Screening Dyslexia for English Using HCI Measures and Machine Learning

Luz Rello, Enrique Romero, Maria Rauschenberger, Abdullah Ali, Kristin Williams, Jeffrey P. Bigham, Nancy Cushen White
Dyslexia

*not* related to intelligence

10% of the population

– Frequent

– Universal

– School failure

[Shaywitz, 2008]
40% of school dropout rate

Why is it so difficult to detect?
Why is Dytective Different?

- Content Design
  - The empirical linguistic analyses of the errors that people with dyslexia make is the source of knowledge to design the exercises

- Predictive Model
  - Using Machine learning
## Content Design
(17 dyslexia indicators)

<table>
<thead>
<tr>
<th>Language Skills</th>
<th>Working Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alphabetic Awareness</td>
<td>Visual (alphabetical)</td>
</tr>
<tr>
<td>Phonological Awareness</td>
<td>Auditory (phonology)</td>
</tr>
<tr>
<td>Syllabic Awareness</td>
<td>Sequential (auditory)</td>
</tr>
<tr>
<td>Lexical Awareness</td>
<td>Sequential (visual)</td>
</tr>
<tr>
<td>Morphological Awareness</td>
<td>Executive Functions</td>
</tr>
<tr>
<td>Syntactic Awareness</td>
<td>Activation and Attention</td>
</tr>
<tr>
<td>Semantic Awareness</td>
<td>Sustained Attention</td>
</tr>
<tr>
<td>Orthographic Awareness</td>
<td>Simultaneous Attention</td>
</tr>
</tbody>
</table>

### Perceptual Processes
- Visual Discrimination and Categorization
- Auditory Discrimination and Categorization
Content Design
Demo!

http://eng.dyctective.com/play.php
Participants

- 267 participants from one specialised center, three schools, and from dyslexia associations.
- Age ranged from 7 to 60 years old.
- We classified these participants into three groups:
  - 52 were diagnosed with dyslexia / Class D (dyslexia) (28 female, 24 male, M = 11.16, SD = 6.31)
  - 206 do not have dyslexia / control group / Class N (Not-Dyslexia) (94 female, 112 male, M = 11.89, SD = 5.11).
  - 9 participants at risk of having dyslexia or suspected of having dyslexia - Class M (Maybe) (4 female, 5 male, M = 17.66, SD = 16.17)

- The first language of all participants was English, although 84 participants spoke another language (mostly Spanish in the Texas area)
Dataset

- Age
- Gender
- Second mother language (bilingualism)
- Spanish subject.
- Performance measures.

226 features per participant

Clicks
Hits
Misses
Score
Accuracy
Missrate
ML Approach

- Support Vector Machine (SVM)
- 10-fold cross validation experiment (normally recommended for smaller datasets when a single train-development test split might not be informative enough)
- We randomised the data and used stratified sampling to ensure a similar distribution of classes in all folds.
- We analysed the data for features whose distributions were different between dyslexic and non-dyslexic participants. To that end, a Kolmogorov-Smirnov test was performed. The number of Hits and Misses showed different distributions for a number of exercises.
### Results

<table>
<thead>
<tr>
<th></th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>84.62%</td>
</tr>
<tr>
<td>Precision – Class D (Dyslexia)</td>
<td>63.76%</td>
</tr>
<tr>
<td>Recall – Class D (Dyslexia)</td>
<td>80.24%</td>
</tr>
<tr>
<td>Precision – Class N (Not-Dyslexia)</td>
<td>93.88%</td>
</tr>
<tr>
<td>Recall – Class N (Not-Dyslexia)</td>
<td>85.83%</td>
</tr>
</tbody>
</table>
Discussion

– Most informative features were a set of 10 features composed of *Hits* and *Misses*, *Misses* being the most informative ones at the individual level.

– These features are performance measures belonging to exercises that target **Alphabetic Awareness, Phonological Awareness, Visual Discrimination and Categorization** and **Auditory Discrimination and Categorization**.

– These features come from exercises where the participant was required **to map (or associate) a letter name or a letter sound with a grapheme (letter or letters)**. This is consistent with previous literature on dyslexia that focus on the deficit on the phonological component in dyslexia.
Future Work

- **Pre-readers**
  - Starting from 3 to 6 years old

- **Large scale study**
  - With ~5000 participants

- **Better predictive model**
  - With recurrent neural networks

- **Language Independent**
  - Musical and visual elements

- **Integration in commercial tool**
  (free screener for dyslexia)
Future Work

Fill the map of dyslexia with English speaking countries.
So far, 130,000 users in 54 countries (Spanish)
Conclusions

– A game uses linguistic and attentional exercises to find differences between people with and without dyslexia.
– A machine learning model able to predict dyslexia with almost 85% accuracy for English.
– Easy to scale, achieved earlier detection of dyslexia and prevents school failure.
Thank you :)