

The Effects of Motor Priming on Categorical Perception



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Our Study



- Presents evidence from priming which supports the motor theory of speech perception
 - Competing Theories of Speech Perception
 - Recent Studies Similar to Ours
 - Experiment Design
 - Results
 - Broader Impacts

Speech Perception



- **Lack of Invariance**
 - Context
 - Speech Conditions
 - Speaker Identity
- **Perceptual Constancy**
- **Categorical Perception**
 - Hear between-category distinctions
 - Do not notice within-category distinction

The Auditory Theory



- *Some* aspect of auditory stimuli IS invariant
 - Acoustic cues/distinctive features/landmarks
- Speech perception is process of decoding *sounds*
- Brain process(es) normalizes stimuli
 - Vocal tract normalization
 - Speech rate normalization
 - Exemplars
- Interactive models
 - Phonemic restoration effect
 - Syntactic & semantic context
 - Natural language statistics

The Motor Theory



- Acoustic stimulus is categorized based on listener's knowledge of articulations
 - “[There is a] more nearly one-to-one correspondence between phoneme and articulation [than] between phoneme & sound” (Liberman et al 1962)
- True objects of speech perception are speaker's intended articulatory gestures
 - “The neural representation of the utterance that determines the speaker's production is the distal object the listener perceives” (Liberman et al 1985)
- Neuroimaging studies show motor cortex is active during speech perception

The Great Divide



- Classical views of cognition & models of language
 - Divide sensory & motor processes
 - Divide speech perception & speech production
 - Acoustic Theories
- Growing body of evidence challenges the strength of these distinctions
 - Motor cortex plays a role in cognitive tasks
 - Speech perception & speech production are linked
 - Motor Theory

Pülvermuller et al. 2006



- Used fMRI to compare brain regions active during speech production and perception
- Compared [p] & [t]
- Found similar activation pattern

“Distinct motor regions in the precentral gyrus sparked by articulatory movements of the lips and tongue were also differentially activated in a somatotopic manner when subjects listened to the lip- or tongue-related phonemes”

D'Ausilio et al. 2009



- Applied (facilitatory) TMS to the parts of the motor cortex controlling lip or tongue movement
- Forced-choice discrimination task
 - Compared ([p] & [b]) ([t] & [d])
- Lower response time for phonemes corresponding to TMS
- Error bias in the direction of TMS

“The perception of a given speech sound was facilitated by magnetically stimulating the motor representation controlling the articulator producing that sound”

Sato et al. 2011



- Investigated effect of motor priming
- Forced-choice discrimination task
 - Compared [p] and [t]
- Subjects were primed by repetitively making either lip or tongue movements
- Found response bias towards primed area

“Use-induced motor plasticity specifically biases subsequent speech processing in an articulator-dependent manner”

Motivation for Study



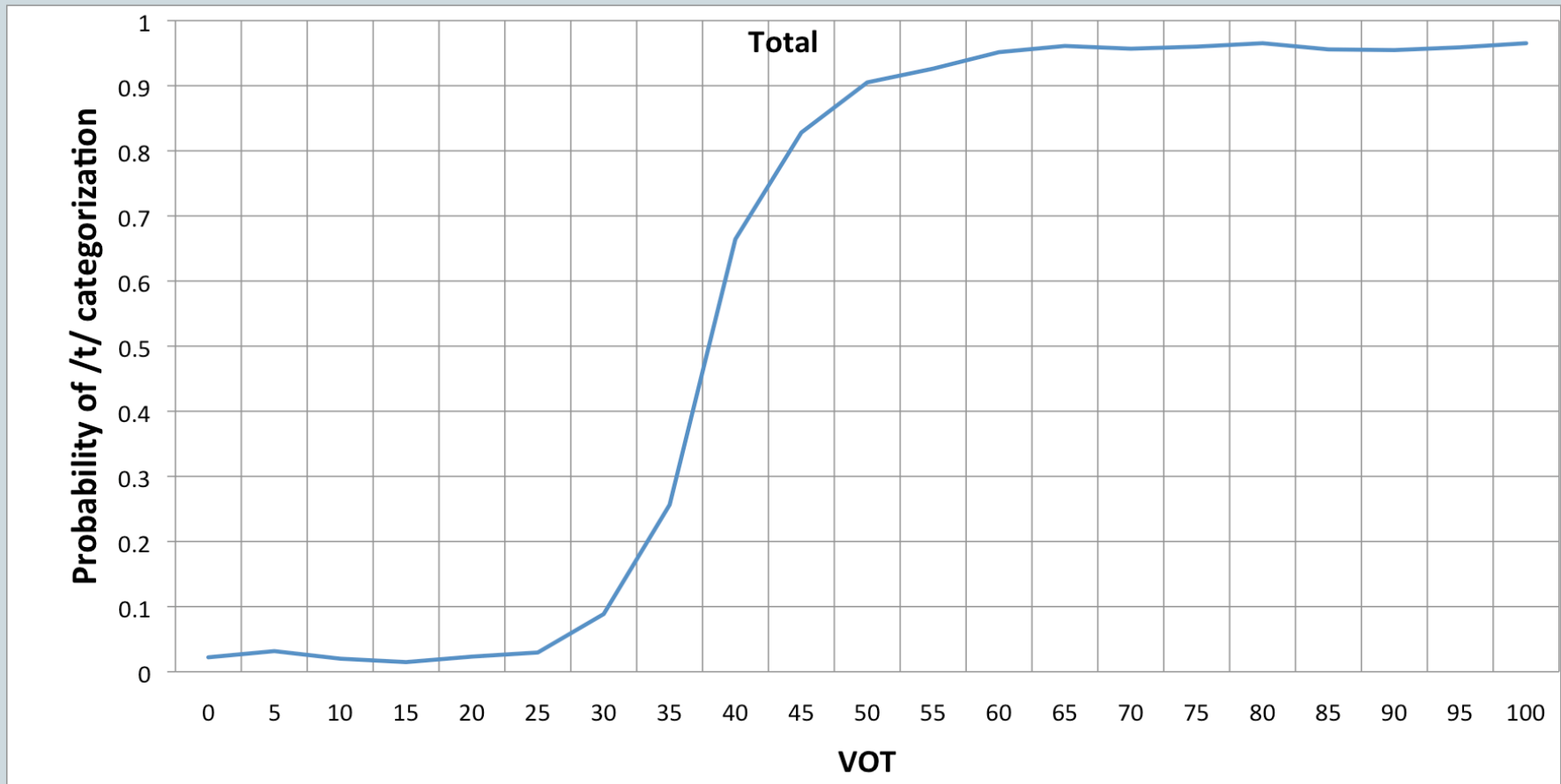
- Motor/Auditory debate goes back 50 years
- Studies suggest motor cortex plays a role, but don't compare it to the role of acoustics
- Our study directly compares auditory & motor aspects of speech perception
- Prime in different modalities
 - Auditory Priming
 - Motor Priming

Methods



- **Forced-choice discrimination task**
 - Compared [t] & [d]
- **21 synthetically manipulated sound files**
 - Each presented 6 times
- **Identify each as “tah” or “dah**
 - Buttons switched every few trials
- **38 adult native speakers of English**
 - 19 in each priming condition

VOT Discrimination Function

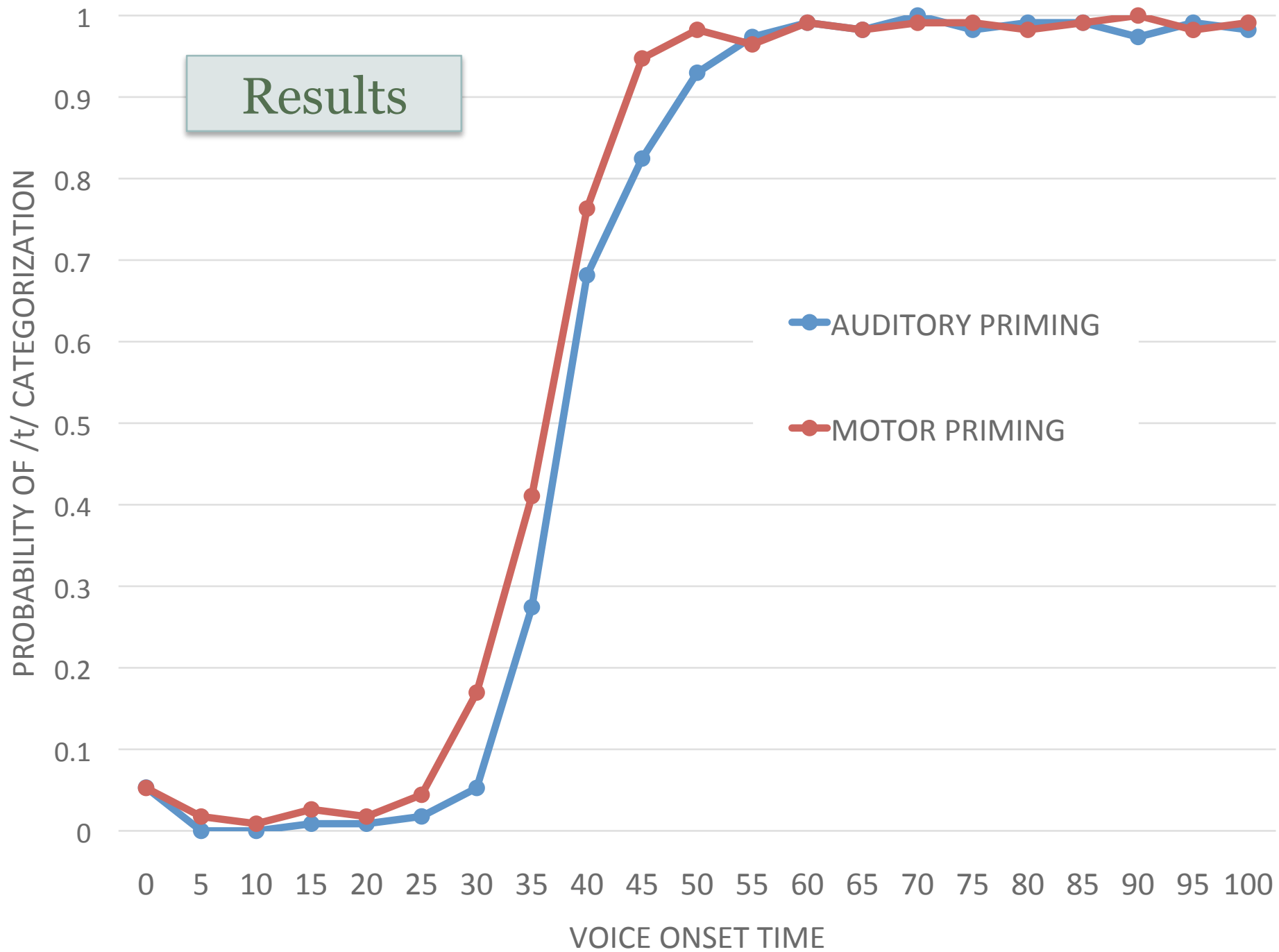


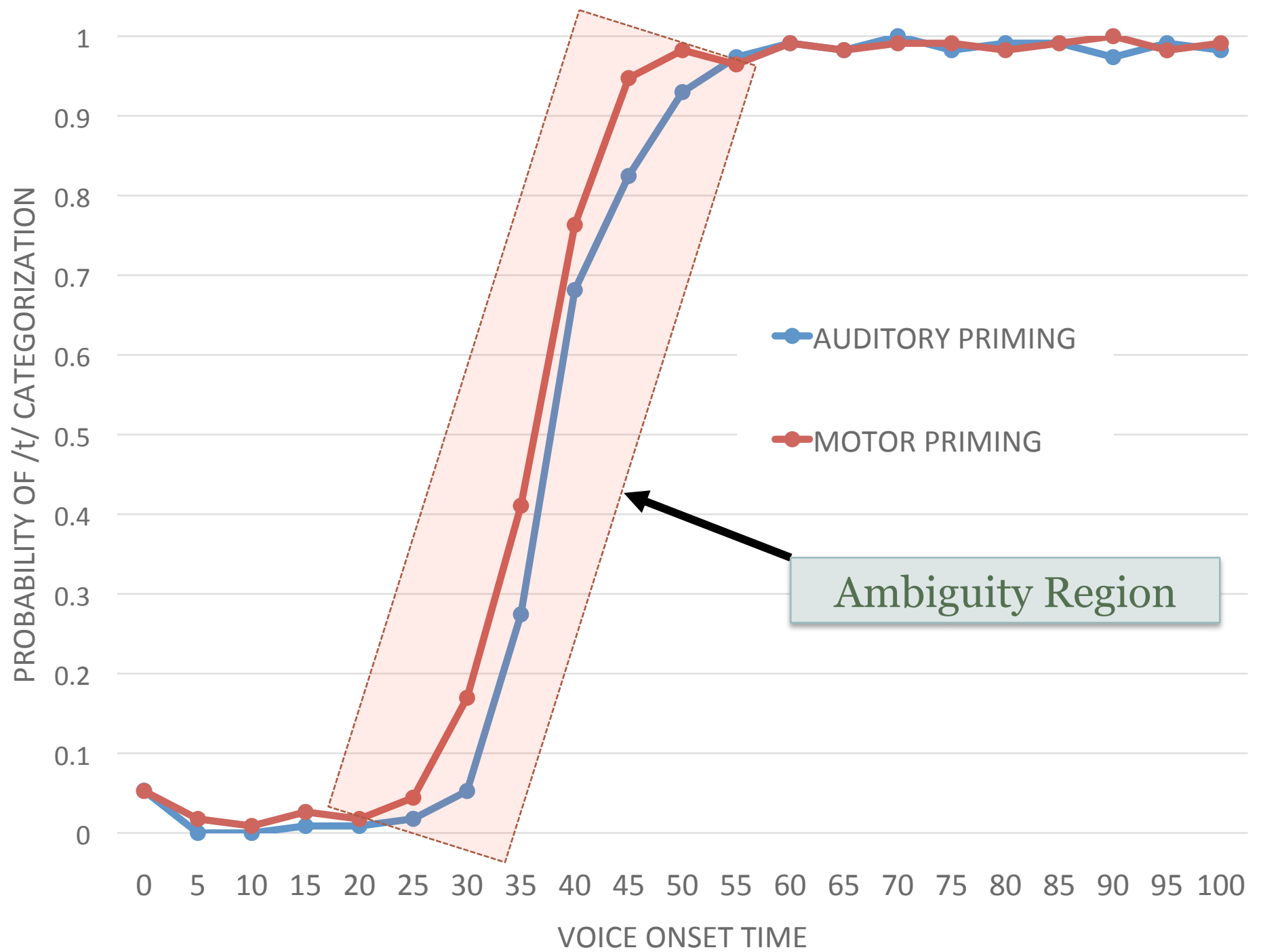
Priming



- Subjects divided into two groups before task
- Both groups were primed to prefer /t/ but using different modalities
- **AUDITORY GROUP**
Listened to 100 words starting with “t”
- **MOTOR GROUP**
Silently pronounced (mouthed) the same words

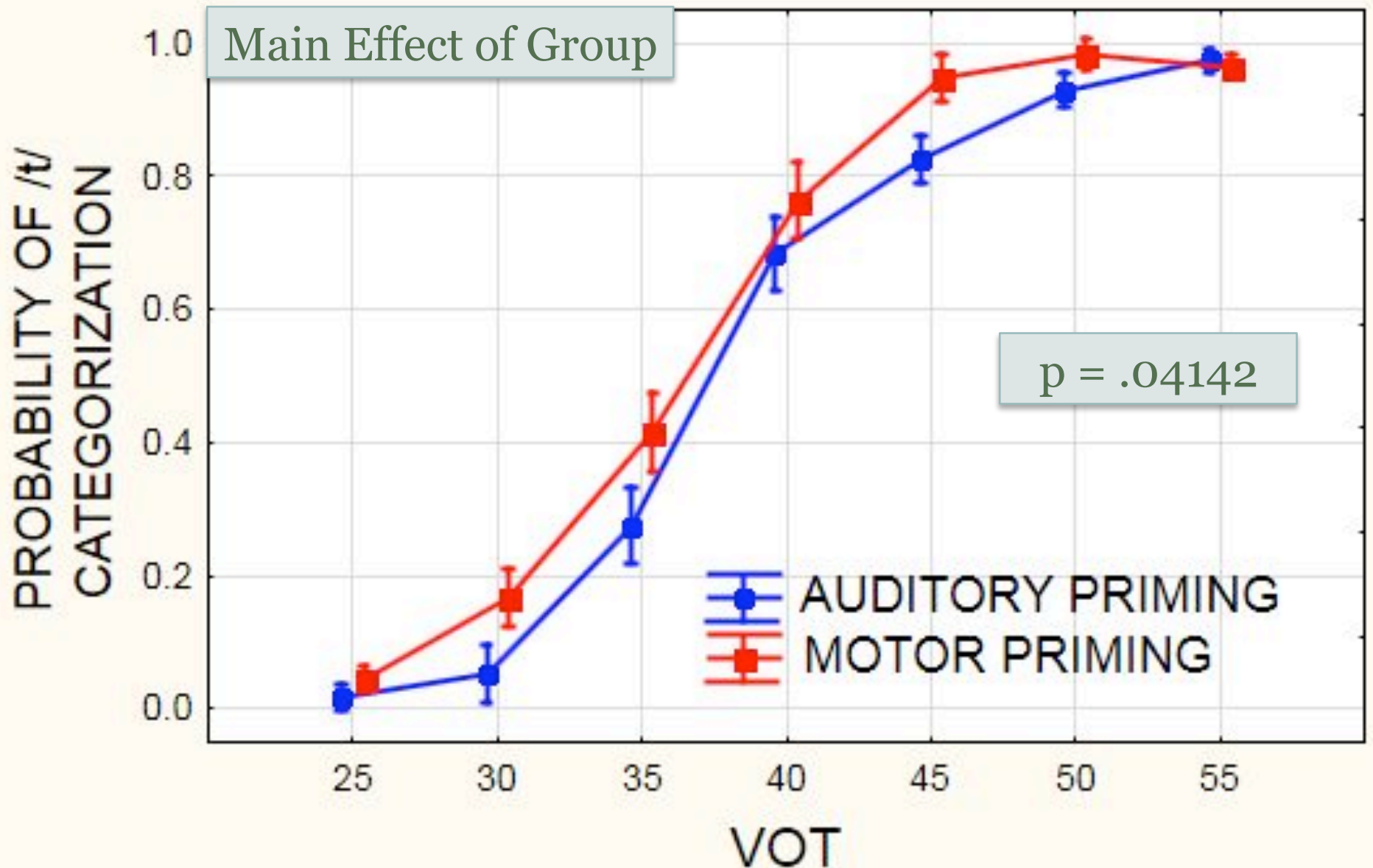
TAMARIND	TELEX	TEAGARDEN	TAUGHT
TANNED	TARSES	TAWANA	TEEMS
TELESCOPE	TANSKI	TELECOMMUNICATIONS	
TEQUILA	TENTACLE	TENNELL	TANKARD
TEN	TESH	TARTAGLIA	TALTON
TANZANIA	TEMPLEMAN	TERMINE	TARALLO
TAXCUT	TEDDY	TAMARA	TELEFUNKEN
TERRIFY	TALKABLE	TELEMANAGEMENT	TEAGLE
TAR	TAMBO	TERRANOVA	TELETRON
TEAL	TELLABS	TATTER	TEETHE
TAYLOR	TEAS	TERRIS	TANDY
TEMPO	TEACH	TEARFUL	TENZA
TEMPERAMENTAL	TAXPAYING	TELETYPES	TERRANO
TERRORIST	TERMITES	TARGETING	TAM
TALKIE	TALLEST	TASTER	TELESAT
TEEING	TENNCARE	TAMPERING	TERRIFIES
TENTH	TASTINGS	TEXTILE	TAPPEN
TAPPER	TETHER	TECOGEN	TERRAIN
TEDMUND	TALK	TANK	TANDYCRAFTS
TATTOO	TELEGRAMS	TELECOM	TEDIOUS
TELFAIR	TEMPERATURE	TECHNOLOGIES	TANGO
TEHRAN	TECOGEN	TASH	TAVENNER



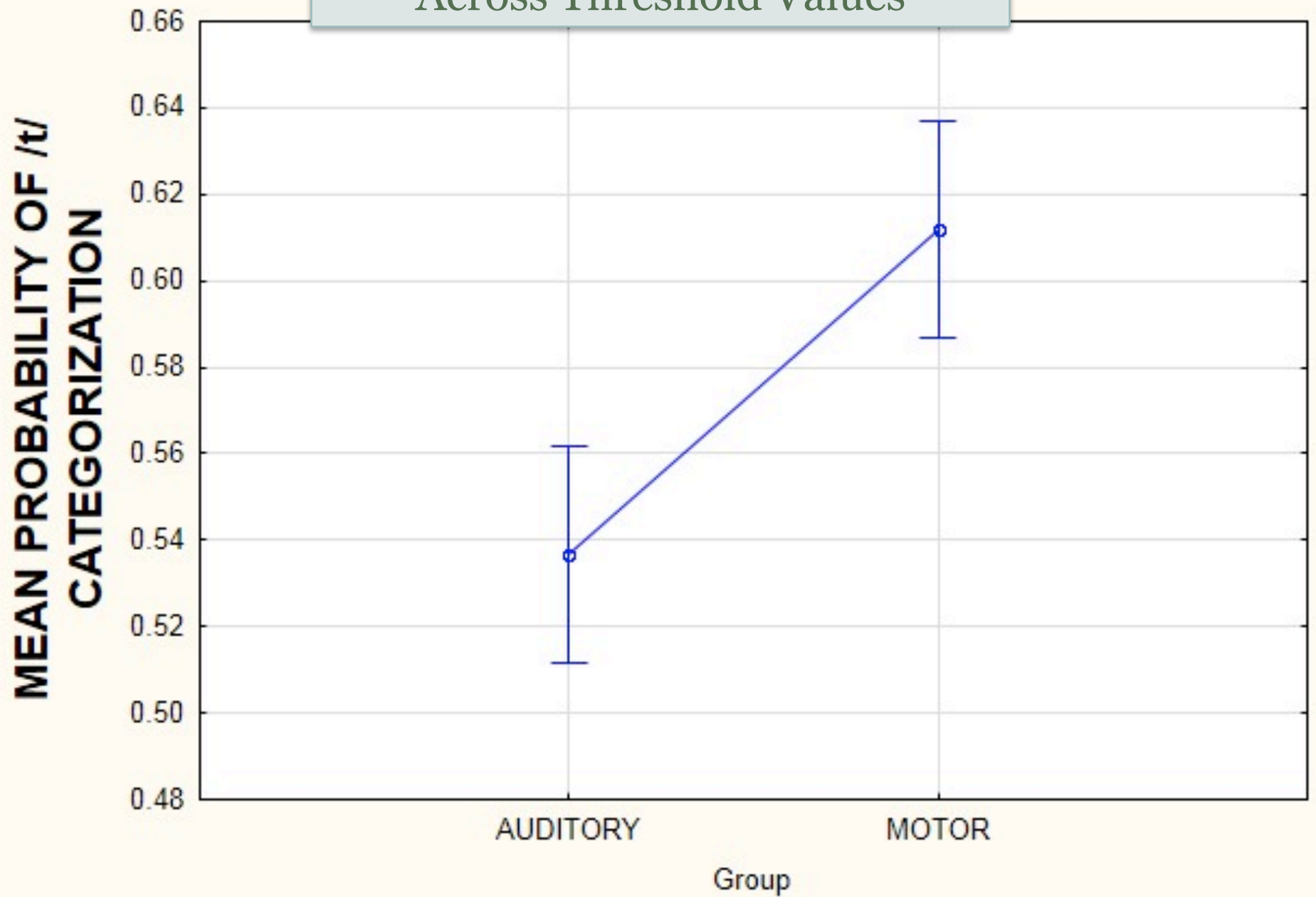


Mixed Factor Repeated Measures ANOVA

For the seven threshold VOT values



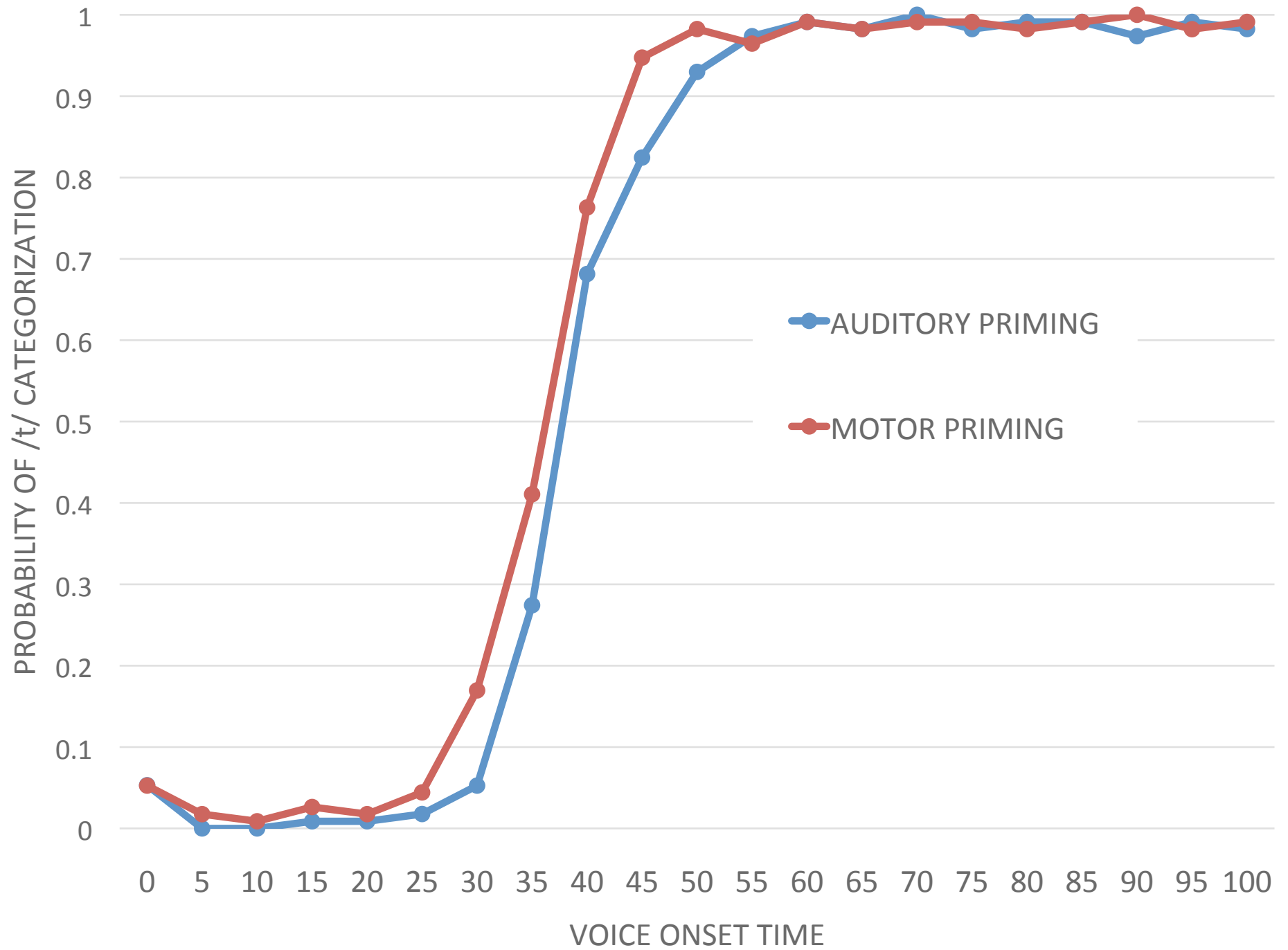
Main Effect of Group Across Threshold Values

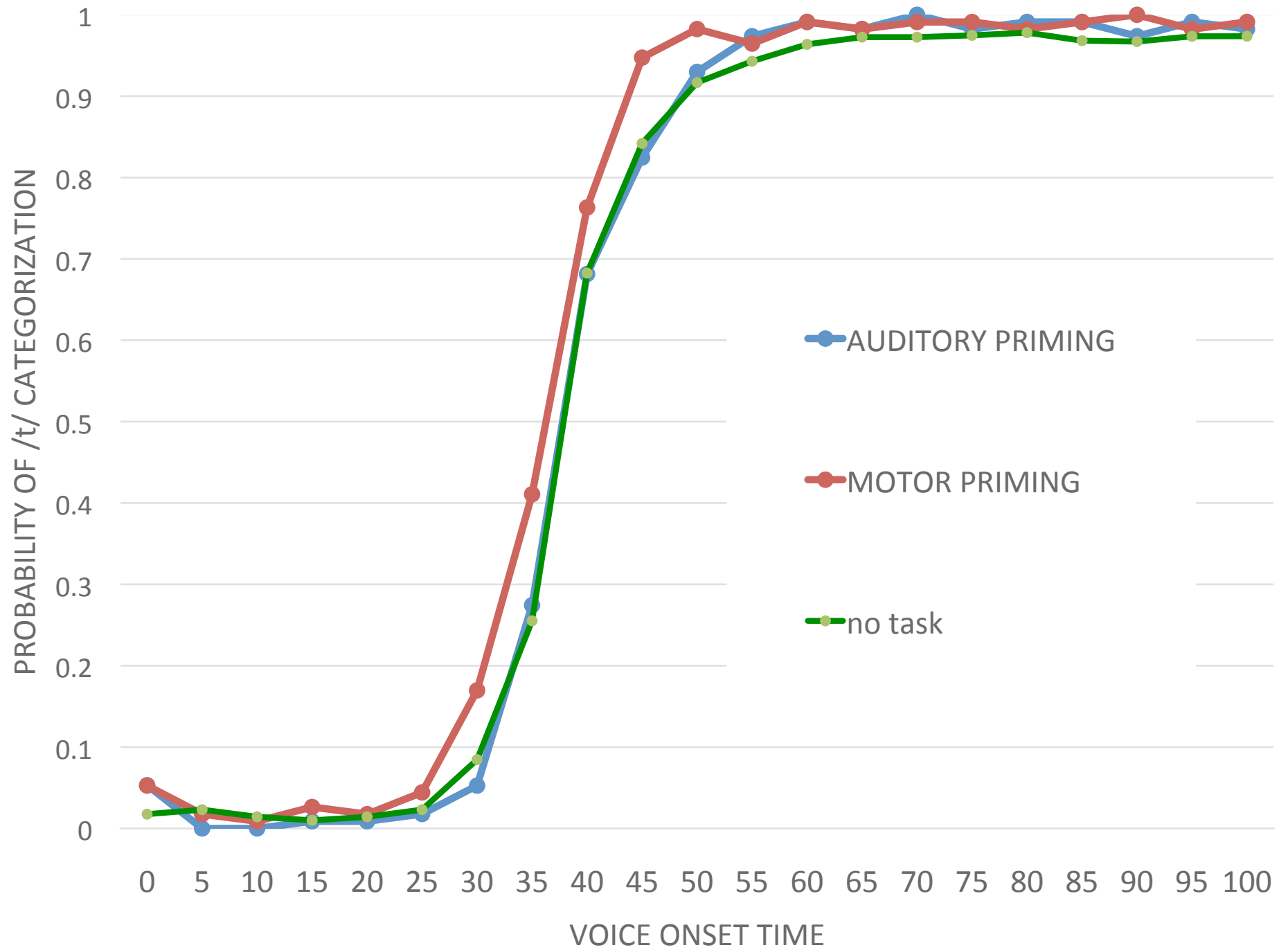


Baseline Data



- Another study run in the EPL at UD required establishing a VOT threshold for each subject
- 158 native speakers of English participated
- Serves as a huge control group
- Confident that baseline data is very good estimate of population mean





Conclusion & Discussion



- Motor priming had significant effect
 - Subjects were more likely to identify ambiguous stimuli as /t/
- Motor movement can bias subsequent auditory stimulation
- Auditory priming had no effect
 - Subjects responses were nearly identical to control group's
- Auditory stimulation does not create a similar bias
- Motor cortex plays an important role in speech categorization

Broader Implications



- A number of studies address the role of the motor cortex in language processing at levels larger than the phoneme
 - Glenberg & Kaschak (2002)
 - ✦ Motor priming involving whole arms
 - ✦ Response time for whole sentences
 - Boroditsky & Ramscar (2002)
 - ✦ Real world spacial & temporal movement affected responses to ambiguous questions
- Motor cortex is used for cognitive functions, not just execution of gestures

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