

## Introduction

People with cochlear implants experience poor spectral resolution

Speech sounds are coarticulated; there are *spectral* cues that help us anticipate upcoming sounds

People with cochlear implants might have difficulty exploiting coarticulation when listening to speech

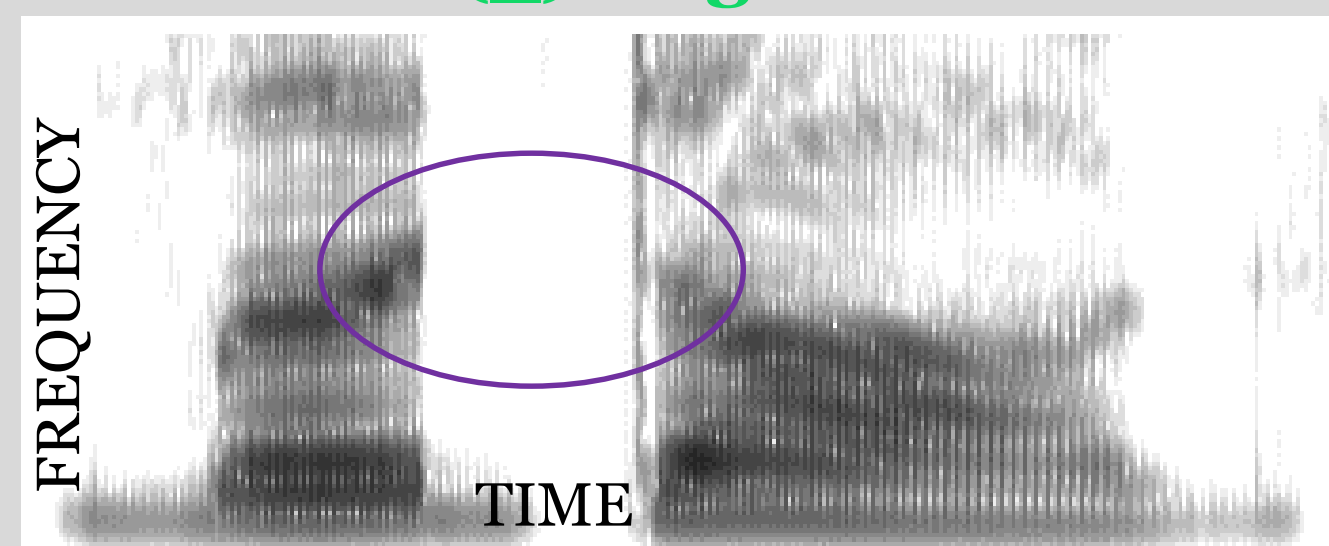
**Coarticulation:** overlap of articulatory gestures in neighboring sounds that provides transitional information between words

### 1. Cooperating (normal):

When the coarticulation cue transitions naturally into the next word

When coarticulation cues are cooperating, listeners are able to identify the next word more quickly and accurately [1]

### 1. "the(d) Dog"

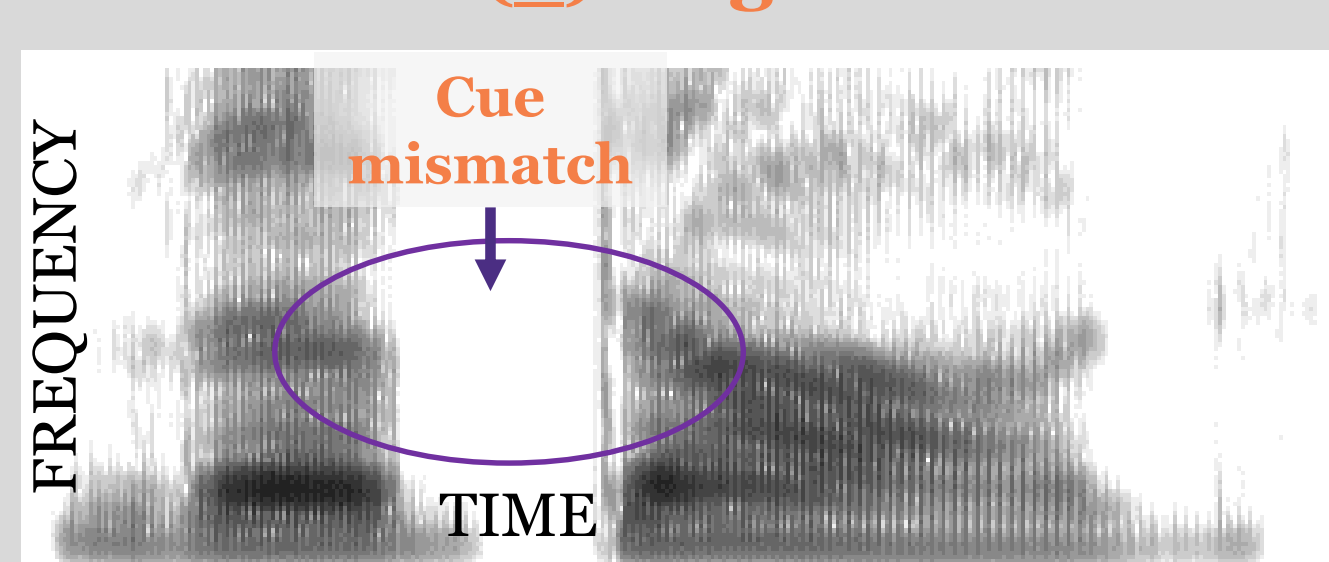


### 2. Conflicting:

When the cue is misleading and does not match with upcoming word

When coarticulation cues are misleading, listeners identify words more slowly after prediction errors [2]

### 2. "the(b) Dog"



### 3. Neutral

Neutral coarticulation provides NO cues for the upcoming word.

It can be used to compare the influence of cooperating and conflicting cues

## Influence in the real world

Listeners with hearing loss and cochlear implant struggle to keep up with conversations because the incoming speech signal is degraded and often rendered ambiguous

This situation can be attributed to their lack of access to cues like coarticulation

**Hypothesis:** Cochlear implant listeners may be unable to access coarticulation cues resulting in decreased speed and accuracy of identifying the target word in comparison with their normal hearing peers

## Methods

**Participants:** 8 Cochlear Implant listeners & 20 Normal Hearing listeners

**Auditory Stimuli:** "Click the" ... [target word] (Dog/Bell/Milk/Net)

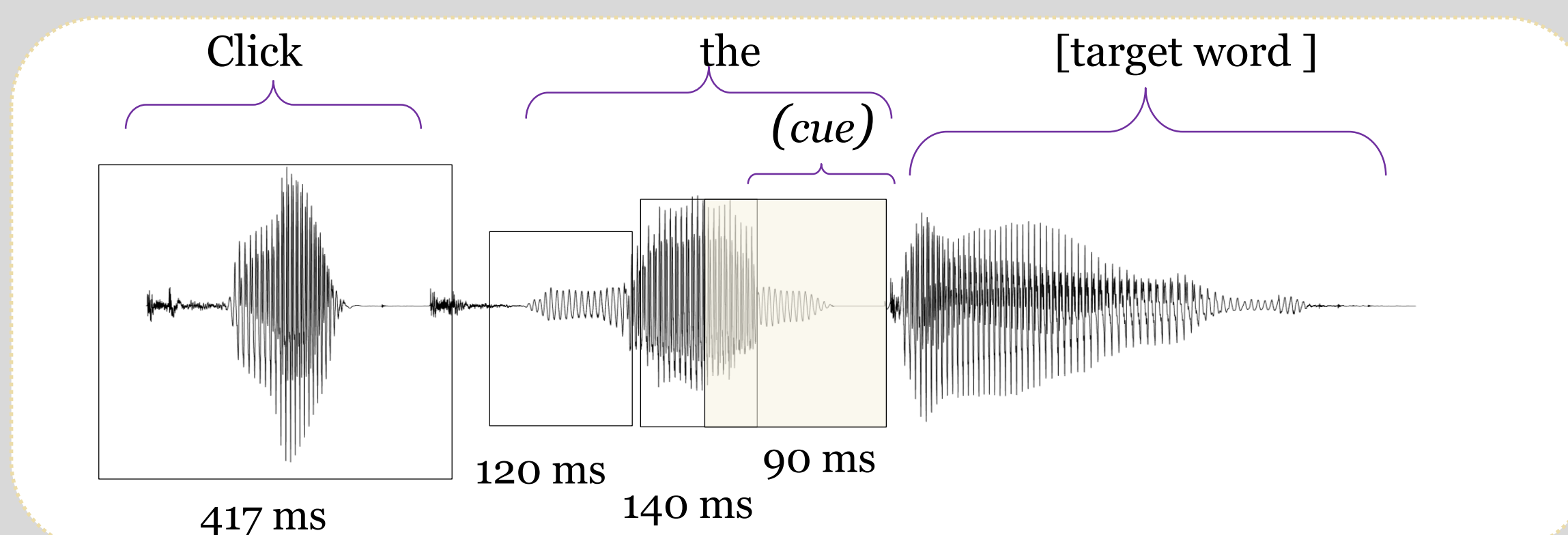
Target words' initial phonemes differed by **place of articulation (/b/ & /d/)** and/or **resonance (oral/nasal)**

**Incorporating the coarticulation cues:** The word "the" contained various types of coarticulation:

**Cooperating:** "Click the(d) Dog"

**Conflicting:** "Click the(b) Dog"

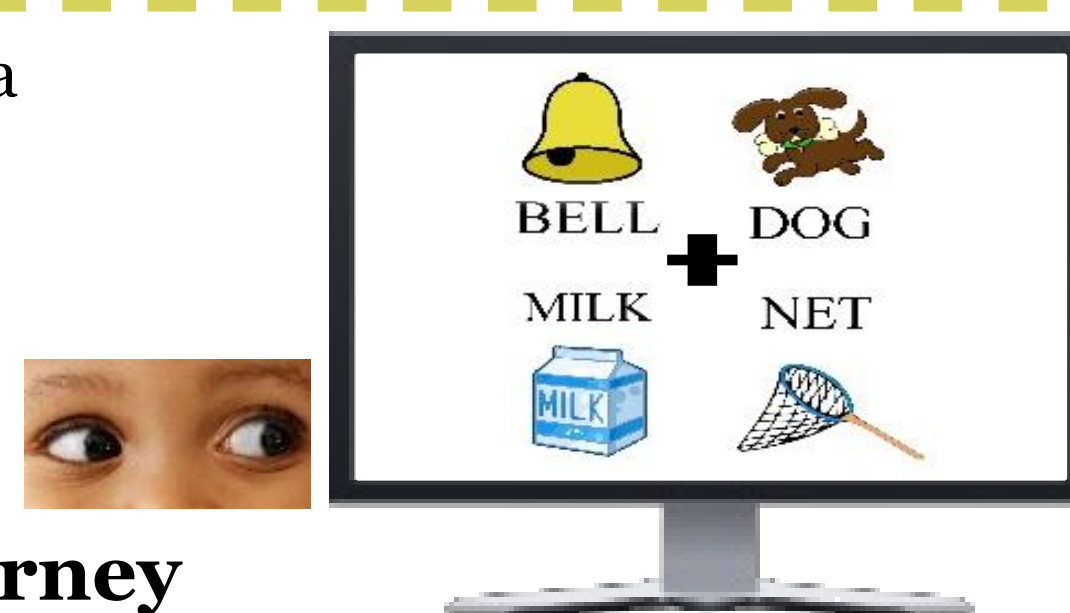
**Neutral:** "Click the( ) Dog"



The **visual word eye-tracking paradigm** is method in which a participant's eye gaze can be tracked during an experiment

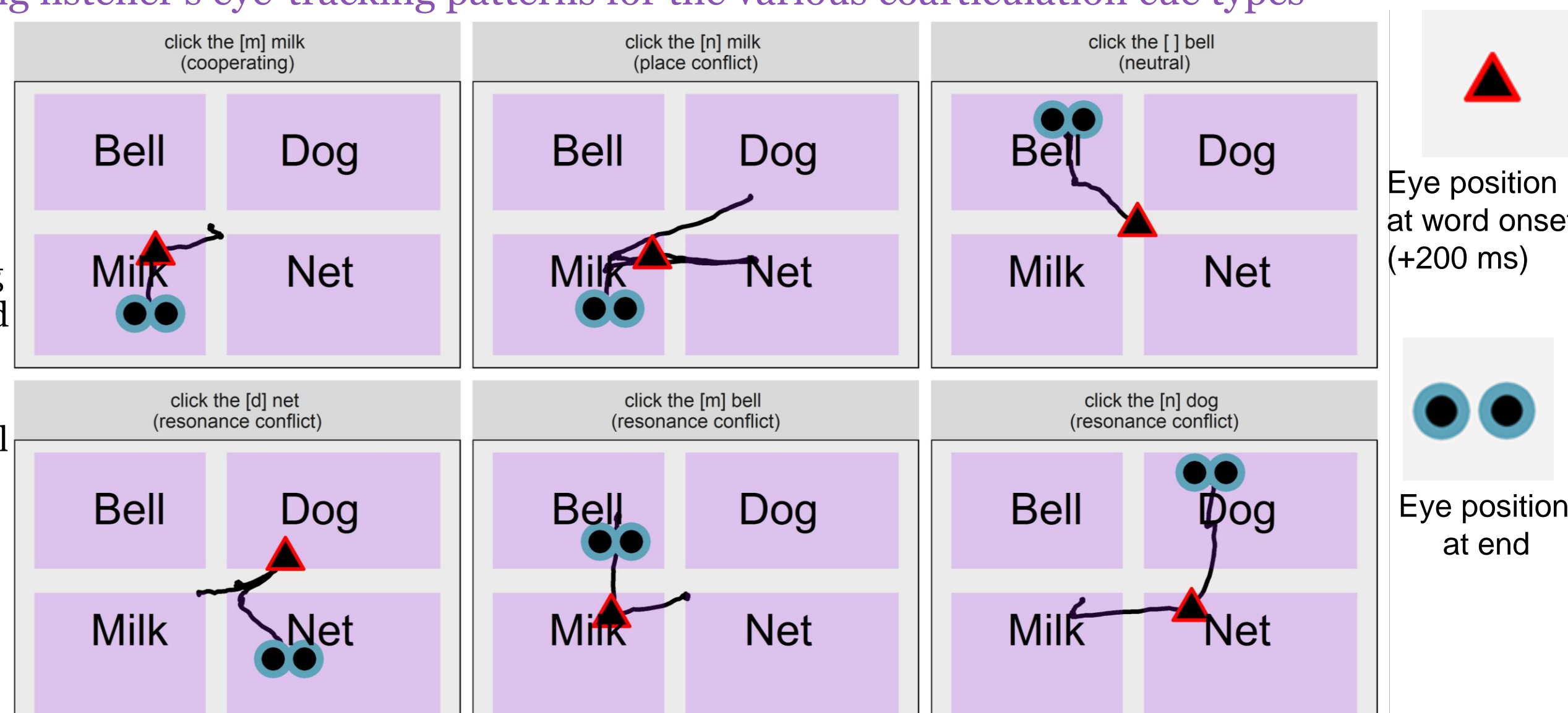
Participants looked at and clicked on the object they heard

The listeners' accuracy and timing of responses were measured with the different coarticulation cues



### Following the eyes' journey

A normal hearing listener's eye-tracking patterns for the various coarticulation cue types



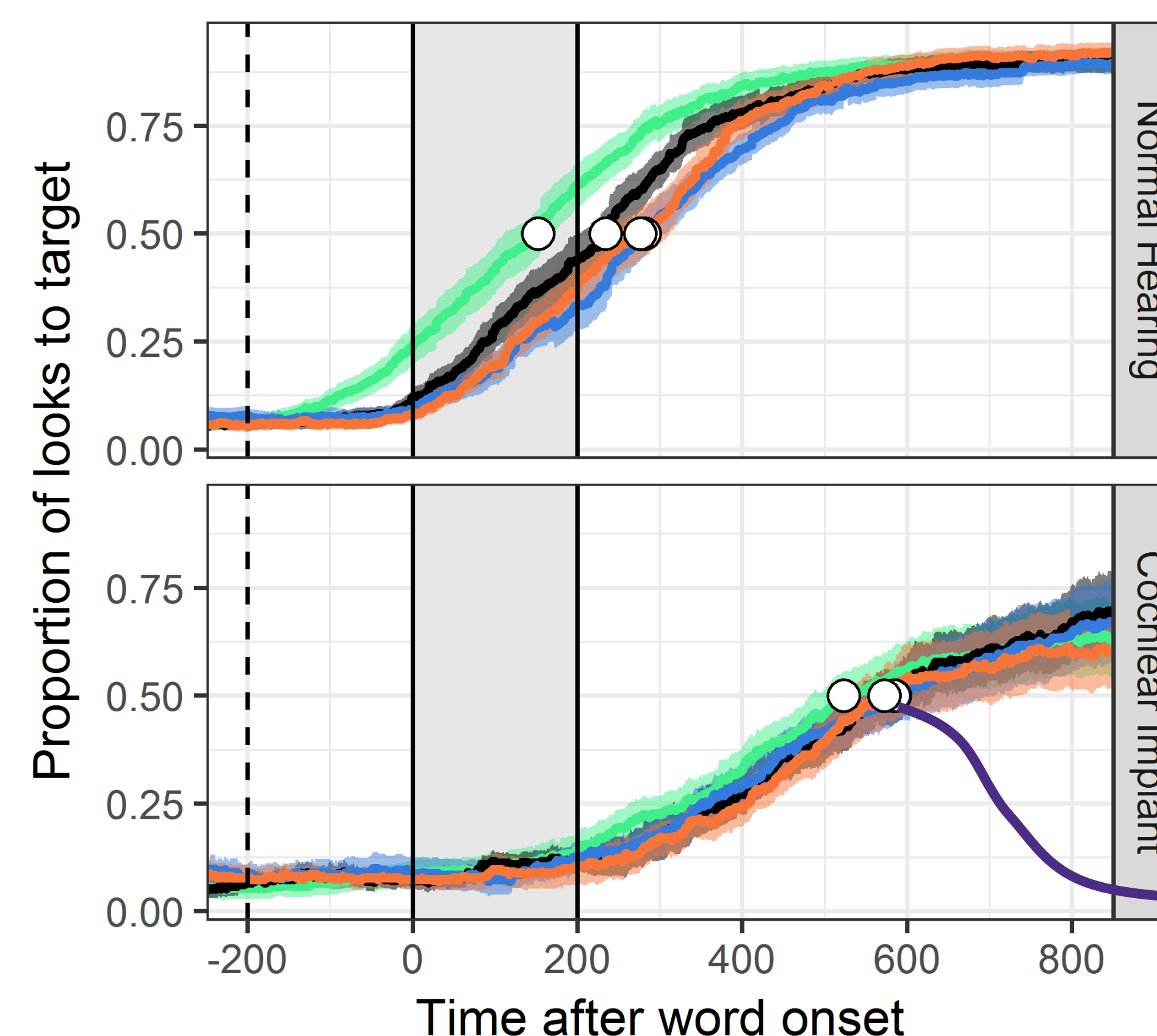
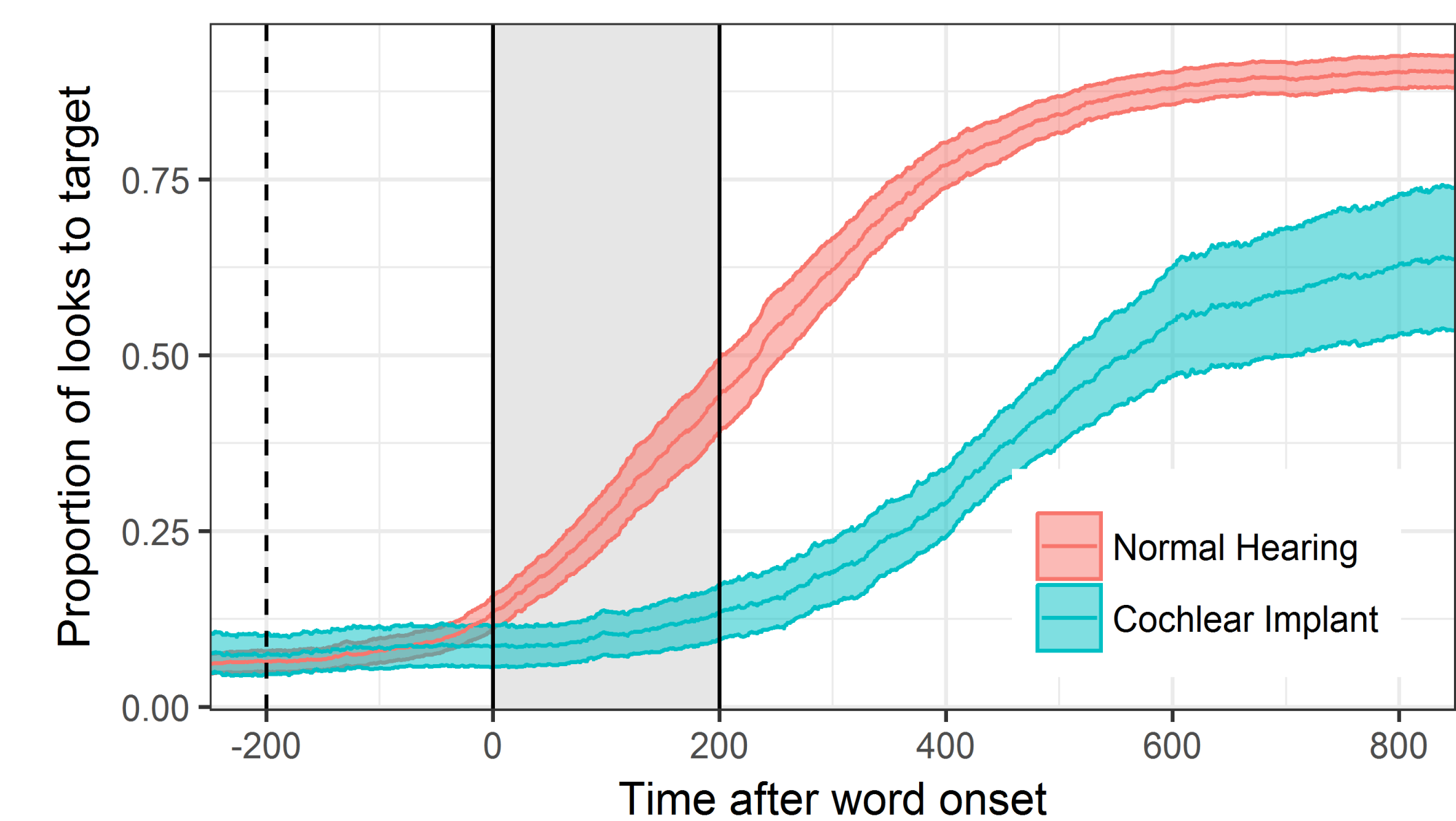
For normal hearing listeners, cooperating cues lead to faster and more direct gaze directions in comparison to neutral or conflicting cues

## Results: Overall

Cochlear implant listeners identify the upcoming word **less accurately** than normal hearing listeners

The time at which listeners with cochlear implant identify the target word is severely **delayed**

It takes 200ms to produce a saccade, meaning a change in looks to **target before 200ms** is due to the coarticulation cue [3]



## Results: Coarticulation

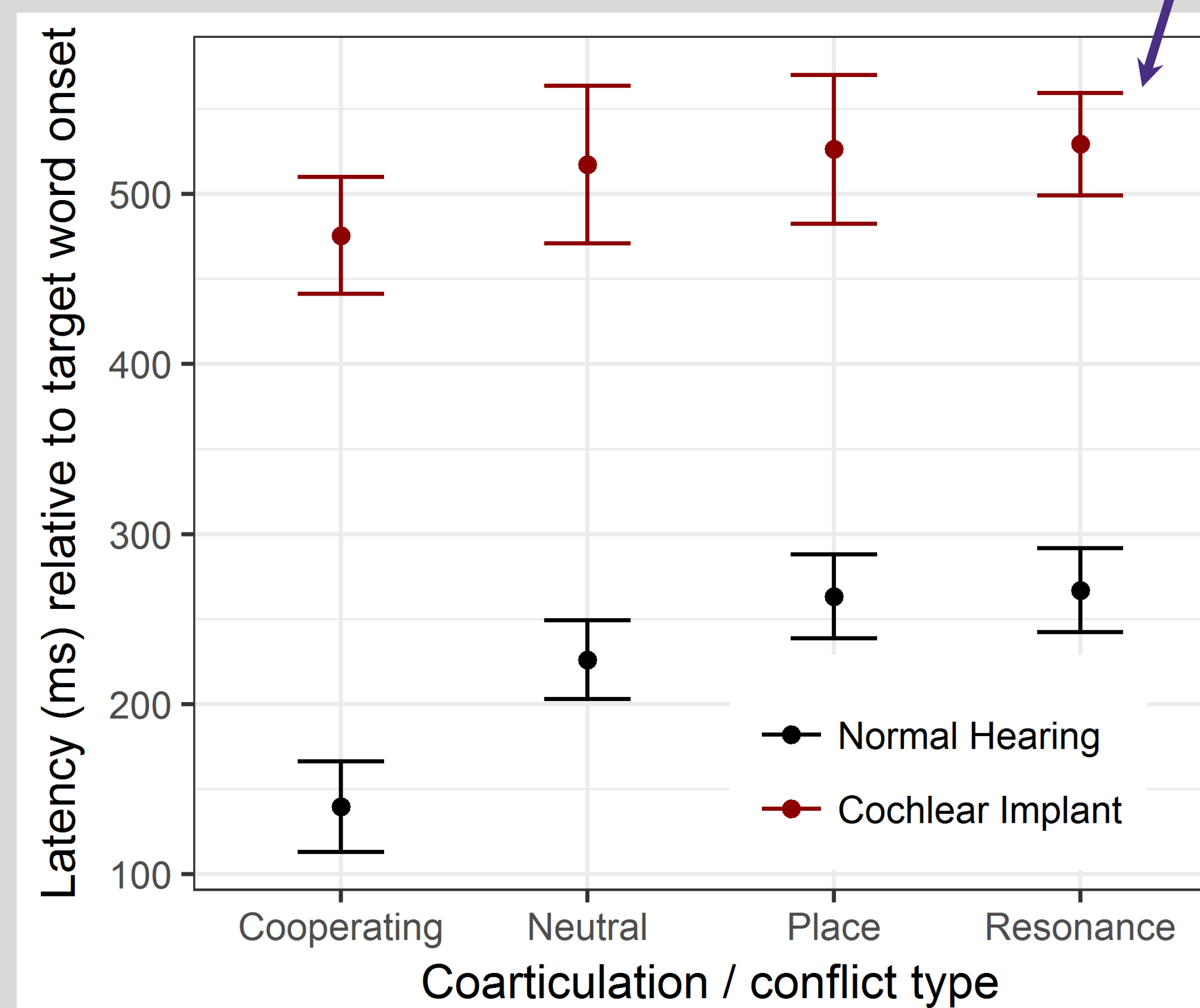
### Cooperating cues...

Enable normal hearing listeners to anticipate the target word before it is spoken

### Conflicting cues...

Slow normal hearing listeners ability to anticipate the next word

**CI listeners appear to be waiting until almost the entire target word is spoken** before committing to a decision, instead of predicting the word before it has begun



- When the transitional cue is **neutral**, cochlear implant listeners identified the target **250-300ms slower** than NH listeners

- When the cue is **cooperating**, normal hearing listeners identified the target **350ms faster** than cochlear implant listeners

- With **conflicting cues**, normal hearing listeners identified the wrong target and self corrected **before** cochlear implant listeners responded correctly

NH Listeners				
Coarticulation	Latency	Std Er	t	p
Neutral	226.15	24.80	9.12	< 0.001 ***
Cooperating	-86.35	11.77	-7.34	< 0.001 ***
conflict - place	37.25	11.77	3.16	0.002 **
conflict - resonance	40.80	11.77	3.47	< 0.001 ***

NH Listeners: ALL Coarticulation conditions significantly different from Neutral

CI Listeners				
Coarticulation	Latency	Std Er	t	p
Neutral	517.29	40.185	12.87	< 0.001 ***
Cooperating	-41.71	32.77	-1.27	0.20
conflict - place	9.00	32.77	0.27	0.78
conflict - resonance	32.98	34.48	0.96	0.34

CI Listeners: NO significant differences between coarticulation conditions

## CONCLUSIONS

- Cooperating coarticulation **aids** NH listeners to **more quickly anticipate and process the next word**
- Listeners with cochlear implants look to the target word up to **350 ms later than NH listeners**. (they seem to be waiting until the end of the word before committing to a decision)
- Listeners with cochlear implants appear to be entirely **unable to take advantage of coarticulation cues**
- Listeners with cochlear implants have a **delayed** ability to anticipate upcoming words which may lead to **slower sentence processing**, causing them to **fall behind in conversation**

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### References:

- [1] Martin, J.G. & Bunnell, H.T. (1981). Perception of anticipatory coarticulation effects. The Journal of the Acoustical Society of America, 69(2):559-567.  
 [2] Whalen, D.H. (1984). Subcategorical phonetic mismatches slow phonetic processing in perception of spoken words. Psychol. Sci. 9, 325-329.  
 [3] Matin, E., Shao, K., Boff, K. (1993). Saccadic overhead: Information-processing time with and without saccades. Perception & Psychophysics, 53, 372-380.

