WHAT'S, UHH, COMING NEXT? EFFECTS OF SPEECH DISFLUENCY ON EVENT-RELATED POTENTIALS DURING SENTENCE PROCESSING

Meredith Brown[a,b,c,*], Nathaniel Delaney-Busch[a,b,c,*], Barbara Storch[b,d], Edward W. Wlotko[b,e], Gina R. Kuperberg[a,b,d]

[a] Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, USA   [b] Department of Psychology, Tufts University, USA   [c] Q-State Biosciences, Inc., USA
[d] Department of Psychiatry, Massachusetts General Hospital, USA   [e] Moss Rehabilitation Research Institute, USA

Background

- Speakers tend to be disfluent before saying something difficult, so disfluencies tend to precede unpredictable words[1,2], making disfluency a **potentially useful pragmatic cue** to "expect the unexpected"[3]
- Evidence that listeners are sensitive to the association between disfluency & unpredictable words:
  - **from ERPs:** smaller N400 effect following disfluency than following a fluent context[4]
  - **from eyetracking:** more fixations to unpredictable or difficult-to-name objects following disfluency[5-6]
  - **from memory tasks:** a preceding disfluency boosts word memory, especially for predictable words[4]
- But this evidence is mixed:
  - During discourse processing, **disfluency boosts memory equally** for predictable and unpredictable (but plausible) words[7] (contra [4], which used unpredictable words of questionable plausibility)
  - Distribution of disfluencies may not be systematic enough to consistently modulate **content** of predictions across a variety of contexts (cf. [8]) – and may instead, in these contexts, more generally **orient attention** toward upcoming words[7]
- The processing effects of disfluency are also **not automatic or obligatory:** When listeners are explicitly informed that a speaker is likely to have difficulty producing fluent speech, they are much less likely to preferentially fixate unpredictable or difficult-to-name objects in response to disfluency[6,9]
- Less clear whether and how listeners can adjust their use of disfluencies during processing based **only on implicit information about the distribution of disfluencies** with respect to unpredictable vs. predictable words over the course of an experiment

Design

CRITICAL ITEMS (192)

HIGH (128) contextual constraint

FLUENT (96) vs. **DISFLUENT** (96)   **EXPECTED** (64) vs. **UNEXPECTED** (64)

Every morning before school his mother laid out his clothes and packed → his → lunch / his uhhh → flute

Arrows indicate where stimuli were cross-spliced to minimize potential coarticulatory confounds across conditions

plus 64 **low-constraint** items not discussed here (32 **fluent**, 32 **disfluent**)

FILLER ITEMS (192)

MEDIUM-HIGH contextual constraint

FLUENT vs. **DISFLUENT**   **EXPECTED** vs. **UNEXPECTED**

The woman in the grocery store was handing out → free / free uhhh → samples

Her parents were afraid she had joined some sort of → strange / strange ummm → band

QUESTION 1
Evaluating effects of disfluency on N400 when comparing **predictable** with **unpredictable (but plausible)** words

QUESTION 2
Assessing how manipulating distributional characteristics of disfluency influences **memory** for predictable words

QUESTION 3
Comparing effects of disfluency on N400 when disfluency is **reliably associated** with unexpected words vs. when this association is **relatively unreliable**

Procedure

- Fillers intermixed with critical items, with items pseudorandomized such that unexpected critical words appearing twice in the same list appeared first in the high-constraint context (and with at least 20 items separating)
- Unique pseudorandomized list for each participant
- Stimuli presented over headphones
- Task: answering occasional yes/no questions about filler items
- ERPs measured with 29 active tin electrodes & sampled at 200 Hz
- Participants: 48 native English speakers, age 18-35, 31 female
- Surprise memory post-test (n = 41 out of 48) to assess whether disfluency affects incidental memory for critical words in each participant group (limited to expected words due to details of how the ERP experiment lists were constructed)

TWO PARTICIPANT GROUPS (n = 24 each)

RELIABLE association between disfluency & unexpected word

	EXP	UNEXP
FLU	33%	17%
DIS	8%	42%

96 **FLUENT** / **EXPECTED** fillers
96 **DISFLUENT** / **UNEXPECTED** fillers

UNRELIABLE association between disfluency & unexpected word

48 **FLUENT** / **EXPECTED** fillers
48 **DISFLUENT** / **UNEXPECTED** fillers

	EXP	UNEXP
FLU	21%	29%
DIS	21%	29%

48 **FLUENT** / **UNEXPECTED** fillers
48 **DISFLUENT** / **EXPECTED** fillers

Results & discussion

QUESTION 1: DOES DISFLUENCY MODULATE THE N400 EFFECT?

Disfluency x Expectedness (n=48)

Answer: Not in this experiment (when averaging across groups)

- Expectancy effect: **Larger (more negative) N400s for unexpected** words than for **expected** words (p<.0001)
- Disfluency effect: **Larger N400s** for words in **disfluent** contexts than in fluent contexts (p<.0001)
- No interaction between disfluency & expectedness

QUESTION 2: IS LISTENERS' MEMORY FOR PREDICTABLE WORDS SENSITIVE TO DISTRIBUTIONAL CHARACTERISTICS OF DISFLUENCIES?

Answer: Yes, effects of disfluencies on word memory **diverge** between groups

- Significant three-way interaction between disfluency, group, and trial number (p<.05)
- When disfluency precedes unexpected words **relatively unreliably**, listeners are **significantly less likely** to remember expected words that follow a disfluency late in the experiment, suggesting that they become **less surprising**, & thus less memorable
- When disfluency precedes unexpected words **more reliably**, there is no significant difference in memory for items with and without disfluency, nor interaction with trial number
- Indicates that listeners are **sensitive** to distributional characteristics of disfluency, & **adapt** their processing of disfluency accordingly

QUESTION 3: DO DISTRIBUTIONAL CHARACTERISTICS OF DISFLUENCIES MODULATE THEIR EFFECTS ON THE N400?

Disfluency x Expectedness x Group (n=24 per group)

Answer: Effects of disfluencies on late N400 effects **diverge** between groups (p<.05)

- **Reliable group:** More of an expectancy effect for disfluent items than fluent items, consistent with attentional orienting hypothesis (disfluency orients listeners' attention to the speech signal, without necessarily changing content of listeners' predictions about what word might come next)
- **Unreliable group:** Less of an expectancy effect for disfluent items than for fluent items, suggesting that the N400 effect is in fact sensitive to distributional association between disfluency & unpredictable words: **disfluency orients attention less** when these distributional relationships change

Conclusions

- ERP and memory effects show that **listeners are sensitive to distributional associations** between disfluency & unexpected words
  - **Disfluency amplifies N400 effects when disfluency is typically distributed** (reliable group), suggesting that disfluency is generally orienting attention toward what the speaker is saying[7] (in this experiment)
  - **Disfluency attenuates N400 effects when disfluency is atypically distributed** (unreliable group), suggesting that unreliable associations between disfluency & unexpected words **disrupt** attention-orienting effects of disfluency
  - Atypical distributions of disfluencies also result in **reduced memory** for expected words preceded by disfluency over the course of the experiment (relative to the reliable group)
- First demonstration, to our knowledge, that listeners flexibly **adapt how they process disfluency** based solely on implicit distributional information
- Possible that disfluencies are systematically distributed enough to reliably modulate the content of predictions as well as to cue attention toward upcoming material only in contexts where potential alternative outcomes are limited[5-6] &/or are considerably different in terms of their predictability/plausibility[4-5] or ease of naming[6]

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