# Speech interaction with personal assistive robots supporting aging-at-home for individuals with Alzheimer's disease

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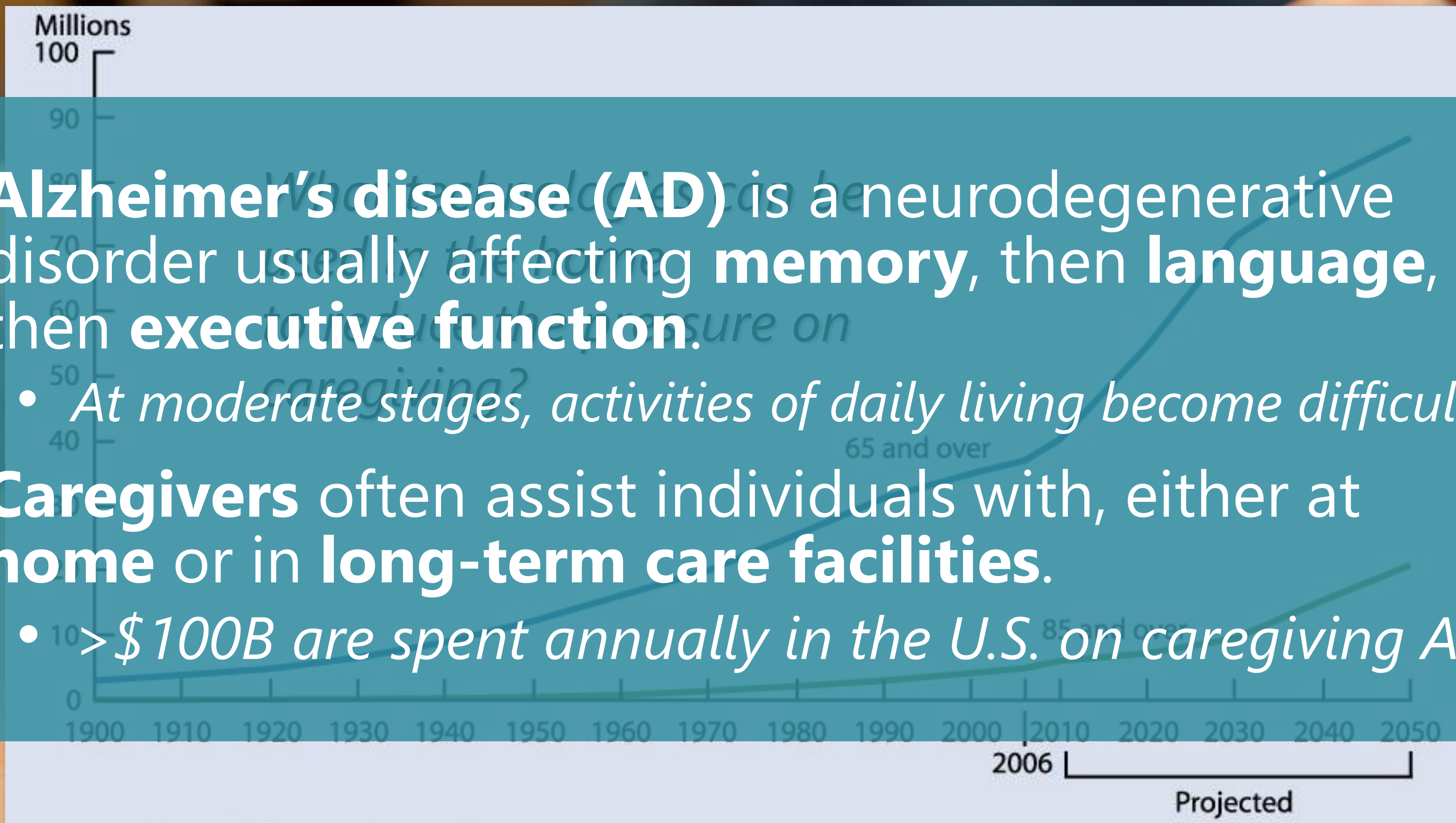
# Introduction



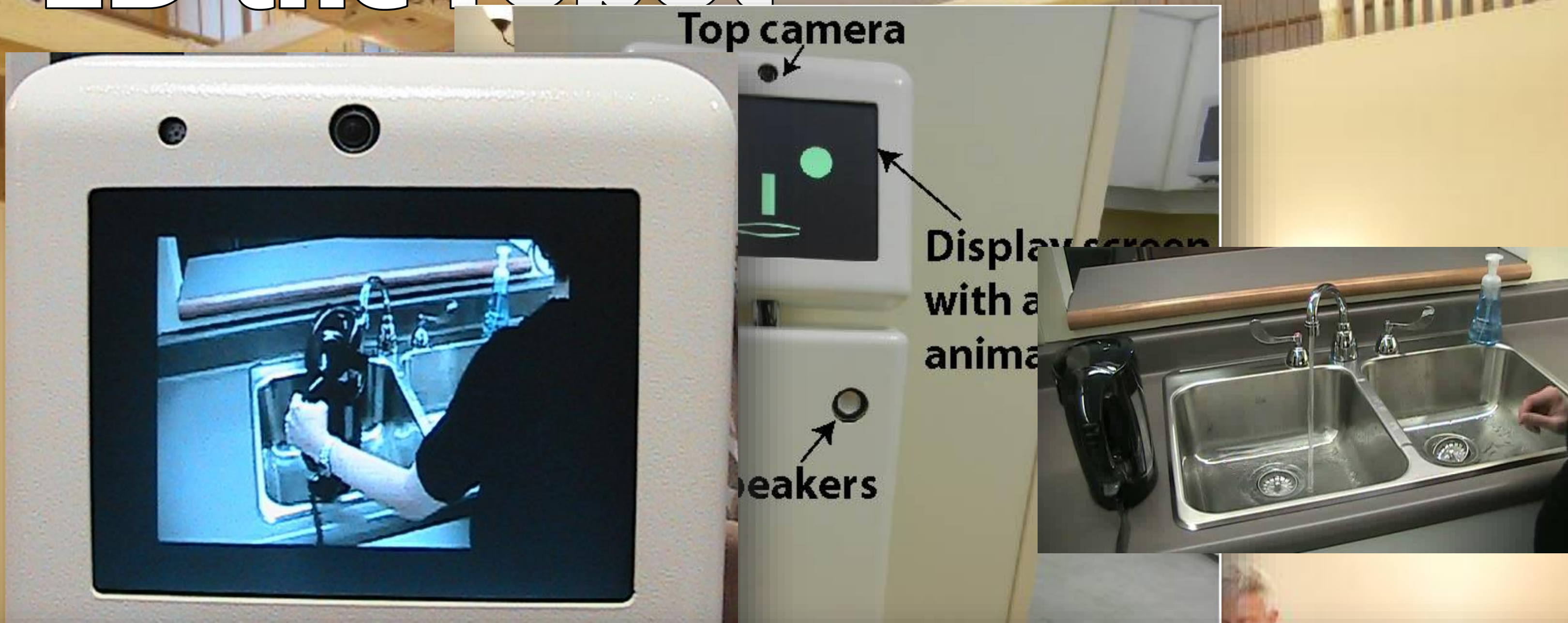

- **Alzheimer's disease (AD)** is a neurodegenerative disorder usually affecting **memory**, then **language**, then **executive function**.
  - *At moderate stages, activities of daily living become difficult.*
- **Caregivers** often assist individuals with, either at **home** or in **long-term care facilities**.
  - *>$100B are spent annually in the U.S. on caregiving AD.*

# The HomeLab

- **'COACH'** automates support of daily activities.
  - E.g., hand-washing,
    tooth-brushing.
  - Uses partially-observable Markov decision processes (POMDPs) and **camera-only** input.

- *But what if the user does not want to spend their whole day in front of the sink?*

# ED the robot




Early qualitative analysis indicated that **speech** is the most **desired** form of interaction with such a system.

Our **goal** is to implement two-way **spoken dialogue** that ***identifies*** and ***recovers*** from communication breakdowns.

# Related work

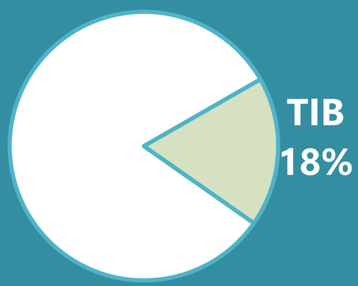
- There has been a *lot* of great work on supporting **older adults** with robots.

  - *However, speech interaction has been superficial.*

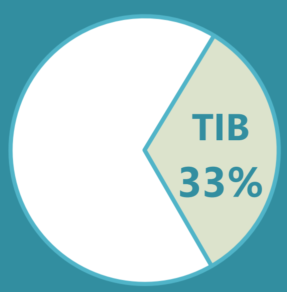
- We know a lot about how AD **affects language**.
  - Repetition, disfluency, paraphrasing (Guinn and Habash, 2012).
  - Can be used for **diagnosis** (Fraser, Meltzer, and Rudzicz., 2015).

# Communication difficulties and Trouble-Indicating Behaviors

TYPICAL




AD




- In **dialogue**, people with AD have more **discourse-related difficulties**, including:
  - inattention,
  - Poor tracking of propositions and themes, and
  - deficits in working memory.

- **Trouble Indicating Behaviors (TIBs)** (Watson, 1999).
  - Difficulties can be **phonological**, morpho/**syntactic**, **semantic** (e.g., lexical access), or **discourse** (e.g., misunderstanding topic).
  - **Seniors with AD use TIBs significantly more** ($p$<0.005) than matched controls (Watson, 1999).

- ***What are these TIBs?***

# Some common TIBs

1. **Neutral or non-specific requests for repetition (local).**
   E.g., ***What? Huh?***

2. **Request for confirmation – repetition with reduction.**
   E.g., Speaker 1: *I went to the museum last night.*
   Speaker 2: ***Last night?***

…

# Some common TIBs *(cont.)*

…

8. **<u>Lack of uptake / lack of continuation</u>**.
   Include
   i) *<u>minimal feedback</u>* indicating non-understanding,
   ii) *<u>lack of contribution</u>* to topic extension;
   iii) overriding/*<u>interrupting</u>*; and
   iv) abrupt *<u>switch of topic</u>*.

   E.g., Speaker 1: *Do you know what 'rhetorical' means?*
   Speaker 2: *Yes.*
   Speaker 1: *What?*
   Speaker 2: ***Oh, its a bit too hard, bit late too late to.***

# Some common TIBs *(cont.)*

…

11. **Reprise / minimal dysfluency.**
    *Reprises*: partial or whole repetition/revision.
    *Minimal dysfluencies*: sound, syllable, or word repetition, pauses, and fillers.
    E.g., ***Eerrr, I want to we went to*** *the river.*

# How do people avoid TIBs?

- ED should mimic **verbal strategies** of caregivers.
  - E.g., (Wilson et al., 2012) :
    1. **Speak slowly**.
    2. **Repeat** misunderstood prompts **verbatim**.
    3. Ask **closed-ended questions** (i.e., eliciting yes/no responses).
    4. Simplify sentences using **reduced syntactic complexity**.
    5. Give one question or **one direction at a time**.
    6. **Use pronouns minimally**.

*How can we mimic this in a robot?*
*How will people with AD respond?*

# Data

- 10 individuals (6 female) with AD recruited at Toronto Rehab.
  - Age: 77.8 years ($\sigma$ = 9.8)
  - Education: 13.8 years ($\sigma$ = 2.7)
  - MMSE: 20.8/30 ($\sigma$ =5.5)
- Three phases:
  - **Familiar human-human** dyad (during informed consent),
  - **Human-robot** dyad (during *tea-making*), and
  - **Unfamiliar human-human** dyad (during post-study interview).

# Speech interface

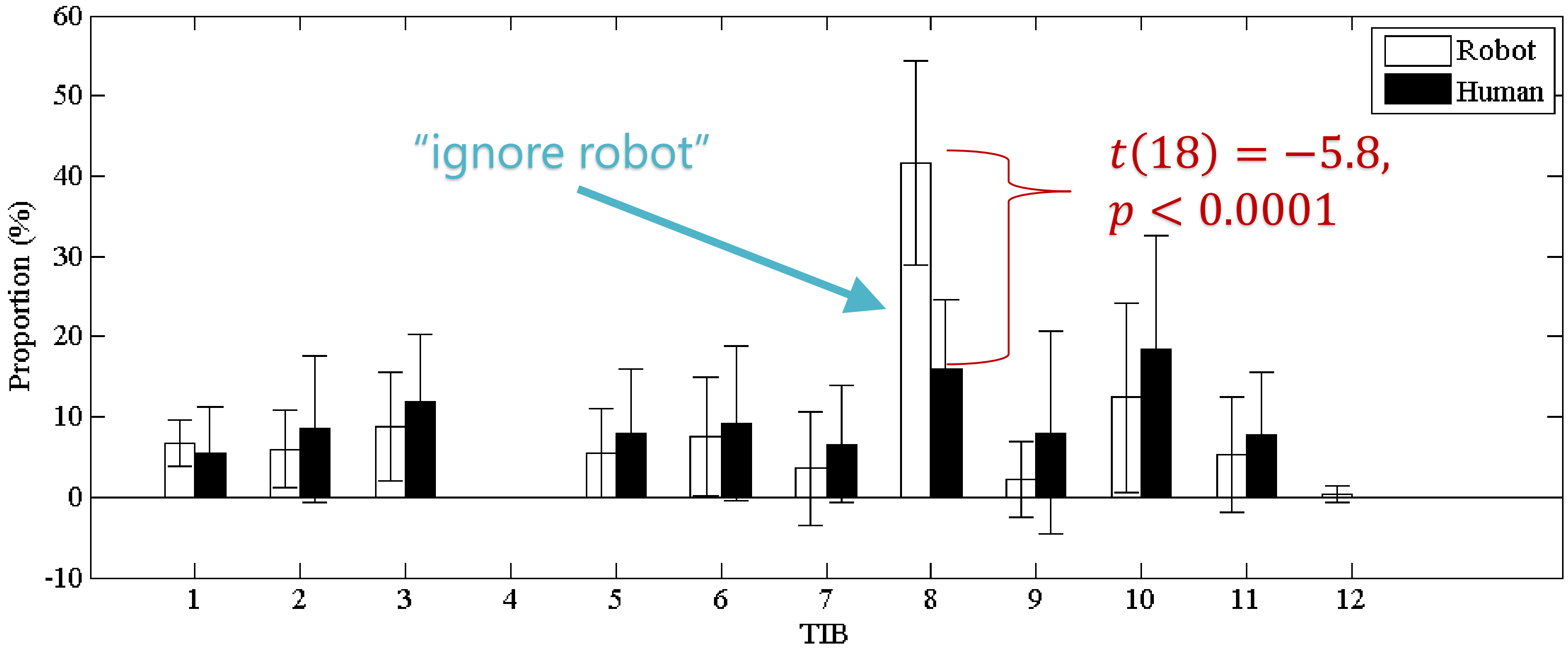
- **Synthetic speech**: ‘David’ voice from Cepstral.
  - Qualitative feedback was **positive**;
  - Despite being ‘**robotic**’, the voice was ‘***clear***’ and ‘***confident***’.

- We **split** the tea-making task into **phases**.
  - **(1)** *go to kitchen*, …, **(6)** *put teabag in cup*, …
  - We recorded audio (+video) prompts for **each phase**, at several **levels of detail**.

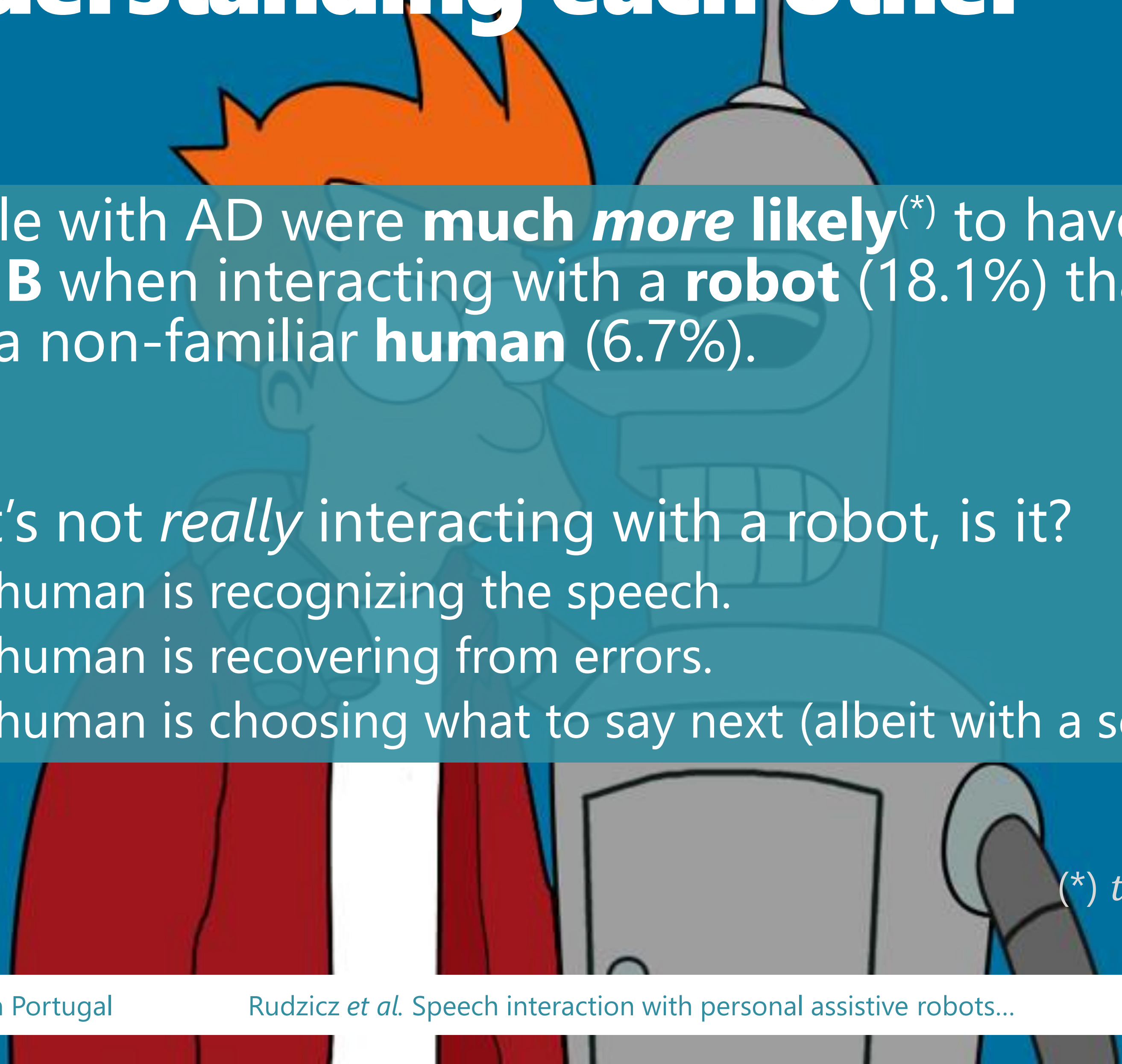
- A human navigator followed a **flowchart** of **scripts**.
  - **Respond to questions** with **pre-recorded prompts**;
  - When possible, engage in **novel social conversation**.

# Language use and interaction

- A speech-language pathologist (SLP) **transcribed** all of the data and **annotated** TIBs.
  - For sanity, a second SLP annotated 20%; Fleiss' $\kappa = 0.84$.



# Understanding each other



- People with AD were **much *more* likely**(*) to have ***no* TIB** when interacting with a **robot** (18.1%) than with a non-familiar **human** (6.7%).

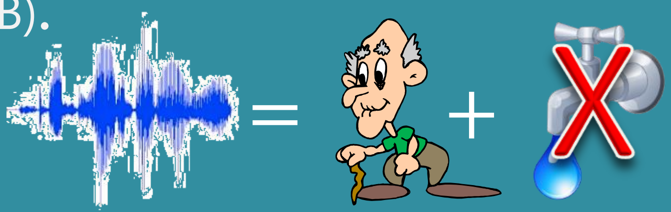
- But it's not *really* interacting with a robot, is it?
  - A human is recognizing the speech.
  - A human is recovering from errors.
  - A human is choosing what to say next (albeit with a script).

(*) $t(18) = -4.78$, $p < 0.0001$

# Speech recognition and automation

- We developed methods that **automatically identify** TIBs in speech with **>80%** accuracy (Rudzicz et al., 2014).
  - Indicative features are mostly things like **skewness of the derivatives** of particular Mel-frequency cepstral coefficients, but some have more clinical value e.g., **phonation rate**.

- **ASR** is a standard HMM with mixtures of Gaussians.
  - Data are very noisy (SNR $[-3.42..8.14]$ dB).
    - *LSAE spectral noise subtraction*

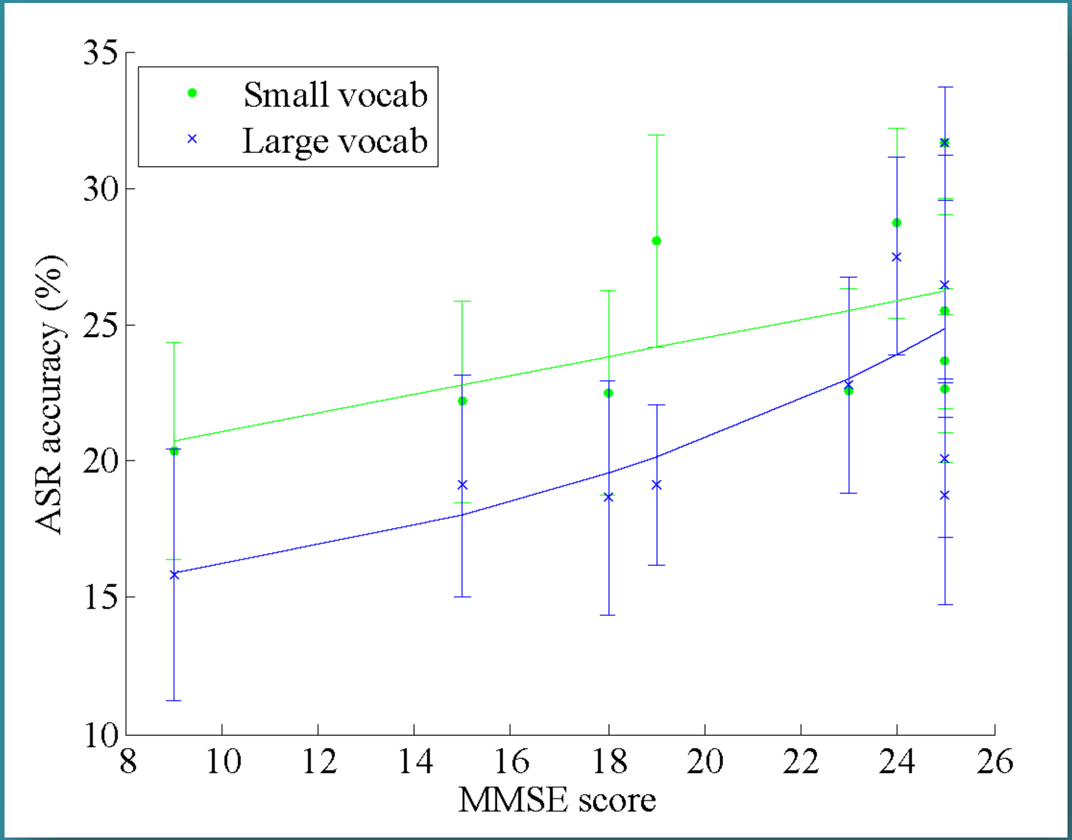


  - Two LMs derived from English Gigaword corpus:
    - *Large: 64,000 words* *Small: 5000 words*

# Speech recognition and cognition

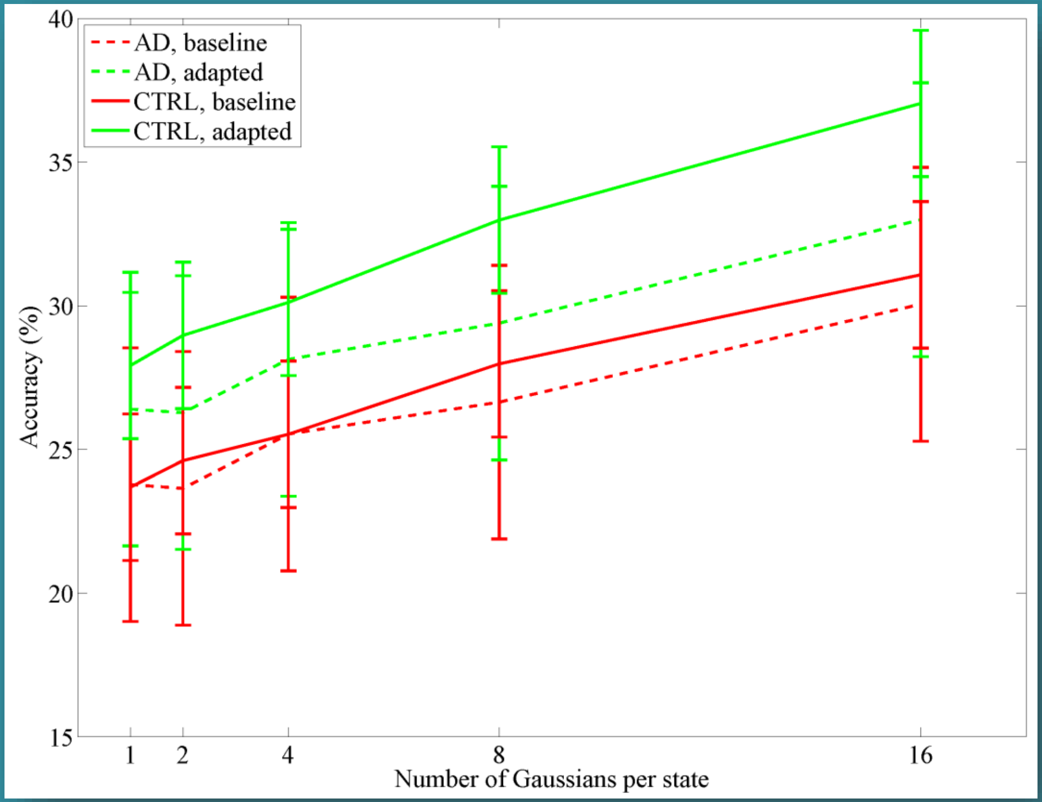
- Clear increases in accuracy with MMSE.

ANOVA: $F_1 = 47.07, p = 0.164$.

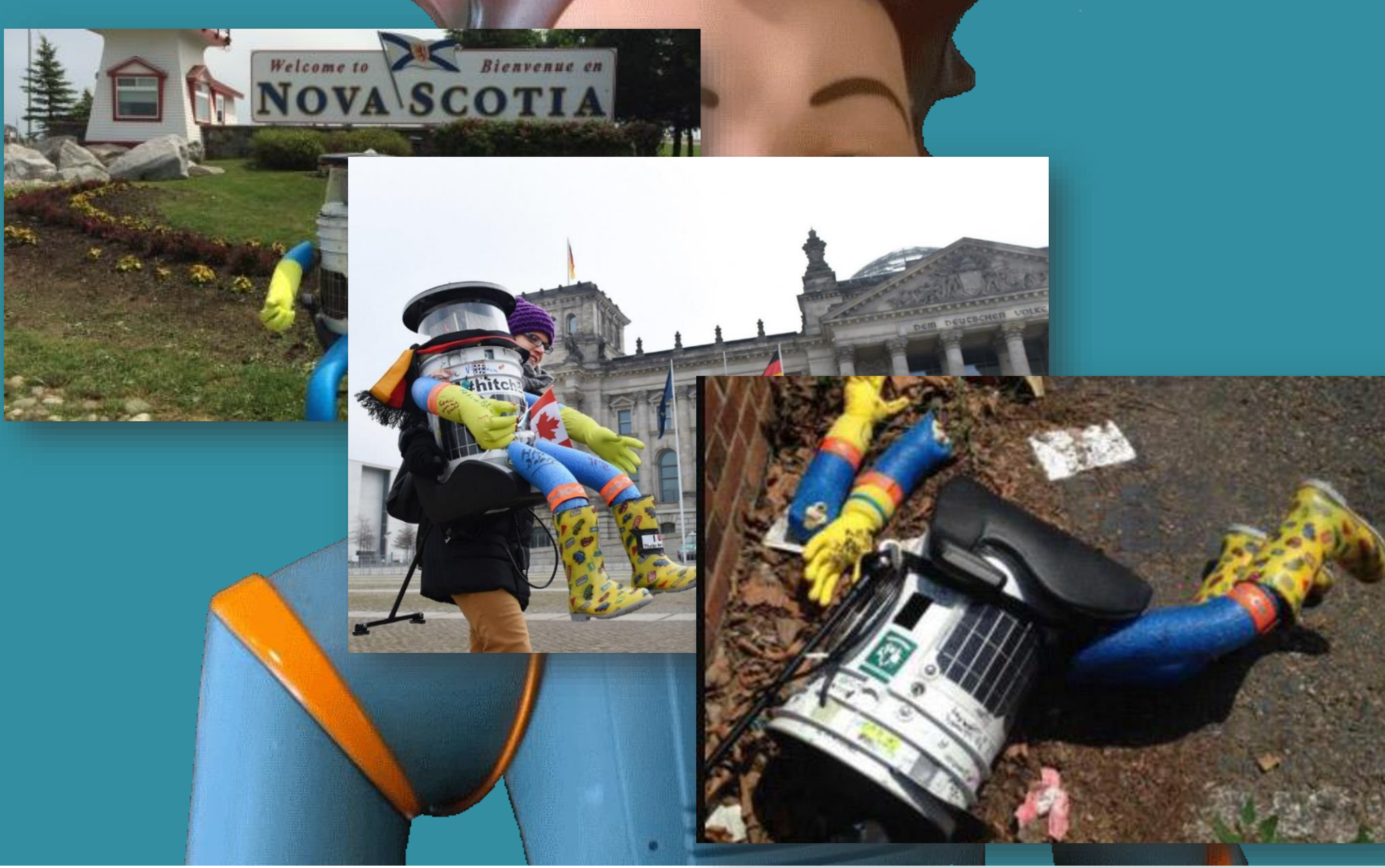


# Adapting ASR to older voices

- We adapted ASR using data from DementiaBank and Carolina Conversations, and varied model complexity.



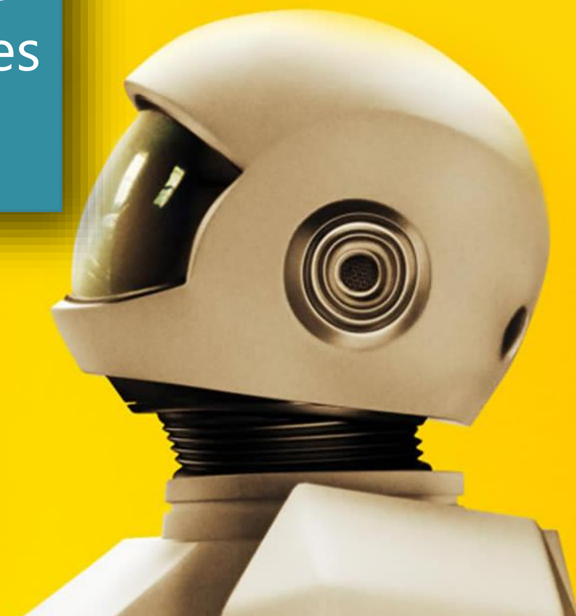
# Automating choice of response



# Silicon friends for golden years

Speech is increasingly important for interaction.

Our robot friends will need to be sensitive to differences in language as we age.



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SLPAT

- Joint **Special Interest Group** of
  the Association for Computational Linguistics (**ACL**) &
  the International Speech Communications Association (**ISCA**)
- **S**peech and **L**anguage **P**rocessing for **A**ssistive **T**echnologies.
  - *Yearly workshops (next: w/ Interspeech in SanFran).*
  - *Recent special issue of TACCESS.*
  - *Possible Jelinek JHU workshop.*

**www.slpat.org**