Classifying if a person knows a word using speech data

Marijn Schraagen

NLP Group Meeting

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Universiteit Utrecht

Project overview

- AI Labs project about low literacy in Dutch high school students
- Collaboration between Computer Science (me, Mehdi Dastani), Social Science (Hans Marien, Henk Aarts), Humanities (Els Stronks)
- Goal to start an ELSA Lab (Ethical, Legal, Societal Aspects) in NL AI Coalition
- Topics: speech and text models for low literacy, (personalized) interventions
- Today: speech classification for **vocabulary knowledge**

Data

- Data collection for a separate FSS master project
- Data re-used by me for different experiments
- *Discussion:* can we collect more suitable data?
- Recordings of 40 single Dutch words repeated from TTS spoken prompts
- 50 high-literate participants, mostly students, native speakers
- Questionnaire at the end with many questions
- Did you know the words that are used in the experiment?

```
keen  - yes no
rente - yes no
twee  - yes no
zijp  - yes no
omzet - yes no
zeeg  - yes no
```

Research goal

Assumption: if a person knows a word then their voice will sound different – confidence, fluency, pitch, lower-level features

Assumption: this is measurable in principle

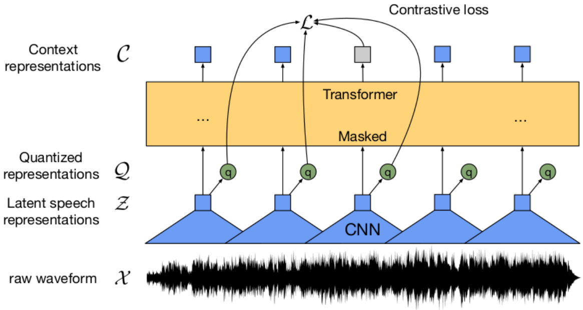
Assumption: current (transformer) models for audio can pick up on this

Assumption: the collected data exhibits the characteristic under study

Research goal: Build a model to classify from a spoken word if the person knows this word

Experiments

Classification task using the `wav2vec` model with a classification head for the binary *word_known* variable



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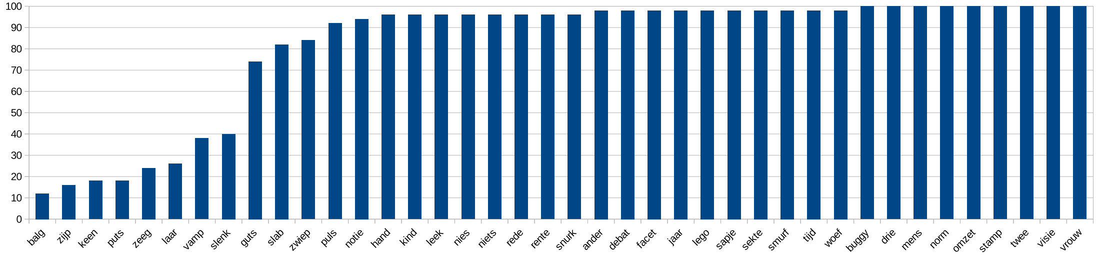
Data imbalance

- Data is imbalanced: 82% known word examples
- Use all 734 unknown word examples and an equal number of random known word examples
- Words range from largely unknown to known by everyone (more on that later)



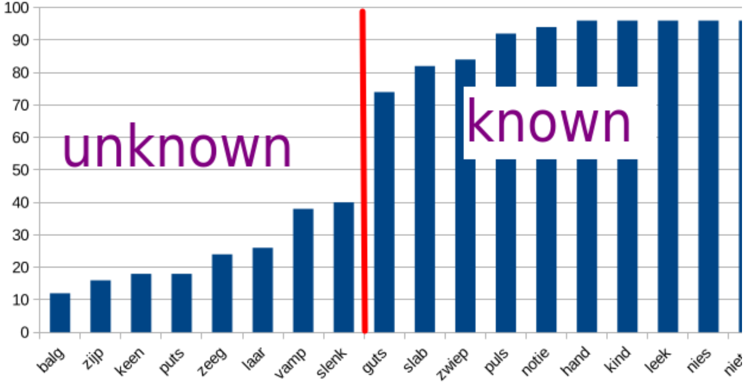
Results

```
              precision    recall  f1-score   support

     unknown       0.82      0.88      0.85       110
       known       0.87      0.81      0.84       111

    accuracy                           0.85       221
```

Not bad?

Baseline

- Random baseline: 50%
- Second baseline: majority label *per word* from the training set



Results majority baseline

Trained classifier:

```
              precision    recall  f1-score   support

     unknown       0.82      0.88      0.85       110
       known       0.87      0.81      0.84       111

    accuracy                           0.85       221
```

Majority baseline:

```
     unknown       0.82      0.84      0.83       111
       known       0.83      0.81      0.82       110

    accuracy                           0.82       221
```

Bad! The model just learns to predict the word.

Word split

- Rearrange train and test: split on vocabulary items
- Six words manually selected for test set: from frequently unknown to frequently known, other 34 words in training set

```
              precision    recall  f1-score   support

     unknown       0.49      0.13      0.20       188
       known       0.33      0.76      0.46       104

    accuracy                           0.35       292
```

Very bad!

Adding information

- Hypothesis: if a speech recognition system has trouble recognizing the word then the person did something strange – and may not know the word
- Far fetched? Let's try :)
- Three models: Kaldi-NL, Whisper small, Whisper large (with `language="nl"`)
- Whisper models are highly accurate, but regularly hallucinate

word	transcription
notie	mankind. Uwanners van vandaag van de VLaughter. Bedankt voor uw tijd.
debat	대박 (Korean, pronunciation: *daebak*)
vamp	FAM vieleLijke
ander	Am there. Sorry voor het idee! Alująsfteroki
stomp	Stomp Stomp Stomp Stomp Stomp Stomp Stomp
notie	然后勾她一点

- Kaldi doesn't hallucinate and makes more mistakes (=good!)

Adding speech recognition

- Perform ASR on the recording
- Input for the model: recording (audio) + ASR transcription (text)
- Multimodality for the lazy: use TTS to convert transcription back to audio and concatenate

```
             precision    recall  f1-score   support

           0       0.95      0.88      0.92       111
           1       0.89      0.95      0.92       110

    accuracy                           0.92       221
```

Seems better...

Adding speech recognition

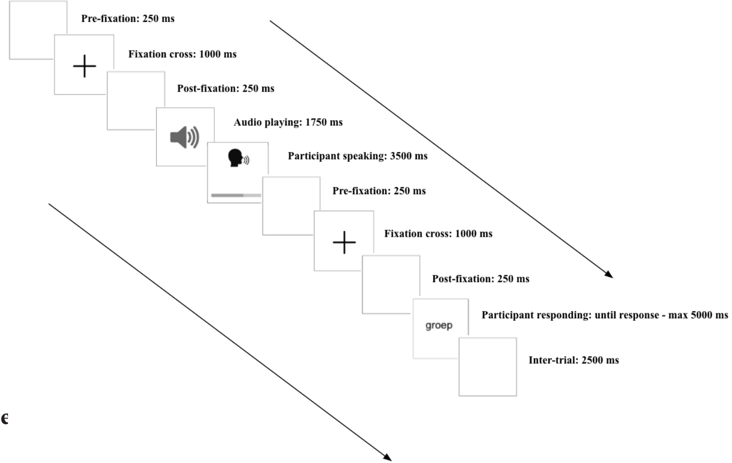
Audio + transcription on word split:

```
              precision    recall  f1-score   support

           0       0.37      0.16      0.23       188
           1       0.25      0.50      0.33       104

    accuracy                           0.28       292
```

Still bad

Relation ASR and words known

Experimental task: after reading a word participants were shown either that word (A) or a different word (B) and has to press button A or button B



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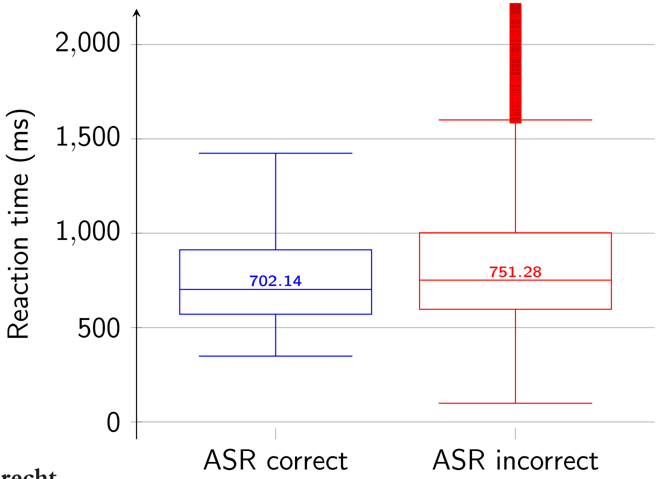
Reaction time vs ASR correct



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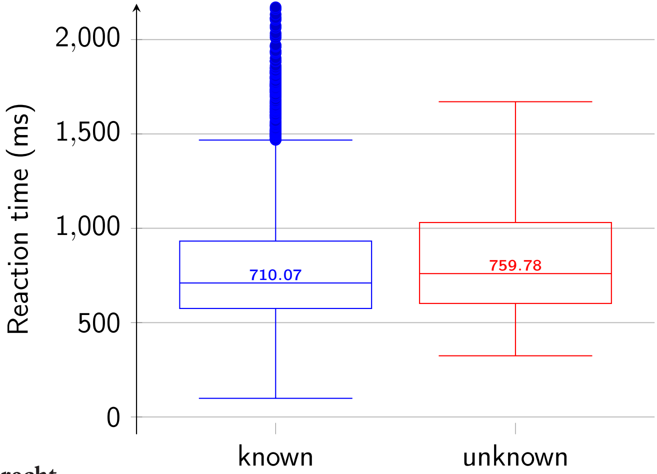
Reaction time vs word known



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ASR correct vs. known–unknown

	known	unknown
ASR correct	2096	329
ASR incorrect	1170	405

Preliminary conclusions

- The content of the word is rather important
    - Models like Word2Vec are trained on content
- ASR performance does seem to contain information
    - Even if you don't know if the ASR was right!
- Speaking style by itself does not seem to be sufficient

Issues

- Speech may not carry this kind of information
- Models are not pretrained to support this task
- The dataset is too small, the words too short, the participants too literate
- Asking people to self-report if they know a word is vague and unreliable
- Repeating a spoken word is easier than reading it from a screen or paper

Next steps: data collection

- Data issue can be addressed
- Reduce the influence of content
  1. Speak an unknown word
  2. Learn this word: see/create example sentences, answer questions etc
  3. Speak the same word again
  4. Train models to find the difference between the two recordings

Next steps: data collection

- Data issue can be addressed
  - Read a word instead of repeating a spoken word
  - Test vocabulary knowledge by asking to provide a definition
  - Speak a longer sentence, post-process to isolate the word
  - Use longer words
  - Ask low-literate participants (but: first more trials)

  - Use actual multimodal model
- Suggestions?