A climber scaled every cliff.

OUR ROADMAP

• Review of quantifier scope: surface and inverse interpretations
• Big-picture questions this study investigates
• Broad overview of the findings
• The experiments in detail
My friend David just made partner at his law firm. I meet David at his office for lunch. As I’m pulling into the parking lot, I notice all of the partners’ names on their respective parking spaces. I see that Thomas and Beth drive Porsches, Andrew drives a BMW, William drives a Lexus, and Sandra drives a Jaguar. David currently drives a Honda Civic, but he’s considering upgrading since he just made partner.

I advise David that he should get a nicer car since “Every partner at the firm drives an expensive car.”
a. Our set of partners: Thomas, Sandra, Andrew, Beth, William
Our set of expensive cars: BMW, Porsche, Lexus, Jaguar, Audi

Scenario 1: Every partner drives a different expensive car. – surface scope

<table>
<thead>
<tr>
<th>Partner</th>
<th>The car s/he drives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas</td>
<td>Porsche</td>
</tr>
<tr>
<td>Sandra</td>
<td>Jaguar</td>
</tr>
<tr>
<td>Andrew</td>
<td>BMW</td>
</tr>
<tr>
<td>Beth</td>
<td>Mercedes</td>
</tr>
<tr>
<td>William</td>
<td>Lexus</td>
</tr>
</tbody>
</table>

Scenario 2: Some partners drive the same expensive car. – surface scope

<table>
<thead>
<tr>
<th>Partner</th>
<th>The car s/he drives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas</td>
<td>Porsche</td>
</tr>
<tr>
<td>Sandra</td>
<td>Jaguar</td>
</tr>
<tr>
<td>Andrew</td>
<td>Jaguar</td>
</tr>
<tr>
<td>Beth</td>
<td>Porsche</td>
</tr>
<tr>
<td>William</td>
<td>Lexus</td>
</tr>
</tbody>
</table>

In Scenario 2, no partner drives a Mercedes or a BMW, but it is still true that every partner drives an expensive car.

Scenario 3: Every partner drives the same expensive car. – inverse scope

<table>
<thead>
<tr>
<th>Partner</th>
<th>The car s/he drives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas</td>
<td>BMW</td>
</tr>
<tr>
<td>Sandra</td>
<td>BMW</td>
</tr>
<tr>
<td>Andrew</td>
<td>BMW</td>
</tr>
<tr>
<td>Beth</td>
<td>BMW</td>
</tr>
<tr>
<td>William</td>
<td>BMW</td>
</tr>
</tbody>
</table>

b. The sentence is false under this scenario

- Of course, there’s an ambiguity that arises because “an expensive car” is underspecified.
  - Token interpretation: same car
  - Type interpretation: same kind of car
Surface scope: Matches the actual order of the sentence.

For every partner at the firm, that person drives an expensive car.

*Every* has scope over *an*.

• ‘every partner’ is moved to a position higher than where it was in the syntactic tree
• A *variable*, represented by *x*, is inserted into the position that the NP moved from.
  • *x* represents the individuals in our set of partners.
• In order for the sentence *Every partner at the firm drives an expensive car* to be true, we have to be able to plug any of the partners into the spot where we placed the variable and get a true sentence.
• This tree does not represent how we actually pronounce the sentence, but we interpret the object before the subject. Hence, inverse scope:
  • There is a particular (kind of) expensive car and every partner at the firm drives that car.
  A(n) has scope over every.

• Start off with the same syntactic structure and still move the subject.
• The object NP moves to a position higher than the subject NP.

• We plug some particular expensive car into the spot where we moved the object from and we plug the partners into the spot that we moved the subject from.
• If each individual sentence comes out true, then the sentence Every partner at the firm drives an expensive car is true.
ANDERSON 2004 - THE BIG PICTURE:
HOW DO SPEAKERS REPRESENT THE MEANINGS OF AMBIGUOUS CONSTRUCTIONS?

- **Option One:** Manipulate the structure at LF.
  - This is what we’ve been exposed to, and what we’ll see evidence for.

- **Option Two:** No LF. Allow the representation to be underspecified and derive the interpretations from conceptual knowledge.
  - Anderson’s findings (as an aggregate) will argue against this option.

Quantifier scope is a good test of the interaction between structure and conceptual knowledge.

The Proposal:

- **Principle of Processing Scope Economy:**
  The human sentence processing mechanism prefers to compute a scope configuration with the simplest syntactic representation (or derivation). Computing a more complex configuration is possible but incurs a processing cost. (p.31)
  - An intuitive, Ockham’s Razor-based principle.
  - Inverse scope interpretations are more complex because they involve moving both the subject and the object.
  - NOTE: Anderson is using “syntactic” here to mean “LF.”
“The results of the experiments presented here show that assigning an inverse scope interpretation to a doubly quantified sentence consumes more processing resources than assigning surface scope even when extralinguistic factors conspire to make the inverse scope interpretation the preferred one.”

(p. 25-26)
(1) A climber scaled every cliff.

- **Surface:** There exists at least one (\(\exists\)) climber and that climber scaled every (\(\forall\)) cliff.
  - \(\exists\) scopes over \(\forall\)

- **Inverse:** For every (\(\forall\)) cliff, there exists at least one (\(\exists\)) climber who scaled that cliff.
  - \(\forall\) scopes over \(\exists\)
    - IMPORTANT: It *could* be that the same climber scaled all the cliffs.
      - The surface interpretation is a possible inverse interpretation.

(2) Every player rubbed a lucky charm.

- **Surface:** For every (\(\forall\)) player, that player rubbed at least one (\(\exists\)) lucky charm.
  - \(\forall\) scopes over \(\exists\)
    - IMPORTANT: It *could* be that every player rubs the same lucky charm.
      - The inverse interpretation is a possible surface interpretation.

- **Inverse:** There exists at least one (\(\exists\)) lucky charm and every (\(\forall\)) player rubbed that lucky charm.
  - \(\exists\) scopes over \(\forall\)
SOME THEORETICAL BACKGROUND: TWO CAMPS

The Context Camp

- Scope interpretations are derived from models of the world.
- There’s one structural representation and multiple concepts are attached to that representation.

- **Principle of Parsimony** (Fodor 1982 and others): The preferred interpretation is the one which requires the fewest changes to the discourse model.
  
  + If multiple climbers are already part of the discourse, then the inverse scope interpretation for “A climber scaled every cliff” should be favored (or at least not disfavored).
  
  + If in isolation, surface scope should be preferred because it only requires accommodating one climber.
The more economical LF representation is preferred.

Surface scope is preferred because it has a simpler structural representation.

**Principle of Scope Interpretation (PSI)** (Tunstall 1998):

“The default relative scoping in a multiply quantified sentence is computed from the required LF-structure of that sentence, where the required LF is determined by required grammatical operations acting on the S-structure. **The default scoping is the preferred scoping unless there is evidence to go beyond it.**” (Anderson, p.30)

Anderson’s Principle of *Processing Scope Economy* builds on the PSI but explicitly states that overriding the simpler derivation incurs a cost.
Three paper questionnaire experiments and five (computer interface) self-paced reading experiments (we’re only discussing three of the self-paced studies).
**EXPERIMENT 1: A...EVERY SENTENCES PRESENTED IN ISOLATION**

**DESIGN**
- Participants received a survey with items such as (47).
- 24 items
- Instructed to circle the paraphrase that corresponds to their initial interpretation.
- 38 NW undergrads

(47) A cashier greeted every customer.
   a. One cashier greeted customers.
   b. Several cashiers greeted customers.

**THE RESULTS AND WHAT THEY TEACH US**

- Surface scope paraphrase chosen 81% of the time.
  - *One* = surface
  - *Several* = inverse

- 12 participants always chose surface (and one item got the surface interpretation from all participants).

- IMPORTANT: Inverse scope is accessible. It’s chosen 19% of the time.
EXPERIMENT 2: SAME SENTENCES FROM EXPERIMENT 1 (A...EVERY) EMBEDDED IN A DISCOURSE CONTEXT THAT SUPPORTS EITHER THE SURFACE OR THE INVERSE INTERPRETATION

4 conditions:

- Context supports surface scope and the target sentence is unambiguously surface scope. = (55)

- Context supports surface scope but the target sentence is ambiguous. = (56)

- Context supports inverse scope and the target sentence is unambiguously inverse scope. = (57)

- Context supports inverse scope and the target sentence is ambiguous. = (58)

(55)/(57) are there to see if participants are answering randomly.

Each participant gets one of the four conditions for each item.

“How many x” question followed each item:
How many climbers scaled cliffs?
One (=surface) Several (=inverse)

27 people: mixture of NW undergrads and other adults
For surface scope context, surface scope answer is chosen 81% of time.
+ Same as Experiment 1. Context doesn’t increase surface interpretation.

For inverse scope context, inverse scope answer chosen 53% of the time.
+ Context does increase inverse interpretation. BUT..., it’s still only 53%.
### EXPERIMENT 3: EVERY A SENTENCES EMBEDDED IN A CONTEXT THAT SUPPORTS EITHER THE SURFACE OR THE INVERSE INTERPRETATION

**DESIGN**
- Rating scale (Experiments 1 and 2 were “forced choice” tasks)
- 10 items
- 23 NW undergrads

**THE RESULTS AND WHAT THEY TEACH US**

- Surface scope context: mean score is 4.3
  - Consistent with findings of Experiments 1 and 2. The inverse interpretation is available but clearly dispreferred.

- Inverse scope context: mean score is 3.3
  - The mean rating for the inverse scope context is closer to the surface scope interpretation than it is to the inverse scope interpretation.

- 1 corresponds to inverse, 5 corresponds to surface
- Below 2.5 is closer to inverse. Above 2.5 is closer to surface.
WHAT HAVE WE LEARNED?

PEOPLE DON’T LIKE INVERSE SCOPE INTERPRETATIONS!

BUT...MAYBE THERE’S SOMETHING ABOUT THE SURVEY METHOD THAT’S SKEWING THE RESULTS...MAYBE MACHINES CAN HELP US...
EXPERIMENT 4: SELF-PACED READING OF “A...EVERY “AND “EVERY...A”

- Part A: 24 a...every  
  Part B: 10 every...a

- Segments of the quantified sentence appear as the participant presses a button and the computer records how long each segment is on the screen.

- The quantified sentence is followed by a disambiguating sentence that’s either the surface or inverse scope interpretation.
  - A “how many x” question follows the disambiguating sentence.

- Measuring reading time and comprehension

- 43 NW undergrads

Measuring reading time and comprehension

If following (65)/(66): one=surface, several=inverse
If following (67)/(68): one=inverse, several=surface
4A: Two findings for a...every:

(1) **Reading Time:** Disambiguating sentence with plural subject (inverse) read **significantly more slowly** than disambiguating sentence with singular subject (surface).
   - Disambiguating sentence in (66) is slower than in (65). What we expect.

(2) **Comprehension:** Even when inverse scope meaning made explicit, the surface scope answer is chosen more often.
   - Inverse scope answer chosen only 41% of time.
   - That’s shocking!

**Experiment 4A Proportion of responses to comprehension question following a...every sentence.**

<table>
<thead>
<tr>
<th></th>
<th>Surface scope response One</th>
<th>Inverse scope response Several</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>surface</strong></td>
<td>0.87</td>
<td>0.13</td>
</tr>
<tr>
<td>singular disambiguating sentence</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>inverse</strong></td>
<td>0.59</td>
<td>0.41</td>
</tr>
<tr>
<td>plural disambiguating sentence</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4B: EVERY...A IS MORE COMPLICATED

- **Reading Time:** No evidence for difference in reading time between singular and plural disambiguating sentence.

- **Comprehension:** Inverse scope answer picked 82% of time when explicitly stated. Twice as often as in a...every sentences.
  - People are a lot better with every...an inverse scope
  - Maybe the *Principle of Parsimony* explains this.
With *a...every*, inverse scope doesn’t require multiple climbers.

- For every cliff, some (maybe the same) climber scaled that cliff.
- Maybe speakers assign inverse scope but leave the number of climbers underspecified.
- The plural disambiguating sentence forces multiple climbers to be added to the discourse.
- Problem is not with the structural representation of inverse scope. The problem is with adding additional climbers.

With *every...a*, both singular and plural continuations could be surface scope.

- Type-token problem: There could be multiple copies of the same document and (68) could mean that each historian is examining the same “type of” document.
- With *every...a*, it’s hard to tease apart the surface and inverse.
What is most surprising in these results is the high proportion of singular responses to the comprehension question following the plural continuation to the a...every sentences. While the singular continuation can be consistent with either a surface-scope or an inverse-scope representation, the plural continuation is compatible only with an inverse-scope interpretation that includes multiple climbers. Yet apparently this interpretation is so strongly dispreferred that even a plural disambiguating sentence does not often lead perceivers to construct a representation with multiple climbers. I return to this puzzle in the discussion of the results of Experiment 5.
EXPERIMENT 5: SAME SENTENCES FROM EXPERIMENT 4 EMBEDDED IN CONTEXT THAT SUPPORTS EITHER SURFACE OR INVERSE

**DESIGN**
- 4 conditions, 41 NW undergrads

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Context</th>
<th>Disambiguating Sentence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface-scope context, singular disambiguating sentence</td>
<td>Context matches disambiguating sentence</td>
<td>With the increased popularity of adventure sports, the cliffs outside Campbellton were becoming a popular destination. One weekend, the climbing equipment shop sponsored a show to demonstrate the sport. While an announcer described the techniques, an experienced climber scaled every cliff. The climber was very skilled. The shop's sales increased substantially the next weekend.</td>
</tr>
<tr>
<td>Surface-scope context, plural disambiguating sentence</td>
<td>Context matches disambiguating sentence</td>
<td>With the increased popularity of adventure sports, the cliffs outside Campbellton were becoming a popular destination. One weekend, the climbing equipment shop sponsored a show to demonstrate the sport. While an announcer described the techniques, an experienced climber scaled every cliff. The climbers were very skilled. The shop's sales increased substantially the next weekend.</td>
</tr>
<tr>
<td>Inverse-scope context, singular disambiguating sentence</td>
<td>Context doesn't match disambiguating sentence</td>
<td>With the increased popularity of adventure sports, the cliffs outside Campbellton were becoming a popular destination. One weekend, the climbing equipment shop sponsored a race between climbing enthusiasts. While an official timed the event, an experienced climber scaled every cliff. The climber was very skilled. The shop's sales increased substantially the next weekend.</td>
</tr>
<tr>
<td>Inverse-scope context, plural disambiguating sentence</td>
<td>Context doesn't match disambiguating sentence</td>
<td>With the increased popularity of adventure sports, the cliffs outside Campbellton were becoming a popular destination. One weekend, the climbing equipment shop sponsored a race between climbing enthusiasts. While an official timed the event, an experienced climber scaled every cliff. The climbers were very skilled. The shop's sales increased substantially the next weekend.</td>
</tr>
</tbody>
</table>

- Scenario followed by “How many x? One Several”
- Same procedure as Experiment 4.
- Measuring three things:
  - Reading time for quantified sentence
  - Reading time for disambiguating sentence
  - Responses to comprehension question
**READING TIME**

- No effect of context on reading time of quantified sentence.
- Plural disambiguating sentence (inverse) read significantly more slowly than the singular sentence (surface).
  - What we expect

**COMPREHENSION**

- Participants chose surface scope answer more often with the surface scope disambiguating sentence than they chose the inverse scope answer with the inverse scope disambiguating sentence.
  - 75% “right” answer when context and disambiguating sentence match for surface scope.
  - 56% “right” answer when the context and disambiguating sentence match for inverse scope.
**READING TIME**

- No effect of context on reading time of quantified sentence.
  + Same as a...every results.
- Singular disambiguating sentence (inverse) read significantly more slowly than the plural disambiguating sentence (surface).
  + What we expect
- **Argues against Principle of Parsimony**
  + Predicts that inverse scope should be fine because inverse scope requires fewer entities in the discourse.

**COMPREHENSION**

- As in Experiment 4B, participants are better at picking the right answer when the context and the disambiguating sentence match for every...a sentences.
  + Surface: 87% “right” answer when context and disambiguating sentence match.
  + Inverse: 69% “right” answer when the context and disambiguating sentence match.
- **BUT...there are still a lot of responses that are inconsistent with the meaning that has been primed.**
  + Maybe contrived experimental contexts just aren’t that good at biasing an interpretation.
EXPERIMENT 6: A...EVERY WITHOUT CONTEXT

DESIGN

- Same 24 a...every sentences from Experiment 4.
- Followed by a sentence that does not disambiguate.
- Followed by “How many x? One(surface) Several (inverse)”
- One word at a time appeared on the screen.

- 36 NW undergrads
- A paratrooper jumped from every plane. [Followed by some random sentence.]

THE RESULTS AND WHAT THEY TEACH US

- Sentence is read more slowly when the participant assigns it inverse scope.
- With earlier experiments, it might be that people commit to the surface interpretation and then have to reanalyze when they get the inverse-scope forcing context.
  - If this is true, it’s not the inverse scope that’s problematic. The reanalysis is problematic.

- The results of this study suggest that it’s the inverse scope itself that is problematic.
As repeatedly illustrated, inverse scope interpretations are strongly dispreferred and incur a processing cost.

This is shown both for isolated inverse scope interpretations and for ones embedded within an inverse-scope biasing context. 

There is a contrast between a...every and every...a sentences, 

- Inverse scope is more acceptable with every...a and this may be because the inverse scope reading is a subset of the surface scope reading.