

Investigating Island Sensitivity in the Processing of Wh- Dependencies: An ERP Study

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INTRODUCTION

Resolution of *wh*- dependencies has been characterized as a predictive process; once a *wh*- word has been identified, the parser predicts upcoming potential gap sites before encountering information in the bottom-up signal confirming an actual gap

Filled-gap effects

In the psycholinguistics literature, filled-gap effects are observed when the parser predicts the presence of a gap in a position that is already filled with lexical material, resulting in a reading time slowdown (Clifton & Frazier, 1989; Stowe, 1986)

Finding evidence of subject filled-gap effects would provide evidence that the parser makes structural predictions about gap sites prior to encountering a gap-licensing verb, but results in the literature have been mixed (Lee, 2004)

Island sensitivity

It has also been shown that the parser avoids predicting gaps within illicit grammatical domains known as 'islands' (Stowe, 1986)

Debates continue regarding whether gap-filling in islands is avoided due to syntactic constraints (Sprouse et al., 2012) or to processing difficulty (Hofmeister & Sag, 2010; Kluender, 2004)

Sproue et al. (2012) suggest that one way to bring evidence to this debate is to examine individual differences in cognitive abilities, with processing approaches predicting that increased processing resources should be related to positing gaps in islands

ERP EVIDENCE: WH- DEPENDENCIES

Few studies in the ERP literature have used filled-gap paradigms (Hestvik et al., 2007, 2012), and no study has examined island sensitivity using fully grammatical sentences

Studies examining *wh*- dependency resolution have reported two ERP components:

N400: Michel (2014) reported N400s modulated by gap predictability, suggesting that the parser revises its prediction that a gap is forthcoming upon encountering an island boundary

P600: In successful filler-gap dependency resolution in licit contexts, P600s have been found at an actual gap site (Kaan et al., 2000; Phillips et al., 2005)

CURRENT STUDY

The current study uses ERP components to track the processing of *wh*- dependencies across the sentence, examining sentences with and without islands at three critical regions:

1. Pre-verbal filled gap site (subject position)
2. Post-verbal filled gap site (object position)
3. The ultimate resolution site (actual gap)

Individual difference measures included:

- Working Memory (Reading Span; Counting Span)
- Attentional Control (Number Stroop task)

Predictions

1. **Subject position:** If readers attempt to posit a gap in subject position, a filled-gap effect will emerge, indexed by N400

2. **Object position:**

• *In licit positions:* If readers attempt to posit a gap in object position, a filled-gap effect will emerge, indexed by N400

• *In islands:* If readers avoid positing a gap within an island domain, no filled-gap effect should emerge

3. **Actual gap site:** If readers successfully resolve the *wh*- dependency, P600 should emerge

If gap filling in islands is avoided due to processing difficulty, then individuals with greater processing resources should show larger filled-gap effects (N400) in the island context

Cognitive abilities may also affect prediction in grammatical contexts, with individuals with greater processing resources showing larger filled-gap effects in licit contexts (Hutchison, 2007; Johnson et al., 2016; Nicenboim et al., 2015)

STIMULI

40 targets per condition, plus 80 filler sentences (all grammatical)

Non-Island Conditions

No Extraction

(1a) Jamie wondered if the editor interviewed Dave Campbell with the reporter from the department.

Wh- Extraction

(1b) Jamie wondered **who** the editor interviewed Dave Campbell with ___ from the department.

Subject filled gap

Object filled gap

Actual gap site

Island Conditions

No Extraction

(1c) Jamie wondered if the editor [that interviewed Dave Campbell] kissed the reporter after the meeting.

Wh- Extraction

(1d) Jamie wondered **who** the editor [that interviewed Dave Campbell] kissed ___ after the meeting.

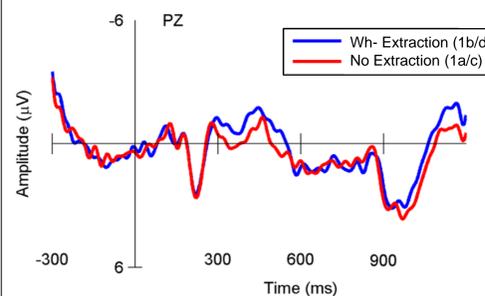
Subject filled gap

potential Object filled gap (in island)

Actual gap site

RESULTS: SUBJECT FILLED GAP

(300-500 ms)

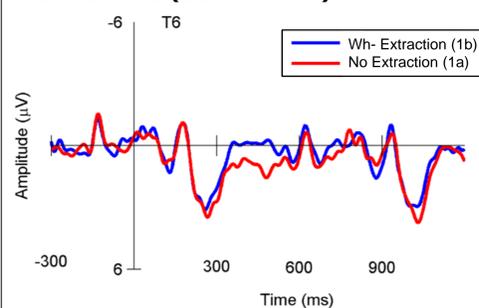


Collapsing across Island/Non-Island conditions for analysis

- Extraction*Anteriority
- Significant effects of Extraction in Central and Posterior regions
- Wh- extraction yielded significant negativity (N400)

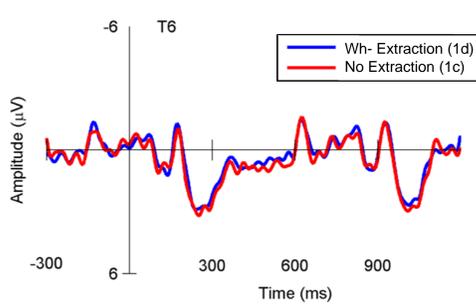
RESULTS: OBJECT FILLED GAP

Non-Islands (300-500 ms)



- Extraction*Anteriority
- Negativity for Wh- Extraction in Anterior, Central, and Posterior regions (N400)

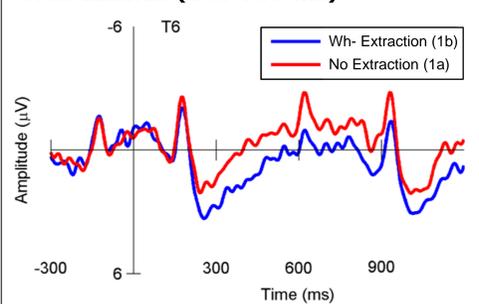
Islands (300-500 ms)



- No effect of Extraction in Island model

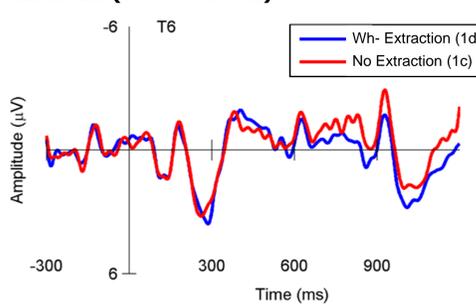
RESULTS: GAP SITE

Non-Islands (600-900 ms)



- Extraction*Anteriority
- Positivity for Wh- Extraction in Central and Posterior regions (P600)

Islands (600-900 ms)



- Main effect of Extraction
- Positivity for Wh- Extraction across regions (P600)

METHODS & DATA ANALYSIS

Participants: 26 right-handed native English speakers recruited from university population (6 males, mean age 21.3, range: 18-30)

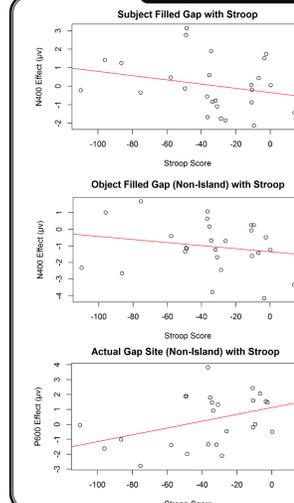
Individual differences: Attentional control assessed via number Stroop task (Bush & Shin, 2006); Working memory assessed via Reading Span and Counting Span tasks (Conway et al., 2005)

Stimuli presentation: Stimuli presented using RSVP (450ms/300ms) via Paradigm (Tagliaferri, 2005); yes-no comprehension questions follow 1/3 of trials

EEG recording: EEG continuously recorded using Synamps2 amplifier (Compumedics Neuroscan, Inc.) and 32-channel Ag/AgCl electrode cap (Electro-Cap International, Inc.).

Data analysis: Linear mixed-effects models with *lme4* package (Bates et al., 2015) in R; *LMEConvenience Functions* used to progressively backwards-fit model including all possible interactions and fixed effects via log-likelihood ratio tests to arrive at the simplest/best-fitting model (Tremblay & Rasijn, 2015)

INDIVIDUAL DIFFERENCES



Subject filled gap

- Stroop*Extraction significant: increasing attentional control was associated with increased negativities (larger N400)

Object filled gap

- Stroop*Island*Extraction significant: in only Non-Island condition, increasing attentional control was associated with increased negativities (larger N400)

Actual gap site (Non-Island condition)

- Stroop*Extraction*Anteriority significant: increasing attentional control was associated with increased positivities (larger P600) in anterior and central sites

DISCUSSION

Our results reveal the dynamics of *wh*- dependency resolution in fully grammatical sentences at three critical regions:

1. Subject position

- One of few studies reporting subject filled-gap effects (Lee, 2004); N400 emerged, in line with Michel (2014), indicating that the parser makes structural predictions prior to encountering gap-licensing verb
- N400 effect related to Stroop scores, suggesting that individuals with greater attentional control were better able to predict upcoming gaps (Johnson, 2015)

2. Object position

- An object filled-gap effect emerged in only licit contexts, indexed by N400
 - Licit N400 effect related to Stroop scores, suggesting that individuals with greater attentional control were better able to predict upcoming gaps

• No effects emerged in the island context, consistent with Michel (2014) that the parser updates its prediction that a gap is forthcoming inside an island

- Contrary to predictions of processing account of island sensitivity, processing capabilities did not predict ERP effects in at the filled gap located with the island

3. Actual gap site

• In line with Kaan et al. (2000) and Phillips et al. (2005), successful *wh*- dependency resolution yielded P600s, in both Island and Non-Island conditions

- Although Stroop scores were only related to the P600 effect in Non-Island conditions, the P600 at the actual gap site for sentences containing islands indicates that the parser was able to resolve the dependency (i.e., processing did not completely break down)

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