LEARNING TO EXPECT THE, UHH, UNEXPECTED: ADAPTATION TO SPEECH DISFLUENCIES IN AN ERP PARADIGM

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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

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

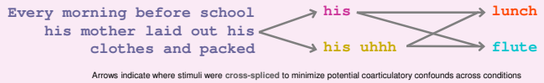
QUESTION 2
Assessing how manipulating distributional characteristics of disfluency influences **memory** for predictable words

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

Design

CRITICAL ITEMS (192)

HIGH (128) contextual constraint | **FLUENT** (96) vs. **DISFLUENT** (96) | **EXPECTED** (64) vs. **UNEXPECTED** (64)

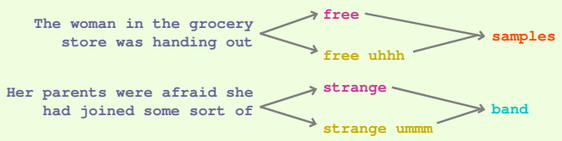


Arrows indicate where stimuli were cross-spliced to minimize potential coarticulatory confounds across conditions

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**



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 (current n = 24; target n = 48)
- Surprise memory post-test (current n = 28) 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

RELIABLE association between disfluency & unexpected word

96 FLUENT / EXPECTED fillers
96 DISFLUENT / UNEXPECTED fillers

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

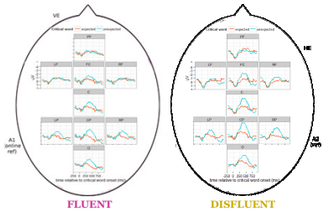
UNRELIABLE association between disfluency & unexpected word

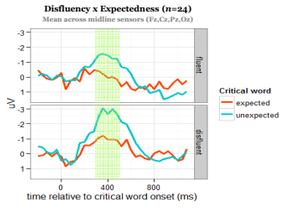
48 FLUENT / EXPECTED fillers
48 DISFLUENT / UNEXPECTED fillers
48 FLUENT / UNEXPECTED fillers
48 DISFLUENT / EXPECTED fillers

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

Results & discussion

QUESTION 1: DOES DISFLUENCY ATTENUATE THE N400 EFFECT?

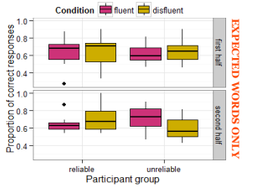




ANSWER: No, it actually **enhances** it

- **Larger N400 effects** (exp<unexp 300-500 ms after stimulus onset) for words in **disfluent** contexts than in **fluent** contexts
- Somewhat higher N400 amplitudes overall in the disfluent condition (possibly due to baseline amplitude differences)
- 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

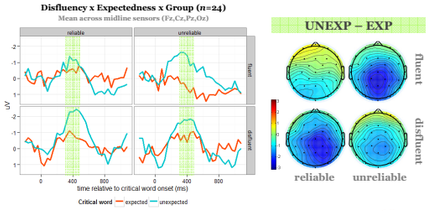
QUESTION 2: ARE LISTENERS SENSITIVE TO DISTRIBUTIONAL CHARACTERISTICS OF DISFLUENCIES?

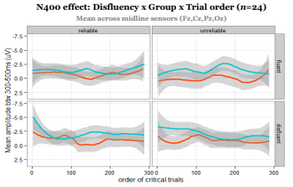


ANSWER: Yes – effects of disfluencies on word memory **diverge** between groups

- When disfluency precedes unexpected words **relatively reliably**, listeners are **more likely** to remember expected words that follow a disfluency late in the experiment, suggesting that they become **more surprising**, & thus more memorable
- When disfluency precedes unexpected words **less reliably**, listeners are **less likely** to remember expected words that follow a disfluency late in the experiment, suggesting that they become **less surprising**, & thus less memorable
- 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?





ANSWER: Yes – whereas disfluency **enhances** N400 effects in the reliable group, it **attenuates** N400 effects in the unreliable group

- Effect of disfluency on N400 effect seems to be present from start of experiment, and then to **increase** in the reliable group and **lessen** in the unreliable group
- Suggests 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

- Disfluency **enhances** the N400 effect (*contra* [4]), suggesting that at least for some listeners and/or in some contexts, disfluency may serve to **generally orient attention toward what the speaker is saying**[7] rather than to weaken or broaden listeners' predictions about upcoming words
- However, other aspects of our data show that **listeners are sensitive to distributional associations** between disfluency & unexpected words
  - **Reliable** associations between disfluency & unexpected words **reinforce** attention-orienting effects of disfluency and **boost memory** for expected words preceded by disfluency
  - **Unreliable** associations between disfluency & unexpected words **disrupt** attention-orienting effects of disfluency and **reduce memory** for expected words preceded by disfluency
  - 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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