Timing of Turntaking: Early Responses and Use of Intonation in an Elicited Minimal Response Task

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Introduction: Motivation

In understanding language, different sources of information are used:

- syntactic information
- semantic information
- visual cues (e.g. gaze direction, gestures)
- prosodic information (loudness, duration, tempo, pauses, pitch)

Main Question:
What is their relative importance?
Timing of Turntaking

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Introduction: Task

Minimal Response Task:

Identification of TRP’s in Dialogue

- Reaction Time (RT) task
- Identify when to start speaking
- by saying ’AH’
- more ’natural’ task than pushing button
- responses recorded with laryngograph

Assumption: at this point there is recognition of (at least part of) the previous utterance
Introduction: Questions

Questions addressed in this talk:

- Is intonation enough for TRP projection?
- How is the use of intonation integrated with other sources of information?
- What do we know about the time course of TRP projection?
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Introduction: Reaction-Time Model
Sigman & Dehaene (2005)

Three temporal stages in Reactions to Stimuli:

- Perceptual component \((P)\) and Motor component \((M)\), both with deterministic response-times \((t_p\) and \(t_m\))
- Central **decision making component** \((C)\) characterized by a random walk to a decision threshold
- Mean Reaction Time: \(\overline{RT} = t_0 + \tau\)
Relative integration time to decision, $\tau$, can be determined from the relative variances of the Reaction Times

$$\frac{\tau_1}{\tau_2} = \sqrt[3]{\frac{S_1^2}{S_2^2}}$$

with ($S^2 = \text{variance}$)
Experiment: Materials

**Full Set**
- 61 dialogues from CGN, telephone & face-to-face
- informal and spontaneous
- orthography, hand aligned on word level
- extra transcription on turn switches and minimal responses

**Stimulus Set**
- 7 telephone & 11 face-to-face dialogues (165 minutes)
- for each utterance: boundary tones are estimated as
  \[
  Z_i > 0.2 \quad \rightarrow \quad \text{high boundary tone}
  
  -0.5 \leq Z_i \leq 0.2 \quad \rightarrow \quad \text{mid boundary tone}
  
  Z_i < -0.5 \quad \rightarrow \quad \text{low boundary tone} \quad (Z_i = \frac{\bar{F}_0 - F_0}{sd(F_0)})
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Experiment: Stimuli

Two sets of stimulus files:

1. **FS** Full Speech
2. **IO** Intonation Only: nothing but intonation and pause structure

resynthesized as reiterated 'UH' sequences with the original pitch contour

2x2 min | 10x6 min stimulus file (randomized)

FS | IO | pause | FS | IO | FS | IO | pause | FS | IO | FS | pause | IO | FS | IO

practise set
Figure: Response recording from laryngograph and microphone
Experiment: Recordings
Example response waveform and segmentation

- **Top**: Mono waveform of the stimulus
- **Center**: Laryngograph signal of a single response
- **Bottom**: Annotation tiers for the two speakers and the automatic segmentation of a *voiced* and *early response*.
- **Intervals**: The two classes of response delays and their difference in color
- **Number of responses**: FS/IO 6084/6575 (Early: 2349/2377)
Results: Distribution of Reaction-Time Delays

- Response counts are already increasing before end of utterance → Projection of TRPs takes place.
- Delays are shorter for Full Speech stimuli (But note similar shape!)
Results: Boundary Tones
Mean Delays & Standard Deviations for Three Categories of Boundary Tones.

- **Intonation Only** stimuli get longer delays for mid tone endings.
- in **Intonation Only** stimuli, mid tone endings have longer delays than low and high tone endings.
- For all boundaries tones, more variance for **Intonation Only** responses
- No differences between boundary tones

\*: \( p < 0.01 \)
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Results: Early Responses
Mean Delays & Standard Deviations for Three Types of Response Delays.

- NB: *Early* & *voiced* resp. differ by construction!
- Mean delays for *FS* are shorter than those for *IO* for both *voiced* and *early* responses.
- The mean delay of the difference RT is also longer for *IO* stimuli.
- More variance in responses to *IO* stimuli for both *voiced* and *early* responses.
- No difference in variance of the difference RTs.
- The variance of the difference RTs was much lower than the variance of the *voiced* and *early* RTs.
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- Rapid responses + effect of boundary tones rule out that subjects reacted to the utterance ends themselves.

  ➔ Mid tones: subjects have to wait for the pause.
  ➔ Intonation into a high or low boundary tone is sufficient to predict an upcoming utterance end, at least some of the time.
Second question:

- How is the use of intonation integrated with other sources of information?

- Both boundary tones and verbal and prosodic information help TRP projection (reduced delays).
- The difference between voiced and early responses was not affected by the stimulus-type.
- *Intonation Only* stimuli mostly affect early integration-times, not the timing after early responses.

$\Rightarrow$ There seems to be a perceptual, $P$, type of delay.
$\Rightarrow$ Removing everything but intonation & pauses increases the integration time with around $10 \pm 1.3\%$. 
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Third question:

- What do we know about the time course of TRP projection?

- We can determine the relative amounts of (integration) time for early and voiced responses \( \frac{\tau_{\text{diff}}}{\tau_{\text{early}}} \approx 0.55 \).

- Early integration time \( \tau_{\text{early}} \) is about 2 x difference integration time \( \tau_{\text{diff}} \).

- \( \tau_{\text{voiced}} = \tau_{\text{early}} + \tau_{\text{diff}} \iff \tau_{\text{diff}} = RT_{\text{voiced}} - RT_{\text{early}} \).

- With a \( t_0 \) of \( \geq 50 \) ms under the most favorable circumstances (shadowing tasks) we can conclude that planning (elicited) minimal responses starts more than 300 ms before the actual utterance end (TRP).
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- Early integration time $T_{early}$ is about $2 \times$ difference integration time $T_{diff}$

- $T_{voiced} = T_{early} + T_{diff} \iff T_{diff} = RT_{voiced} - RT_{early}$

→ With a $t_0$ of $\geq 50$ ms under the most favorable circumstances (shadowing tasks) we can conclude that planning (elicited) minimal responses starts more than 300 ms before the actual utterance end (TRP).
Conclusions

- End-intonation sufficient cue for upcoming TRP in *intonation only* stimuli, but: more time is needed to predict an utterance end.
- Subjects can predict an upcoming TRP from *high* or *low* boundary tones.
- but, most likely, have to wait until they perceive the end of the utterance (pause) in *mid* boundary tone *intonation only* stimuli.
- The articulation of elicited minimal responses has at least one intermediate stage, visible as an articulatory preparation step.
- Planning (elicited) minimal responses starts more than 300 ms before the utterance end (TRP).
Thank you!


Probability of a random walk crossing a threshold for the first time at time $t$:

$$g(t) = \frac{1}{\sigma \cdot \sqrt{2\pi \cdot (t - t_0)^3}} \cdot \exp\left(-\frac{(1 - \alpha \cdot (t - t_0))^2}{2 \cdot \sigma^2 (t - t_0)}\right)$$

Mean Reaction Time: $\bar{RT} = t_0 + \tau$

Variation of Reaction Time: $\text{var}(RT) = \frac{1}{2} \sigma^2 \tau^3$

Relative Integration Times: $\frac{\tau_i}{\tau_j} = \sqrt[3]{\frac{s_i^2}{s_j^2}}$
Relative amounts of (integration) time for $\tau_{early}$ and $\tau_{diff}$,

\[
\frac{\tau_{diff}}{\tau_{early}} \approx 0.55
\]

$\rightarrow \tau_{early}$ is about $2 \times \tau_{diff}$

With a simple model: $\tau_{voiced} = \tau_{early} + \tau_{diff}$

\[\Leftrightarrow \tau_{diff} = RT_{voiced} - RT_{early}\]

For full speech, average difference RT is 130 ms, integration-time, $\tau_{early}$, is 235 ms and the total effective integration-times $\tau_{voiced}$ is 370 ms.

For intonation only, the average difference RT is 140 ms, $\tau_{early}$ is 255 ms and $\tau_{voiced}$ is 400 ms.

With a $t_0$ of $\geq 50$ ms (taken from shadowing tasks), planning starts more than 300 ms before the actual utterance end.
Appendix: Recordings

Timing of Turntaking
Appendix: Reaction Time Distribution under PCM model

Figure: Distribution of RTs for $\tau = 1$ and $\sigma = [1.5, 1.0, 0.5]$
### Number of Responses

**Table:** Total number of articulated (voiced) and early responses to stimuli for each of the 3 end-tone categories and minimal responses for the total conversation set.

<table>
<thead>
<tr>
<th>response category</th>
<th>low</th>
<th>mid</th>
<th>high</th>
<th>total</th>
</tr>
</thead>
<tbody>
<tr>
<td>full speech voiced</td>
<td>1860</td>
<td>2850</td>
<td>1374</td>
<td>6084</td>
</tr>
<tr>
<td>early</td>
<td>690</td>
<td>1144</td>
<td>515</td>
<td>2349</td>
</tr>
<tr>
<td>intonation only voiced</td>
<td>1917</td>
<td>3205</td>
<td>1453</td>
<td>6575</td>
</tr>
<tr>
<td>early</td>
<td>663</td>
<td>1180</td>
<td>534</td>
<td>2377</td>
</tr>
<tr>
<td>full dialog set (min. resp.)</td>
<td>386</td>
<td>539</td>
<td>281</td>
<td>1206</td>
</tr>
</tbody>
</table>

For roughly $\frac{1}{3}$ of all responses we can measure a so called *Early Response*