Fodor (1978)

GAP FINDING

(1) How does the parser decide where a moved constituent has moved from? How does the parser recognize gap positions?

(2) How do the gap-finding/gap-filling routines relate to constraints on transformations?

(3) a. **Who** did you expect ___ to make a potholder?
   b. **Who** did you expect [you] to make a potholder for ___?

(4) Temporary ambiguities:
   a. Who did you expect ...
   b. Who did you expect to make ...

(5) **Doubtful v. doubtless gaps**
   a. What do you want Mother to make ___ for Mary?  
      **DOUBTLESS**
   b. What do you want Mother to sing ___ to Mary?  
      **DOUBTFUL**
   c. What do you want Mother to sing (___) to Mary about ___?  
      “”

(6) Are sentences harder to understand if the true gap is doubtful?
   a. Which book did the teacher read to the children?
   b. Which picture did the teacher show to the children?

(7) Are sentences with a false doubtful gap as complex as sentences without one?
   a. Which book did the teacher read (___) to the children from ___?
   b. Which student did the teacher go to the concert with ___?

(8) Who did Tom ask Meg to persuade Jill to inform Ted that Bob had spoken to ___?

(9) **Role of lexical expectations**
   a. Who did John kill (___) for the sake of ___?
   b. Who did John kill ___ for the sake of his uncle?
   c. Which student did the teacher walk (___) to the cafeteria with ___?
   d. Which student did the teacher walk ___ to the cafeteria?

(10) Putting the observations together
    a. Verbs have ordered subcategorizations.
    b. When a direct object is expected, a gap is posited if ‘trying the next constituent’ doesn’t work.
Dative movement restriction

(11) a. *? Who did John give ___ a book? 
    b. What did John give Mary ___? 
    c. Who did John give a book to ___? 
    d. What did John give ___ to Mary?

(12) Hankamer (1973) no-ambiguity constraint “Unacceptable Ambiguity”

Gapping

a. Max seemed to want Alice to get lost, and Susan to stay
b. ___ and [Max seemed to want] Susan to stay

(13) The XX Extraction Constraint
If at some point in its derivation a sentence contains a sequence of two constituents of the same formal type, either of which could be moved or deleted by a transformation, the transformation may not be apply to the first constituent in the sequence.

(14) “... though the general theory of parsing-motivated constraints I have proposed is only preliminary ... it does clear the ground for the claim that dative questions are restricted in the grammar because of the parser’s strategies for finding gaps.” p. 446

FILLER FINDING

(15) a. What, are boxes, easy to store ____ in ____
    b. *What, are boxes, easy to store ____ in ____
    c. This is the violin that I wonder which sonatas to play on
    d. These are the sonatas that I wonder which violin to play on

(16) Kuno & Robinson (1972): Constraint on Crossing Dependencies
a. Two wh-dependencies cannot cross.
b. Crossing: C_{head} ... C'_{head} ... C_{tail} ... C'_{tail}
c. Nested: C_{head} ... C'_{head} ... C'_{tail} ... C_{tail}

(17) The Nested Dependency Constraint (NDC)
If there are two or more filler-gap dependencies in the same sentence, their scopes may not intersect if either disjoint or nested dependencies are compatible with the well-formedness conditions of the language.

(18) What is Fodor's motivation for the NDC?
Filler-gap routines

Latest evidence
Syntax Seminar, W’10, McCloskey & Wagers
Active Gap Creation

My brother wanted to know who Ruth will bring us home to at Christmas.

My brother wanted to know if Ruth will bring us home to at Christmas.

Readers slow down upon encountering an NP where a gap was expected.

(Stowe 1986, Crain & Fodor 1985)
Active dependency formation

* overwhelmingly supported by the data

  * across methodologies:

  * Filled gap effects (Crain & Fodor 1985; Stowe 1986; et seq.)
  * Plausibility manipulations (Boland et al. 1990; Traxler & Pickering 1996)
  * Cross-modal priming (Nicol & Swinney 1989)
  * Eye-movements in visual world paradigm (Sussman & Sedivy 2003)
  * Electrophysiological indices (Garnsey et al. 1989; Kaan et al. 2000; etc.)

  * ... and numerous languages
    English, Dutch, German, Hungarian, Italian, Japanese, Russian
Active dependency formation

**Evidence**

**Immediate semantic anomaly detection**

the song that the student *listened* ...  
the painting that the student *listened* ...  

\( \text{RT} \uparrow \)  
\( \text{N400} \)

Garnsey, Tanenhaus & Chapman, 1989  
Traxler & Pickering, 1996
Head-mounted Eye-Tracking
Jody was eating breakfast one morning when she saw a big hairy spider creeping across the table towards her. Jody, whose terrible arachnophobia had caused her to seek therapy a few years ago, drew on the techniques of relaxation and anxiety management that her psychologist had taught her. Instead of screaming or freaking out, she calmly took off her shoe and slammed it down on top of the spider. She ate the rest of her Froot Loops in peace.

Did Jody squash the spider with her shoe? What did Jody squash the spider with?

Figure 1. Visual display.
Figure 2. Fixation proportions to display items averaged across subjects. Pre-verb, verb, noun phrase, and preposition regions averaged across items are as marked.
WH v. Yes/No

Figure 1. Visual display.

Figure 3. A comparison of looks to the competitor and looks to the target across the two conditions. Regions of significant difference (α = .05) are shaded.

(Sussman & Sedivy, 2003)
1) Recognizing the verb alternative interpretations if we take seriously the linking active filler-gap processing, but their evidence is amenable to Sussman & Sedivy (2003) proposed a visual world measure of Wh+Verb dependency formation and semantic composition. The visual world paradigm reveals incremental processing and theme saliency may allow one to expect the questions to be diverged around than yes/no-questions.

2) The difference between our wh- and Y/N-questions lies in the identification of the correct theme is what the difference lies in the event 1: eat the cake with a fork. In other words, the increased looks to themes in the wh-condition, and the display region) of the wh-condition does not yield significant effects in the same direction. However, given that the fixation pattern is very similar to the pattern observed in Experiment 1, addition of more data may support the difference found in Experiment 1. As in Experiment 1, looks towards the correct theme diverge 16 ms after verb onset, the difference between the wh-condition and the Y/N-condition is 16 ms. This increased looks to theme object may be a marker for the identification of the correct theme. Preliminary Results (N=18) showed that looks towards the correct theme began to diverge around 350 to 500ms after verb onset in the wh-condition, and around 250 to 350ms after verb onset in the Y/N-condition. However, given that the fixation pattern is very similar to the pattern observed in Experiment 1, addition of more data may support the difference found in Experiment 1.
Electrophysiology

★ EEG: electroencephalography
ERP Responses to Syntactic Difficulty

Left Anterior Negativity (LAN)

(from Kaan, 2001)
Long-Distance Dependencies

Emily wondered who the performer in the concert had imitated for the audience’s amusement.

Control Emily wondered whether the performer in the concert had imitated a pop star for the audience’s amusement.

---

V preceded by "whether"

V preceded by "which N"

V preceded by "who"

(Kaan, Harris, Gibson, & Holcomb, 2000)
Embedded Verb
Trace Reactivation Studies

Which boy did the old man from Osaka meet at the station?

(e.g. Nicol & Swinney 1989, Bever & McElree 1988, MacDonald 1989)
Trace Reactivation Studies

Which boy did the old man from Osaka meet at the station?

- boy
- girl

- boy
- girl

(faster decision)

(same speed)

(e.g. Nicol & Swinney 1989, Bever & McElree 1988, MacDonald 1989)
<table>
<thead>
<tr>
<th>Study</th>
<th>Measure</th>
<th>Structure</th>
<th>Example</th>
<th>Island sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stowe 1986</td>
<td>self-paced reading</td>
<td>PP in subject NP</td>
<td>The teacher asked what the silly story about Greg’s older brother was supposed to mean.</td>
<td>Yes</td>
</tr>
<tr>
<td>Pickering et al. 1994, exp. 2</td>
<td>eye-tracking, self-paced reading</td>
<td>PP in subject NP</td>
<td>I know what a book about the local election discussed the most</td>
<td>Yes</td>
</tr>
<tr>
<td>Traxler &amp; Pickering 1996</td>
<td>eye-tracking</td>
<td>Relative clause in subject NP</td>
<td>We like the city that the author who wrote unceasingly and with great dedication saw while waiting for a contract.</td>
<td>Yes</td>
</tr>
<tr>
<td>Bourdages 1992</td>
<td>self-paced reading</td>
<td>Relative clause in object NP (French)</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>McElree &amp; Griffith 1998</td>
<td>speeded grammaticality</td>
<td>Relative clause in object NP</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Yoshida et al. 2004</td>
<td>self-paced reading</td>
<td>Relative clause in object NP (Japanese)</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Freedman &amp; Forster 1985</td>
<td>sentence-matching</td>
<td>Complex NP with possessor</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Kurtzman &amp; Crawford 1989</td>
<td>speeded grammaticality</td>
<td>Infinitival in subject NP</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Clifton &amp; Frazier 1989</td>
<td>speeded grammaticality</td>
<td>Relative clause in subject NP</td>
<td></td>
<td>No?</td>
</tr>
<tr>
<td>Pickering et al. 1994, exp. 1</td>
<td>eye-tracking, self-paced reading</td>
<td>Relative clause in subject NP</td>
<td></td>
<td>No?</td>
</tr>
<tr>
<td>Kluender &amp; Kutas 1993</td>
<td>event-related potentials</td>
<td>Wh-island</td>
<td></td>
<td>boundary detected</td>
</tr>
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<td>event-related potentials</td>
<td>Wh-island</td>
<td></td>
<td>boundary detected</td>
</tr>
<tr>
<td>Neville et al. 1991</td>
<td>event-related potentials</td>
<td>Complex NP with possessor</td>
<td></td>
<td>boundary detected</td>
</tr>
</tbody>
</table>

**Table 1:** Summary of previous experimental studies of island constraints in language processing. Critical regions of example sentences are underlined where applicable.

Phillips (2006)
The **adhesive coating** which the talented engineer ... computer program
Intransitivity

• Staub 2007: eye-tracking study on unaccusatives in filler-gap environment

1. Filler-Gap: Intransitive, Relative clause
   The party that the student arrived promptly for...

2. Baseline: Intransitive, no filler
   The student arrived promptly for...

No difference in gaze duration measures
Intransitivity

• Staub 2007: eye-tracking study on unaccusatives in filler-gap environment

1. Filler-Gap: Transitive, Relative clause

   The gadget that the manager called ...

2. Baseline: Transitive, no filler

   the manager called ...

Plausibility Mismatch Effect!
Omaki, Lau, Phillips 2010

Non-cumulative, word by word self-paced reading experiment

a. Transitive, no island
   The city that the author **wrote** regularly about ____ was...

b. Intransitive, no island
   The city that the author **chatted** regularly about ____ was...

c. Transitive, RC island
   The city that the author \( [R_C \text{ who } wro \text{te } \text{ regularly } ] \) saw ____ was...

d. Intransitive, RC island
   The city that the author \( [R_C \text{ who } cha \text{tted } \text{ regularly } ] \) saw ____ was...
Altogether

Island **; n.s. interaction

Spill-over

verb

Trans, Non-Isl
Intrans, Non-Isl
Trans, Isl
Intrans, Isl
Omaki et al. *cont.*

**Experiment 2**

**a. Intransitive, no island**

The costume party that the student *arrived* eagerly for ____ ...

**b. Transitive, no island**

The costume party that the student *planned* eagerly for ____ ...

**c. Intansitive, RC island (BASELINE)**

The costume party that the student \[_{RC} \text{who arrived} \text{ eagerly}] \text{ threw} ____ ...

**d. Intransitive, RC island (BASELINE)**

The costume party that the student \[_{RC} \text{who planned} \text{ eagerly}] \text{ threw} ____ ...
First fixation duration

![Bar chart showing first fixation duration for no-island and island conditions. The chart compares intransitive and transitive sentences. The no-island condition has a significantly higher fixation duration (* for p < 0.05). The island condition shows no significant difference (NS).]
Japanese Filled-Gap Effect

Aoshima et al. 04
Japanese readers exhibit Filled Gap effect. Confirms that they interpret a sentence-initial wh-phrase in the embedded clause before they see the first verb (Region 7).
particular models of memory for sentence processing (e.g., Lewis, 1996). As more information is processed between the point at which the filler item is read and the point at which it is bound to the argument position of the verb, there is an increase in the likelihood that the representation of the filler will decay, that it will be displaced from memory, or that the cues provided by the verb and related linguistic elements will not be sufficient to retrieve the filler item from memory.

However, discriminating between content-addressable and search processes requires measures of processing speed that are unaffected by differences in the likelihood of recovering the relevant memory representation. Unfortunately, simple timing measures like reaction time, reading time, or eye movement measures are affected by both factors (see McElree, 1993; McElree & Nordlie, 1999; McElree & Grieth, 1995, 1998). One solution to this problem is to derive a function that measures how the accuracy of processing varies with processing time (Wickelgren, 1977), so that both speed and accuracy can be jointly measured and separately assessed. Here, the response-signal SAT procedure was used to construct such functions.

Fig. 2 illustrates the procedure. Sentences were visually presented one word at a time (250 ms/word). Readers were required to make binary (yes/no) acceptability decisions at one of 6 randomly determined times (either 50, 300, 500, 800, 1200, or 3000 ms) after the onset of the final word in the string. In the contrasts of primary interest (T1–T6 in Table 1), the final word was the crucial matrix verb that specified the argument position of the filler item. The cue to respond was signaled by a brief (50 ms, 1000 Hz) tone, and readers were trained to respond within 300 ms of the tone. Readers were required to respond at the tone even if processing of the string was not fully completed and the response had to be based on partial information or, in the limit, a guess. This feature of the SAT procedure minimizes the decision processes that are involved in reaction time or other timing tasks, in which a participant must select a criterion for responding that balances the tradeoff between speed and accuracy (Dosher, 1979; Ratcliff, 1978; Wickelgren, 1977). To further control for response biases (tendency to differentially respond ''yes'' or ''no''), accuracy is measured in d0 units by scaling the z-transformation of the hit rate for an acceptable string against the z-transformation of the false alarm rate for the corresponding unacceptable string. The accuracy at various response times provides a relatively direct estimate of the likelihood that processing is completed at that time. The range of response signals was selected to chart the full timecourse of processing, from times when accuracy was near chance to times when accuracy reached an asymptotic level.

<table>
<thead>
<tr>
<th>Construction type</th>
<th>Acceptability</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>No interpolation</td>
<td>Acceptable</td>
<td>T1. It was the scandal that the celebrity relished</td>
</tr>
<tr>
<td>No interpolation</td>
<td>Unacceptable</td>
<td>T2. It was the scandal that the celebrity panicked</td>
</tr>
<tr>
<td>One interpolated clause</td>
<td>Acceptable</td>
<td>T3. It was the scandal that the model believed that the celebrity relished</td>
</tr>
<tr>
<td>One interpolated clause</td>
<td>Unacceptable</td>
<td>T4. It was the scandal that the model believed that the celebrity panicked</td>
</tr>
<tr>
<td>Two interpolated clauses</td>
<td>Acceptable</td>
<td>T5. It was the scandal that the model believed that the journalist reported that the celebrity relished</td>
</tr>
<tr>
<td>Two interpolated clauses</td>
<td>Unacceptable</td>
<td>T6. It was the scandal that the model believed that the journalist reported that the celebrity panicked</td>
</tr>
</tbody>
</table>
Fig. 3 presents hypothetical SAT functions illustrating how different SAT timecourse patterns can discriminate between alternative retrieval processes. Consider first the expected result that interpolating more material between the filler and gap position decreases the accuracy of responding. Recall that this could be because there is a lower probability that a representation of the filler is available when the verb is processed and/or because there is a higher probability of misanalyzing material up to and including the final verb. If additional material decreases only the overall accuracy of responding, the corresponding functions will differ in asymptotic level alone. Panel A depicts two hypothetical conditions that differ in this manner. The pre-asymptotic portion of the SAT function measures processing speed or dynamics, jointly specified by the intercept of the function (when accuracy departs from chance, $d_0 = 0$) and the rate at which accuracy grows from intercept to asymptote. The intercept measures the minimum time needed to form an interpretation that would serve to discriminate acceptable from unacceptable forms. The rate of the SAT function reflects either the rate of continuous information accrual if processing is continuous or the distribution of finishing times if processing is discrete or quantal (Dosher, 1976, 1979, 1981, 1984; Meyer, Irwin, Osman, & Kou-nois, 1988). In either case, differences in intercept or rate implicate underlying differences in the speed of processing. This situation is depicted in Panel B of Fig. 3, where the functions are associated with different intercepts and rates of rise to a common asymptote. If access to the filler’s representation requires a search process when the matrix verb is encountered, then the SAT intercept and/or rate will systematically slow as more material is interpolated between the filler and gap. Rate or intercept differences can arise from factors other than retrieval speed; for example, they might arise from differences in the inherent complexity of computing...
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interpolated between the filler and gap. That conclusion was supported by the fact that asymptotic accuracy decreased as more material was inserted between the filler and gap (squares). Between the filler and gap (circles), and two complement clauses (triangles), one complement clause intervened between the filler and gap (squares). Smooth curves show the best fitting exponential model for all three conditions in parameter estimates across the participants.

Fig. 4 shows the average (over participants) asymptotic estimates for average data and individual participants. Consequently, statistical tests on the resulting parameter estimates were all nonsignificant. Additional properties of the data were examined to check whether participants were performing the task in the same way as they were trained. These properties included checking whether participants were performing the task in the same way as they were trained.

Despite systematic asymptotic differences, there was no evidence that processing speed at the critical verb was affected by the presence of interpolated material. These findings are consistent with previous studies that have shown that interpolated material can interfere with the processing of the critical verb (e.g., McElree & Lorch, 1992). The results of this study suggest that interpolated material can interfere with the processing of the critical verb even when it is not the last verb in the sentence. The results also suggest that interpolated material can interfere with the processing of the critical verb even when it is not the last verb in the sentence.
like (13)–(16) were included to discourage readers from paying particular attention to the two argument constructions.

Table 3 shows the main contrasts employed in the experiment. (The conditions in Table 3 represent 60% of the material used in the experiment. The remaining material served as filler constructions, consisting of two conjoined main clauses of variable lengths.) Each acceptable version of the short and long, single and double gap constructions (T1, T3, T5, and T7) consisted of two versions, denoted as (a) and (b), that exchanged or reversed the order of NP arguments (album and stamp), with appropriate modifications of the final verb complex. This was done to ensure that acceptability could not be predicted from presentation order. As in prior work, we included constructions like (T9) and (T10) with anomalies in the interpolated region to ensure that readers fully processed the middle regions of the longer strings.

In this experiment, the strings were presented in a phrase-by-phrase rather than a word-by-word method. The phrase breaks are indicated by the slashes in Table 3. We initially ran a version of this experiment in a word-by-word fashion, and found that performance was well above chance and nearly asymptotic at the earliest response times (50–300 ms) after the onset of the final preposition (e.g., in in the verb complex mount in).

Apparently, the verb itself provided much of the information needed to assign argument roles to the dislocated NPs. With the fragment This is the album that the stamps were difficult to mount, for example, readers apparently assumed that the stamps was the direct object argument and anticipated that the album was the indirect object. To ensure that our measure included the time to access the relevant NPs, we measured time relative to the onset of the final infinitival verb phrase (e.g., to mount in).

### Method

#### Participants

Eight students from New York University served as participants in the experiment. Each participated in 10 1-h sessions, plus a 1-h practice session for familiarization with the SAT procedure. All participants were native English speakers, and were paid for their participation in the experiment. None had participated in Experiments 1 or 2.

#### Materials

Ten sets of 336 sentences were generated. As in prior studies, each set was composed of 24 instances of the 14 sentence types (eight acceptable and six unacceptable) listed in Table 3. Following the same randomization

<table>
<thead>
<tr>
<th>Construction type</th>
<th>Acceptability</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short double gap</td>
<td>Acceptable</td>
<td>T1a. This is the album/that the stamps/were difficult/to mount in T1b. These are the stamps/that the album/was difficult/to complete without</td>
</tr>
<tr>
<td>Short double gap</td>
<td>Unacceptable</td>
<td>T2. These are the stamps/that the album/was difficult/to mount in</td>
</tr>
<tr>
<td>Long double gap</td>
<td>Acceptable</td>
<td>T3a. This is the album/that the stamps/which obviously angered/the fussy collector/were difficult/to mount in T3b. These are the stamps/that the album/which obviously angered/the fussy collector/was difficult/to complete without</td>
</tr>
<tr>
<td>Long double gap</td>
<td>Unacceptable</td>
<td>T4. These are the stamps/that the album/which obviously angered/the fussy collector/was difficult/to mount in</td>
</tr>
<tr>
<td>Short single gap</td>
<td>Acceptable</td>
<td>T5a. This is the album/that the collector/found difficult/to spread open T5b. These are the stamps/that the collector/found difficult/to spread out</td>
</tr>
<tr>
<td>Short single gap</td>
<td>Unacceptable</td>
<td>T6. This is the album/that the stamps/were difficult/to spread out</td>
</tr>
<tr>
<td>Long single gap</td>
<td>Acceptable</td>
<td>T7a. This is the album/that the customer/who obviously angered/the fussy collector/found difficult/to spread open T7b. These are the stamps/that the customer/who obviously angered/the fussy collector/found difficult/to spread out</td>
</tr>
<tr>
<td>Long single gap</td>
<td>Unacceptable</td>
<td>T8. This is the album/that the stamps/which obviously angered/the fussy collector/ were difficult/to spread out.</td>
</tr>
<tr>
<td>Control</td>
<td>Unacceptable</td>
<td>T9 This is the album/that the stamps/which obviously despised/the fussy collector/ were difficult/to mount in</td>
</tr>
<tr>
<td>Control</td>
<td>Unacceptable</td>
<td>T10. These are the stamps/that the album/which obviously despised/the fussy collector/ was difficult/to complete without</td>
</tr>
</tbody>
</table>
and T4 (long), and the single gap short (open squares) appropriate unacceptable constructions like T2 (short) (long) in Table 3 against the false alarm rate for the rate for acceptable constructions like T1 (short) and T3 (solid triangles) constructions, formed by scaling the hit interest; the double gap short (solid squares) and long a function of processing time for the four conditions of bols). Smooth curves show the best fitting 4 judgments of short (squares) and long (triangles) single gap constructions (open symbols) and double gap constructions (filled sym-

Fig. 6. Average Results and discussion

Each phrase was displayed for 300 ms times the number of words in the phrase. The critical region of the final tone was presented at either 300, 500, 700, 900, 1500, or 3000 ms after the onset of this final phrase. Longer lag showed a dramatic increase in adjusted-

In Experiments 1 and 2, with the following exceptions. The ing) and procedures were the same as described in experimental parameters (stimulus presentation and tim-

Material, as compared to a short distance between the filler and rationing across participants. The ex-

Procedure

as randomized. From 16 to 22 words in length. The order of presentation combined with 2400 filler strings (half acceptable, half unaccepta-

By testing whether each string was a grammatical sentence (short, acceptable), 240 per set. None of these strings used a common set of parameters, produced a very low ad-

As before, each participant performed 10 1-h sessions from 1 to 10 sets of materials, and the order of as compared to a short distance between the filler and

Materials was randomized across participants. The ex-

yielded a significant main e

ANOVA on asymptotic estimates likewise yielded a

An ANOVA on the effect of the number of gaps, time (3000 ms) with length (short and long) and number of gaps (single and double) as repeated measures factors

With no interaction (null) model, in which all four conditions were fit with a

Subsequent model fits found clear evidence for an

limited to two words (short), four (long) and eight (clefted structure, but all included 3 or 4 NPs and ranged

strings were presented in a phrase-by-phrase manner. Unac-

ficient unacceptable constructions like T6 (short) and T7 (long) against the false alarm rate for the