

Gradient effects of continuous acoustic detail revealed by event-related potentials



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Background

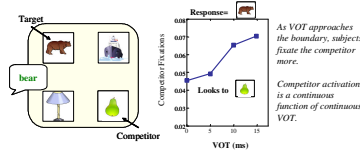
Within Category Sensitivity

- Speech perception is sensitive to continuous acoustic detail:
- Within-category discrimination (Pisoni & Tash, 1974; Garney, Wilder & Viemeister, 1977; Samuel, 1977; Schouten, Gerrits & Van Hoesen, 2003)
 - Prototype ratings (Miller & Volante, 1989; Miller, 1997)
 - * Showed gradient effects using several stimuli within the same category
- Best evidence comes from work on **word recognition**:
- Coarticulatory mismatch (Dahan, Magnuson, Tanenhaus & Hogan, 2001; Marslen-Wilson & Warren, 1994; Whalen, 1991; Sirevaar & Nigro, 1976)
 - Differential priming for within category VOT (Ghahramani, Rosenow & Burton, 1994; Owsen, Rosenow & Burton, 2000)
 - Assimilation (Gow, 2001; Gow & McMurray, in press)
 - Embedded words (Gow & Gordon, 1995; Salvadori, Dahan & McQueen, 2003)

Gradiency

Gradiency: Systematic relationship between detail in the signal and behavioral or neural response.

McMurray, Tanenhaus & Aslin, 2002



Task and Gradiency

Avoiding these issues: Event-Related Potentials (ERPs)

Phoneme goodness

- **Problem:** Offline task that may tap processing after it is complete.
- **Problem:** may not reflect lexical processes

ERPs:

- Time-locked EEG recorded directly from a subject.
- A summation of all electrical activity occurring in the brain at a given moment in time.

However: Previous ERP studies have primarily shown results that suggest discrete processing.

Non-continuous	Somewhat continuous	Continuous processing
Winkler et al. (1999)	Talbot et al. (1999)	Shannon et al. (1995)
Nesonen et al. (2005)	Winkler et al. (1999)	
Tanaka et al. (2005)		
Hill et al. (2006)		
Mauz et al. (1995)		

1) Is lack of gradiency an artifact of the behavioral paradigm used with ERPs?

Prior studies utilized the Mismatch Negativity (MMN) waveform:

- **MMN - Discrimination:** Size of MMN reflects difference between oddball and baseline.
 - Passive listening: only big differences detected.
 - Primarily used non-words.
 - Not realistic listening task.

2) Do early electrophysiological measures show gradient sensitivity?

- Need ERP component analogous to activation.
- Lexical stimuli
- Word identification paradigm

Participants:

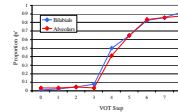
14 undergraduates from the University of Iowa.

Stimuli:

- Two minimal pair continua varying in voice onset time (VOT).
 - Beach/Peach
 - Dan/Tan
- Words constructed using the KlatzWorks (McMurray, in prep) fronted to the Klatz synthesizer (Klatz, 1988).
- VOT of first consonant was manipulated by cutting back onset of voicing (AV) and replacing it with aspiration (AH)
- All other synthesis parameters held constant.
- 9 equal steps per continuum: 0 ms to 40 ms of VOT.

Identification Responses:

- Measured subjects' identification responses for both continua.
- Responses indicate subjects labeled stimuli as expected.



Methods

Assessing gradiency with ERPs

- Utilized two waveforms:
 - **P3:** Reflects activation of a categorization decision
 - No clear consensus about underlying neural or cognitive process
 - Larger amplitude when more effort devoted to task.
 - Smaller amplitude when uncertain if stimulus is target or non-target (Luck, 2005)
 - **N1:** Reflects early sensory processing
 - Negative deflection around 100ms.
 - Generated in the auditory cortex on the dorsal surface of the temporal lobe
- Should reveal continuous neural response to varying VOT.

Task

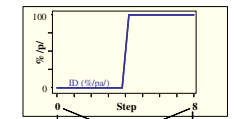
- Target/non-target detection.
- 4 blocks of trials
 - Each word appeared as target in 1 block.
 - 4 stimuli were possible in each block.
 - Target: e.g.: Beach
 - Non-target: e.g.: Peach**, Dart, Tarr
 - (**Peach is competitor; opposite voicing of target.)
- Each stimulus was equally probable.
 - Target appears 25% of time.
- Target hand and block order were counterbalanced between subjects.
- All other variables were counterbalanced within subjects.

ERP Methods

- ERP recording over standard right and left-hemisphere positions at frontal, central, parietal, and temporal sites (International 10/20 Systems sites F3, FZ, F4, C3, CZ, C4, P3, PZ, P4, T3, T4, T5, and T6).
- Impedance kept under 5 k Ω for all electrode sites
- Amplified by a Grass Model 15 Neurodata Amplifier System using a notch filter at 60Hz, a high-pass filter at .01Hz, and a low-pass filter at 100Hz.
- Data were digitized at a rate of 250 Hz.
- All data reported were analyzed from an average of all parietal channels (P3, PZ, and P4).
- Trials containing cortical artifacts, movement artifacts, or amplifier saturation were rejected from data analysis.

ERPs require many trials to see components.

VOT was recoded as distance from target so that all four blocks could be averaged together.



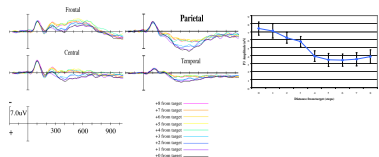
Beach Target : +0
Peach Target : +4

Beach Target : -8
Peach Target : -4

Target becomes +0 and the word with opposite voicing becomes +8.

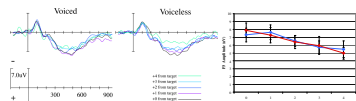
P3 Amplitude Results

Gradiency in the P3



P3 amplitude in the parietal channels decreased significantly ($p < .001$) as stimuli deviated from target.

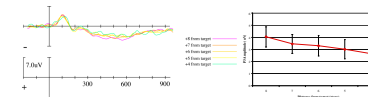
Gradiency for both voicing categories



- Target response trials only
- Significantly decreased P3 amplitude ($p < .001$) as stimulus deviated from target.
- No significant effect of continua.
- No interaction between voicing and distance from target.

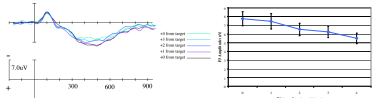
Additional Results

Gradiency for stimuli categorized as competitors



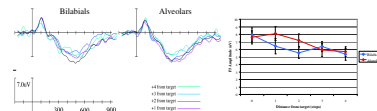
- P3 amplitude decreased significantly as stimuli deviated from competitor ($p < .001$).
- Overall voltage was decreased for trials with competitor responses.

An artifact of averaging across discrete responses?



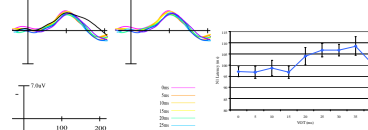
- Filtered trials by subject response and only target responses were included
- P3 amplitude decreased significantly as stimuli deviated from target ($p < .001$).

Gradiency in both continua



- Target response trials only
- Significantly decreased P3 amplitude ($p < .001$) as stimulus deviated from target.
- No significant effects of continua were observed.
- Significant interaction ($p = .033$).
 - But significant effect for both continua (BP: $p = .009$; DT: $p < .001$).

Can gradient effects be seen earlier than in the P3?



- N1 latency increased as VOT increased.
- Gradient effects were marginally significant for all stimuli ($p = 0.083$)
- Gradient effects were highly significant when 40ms VOT stimuli were excluded ($p = 0.014$)

Conclusions

- P3 amplitude in the parietal channels decreased significantly as stimuli deviated from target.
 - This was true for increasingly conservative analyses:
 - All stimuli, regardless of response
 - Only stimuli categorized as target
 - Only stimuli categorized as target grouped by voicing
 - Only stimuli categorized as target grouped by continua
 - Effects of gradiency could be seen even when looking at stimuli categorized as competitor
- Gradiency may be visible as early as 100ms after stimulus onset
 - N1 response grouped by VOT
- Continuous measures of neural response reveal gradient effects of VOT preserved throughout the ERP waveform.

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