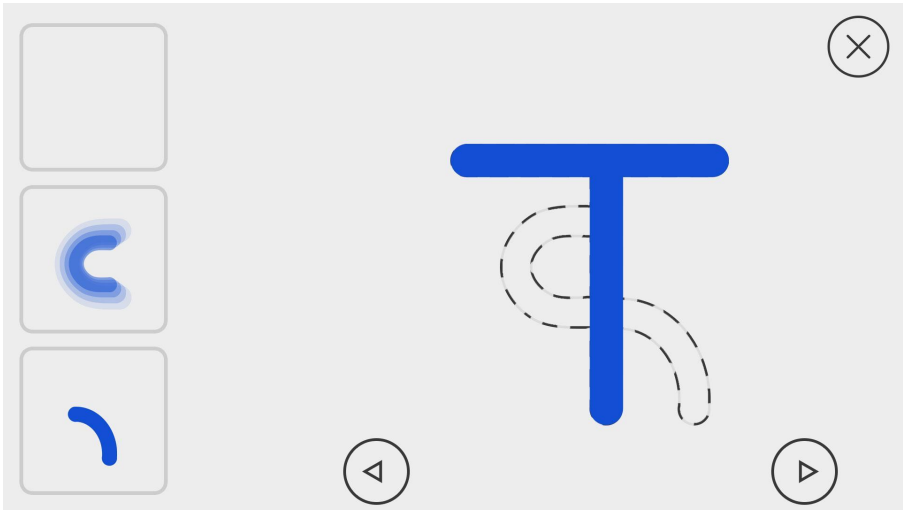

Figure 29: First piece of the alphabet dropped successfully

If the user is able to drop the piece at the correct place then the application greets the user and activates the next piece. When the next piece of the alphabet is activated it flickers a few times to catch the user's attention.

Figure 30: Second piece of the alphabet dropped successfully

This image shows that the second piece of the alphabet has been dropped successfully.

Figure 31: Alphabet puzzle is complete

When the puzzle is complete the application greets the user by playing a success music and also plays an animation image in reference to the alphabet in focus.

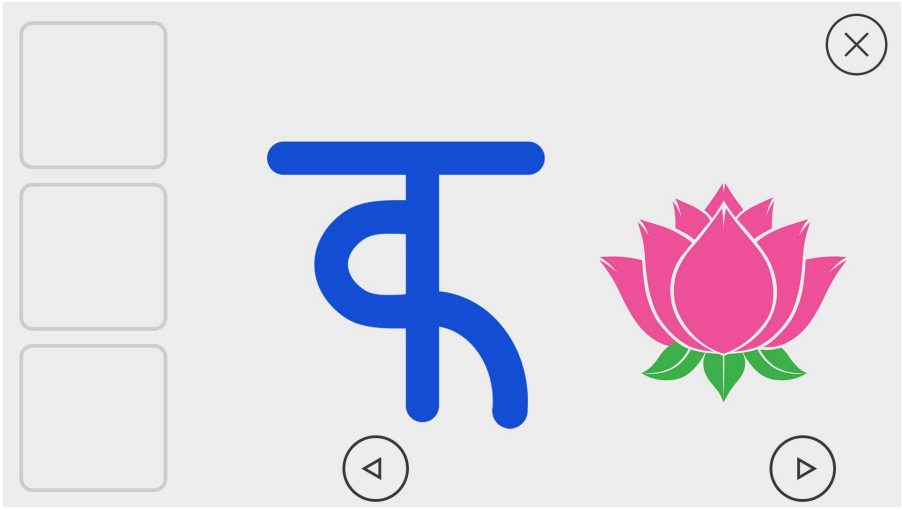

Figure 32: The app gives audio-visual feedback along with an appropriate image

This image shows an animation of an appropriate image along with audio which says ‘क से कमल’ (in this case). Hence the user can relate the alphabet to the image.

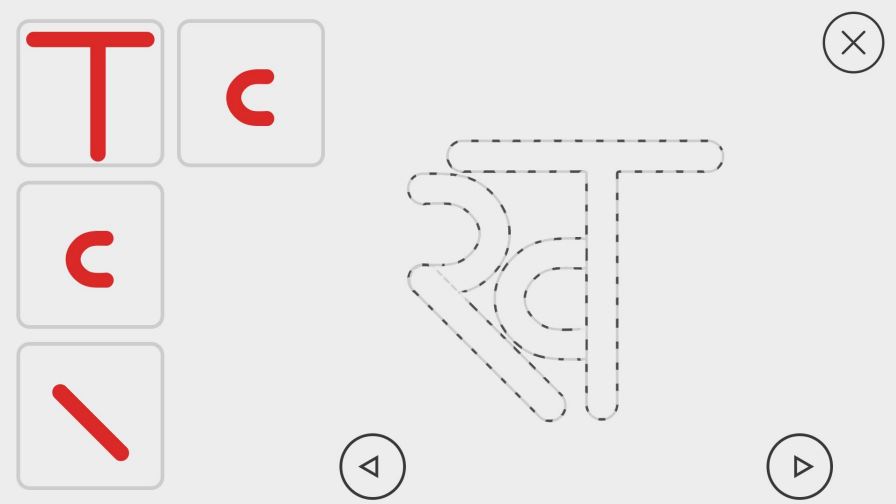

Figure 33: Next page is displayed on tapping the next button

This image shows the next alphabet puzzle, this page is displayed when the user taps on the next button. Similarly, all the following alphabets puzzles will be loaded onto the screen one by one as the user taps on the next or previous button. Once the user leaves the page the page is reset and all the alphabet pieces go back to their original positions i.e. inside the blocks. Users can also use the cross button to dismiss the current screen to go to the home page.

Conclusion

In today's society, there is a very high rise in the demand for literacy. But it becomes very challenging for children with learning disabilities. Thus, we need to design an effective educational and learning tool that is specially designed for them.

The application has been tested for usability and has yielded promising results. The children were able to accomplish the task of completing the puzzle. The application was tested with 12 children with a learning disability. The average time to learn a new alphabet got reduced from 2-3 weeks to one week.

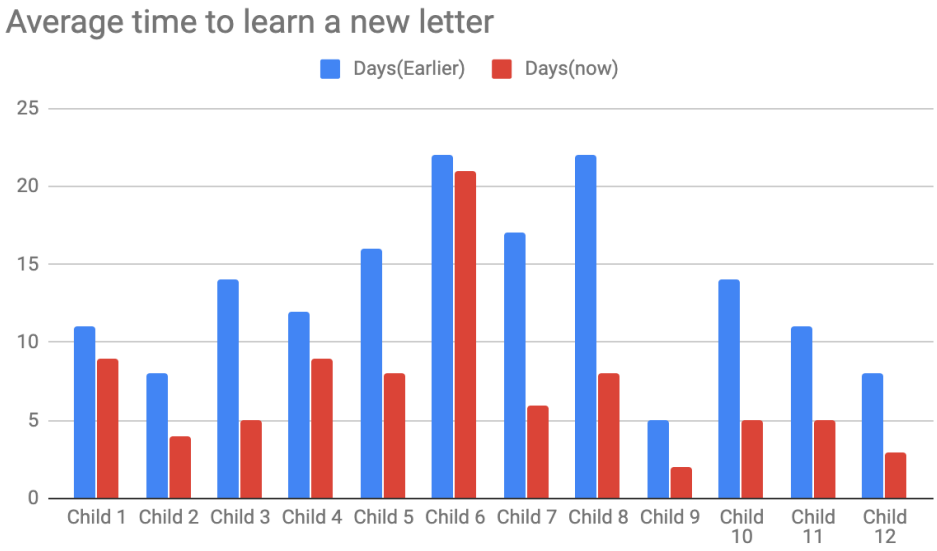

Figure 34: Second piece of the alphabet dropped successfully

Future Scope

In the future, many features can be included such as

1. Points: The child can achieve points on the successful completion of an alphabet puzzle.
2. Awards and badges: The child can unlock new stages and win awards or badges on performing the given task under certain time limits. On successful completion of learning of a certain group of alphabets, the child can unlock badges.
3. Tests and quizzes: The app can also have a feature to conduct tests and quizzes for the child and reward the child with a certain point on passing successfully.
4. The application can be tested for its efficiency by conducting eye-tracking tests on its users.

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Contact email: abhishek.bose@gmail.com, singhjyotsana56@gmail.com