Evaluating Auditory Contexts and Their Impacts on Hearing Aid Outcomes with Mobile Phones

Syed Shabih Hasan, Octav Chipara
Department of Computer Science/Aging Mind and Brain Initiative (AMBI)
Yu-Hsiang Wu
Department of Communication Sciences and Disorders
Nazan Aksan
Department of Neurology

The University of Iowa

Hearing Loss in US

- 35 million people in the US have hearing loss
  - untreated → communication difficulties, depression, dementia etc.
- Primary intervention is hearing aid
  - ≃ 50% users satisfied with their performance in noise

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Underlying causes of user dissatisfaction are poorly understood

Auditory Context

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social interaction

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social interaction

activity


Auditory Context

social interaction

acoustic environment

activity

Existing methods

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  - not representative of real-world auditory contexts

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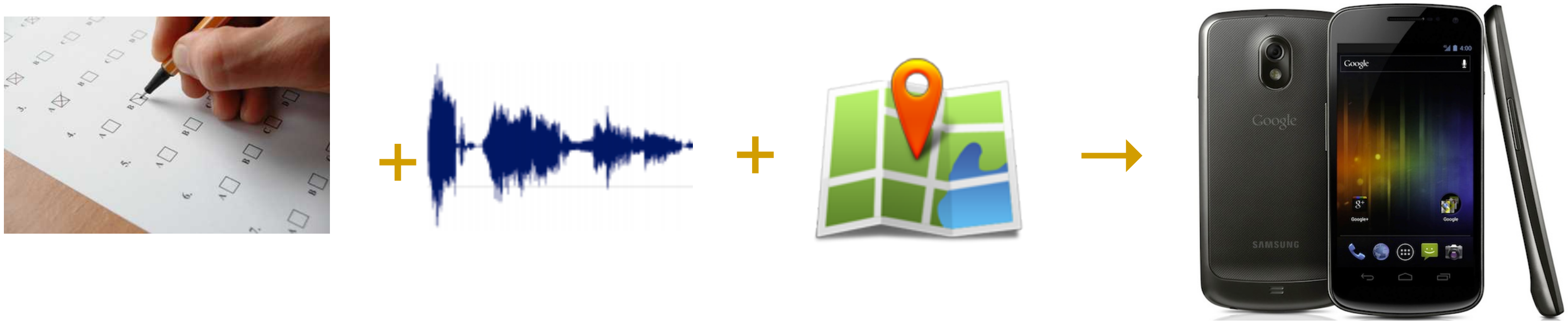
Existing evaluation methods are poor predictors of real-world performance

AudioSense



- Provides clinicians with subjective and objective measures of hearing aid outcomes and auditory contexts
  - subjective: Ecological Momentary Assessment (EMA)
  - objective: derived from audio and GPS
  - data is collected in real-time and in-situ
- EMA has been previous used by Henry et. al. and Galvez et al.
  - we collect sensor data, track subject compliance in real-time

S.S.Hasan, F. Lai, O. Chipara, Y-H. Wu
AudioSense : Enabling real-time evaluation of hearing-aid technology in-situ
CBMS 2013

Remainder of the talk

Remainder of the talk

What are the typical auditory contexts?

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Are the hearing aid outcomes correlated?

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Field Study

- 19 older adults
  - mild-to-moderate hearing loss
  - age range: 65 - 87
- 2 hearing aids
  - Phonak Bolero Q50 : low cost, low-end adaptive directional microphone (DM) and digital noise reduction (DNR)
  - Phonak Bolero Q90 : premium level, advanced DM and DNR
- 6 sessions
  - one unaided, one application practice
  - two allotted to each hearing aid
    - DM, DNR turned on/off

Measuring the auditory context

social interaction

acoustic environment

activity

Measuring the auditory context


social interaction

Could you see the talker's face?

acoustic environment

activity


Measuring the auditory context

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Could you see the talker's face?

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What were you listening to?

Measuring the auditory context

social interaction

Could you see the talker's face?

Where were you?

acoustic environment

activity

What were you listening to?

Measuring the auditory context

How noisy was it?

acoustic environment

social interaction

Could you see the talker's face?

Where were you?

activity

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Measuring the auditory context

How noisy was it?

How important was it to hear well?

acoustic environment

social interaction

Could you see the talker's face?

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activity

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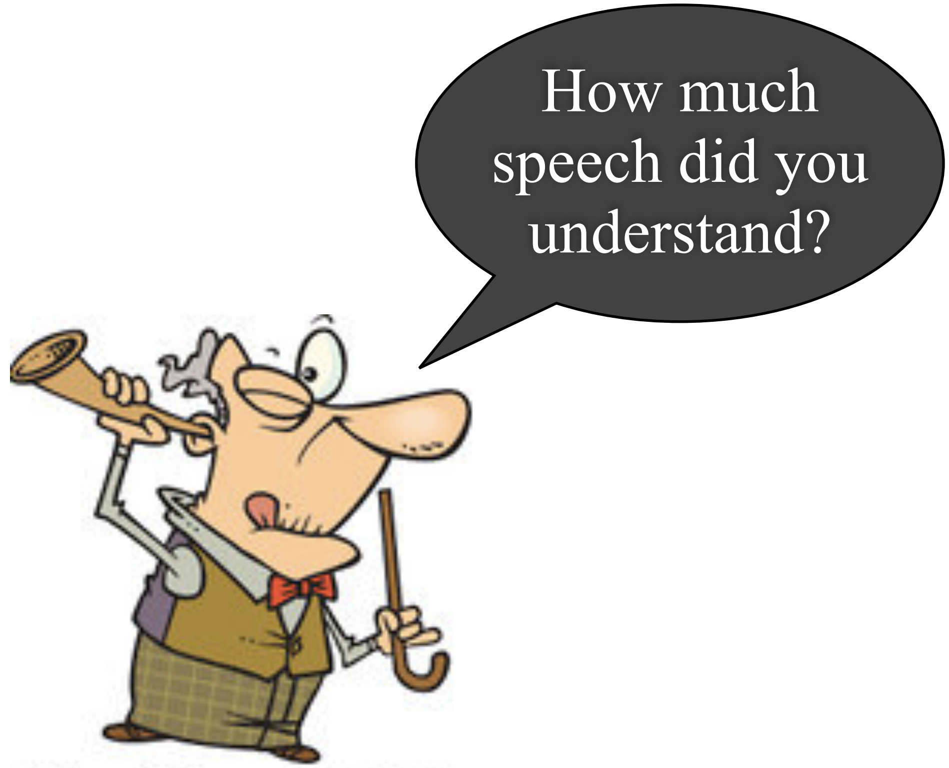
Measuring the outcomes

Measuring the outcomes



Measuring the outcomes

How much speech did you understand?

Could you tell where the sounds were coming from?

Measuring the outcomes

How much effort was required to listen?

How much speech did you understand?

Could you tell where the sounds were coming from?

Measuring the outcomes

How much effort was required to listen?

How much speech did you understand?

How satisfied were you with your hearing-aid?

Could you tell where the sounds were coming from?

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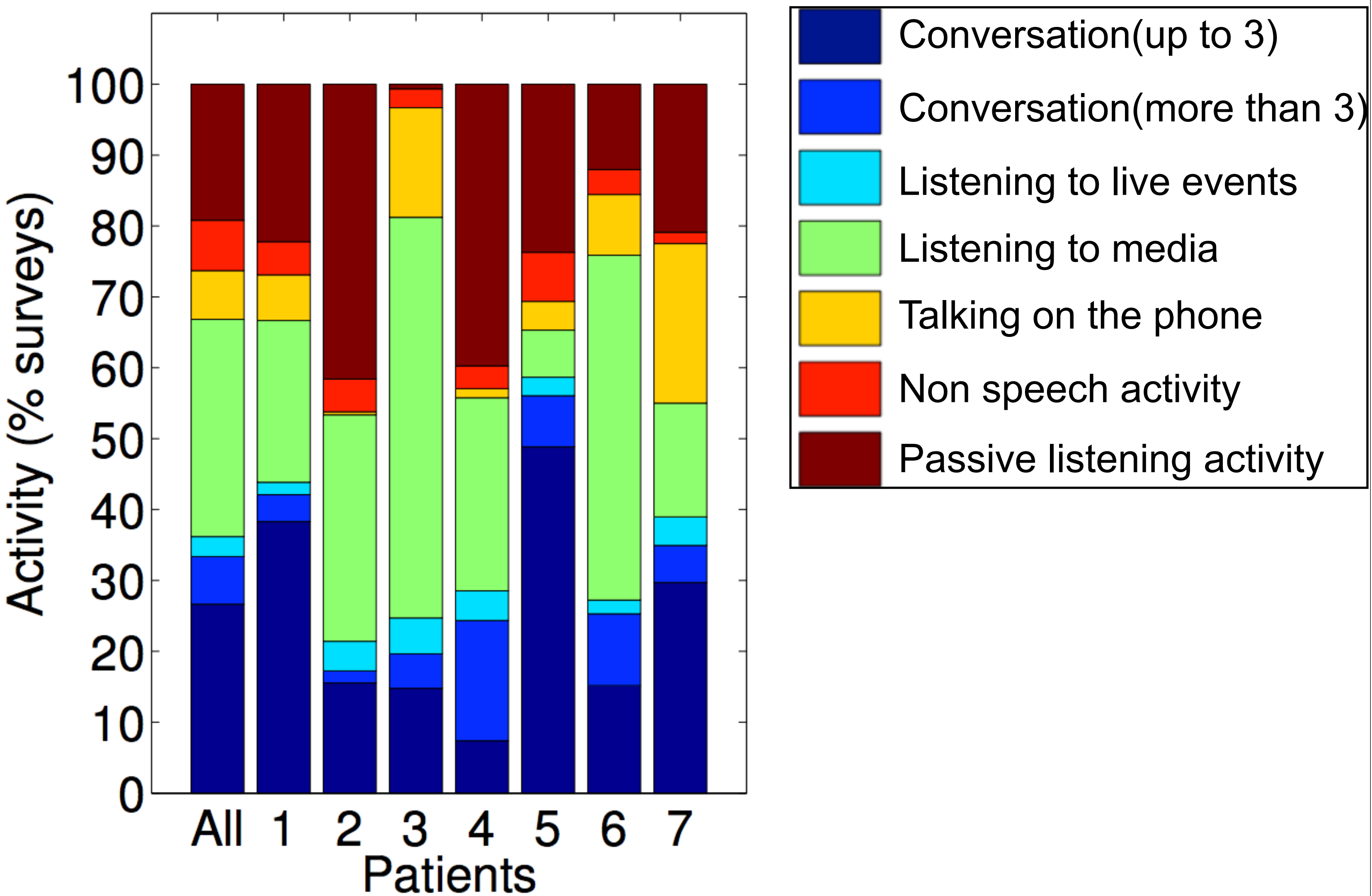
Activity context distribution



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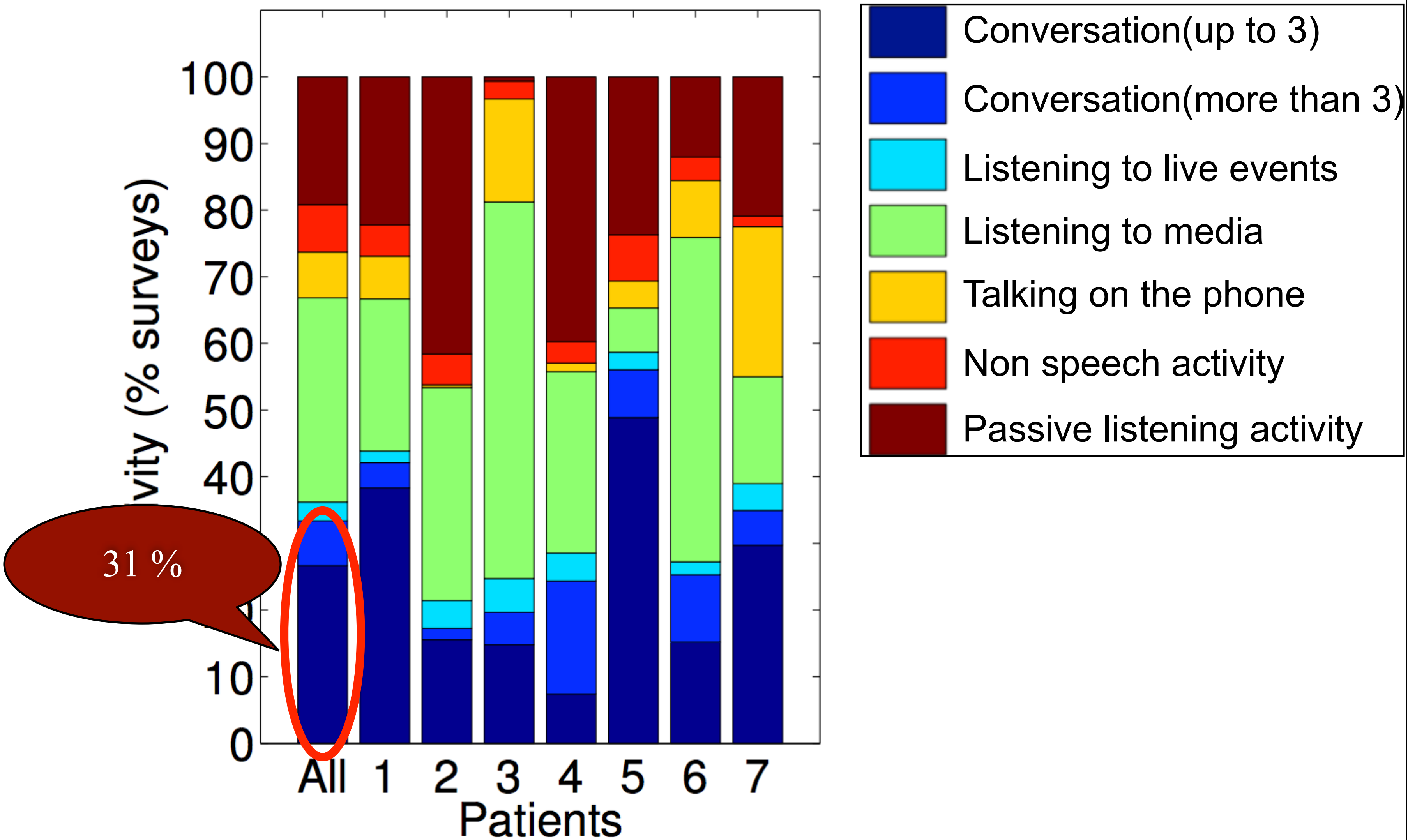

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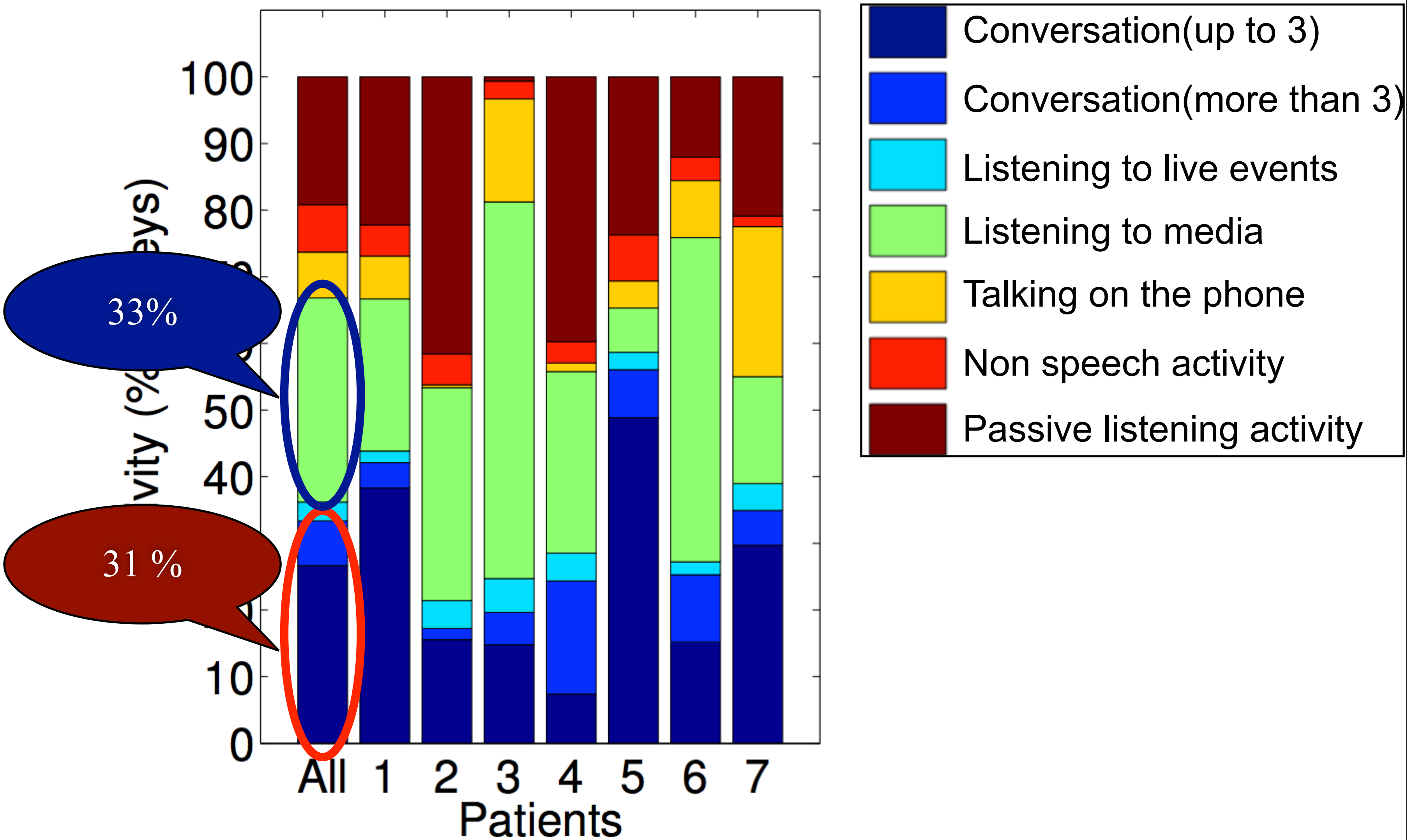

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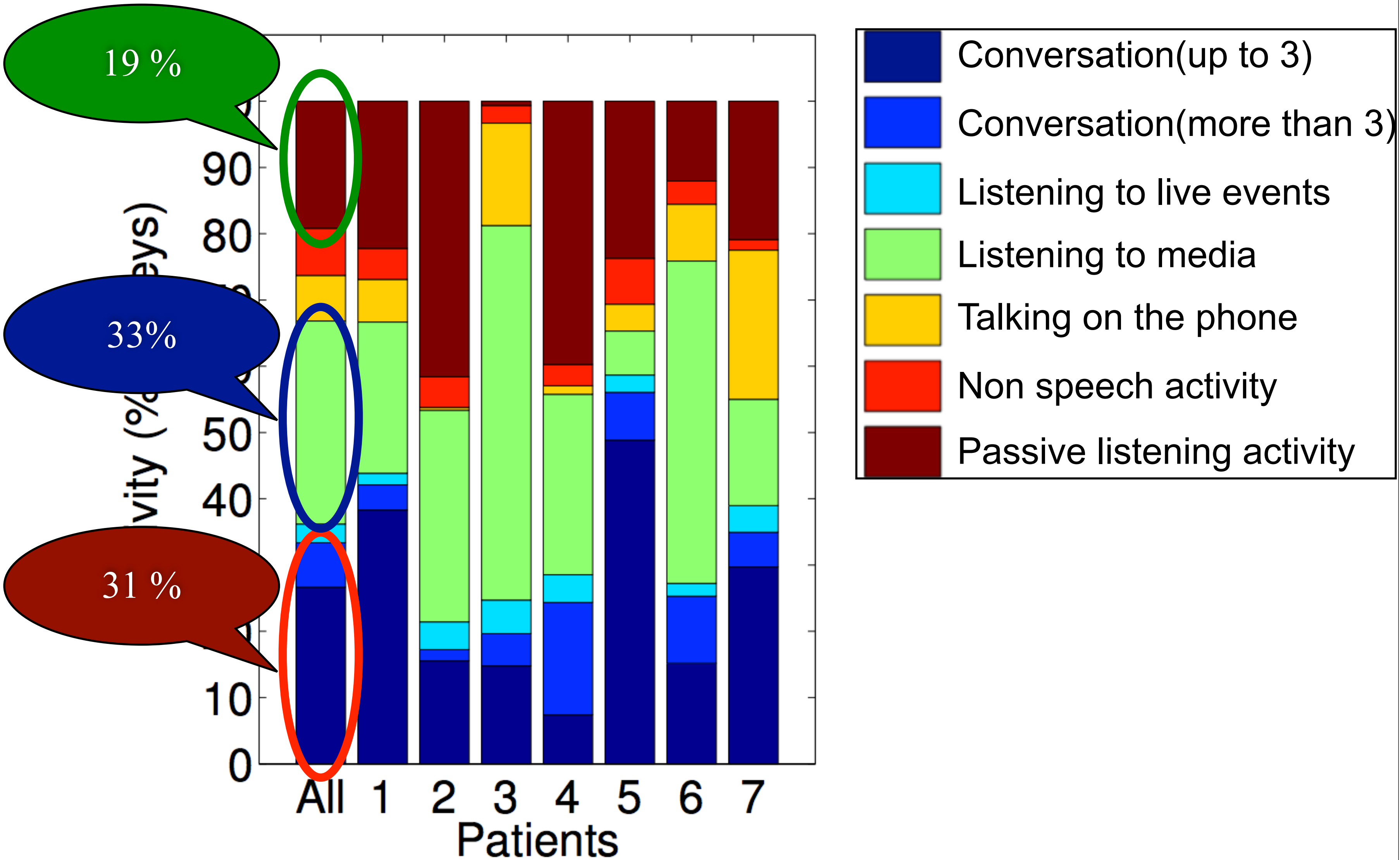

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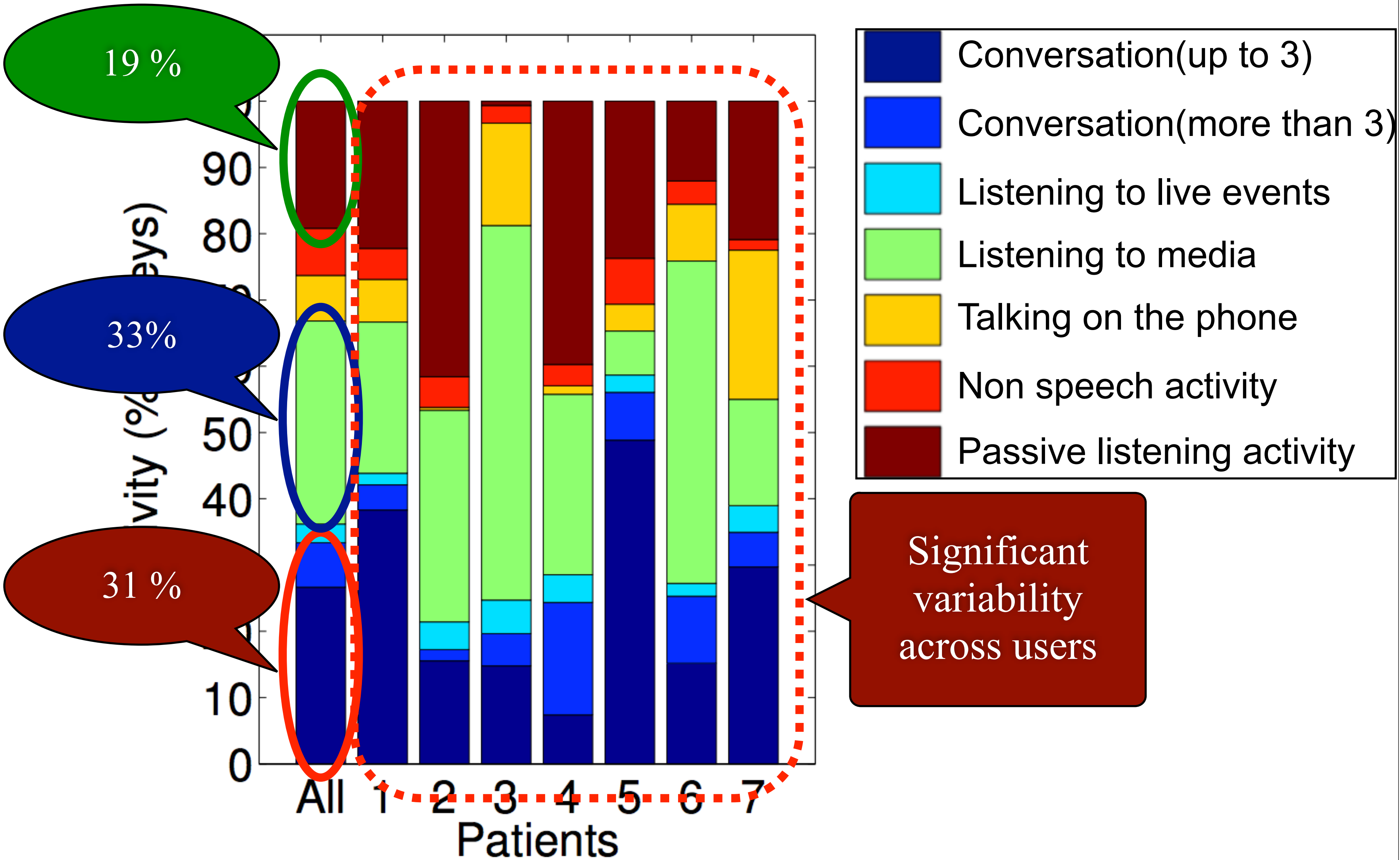
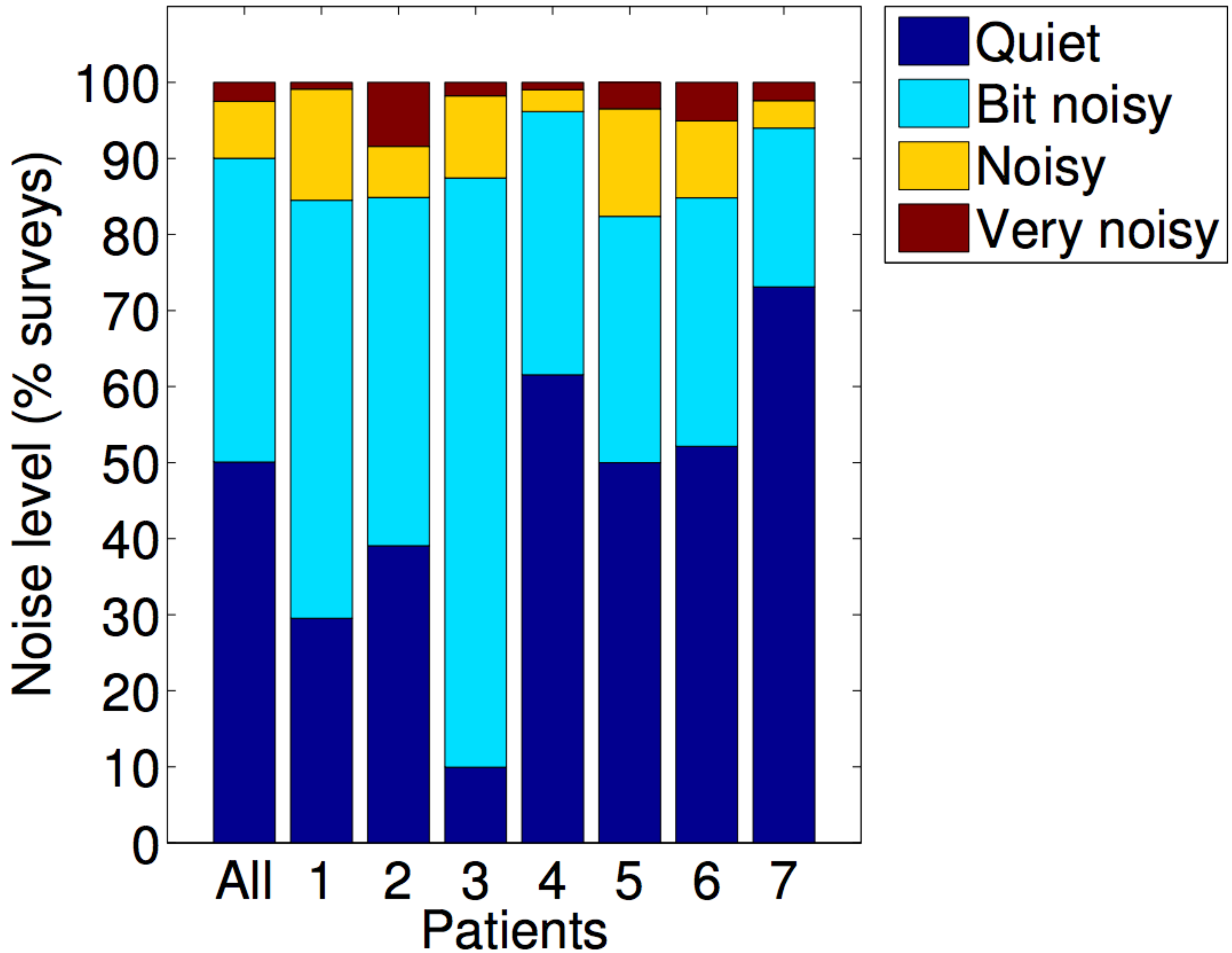


Noise level distribution



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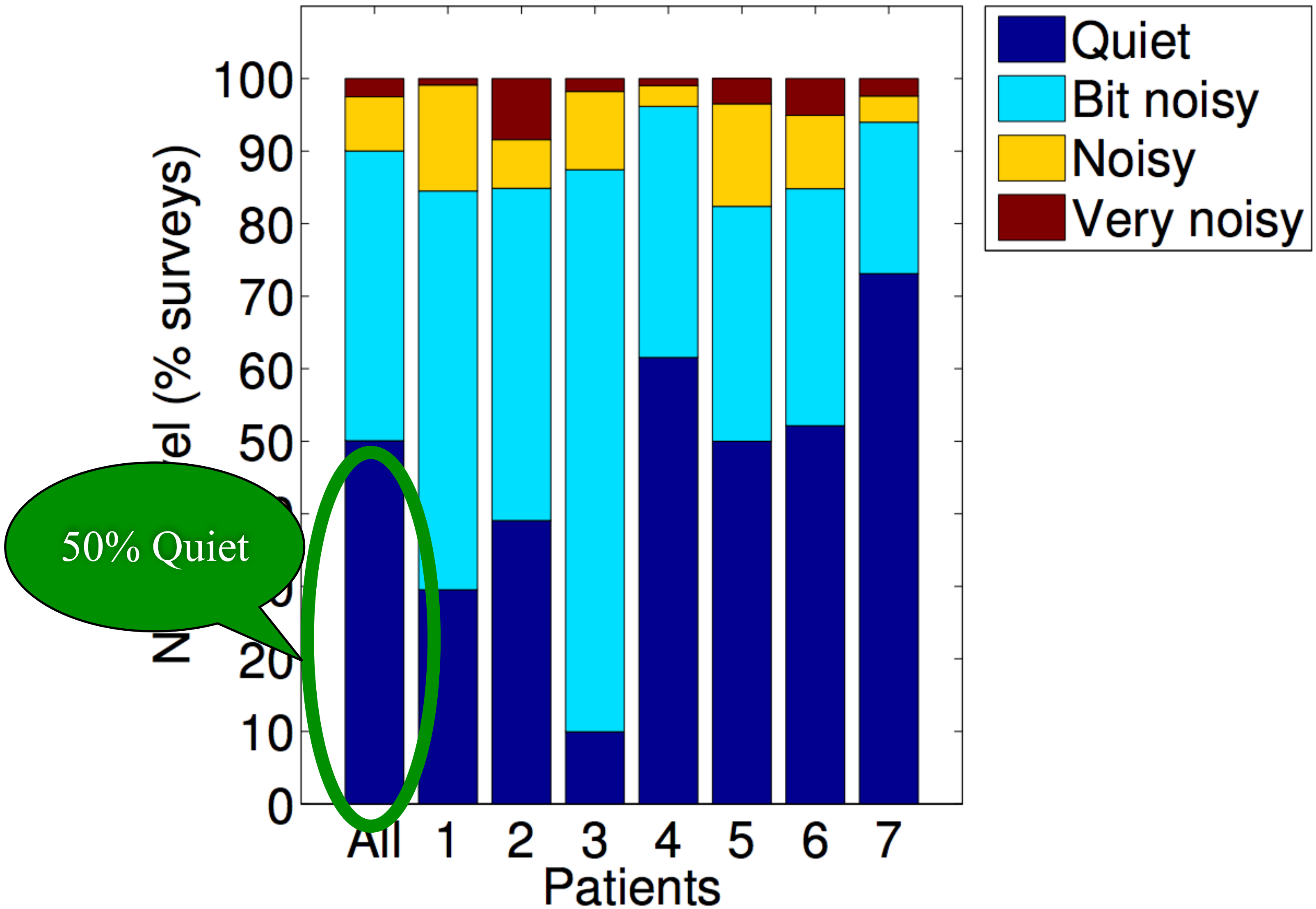

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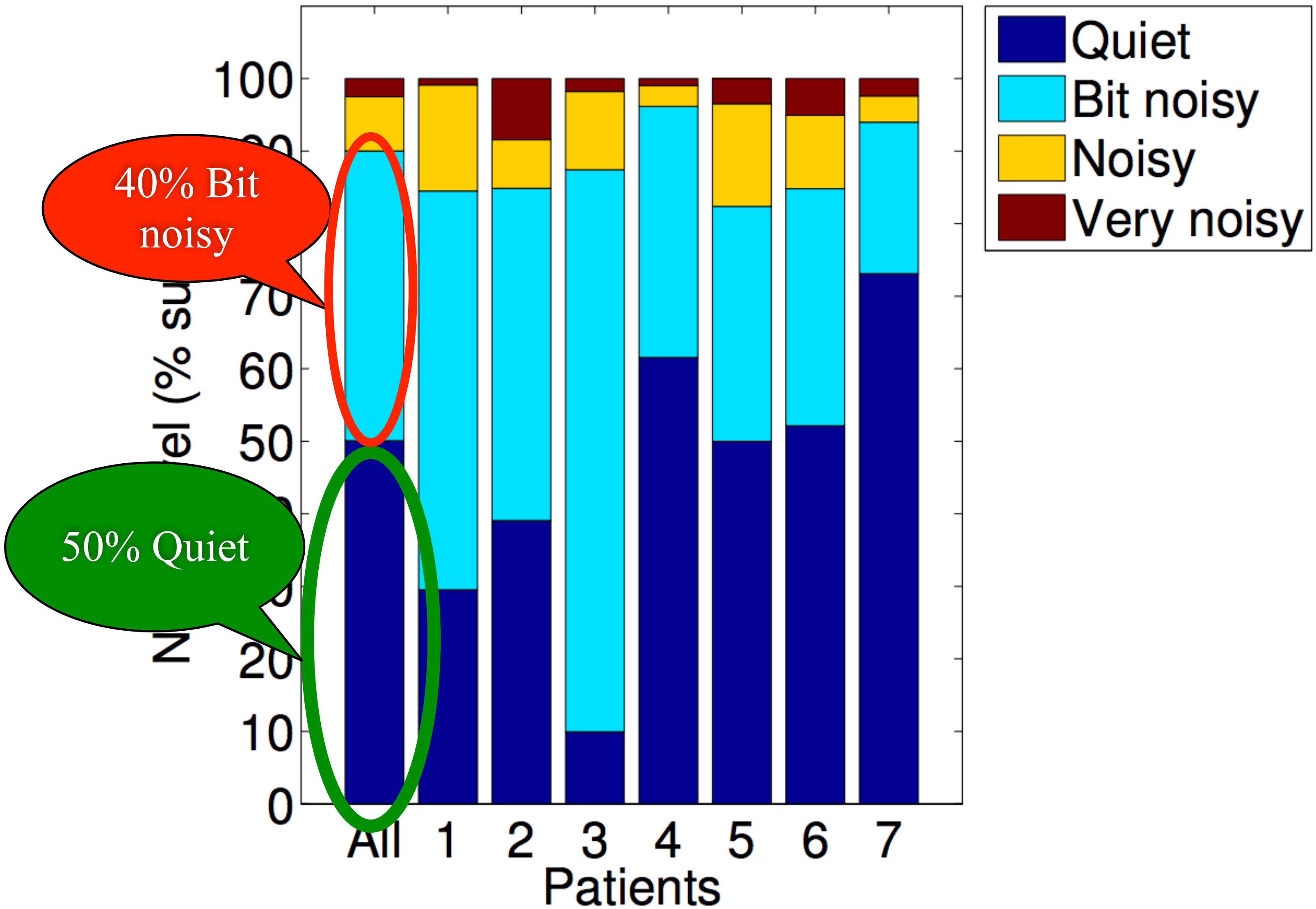

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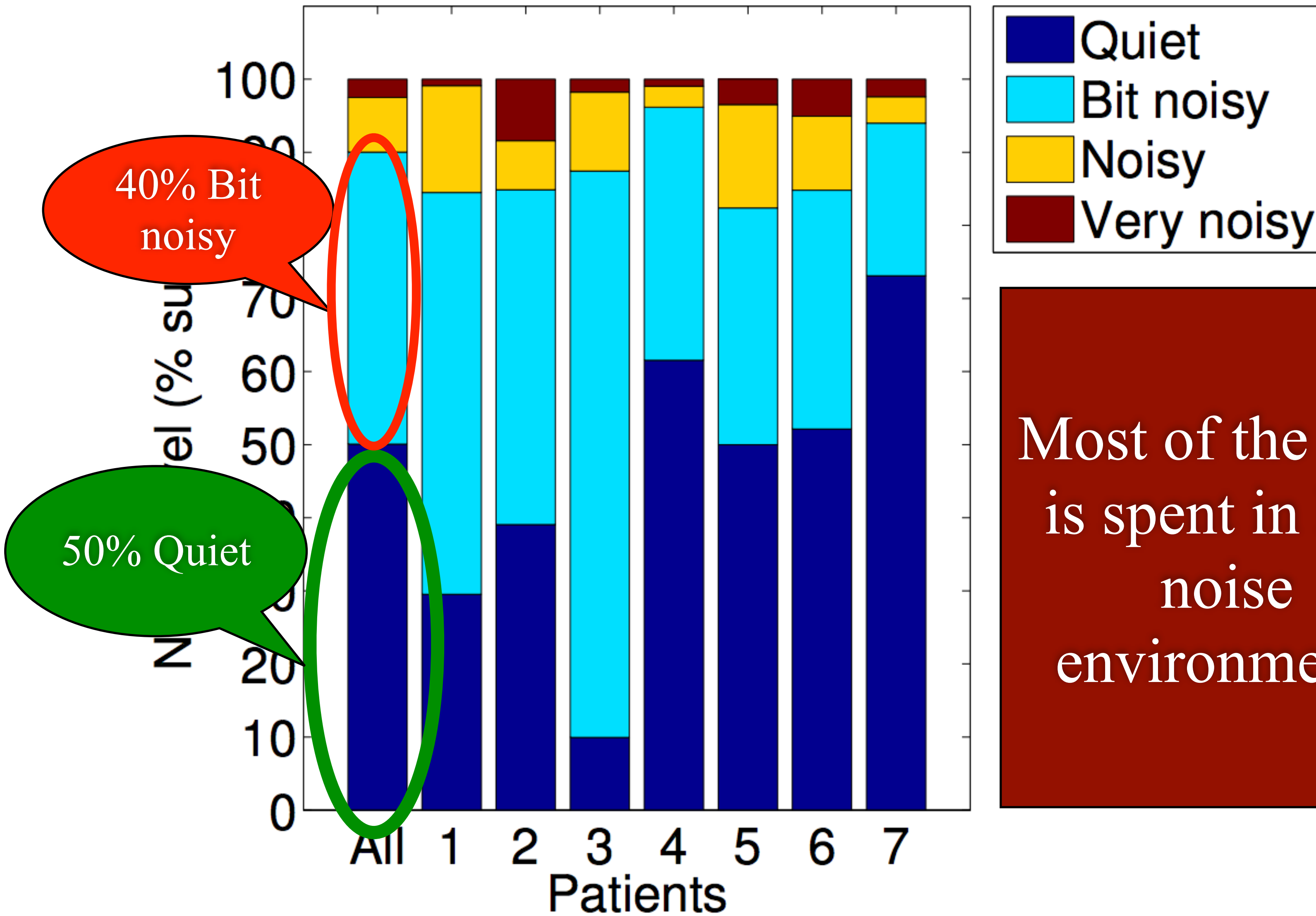
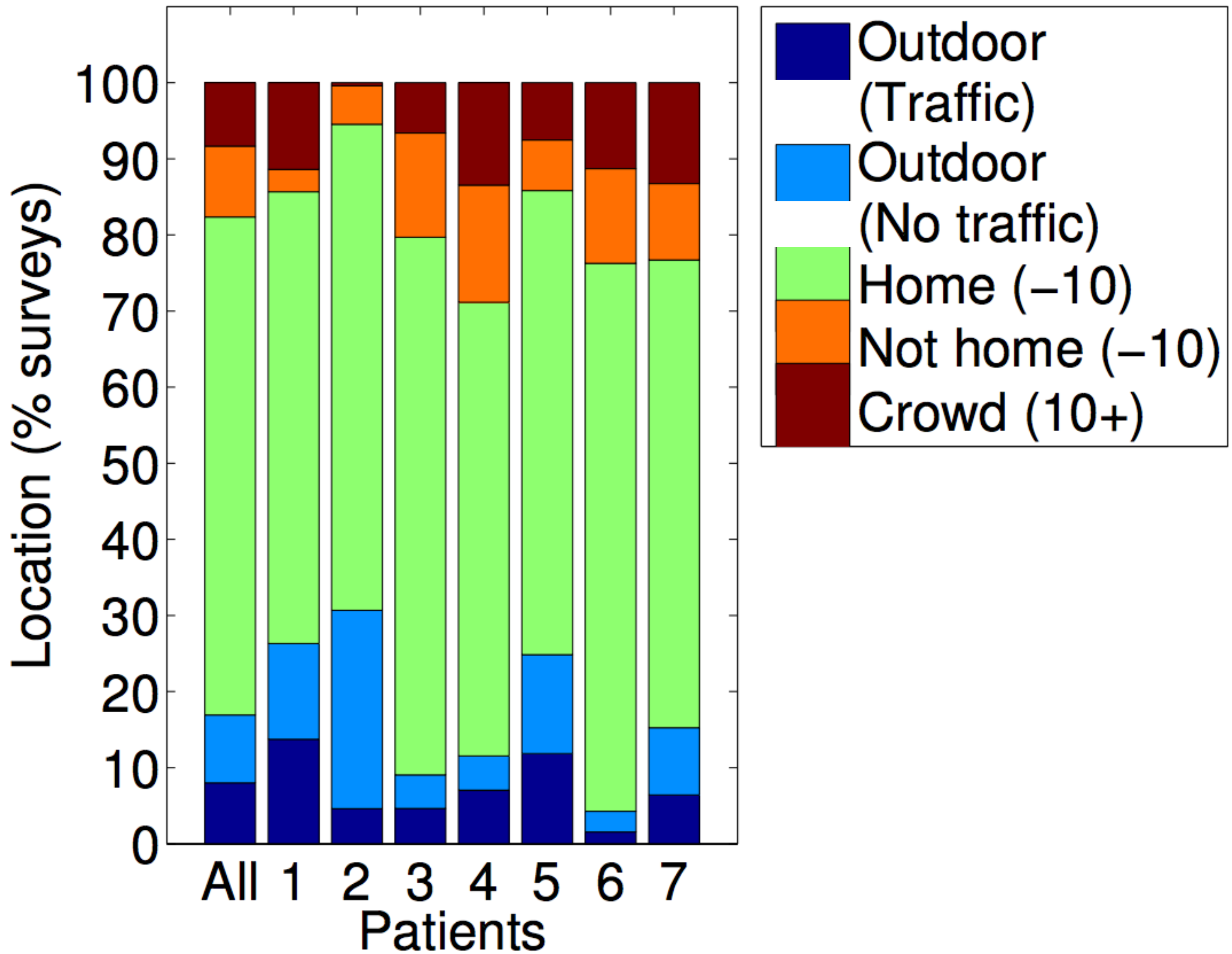


Most of the time is spent in low noise environments

Location context distribution



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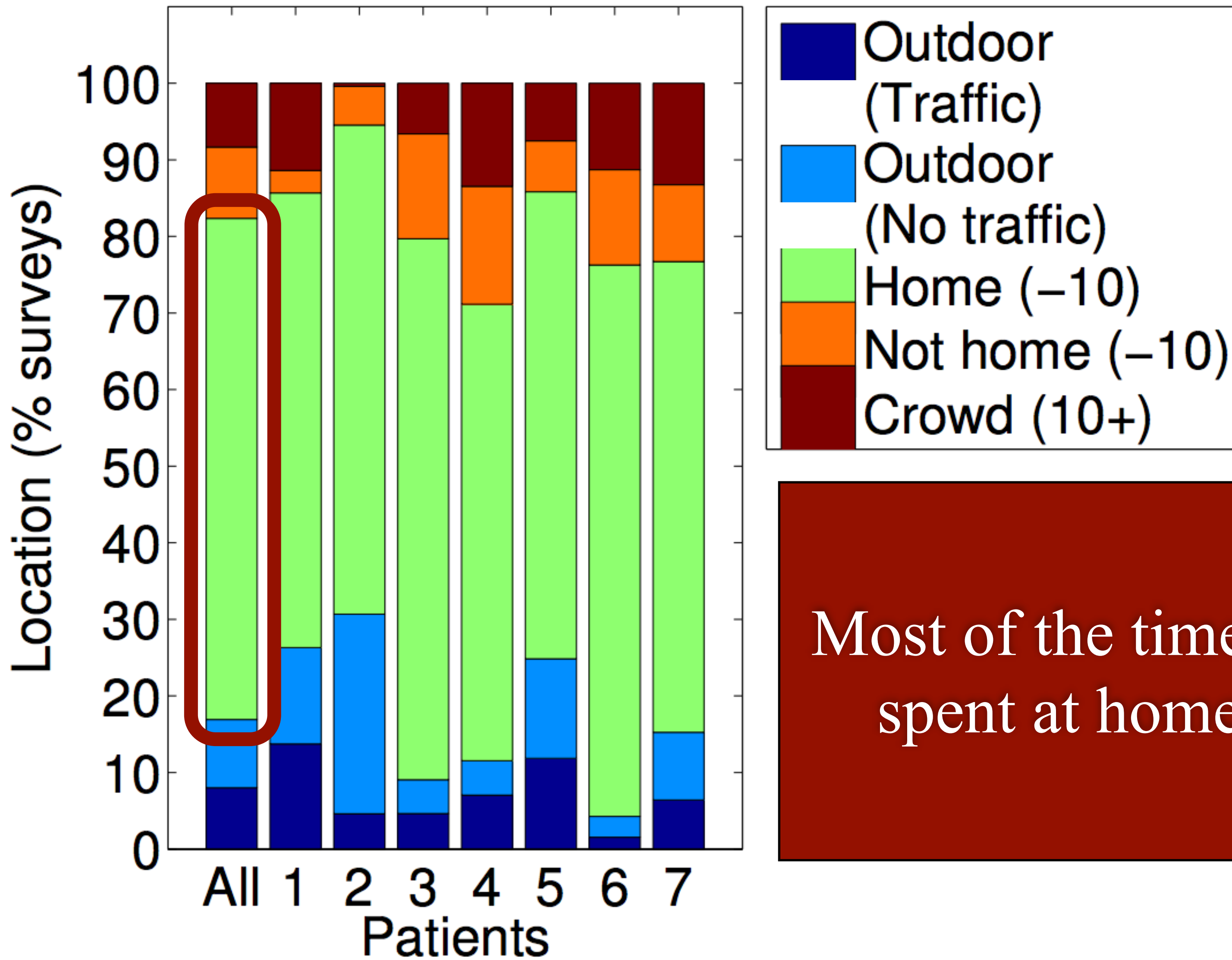
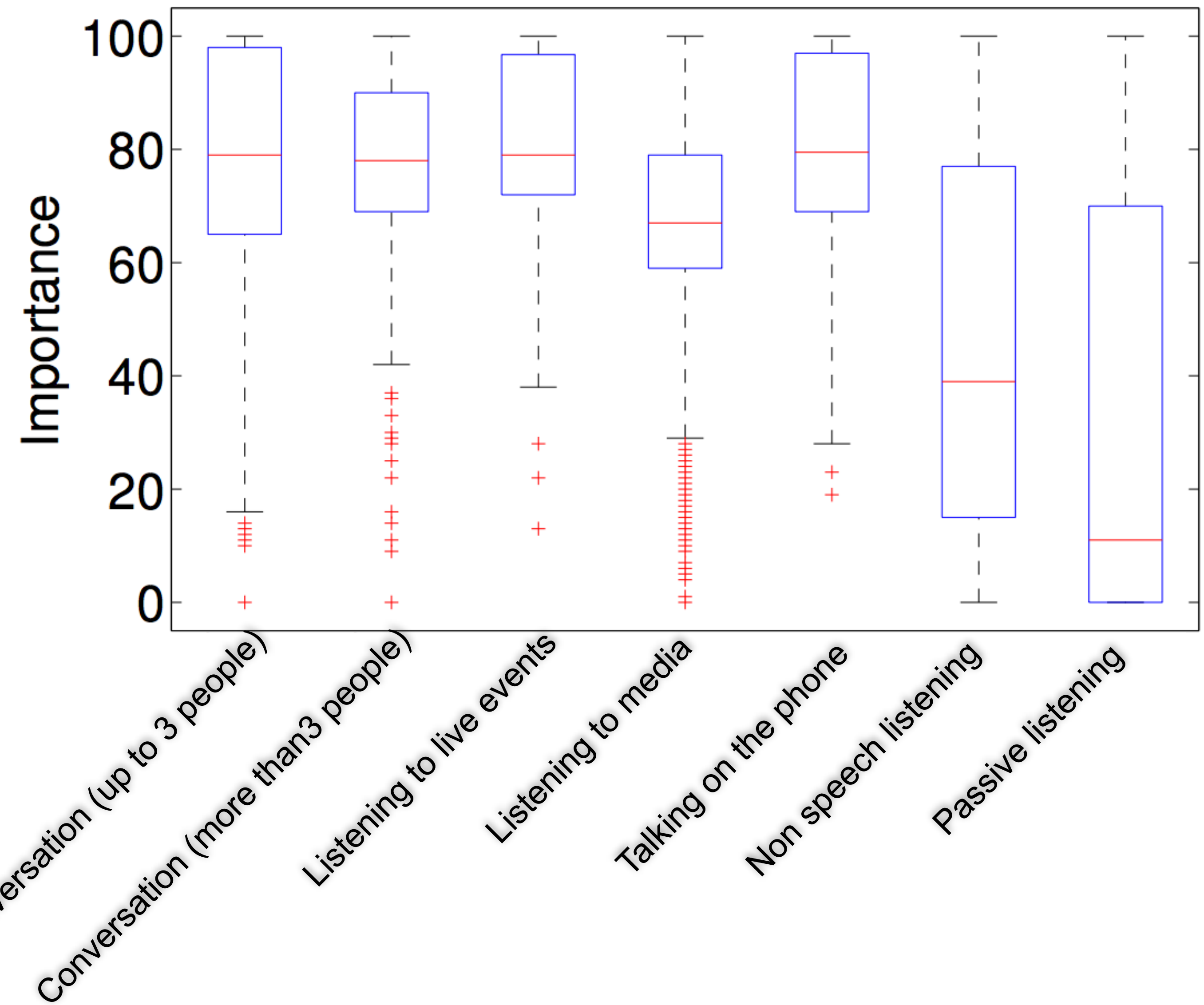


Most of the time is spent at home

Importance of activity context



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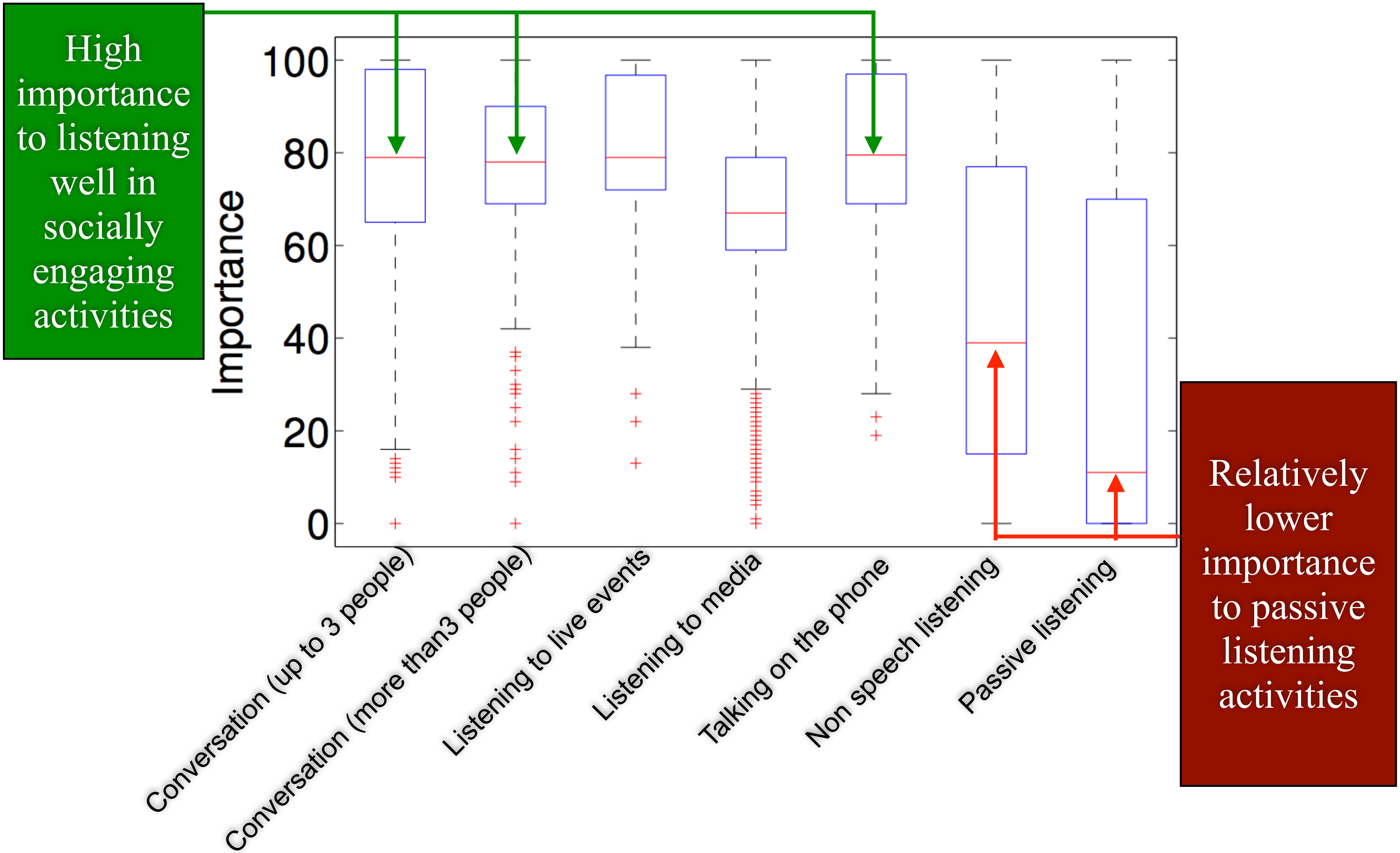
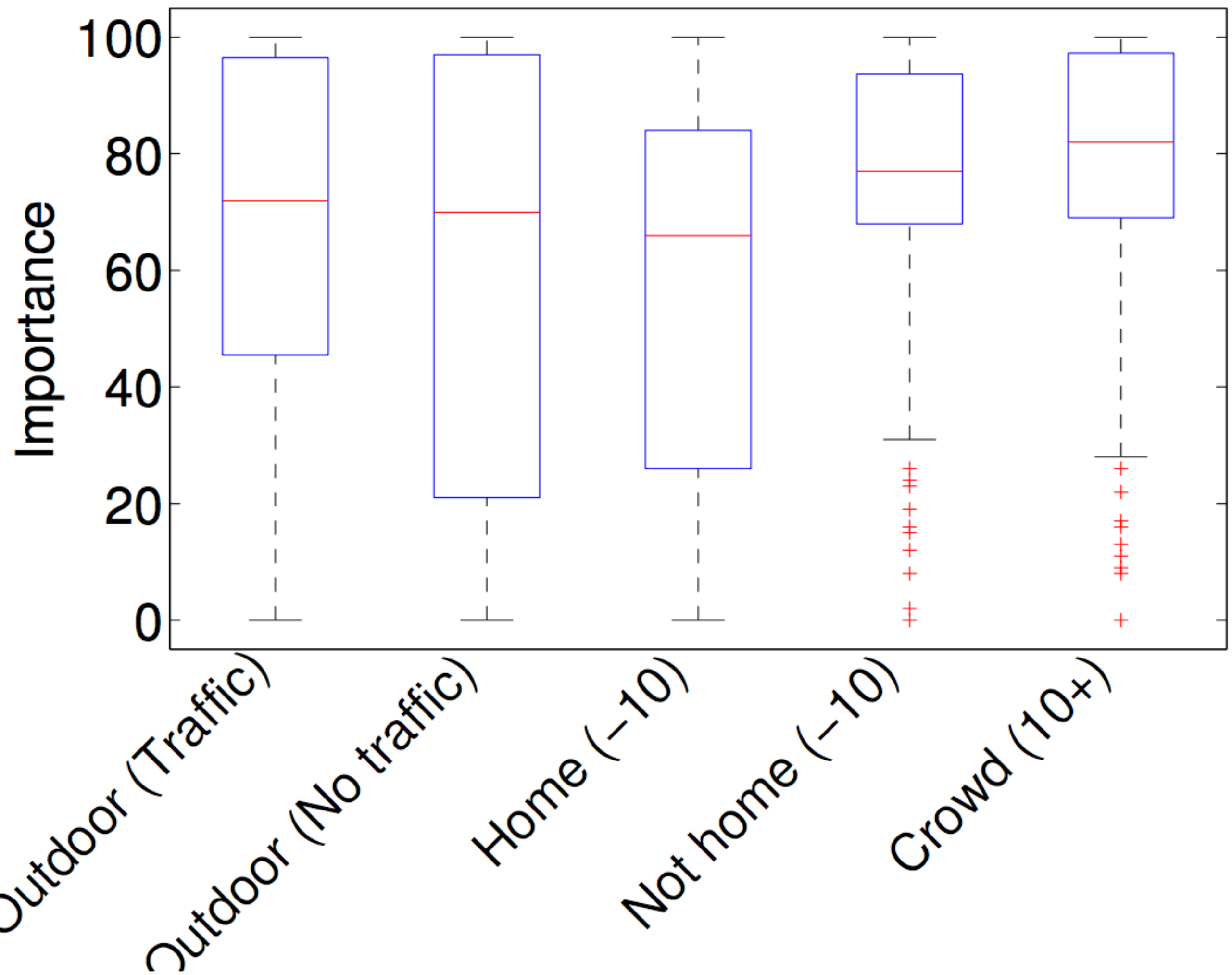
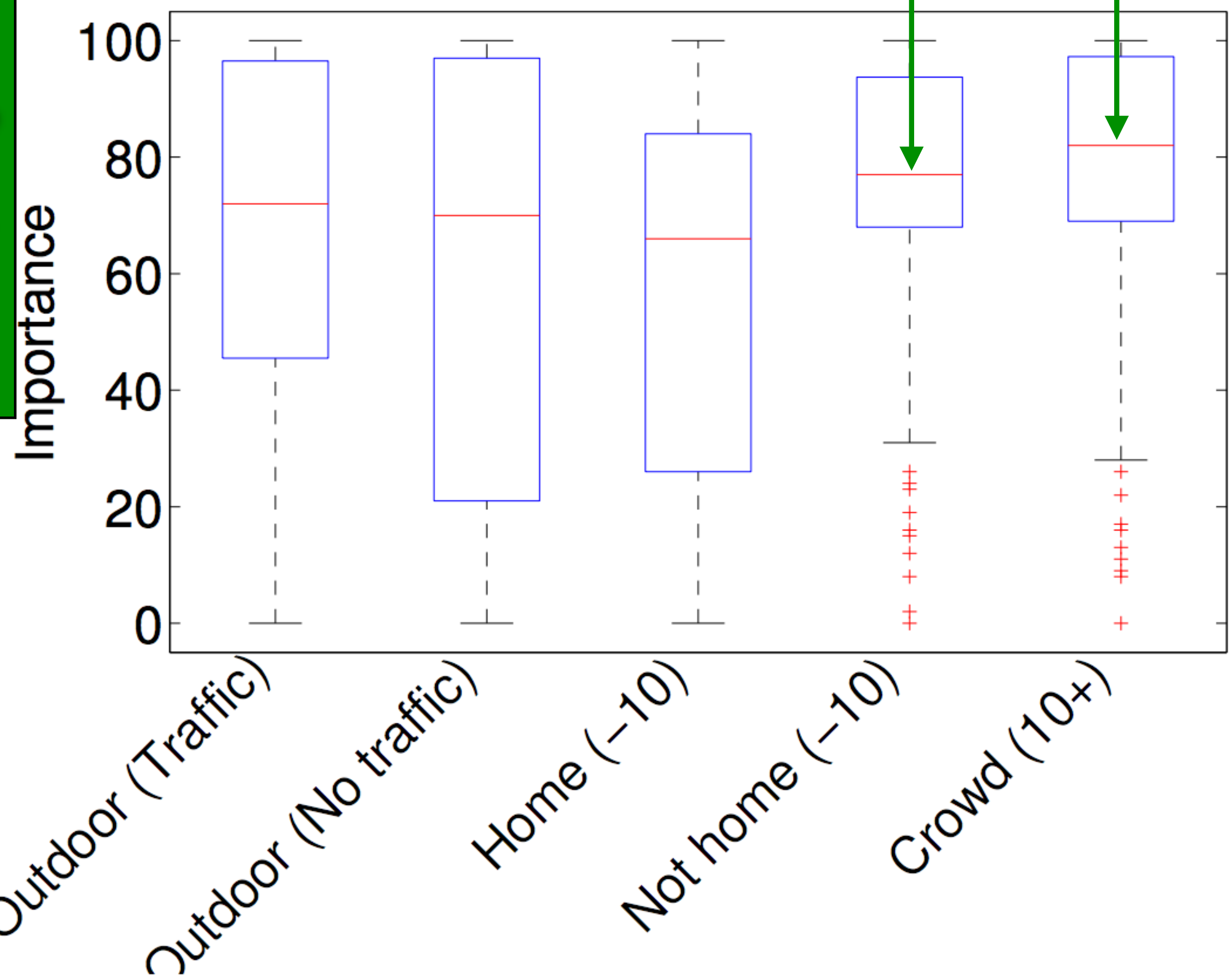


Importance of location context



Importance of location context

High importance to hearing well in unfamiliar locations



On evaluating auditory contexts

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Hearing aid outcome measurement

- Several dimensions are measured:
  - speech perception (**SP**), listening effort (**LE**), loudness (**LD2**), activity participation (**AP**), satisfaction (**ST**), and sound localization (**LCL**)
- Multiple dimensions help in understanding the underlying factors affecting the assessment
- Combining correlated outcomes can
  - reduce inherent noise
  - ease prediction

Existence of correlation

	SP	**LE**	**ST**	**LCL**	LD2	AP
SP	1.0000	0.6178	0.6562	0.5847	0.4785	0.5126
LE	0.6178	1.0000	0.5963	0.5029	0.4732	0.6431
ST	0.6562	0.5963	1.0000	0.5477	0.5429	0.5693
LCL	0.5847	0.5029	0.5477	1.0000	0.3451	0.4030
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- Spearman's rank correlation
- Moderate correlation (**0.34** - **0.65**)
- Consider the four most correlated outcomes to compute the combined score

Creating combined score

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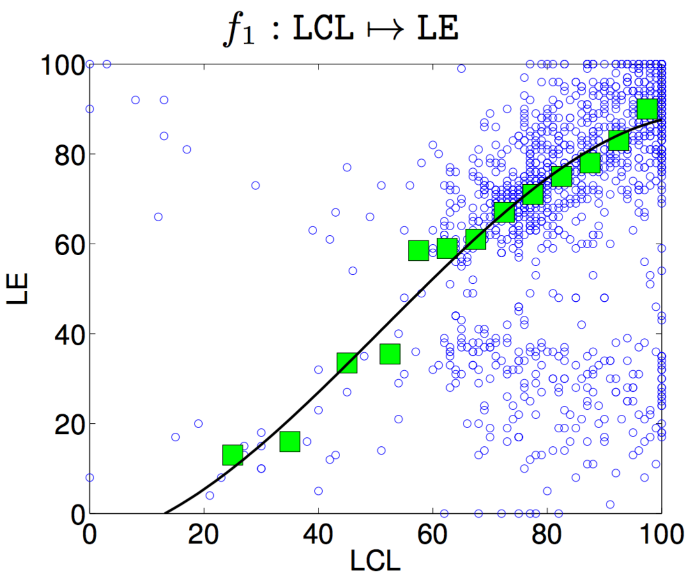

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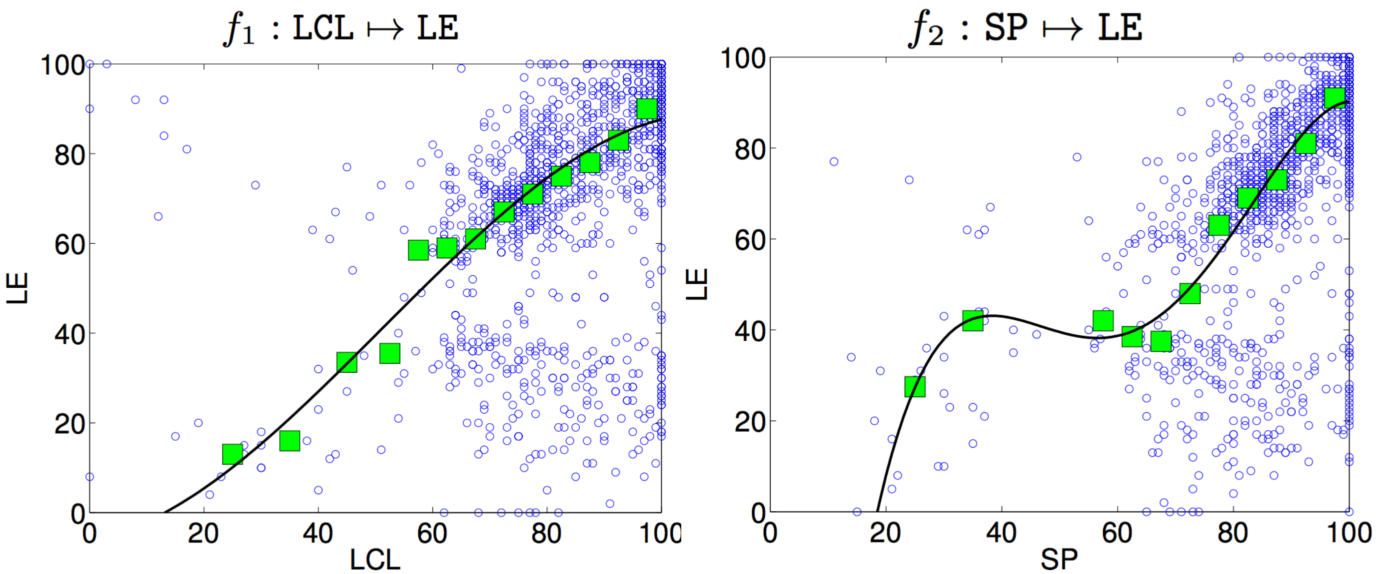

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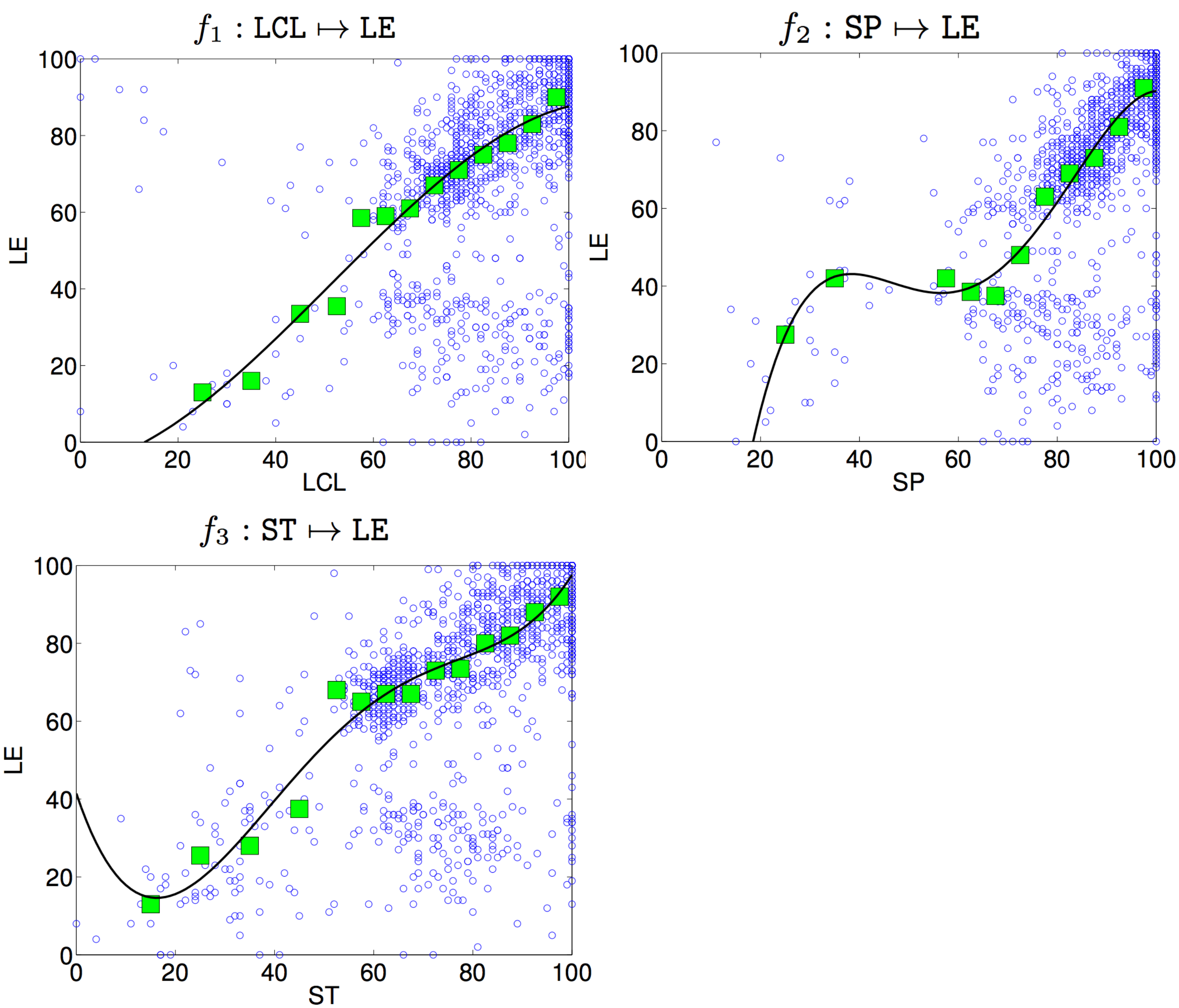

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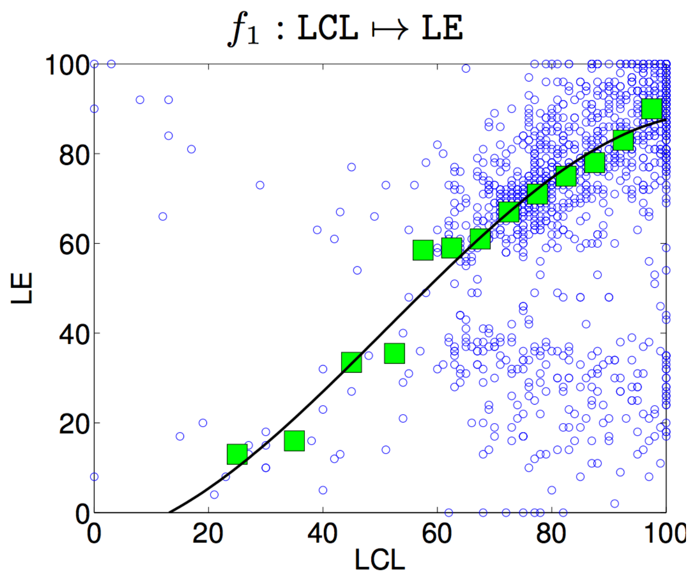

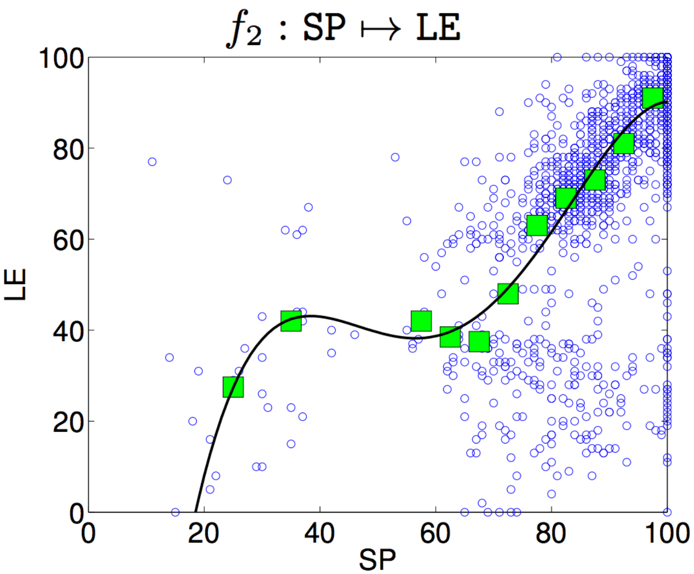

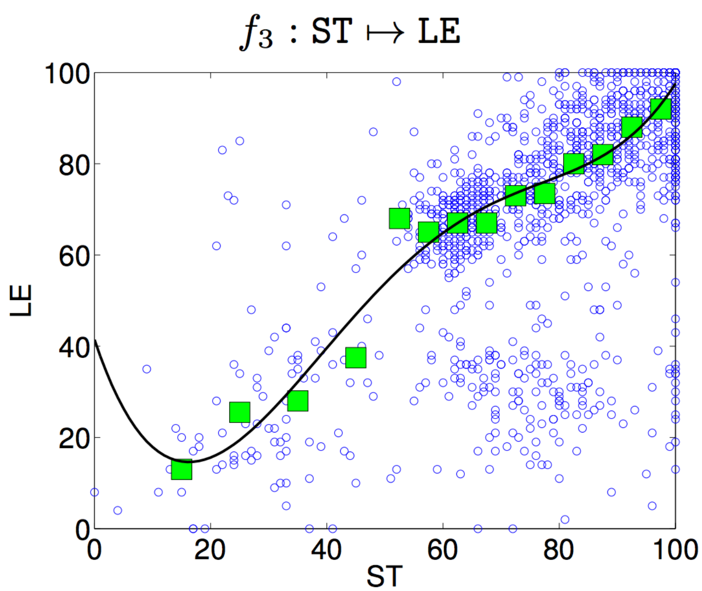

- Mapping to LE as it has the widest distribution
  - better discrimination
- f_1, f_2, and f_3 fit a polynomial
- Combined score (**CB**) = avg(**LE**, f_1, f_2, f_3)

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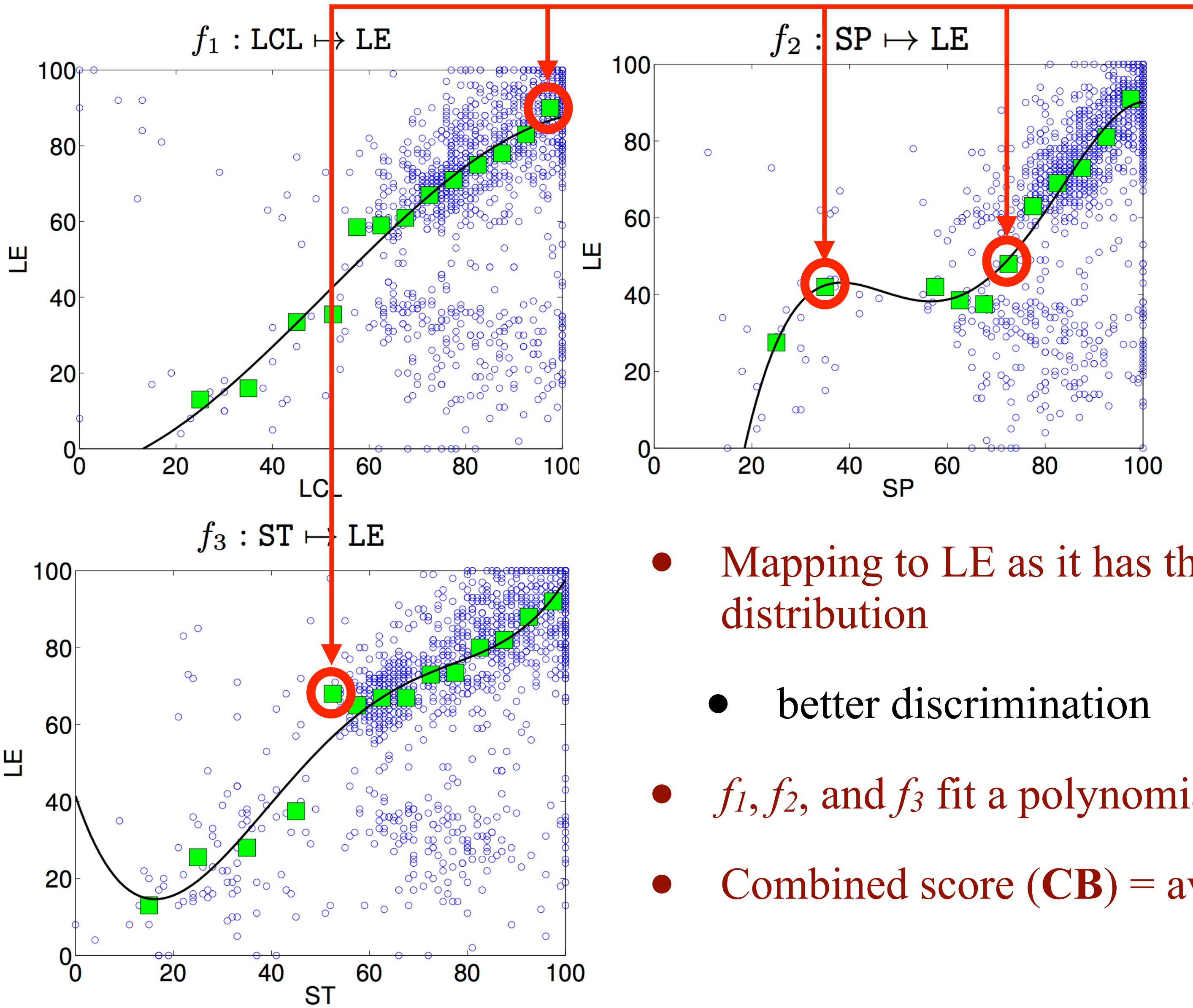

Scores divided into bins, curve fitted through median scores in each bin

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On correlation between outcomes

Auditory contexts:

- *conversations and listening to media are most prevalent*
- *social engagement necessitates hearing well*

Correlation between outcomes:

- ***hearing aid outcomes are moderately correlated***
- ***calculated a combined score***

Can the hearing aid outcomes be predicted?

Remainder of the talk

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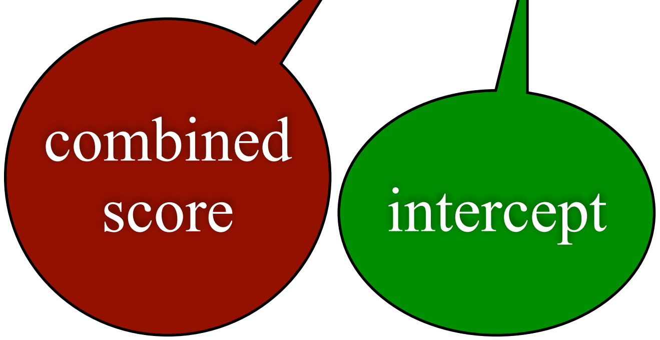

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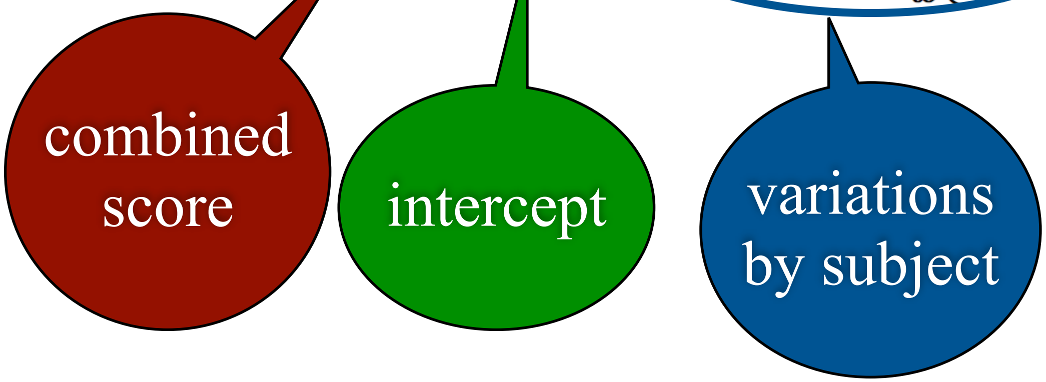

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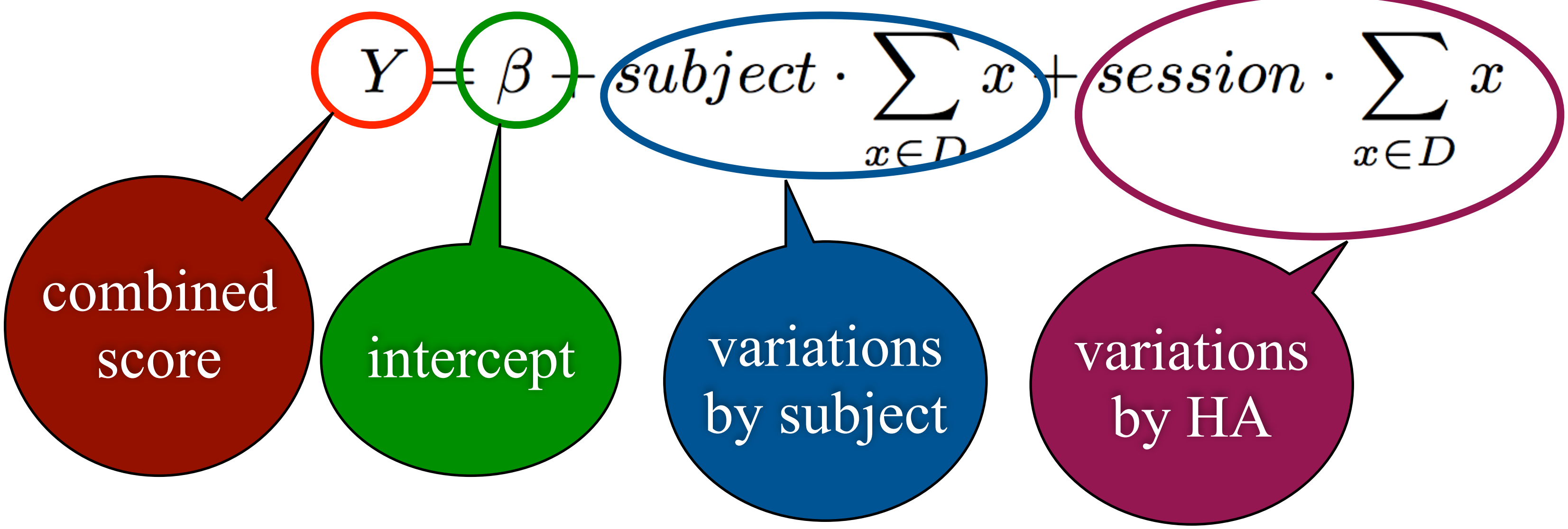

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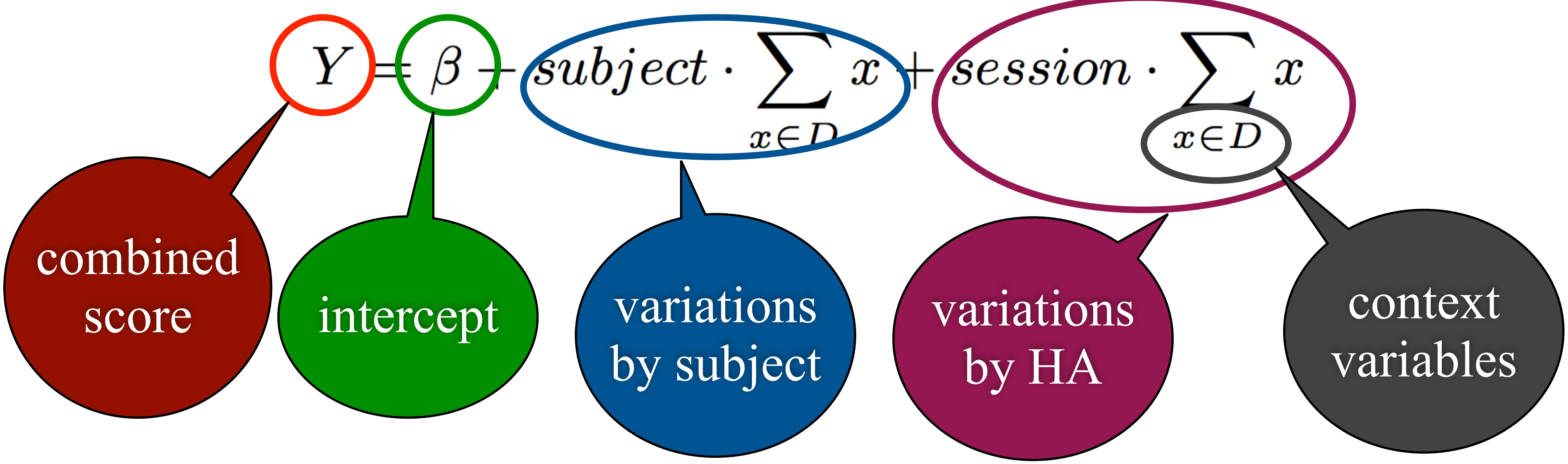

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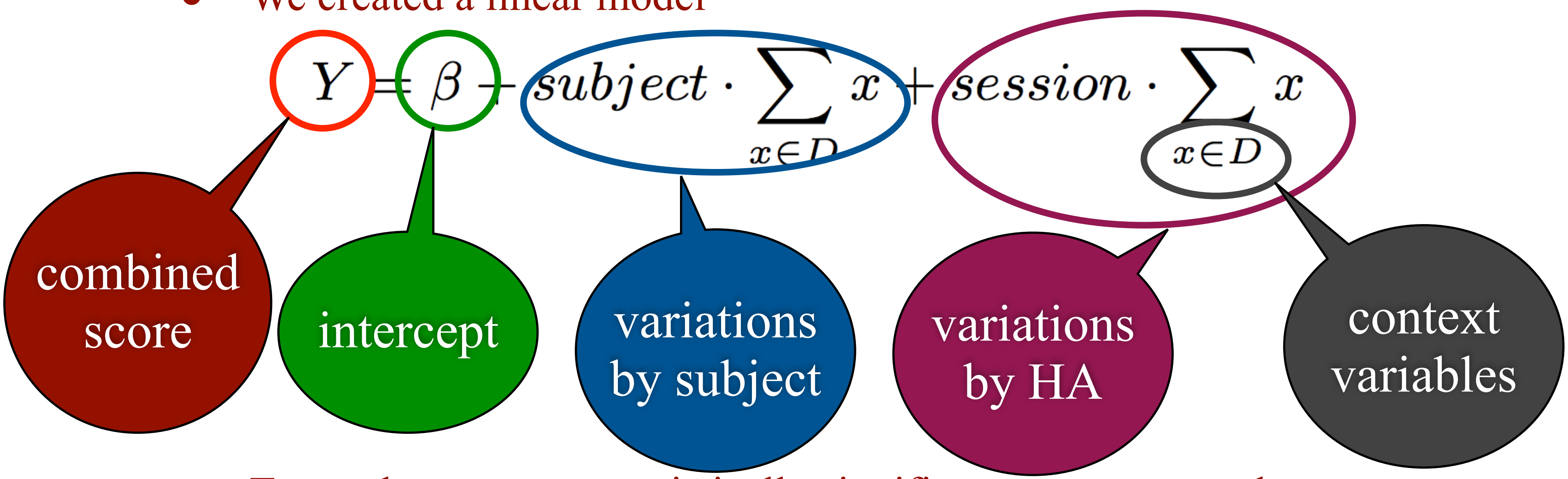

- Terms that were not statistically significant were removed

Evaluating the prediction

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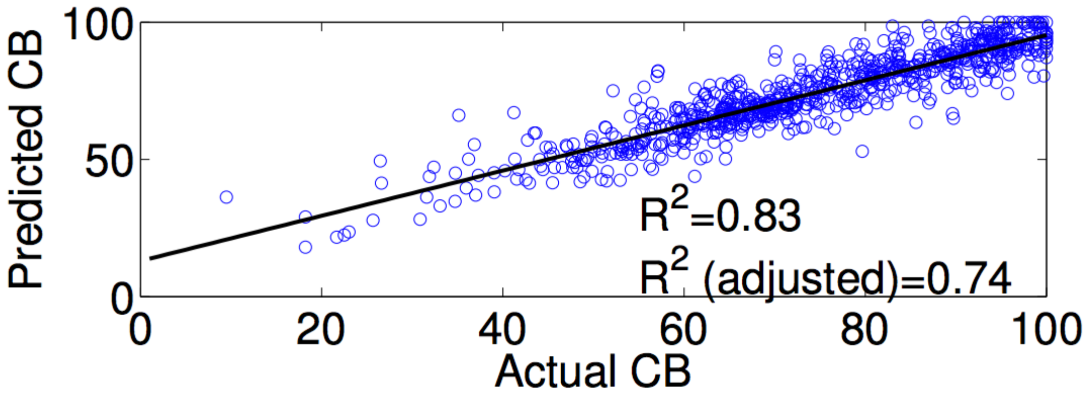

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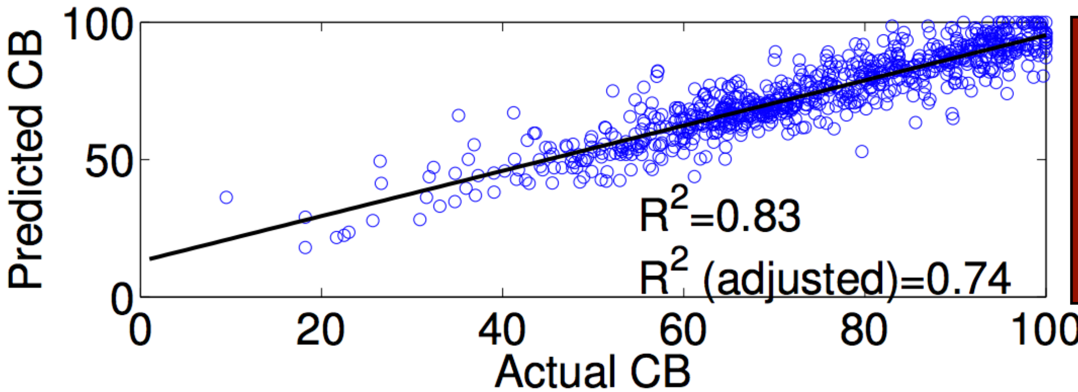

The high R^2 supports the goodness of fit

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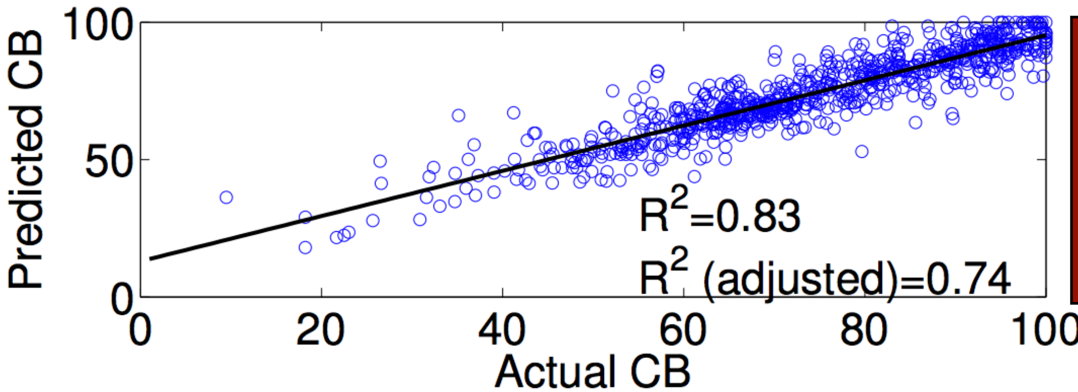

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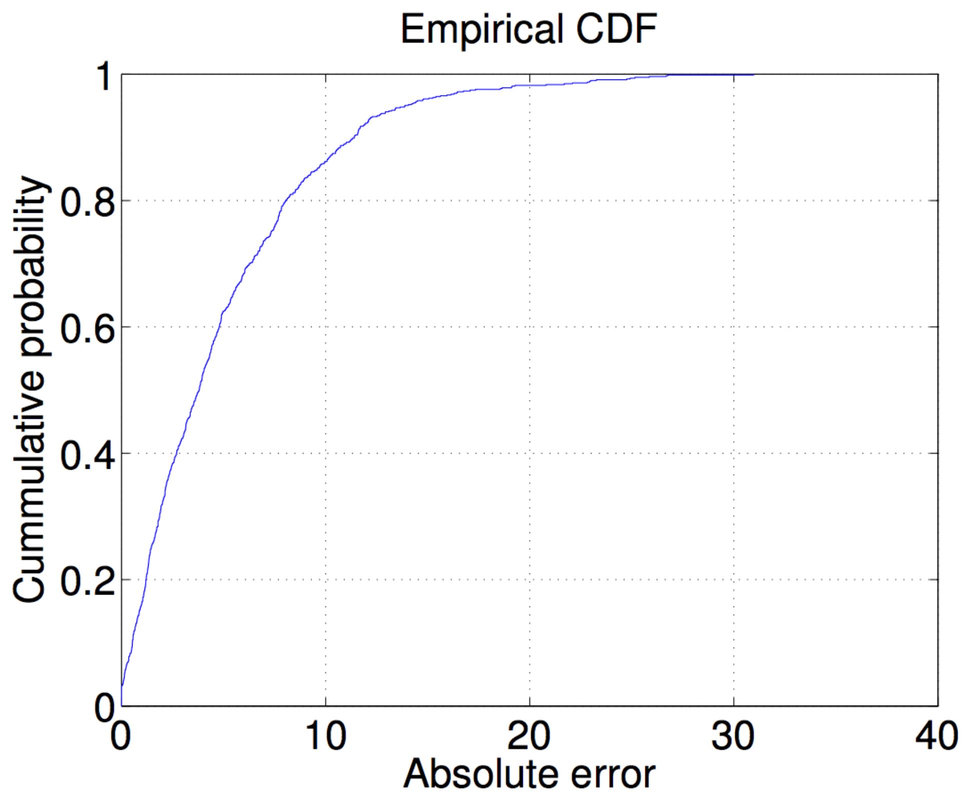

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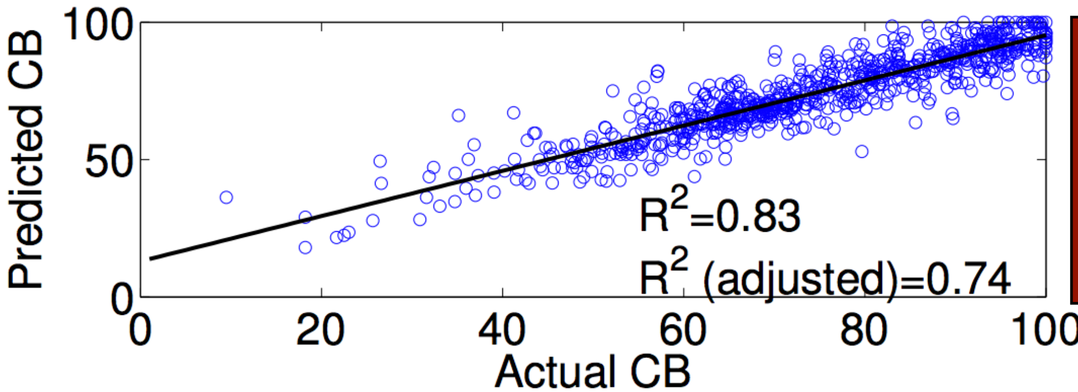

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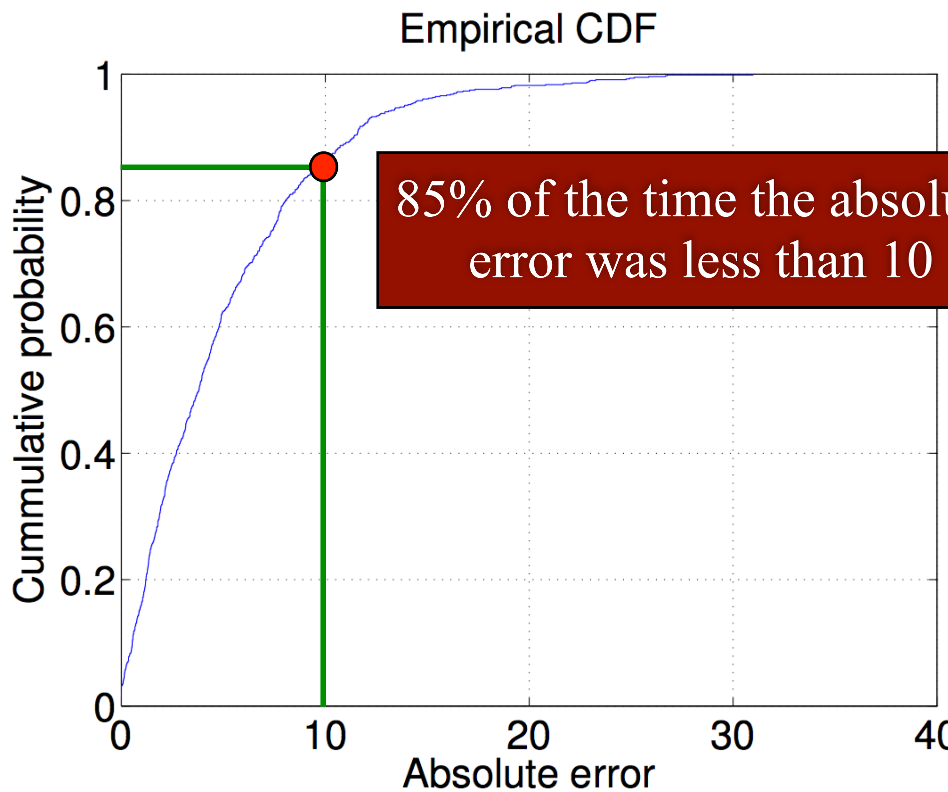

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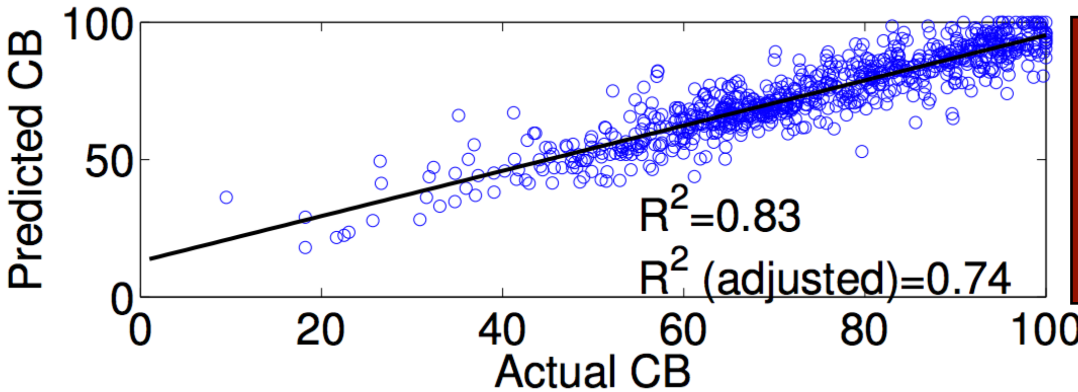

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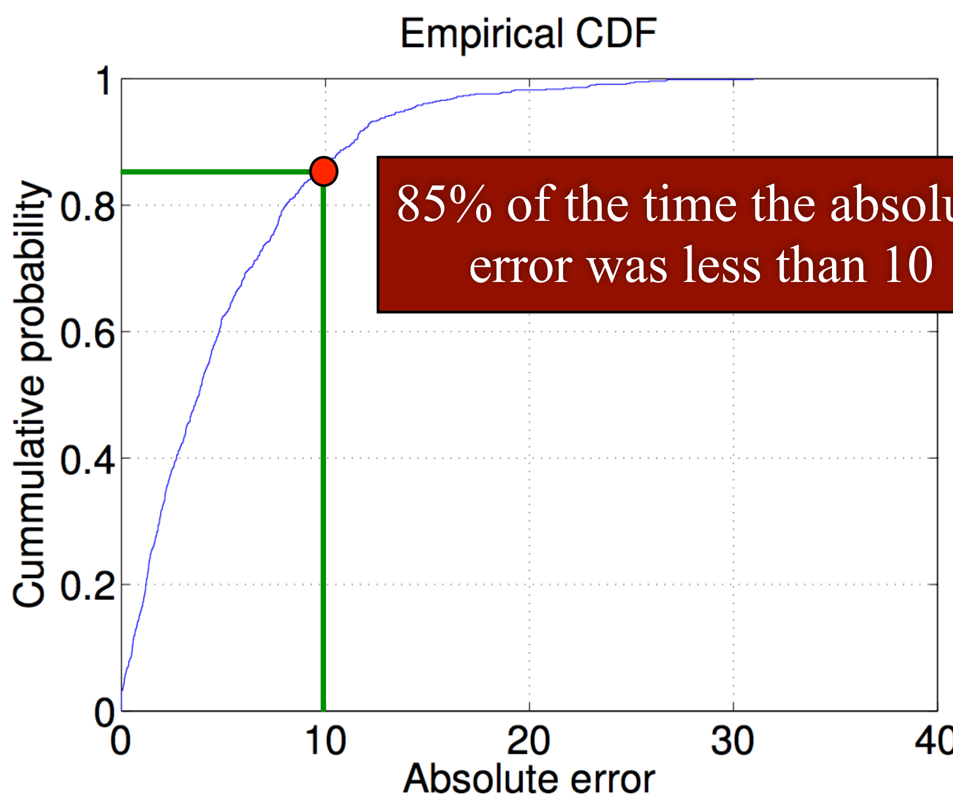
10 fold cross validation based classification of good and bad outcomes was 78% accurate



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Correlation between outcomes:

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Outcome prediction:

- ***auditory contexts + hearing aid features help in understanding outcomes***

Conclusion

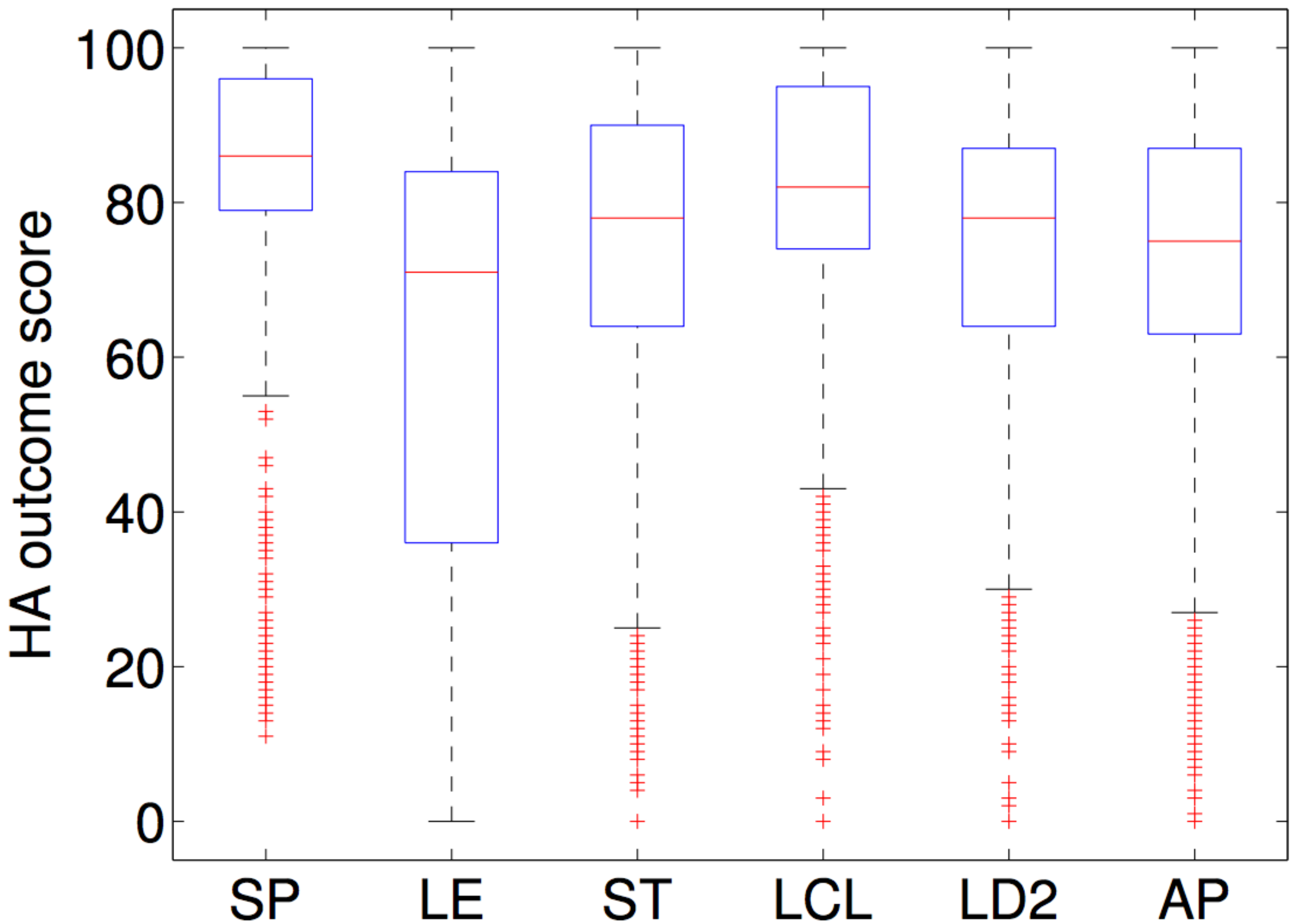
- Hearing aid outcomes depend on auditory contexts
  - AudioSense characterizes auditory contexts and outcomes accurately using subjective and objective data captured in-situ
- The proposed methodology enables new insights
  - prevalence of auditory contexts
  - highlighting the dependence of outcomes on contexts
- Future work
  - extend study to 55 users (largest study to date)
  - use audio data to characterize auditory contexts
  - novel sampling techniques to reduce the evaluation burden

Acknowledgement

- Audiology collaborator: Elizabeth Stangl
- National Science Foundation (1144664)
- Roy J. Carver Foundation (14-43555)
- National Institutes of Deafness and Other Communication Disorders - National Institutes of Health
(R03 DC012551)

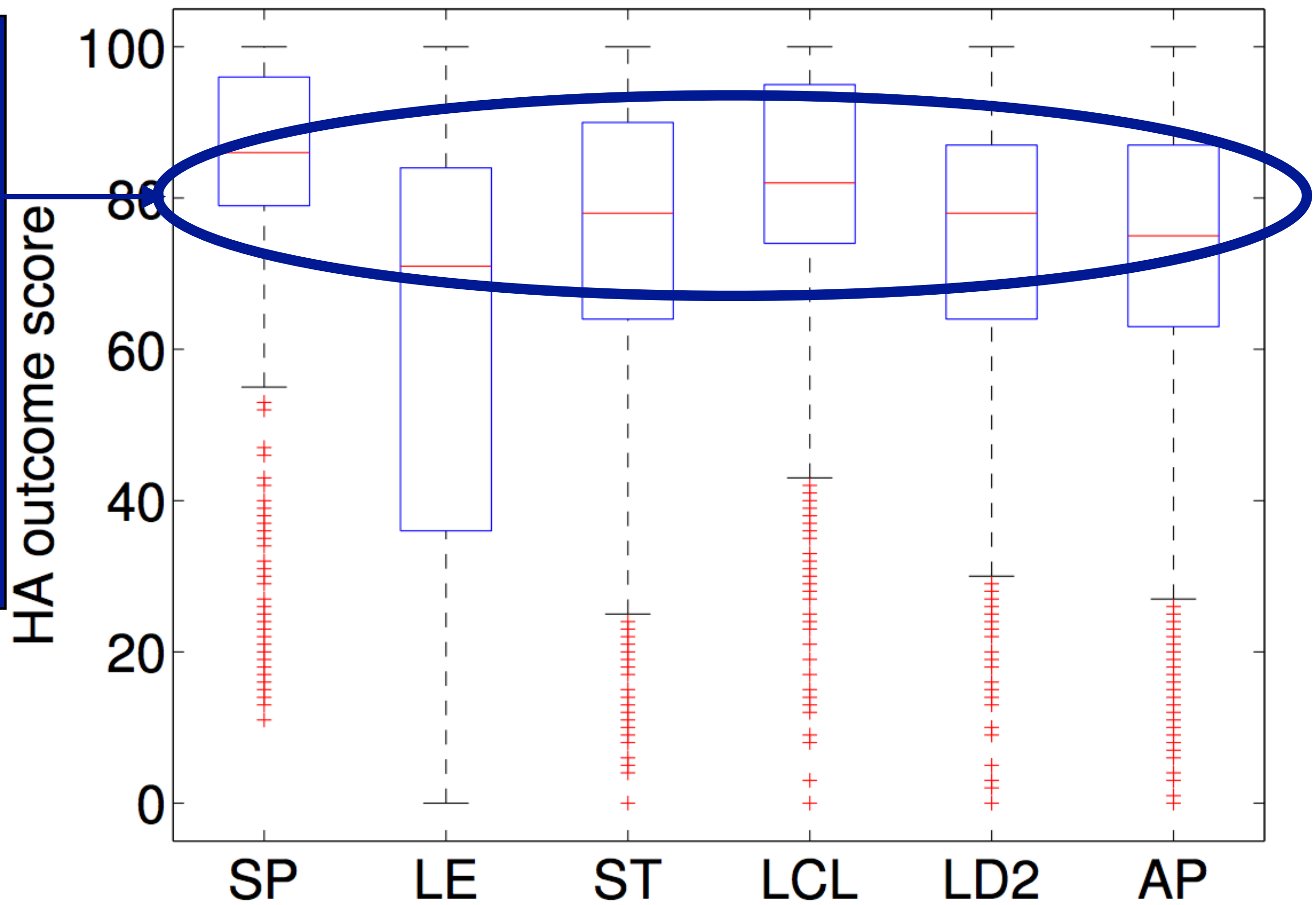
Support slides follow

Distribution of outcomes



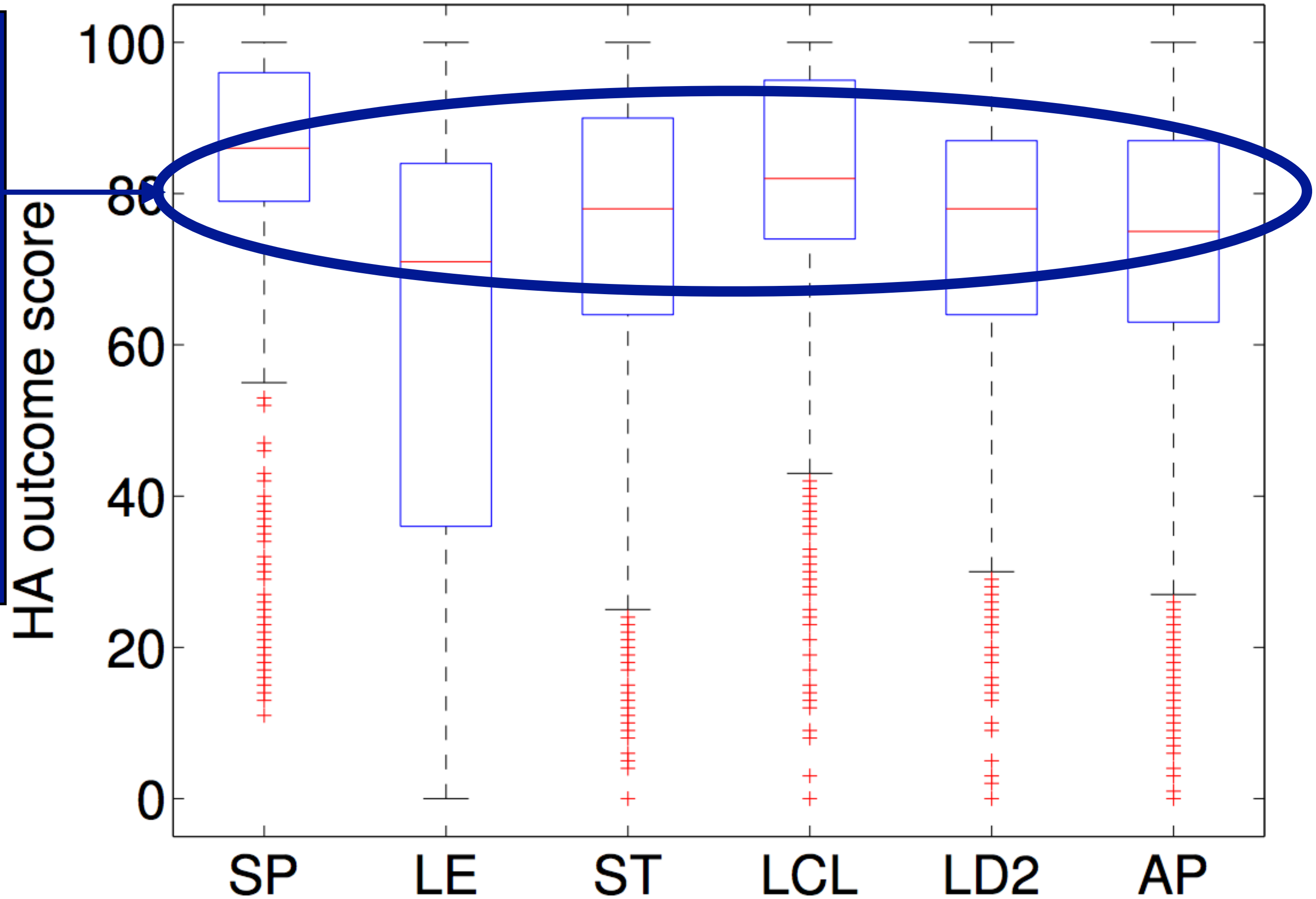
Distribution of outcomes

Scores are generally high, median range 71-86 across all dimensions



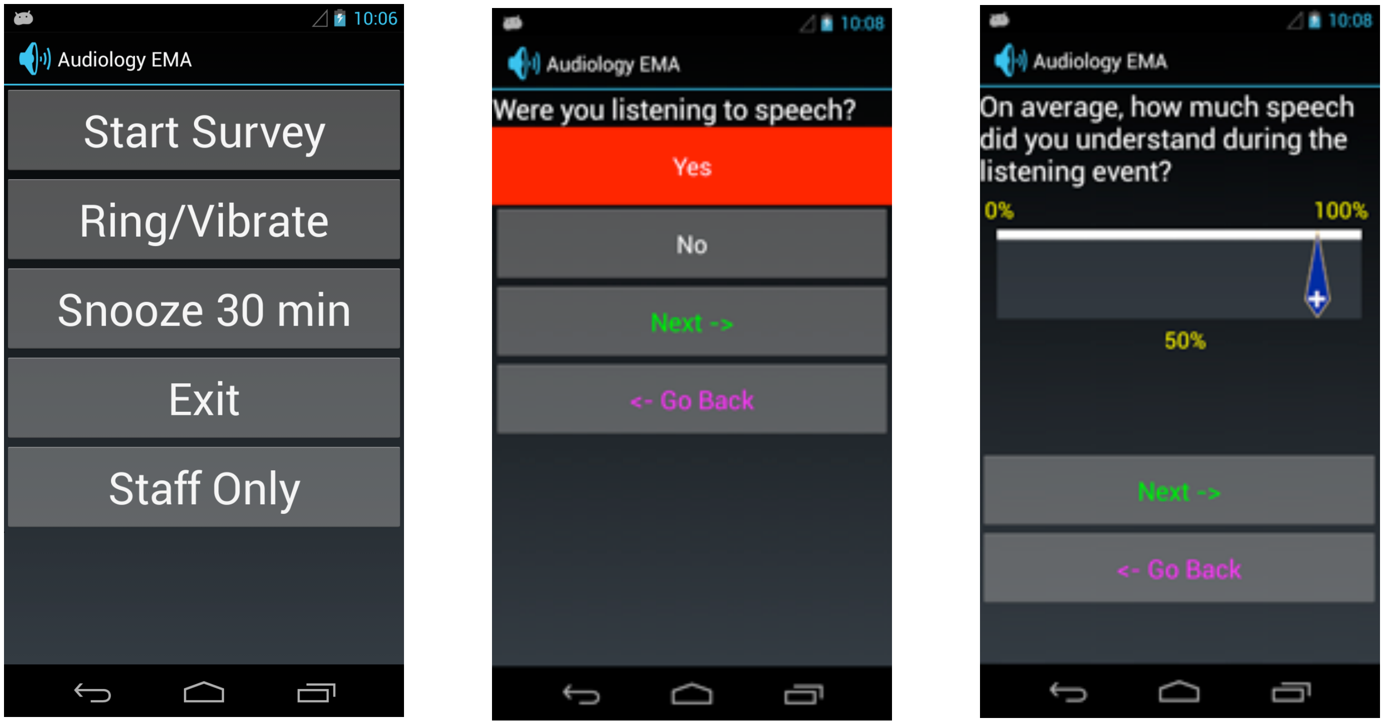
Distribution of outcomes

Scores are generally high, median range 71-86 across all dimensions



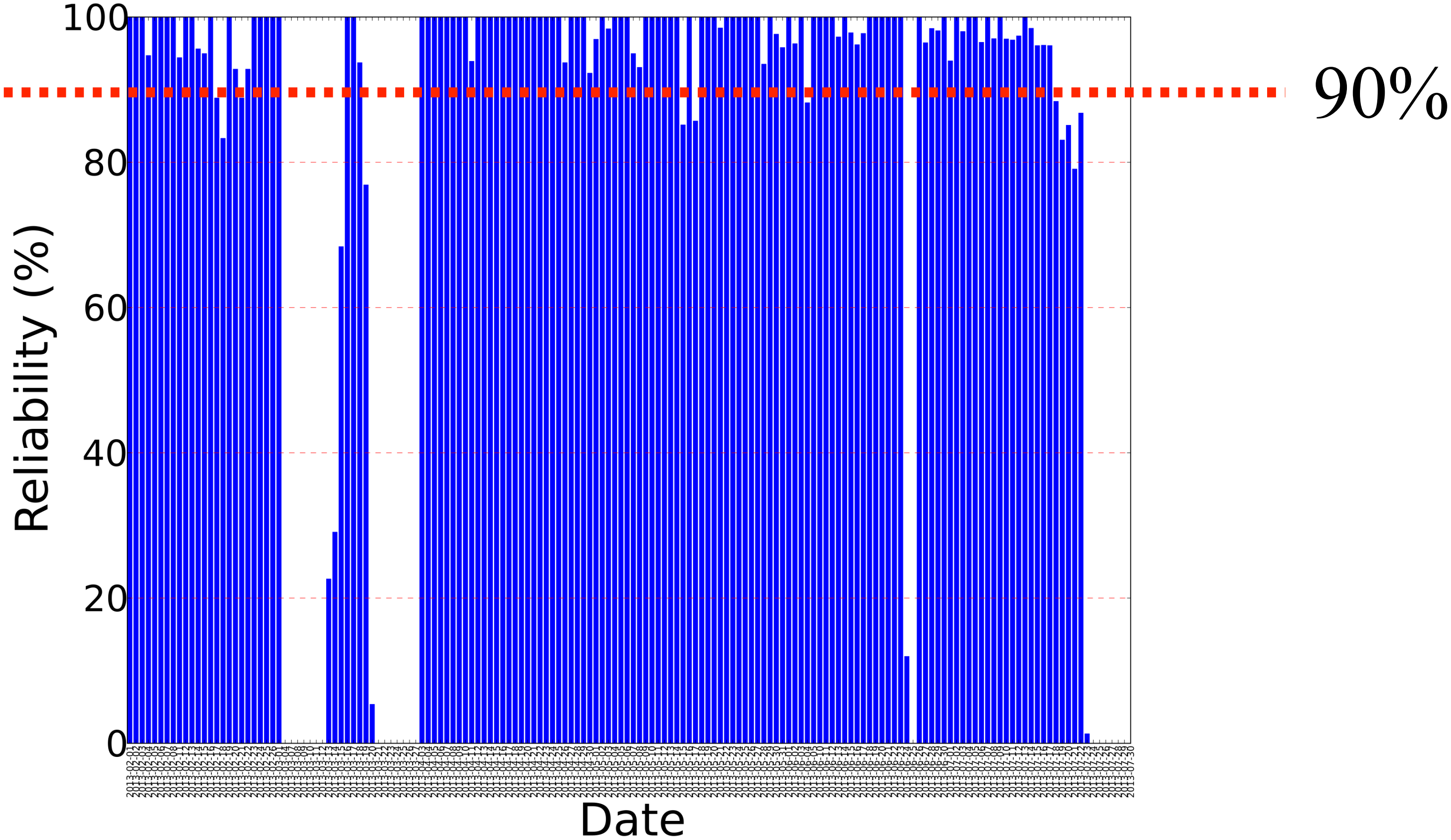
Score variability indicate presence of contexts with scope for improvement

AudioSense application



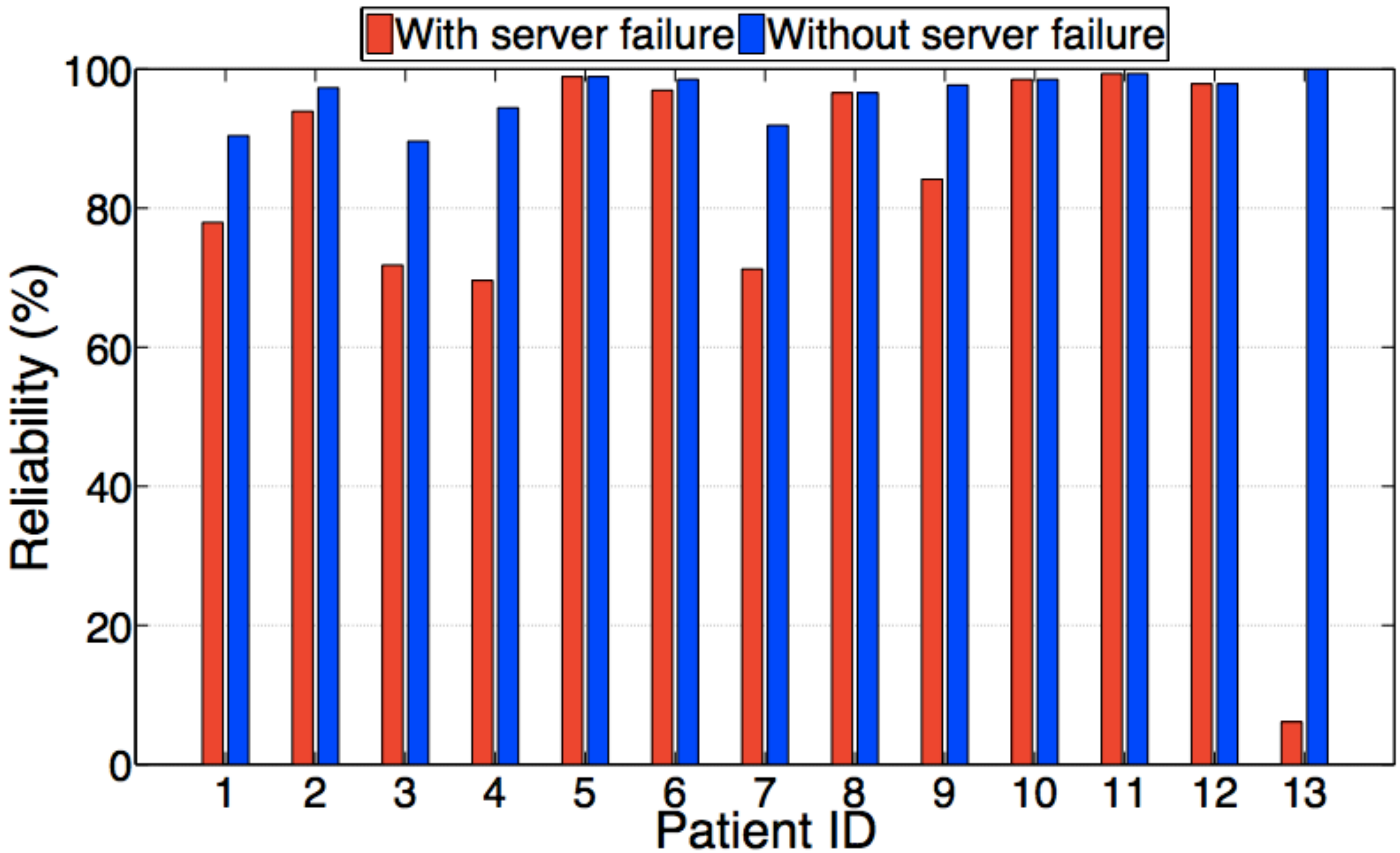
- Iterative design
  - based on feedback from users
  - larger buttons, contrasting colors

Per day reliability



High reliability except in cases of server failures

Reliability of data delivery



Overall reliability of > 90%

Subject demographics

Variable		Statistics
Gender	Male	35%
	Female	65%
Age(years)	Median: 70.5, Range: 65 – 87	
Hearing loss onset(years)	Median:12, Range: 1– 54	
Employment	Full-time	1
	Part-time	1
	Retired	18
Duration of HA use (years)	Median: 8.5, Range : 0 - 40	