Using paraphrases in grammar-based semantic equivalence tests

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(expanding on work of Michael Boettner and Pat Suppes)

Sentence composition in Language Arts & Writing

- Education Program for Gifted Youth (EPGY) at Stanford
- Online course for grades 2–6 (7–11 year-olds)
- Now used in remedial coursework
- Goal: to help students improve writing skills
- Exercise-based course with automatic, detailed feedback

Exercise design for sentence composition

- Present a few sentences of context
- Ask a question
- Provide a set of (fully inflected) words, listed by part-of-speech
- Ask the student to compose an answer as a complete sentence
- Evaluate the answer, and if incorrect, identify error where possible
- Ask the student to try again once

An example from Grade 5

Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.
Why didn't Abigail want to go hiking?

5.G.40.02

Sentence Composition

Write a complete sentence that answers the question by clicking on words from the lists.
To remove a word from your answer, click and drag it out of the box. Use RESET to remove all your words.

Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.

Why didn't Abigail want to go hiking?

Adjective	Adverb	Conjunction	Contraction	Noun	Preposition	Pronoun	Verb
hungry	too	because	didn't	Abigail	to	she	go
sick				hike			hike
tired							hiking
							want
							was
							were

reset ok

An example from Grade 5

Abigail didn't want to go hiking with her parents because she felt too tired and wanted to rest instead.
Why didn't Abigail want to go hiking?

She was tired.
She was too tired.
She was too tired to.
She was too tired to go.
She was too tired to hike.
She was too tired to go hike.
She was too tired to go hiking.
She didn't because she was too tired.
She didn't want to because she was too tired.
She didn't want to go because she was too tired.
She didn't want to hike because she was too tired.
She didn't want to go hike because she was too tired..
She didn't want to go hiking because she was too tired.

More variants

She **didn't** because she was tired.
She didn't because she was too tired to.
She didn't because she was too tired to go.
She didn't because she was too tired to go hike.
She didn't because she was too tired to go hiking.
She didn't because she was too tired to hike.
She didn't **want to** because she was tired.
She didn't want to because she was too tired to.
She didn't want to because she was too tired to go.
She didn't want to because she was too tired to go hike.
She didn't want to because she was too tired to go hiking.
She didn't want to because she was too tired to hike.
She didn't **want to go** because she was tired.
She didn't want to go because she was too tired to.
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And more variants

She didn't because she was tired.
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Abigail didn't because she was tired.
Abigail didn't because she was too tired to.
Abigail didn't because she was too tired to go.
Abigail didn't because she was too tired to go hike.
Abigail didn't because she was too tired to go hiking.
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Abigail didn't want to hike because she was too tired to hike.

And still more variants

Because she was tired, she didn't.
Because she was too tired to, she didn't.
Because she was too tired to go, she didn't.
Because she was too tired to go hike, she didn't.
Because she was too tired to go hiking, she didn't.
Because she was too tired to hike, she didn't.
Because she was tired, she didn't want to.
Because she was too tired to, she didn't want to.
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And even more variants

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Because Abigail was too tired to hike, Abigail didn't want to hike.

Usage of the LA&W course in Memphis

Sentences composed by 29,000 students in 2010 and 2011:

	Correct (stored)	Incorrect (stored)	Parsed (new)	All
Total	2,295,013	510,476	1,386,864	4,192,353
	54.7%	12.2%	33.1%	
			Parsable: 287,198 No parse: 732,856	
Distinct			Parsable: 53,088 No parse: 210,818	

Using semantics to evaluate composition

- Current parser only provides syntactic evaluation
  - Answer is grammatical (but not in list of known answers)
  - Answer is ungrammatical, but error(s) can be analyzed
  - No analysis is available

Using semantics to evaluate composition

- Current parser only provides syntactic evaluation
  - Answer is grammatical (but not in list of known answers)
  - Answer is ungrammatical, but error(s) can be analyzed
  - No analysis is available
- Correct but novel answers should be rewarded.
- Remaining errors fall into two broad classes:
  - (1) Well-formed sentences that have the wrong meaning
  - (2) Sentences that are syntactically ill-formed for intended meaning, but have an irrelevant, alternative grammatical analysis
- Many (correct and incorrect) can be detected via semantic comparison

Examples of correct answers not yet stored

- Repeated modifiers

  Q: *What kind of soccer player is Audrey?*

  A: *She is very very good.*

  (Already stored: *She is very good.*)

Examples of correct answers not yet stored

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  Q: What kind of soccer player is Audrey?

  A: *She is very very good.*

  (Already stored: *She is very good.*)

- Different word order but same semantics

  Q: Ian is happy because all his friends are going to throw him a tenth birthday party tomorrow. What will Ian's friends do for him tomorrow?

  A: *His friends will throw a party tomorrow for him.*

  His friends will throw a party for him tomorrow.

Examples of grammatical but incorrect answers

- Wrong meaning, good syntax:
  - **Q:** *Emilio is excited because he gets to go to the circus this weekend Why is Emilio excited?*
  - **A:** *They are going to the zoo this weekend to the circus.*
- Nearly right meaning, wrong syntax for that meaning:
  - **Q:** *When Josh has the flu, he sees Dr. Sanchez at the hospital. Where does Josh go when he has the flu?*
  - **A:** *Josh has at the hospital.*
- Another example:
  - **Q:** *Rebecca went to a late movie with her friends and didn't get home until after midnight.*
  - **A:** *She got her home late.*

Evaluation by comparing semantics

- Offline, parse all stored answers (good and bad) for each exercise
  Record the semantics of each one for future reference
- Parse student's answer, and compare its semantics to store
  Some variants will have identical semantics
- Use handwritten rules of 'congruence' to set up matching
- Define the rules over the Minimal Recursion Semantics representation produced by the parser

Sample semantics from parser

His friends will throw Ian a party tomorrow.

```
< e2:throw_v [ARG1 x5:friend_n,
              ARG2 x16:party_n,
              ARG3 x15:named(Ian)]
  e9:poss [ARG1 x5:friend_n, ARG2 x8:pron]
  e25:located_a [ARG1 x16:party_n, ARG2 x26:tomorrow_n] >
```

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```

His friends will throw a party tomorrow for Ian.

```
< e2:throw_v [ARG1 x5:friend_n,
              ARG2 x15:party_n]
  e27:for_p [ARG1 e2:throw_v,
             ARG2 x28:named(Ian)]
  e9:poss [ARG1 x5:friend_n, ARG2 x8:pron]
  e20:located_a [ARG1 x15:party_n, ARG2 x21:tomorrow_n] >
```

Sample congruence rule: for-PP vs. double-NP

Example: *They threw a party for Ian.* $\Rightarrow$ *They threw Ian a party.*

Rule's effect: Map the [V + NP + PP(for)] to [V + NP + NP]

```
for_dative_shift := same_pred_mtr &
[ INPUT.RELS  < [ PRED throw_v|..., ARG0 #e0, ARG1 #x1, ARG2 #x2 ],
                [ PRED for_p, ARG1 #e0, ARG2 #x3 ] >,
  OUTPUT.RELS < [ ARG0 #e0, ARG1 #x1, ARG2 #x2, ARG3 #x3 ] > ].
```

Sample congruence rule: Modifier deletion

Example: **A:** *She is very very good.*

Rule's effect: Delete the extra *very* so the answer matches stored answer.

[NB: Modifiers identify their semantic label with that of the phrase they modify, and take that target's inherent variable (ARG0) as their semantic argument (ARG1).]

```
mod_deletion := monotonic_mtr &
[ CONTEXT.RELS < [ LBL #lbl,
                   ARG0 #x1 ] >,
  INPUT.RELS   < [ LBL #lbl,
                   ARG0.TENSE no_tense,
                   ARG1 #x1 ] >,
  OUTPUT.RELS  < > ].
```

Sample congruence rule: Verb alternation

Some verb alternations are only partially congruent, imposing a restriction on their object, as in:

They made breakfast. $\Rightarrow$ *They cooked breakfast.*

but

They made mistakes. $\not\Rightarrow$ *They cooked mistakes.*

```
make_cook := verb_mtr &
[ CONTEXT.RELS < [ PRED breakfast_n,
                   ARG0 #x1 ] >,
  INPUT.RELS   < [ PRED make_v,
                   ARG2 #x1 ] >,
  OUTPUT.RELS  < [ PRED cook_v ] > ].
```

Sample paraphrase

His friends will make Ian a very good breakfast tomorrow.

e2: make_v [ARG1 x5: friend_n
ARG2 x16: breakfast_n,
ARG3 x15: named(Ian)]
e6: very_a [ARG1 e7: good_a]
e7: good_a [ARG1 x16: breakfast_n]
e9: poss [ARG1 x5: friend_n, ARG2 x8: pron]
e25: located_a [ARG1 e2: make_v, ARG2 x26: tomorrow_n]

His friends will cook a good breakfast tomorrow for Ian.

e2: cook_v [ARG1 x5: friend_n,
ARG2 x16: breakfast_n]
e27: for_p [ARG1 e2: cook_v,
ARG2 x28: named(Ian)]
e7: good_a [ARG1 x16: breakfast_n]
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His friends will cook a good breakfast for Ian tomorrow.
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Our data-driven approach to paraphrase

- Identify frequently occurring types of mismatch by inspection of the parser logs

  (Michael, Pat, and I have identified a dozen general types so far.)

- Manually add congruence rules
- Use the rule outputs to generate well-formed variants offline

  (Rules apply in all permissible combinations.)

- Manually edit these candidate variants, and add to the online cache