

# Parsing Sentences Containing Verbs of Perception against Other Verbs in the English Language

S.A. Johnson

*School of Computing  
Teesside University  
m2082166@tees.ac.uk*

J.M. Atkinson

*School of Computing  
Teesside University  
m2016954@tees.ac.uk*

Keywords: artificial intelligence, AI, language processing, grammar, lexicon, perception, verb

## Abstract

This paper explores the grammar of verbs of perception as compared to other verbs in the context of English language, with the main focus being on the use of verbs of perception to express that an actor is experiencing another verb taking place. Using the LKit<sup>1</sup> language processing library, a selection of ambiguous example sentences was chosen and used to test the lexicon and grammar at each stage of development. The resulting outcome was a series of tests demonstrating the complexity involved with verbs of perception.

## Problem Domain

The structure of sentences involving verbs of perception is distinct in the English language as compared to those involving other verbs. Verbs that convey an actor's perception (or observation) of an event such as *to see*, *to feel*, *to hear* and *to notice* can be followed by an object and another verb<sup>2</sup> (either an infinitive or a present participle). For example:

- He noticed her sing/singing.
- She saw it move/moving.
- Samantha hears them run/running.

Non-perception verbs, however, cannot function correctly in these sentences. For example, the verb *to eat*:

- He ate her sing/singing.
- She ate it move/moving.
- Samantha eats them run/running.

From these example sentences, it is clear that the first verb appearing must relate to the subject's *perception* of another action taking place. As the verb *to eat* does not relate to the subject's perception it is grammatically incorrect to use it in this way.

It is possible to construct an ambiguous sentence such that it may or may not have multiple interpretations depending on whether or not the verb used is a verb of perception. For the purposes of this investigation, the following sentence was chosen:

*"We saw her duck."*

*Figure 1 - The sentence used as the basis for the investigation.*

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<sup>1</sup> Lynch, S. (2016) LKit. Available at: [https://www.scm.tees.ac.uk/isg/website/index.php?page=downloads\\_lkit](https://www.scm.tees.ac.uk/isg/website/index.php?page=downloads_lkit) (Accessed: 16 May 2016).

<sup>2</sup> English Grammar (2012) Verbs of perception. Available at: <http://www.englishgrammar.org/verbs-perception/> (Accessed: 15 May 2016).

This sentence can be parsed in two ways, because it contains a verb of perception:

1. He saw her lower herself slightly.
2. He saw a waterfowl belonging to her.

If the verb *to see* is substituted for the non-perception verb *to eat* there is only one valid parse, which is that the subject ate a waterfowl belonging to a specific female.

This investigation will explore a method of using the LKit API to parse or fail to parse sentences based on whether or not they include a verb of perception. LKit is a language parsing library implemented in Lisp, enabling the development of natural language processing applications through specification of a lexicon and a grammar.

### Example Sentences

Five example sentences were chosen to form the basis for this investigation, with increasing grammatical complexity.

- “We saw her duck.” ( $n = 2$ )
- “We ate her duck.” ( $n = 1$ )
- “We saw her eat her duck.” ( $n = 1$ )
- “We drank her eat her duck.” ( $n = 0$ )
- “He saw the duck duck the duck.” ( $n = 1$ )

Where  $n$  is the number of valid parses that should be produced by the application which has been developed for the purpose of this investigation.

### Constructing a Syntax Tree

The subject of this investigation, the sentence “*We saw her duck.*” has two possible and equally valid possible syntax trees in a context-free environment. That is, without wider knowledge about the world in which the observation by the subject is taking place it is not possible to take one syntax tree as more valid than the other.

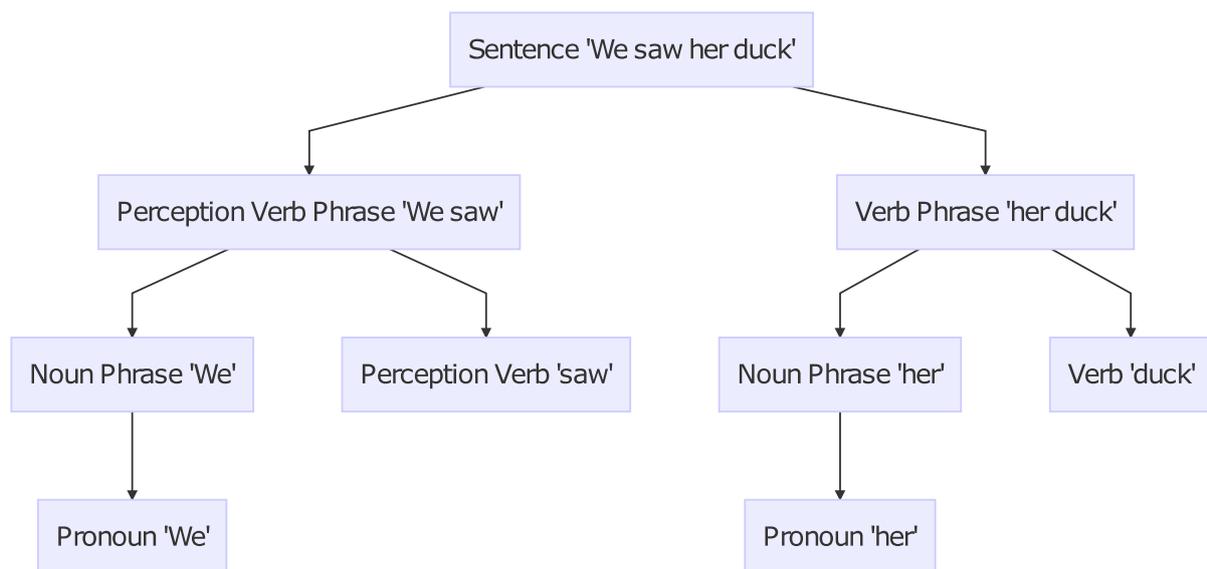


Figure 2 – One possible syntax tree for the sentence “*We saw her duck.*”

As is apparent from Figure 2, “her duck” can be parsed as a verb phrase. Alternatively, her duck can be parsed as a noun phrase consisting of a possessive determiner followed by a noun.

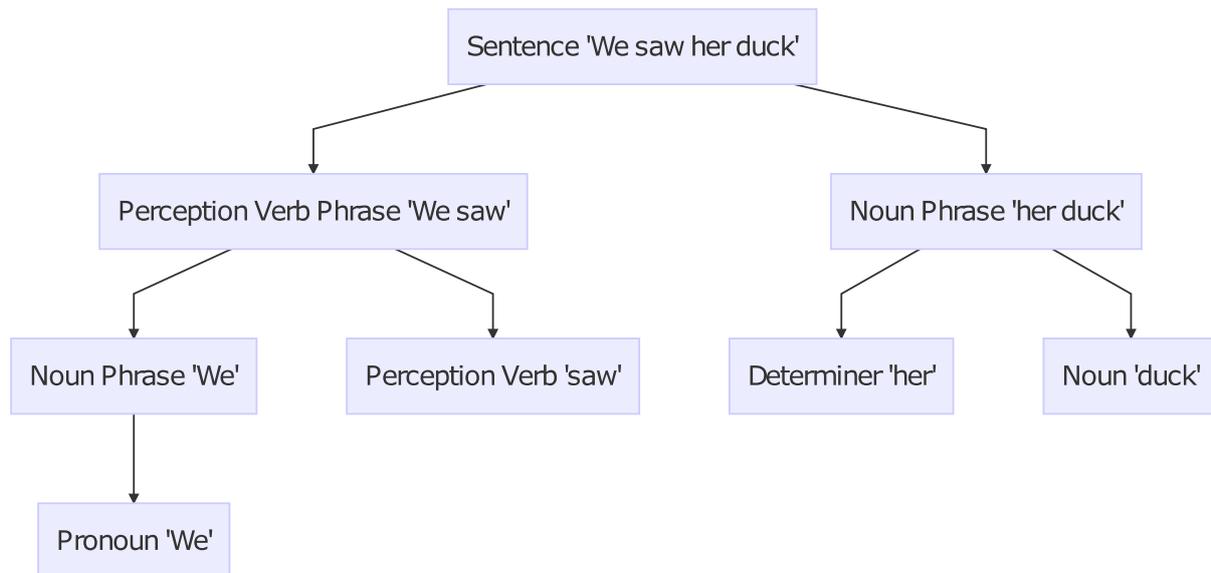


Figure 3 - An alternative syntax tree for the sentence "We saw her duck."

Notably, this ambiguity is only present for the feminine pronoun by the coincidence that the feminine subject pronoun 'her' is the same as the feminine possessive determiner 'her'. This is in contrast to the masculine subject pronoun 'him' and the masculine possessive determiner 'his' – two distinct words.

### Constructing a Lexicon and Grammar

From the syntax trees in Figure 2 and Figure 3, it is possible to derive a lexicon encompassing all words used and their grammatical function as well as metadata about the finer details relating to their use in a sentence.

```

(build-lexicon
  '( (we pronoun plural)
    (saw verb observed (tags perceptive))
    (ate verb consumed)
    (her determiner possessive)
    (her pronoun singular)
    (duck verb avoid)
    (duck noun waterfowl)))

(build-grammar
  '( (s1 (sentence -> verb-phrase noun-phrase))
    (s2 (sentence -> perceptive-verb-phrase verb-phrase))
    (vp (verb-phrase -> noun-phrase verb))
    (pvp (perceptive-verb-phrase -> noun-phrase verb)
      (fail if not verb.tags $* '(perceptive))
      (tags . (lisp ($* verb.tags '(perceptive)))))
    (np1 (noun-phrase -> determiner noun))
    (np2 (noun-phrase -> pronoun))))
  
```

Figure 4 - A minimal lexicon and grammar required to parse the first two experimental sentences.

In defining the above lexicon and grammar:

- Each word in the lexicon has been mapped to its grammatical function.

- Where greater specificity regarding grammar is required, tags have been used to attach metadata to specific words (for example, the verb *saw* is tagged with *perceptive*) to indicate that it is a verb of perception.
- Two possible sentence structures have been created, one following the classical verb-phrase noun-phrase structure and one for a sentence consisting of the subject perceiving another action taking place.
- Distinct parsing rules for verb phrases and perception verb phrases have been created, with perception verb phrases mandating that the verb be tagged with the *perceptive* symbol and failing otherwise.
- Noun phrases have been defined as either a standalone pronoun or a determiner followed by a noun.

This lexicon and grammar can be used successfully to parse the first experimental sentence:

```
CG-USER(1): (parse 'sentence ' (we saw her duck))

-----
COMPLETE-EDGE 0 4 S2 SENTENCE (WE SAW HER DUCK) NIL
S2 SENTENCE -> (PERCEPTIVE-VERB-PHRASE VERB-PHRASE)
Syntax
(SENTENCE (PERCEPTIVE-VERB-PHRASE (NOUN-PHRASE (PRONOUN WE)) (VERB
SAW)) (VERB-PHRASE (NOUN-PHRASE (PRONOUN HER)) (VERB DUCK)))
Semantics
(SENTENCE)

-----
COMPLETE-EDGE 0 4 S1 SENTENCE (WE SAW HER DUCK) NIL
S1 SENTENCE -> (VERB-PHRASE NOUN-PHRASE)
Syntax
(SENTENCE (VERB-PHRASE (NOUN-PHRASE (PRONOUN WE)) (VERB SAW)) (NOUN-
PHRASE (DETERMINER HER) (NOUN DUCK)))
Semantics
(SENTENCE)
T
```

Figure 5 - Output from running the parser against the first experimental sentence with the lexicon and grammar from Figure 4 loaded.

This gives both valid syntax trees as expected when a verb of perception immediately follows the subject of the sentence. If the verb of perception is substituted with a non-perception verb, however, only one valid syntax tree is obtained as expected:

```
CG-USER(2): (parse 'sentence ' (we ate her duck))

-----
COMPLETE-EDGE 0 4 S1 SENTENCE (WE ATE HER DUCK) NIL
S1 SENTENCE -> (VERB-PHRASE NOUN-PHRASE)
Syntax
(SENTENCE (VERB-PHRASE (NOUN-PHRASE (PRONOUN WE)) (VERB ATE)) (NOUN-
PHRASE (DETERMINER HER) (NOUN DUCK)))
Semantics
(SENTENCE)
T
```

Figure 6 - Output from running the parser against the second experimental sentence with the lexicon and grammar from Figure 4 loaded.

## Developing the Grammar for Verb Transitivity

While the lexicon and grammar in Figure 4 is effective in distinguishing between verbs of perception and other non-perception verbs when generating syntax trees for a sentence, it does not take into account verb transitivity and as a consequence will fail to parse the third experimental sentence “*We saw her eat her duck.*” in which the verb *to eat* becomes transitive. Notably, the structure of the *s1* grammar rule in Figure 4 is such that the verb used *must* be transitive.

To remedy this, the grammar must be modified to allow a verb to optionally be used transitively to act upon a noun phrase. To make the grammar even more flexible, it is possible to add optional verb transitivity to the *s1* rule to allow the parsing of sentences such as “*We ate.*”

```
(build-lexicon
 '( (we pronoun plural)
   (saw verb observed (tags perceptive))
   (ate verb consumed)
   (eat verb consume)
   (her determiner possessive)
   (her pronoun singular)
   (duck verb avoid)
   (duck noun waterfowl)))

(build-grammar
 '( (s1 (sentence -> verb-phrase ?noun-phrase))
   (s2 (sentence -> perceptive-verb-phrase verb-phrase ?noun-phrase))
   (vp (verb-phrase -> noun-phrase verb))
   (pvp (perceptive-verb-phrase -> noun-phrase verb)
        (fail if not verb.tags $* '(perceptive))
        (tags . (lisp ($* verb.tags '(perceptive)))))
   (np1 (noun-phrase -> determiner noun))
   (np2 (noun-phrase -> pronoun))))
```

Figure 7 - The modified lexicon and grammar to allow verb transitivity; note the '?' prefixes on both usages of noun-phrase in sentence-level grammar rules.

With optional verb transitivity in place, the parser can be run against the third experimental sentence to produce a syntax tree as expected:

```
CG-USER(5): (parse 'sentence '(we saw her eat her duck))

_____  
COMPLETE-EDGE 0 6 S2 SENTENCE (WE SAW HER EAT HER DUCK) NIL  
S2 SENTENCE -> (PERCEPTIVE-VERB-PHRASE VERB-PHRASE ?NOUN-PHRASE)  
Syntax  
(SENTENCE (PERCEPTIVE-VERB-PHRASE (NOUN-PHRASE (PRONOUN WE)) (VERB  
SAW)) (VERB-PHRASE (NOUN-PHRASE (PRONOUN HER)) (VERB EAT))  
(NOUN-PHRASE (DETERMINER HER) (NOUN DUCK)))  
Semantics  
(SENTENCE)  
T
```

Figure 8 - Output from running the parser against the third experimental sentence with the grammar from Figure 7 loaded

The fourth experimental sentence is an expected failure case. Superficially, the syntax of both of the third and fourth experimental sentences can be seen to be the same:

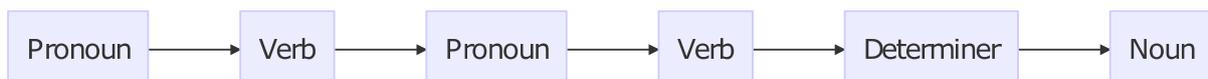


Figure 9 - The superficial syntactical structure of both the third and fourth experimental sentences.

The sentence structure in Figure 9 is not specific enough, however, and would produce an undesirable valid parse for the fourth experimental sentence.



Figure 10 - The fourth experimental sentence, shown to fit the superficial syntax structure shown in Figure 9.

Despite this, the grammar defined in Figure 7 (with an added lexicon entry for “drank”) correctly fails to parse the fourth experimental sentence.

```

cg-user(1): (parse 'sentence ' (we drank her eat her duck))
nil
  
```

Figure 11 - The expected failed parse for the grammatically incorrect fourth experimental sentence.

### Finalising the Lexicon and Grammar

By adding a small number of additional entries to the lexicon, a grammar that correctly parses all five example sentences can be finalised.

```

(build-lexicon
 '( (we pronoun plural)
    (he pronoun singular)
    (the determiner specific)
    (saw verb observed (tags perceptive))
    (ate verb consumed)
    (eat verb consume)
    (drank verb imbibed)
    (felt verb sensed)
    (her determiner possessive)
    (her pronoun singular)
    (duck verb avoid)
    (duck noun waterfowl)))

(build-grammar
 '( (s1 (sentence -> verb-phrase noun-phrase))
    (s2 (sentence -> perceptive-verb-phrase verb-phrase ?noun-phrase))
    (vp (verb-phrase -> noun-phrase verb))
    (pvp (perceptive-verb-phrase -> noun-phrase verb)
         (fail if not verb.tags $* '(perceptive))
         (tags . (lisp ($* verb.tags '(perceptive)))))
    (np1 (noun-phrase -> determiner noun))
    (np2 (noun-phrase -> pronoun))))
  
```

Figure 12 - The finalised lexicon and grammar.

## Conclusion and Limitations

While the grammar in Figure 12 realises the aim of this investigation, it is simplistic and limited in many respects.

The grammar and lexicon lack any facility for recognising and validating the tenses of verbs. While using the incorrect tense would not necessarily affect the broad meaning of the sentence (and should therefore not affect the parsability of the sentence) LKit contains a glitch facility for notifying the caller of minor errors while still producing a valid syntax tree.

```
cg-user(2): (parse 'sentence '(we saw her ate her duck))
_____
complete-edge 0 6 s2 sentence (we saw her ate her duck) nil
s2 sentence -> (perceptive-verb-phrase verb-phrase ?noun-phrase)
Syntax
(sentence (perceptive-verb-phrase (noun-phrase (pronoun we)) (verb
saw)) (verb-phrase (noun-phrase (pronoun her)) (verb ate))
(noun-phrase (determiner her) (noun duck)))
Semantics
(sentence)
t
```

Figure 13 - The finalised grammar producing an undesirable successful parse of a grammatically incorrect sentence due to lack of verb tense awareness.

The lexicon is somewhat limited, but intentionally succinct such as to allow the experimental sentences to be parsed successfully while keeping complexity to a minimum. For useful application of the grammar and lexicon, however, a larger and more detailed lexicon would be required.

The grammar and lexicon lack support for adjectives, adverbs and other grammatical features of English. This is intentional as creating a full English language grammar and lexicon is outside the scope of this investigation. Notably the ambiguity of sentences such as “*We saw her duck.*” seems to be confined to the English language<sup>3</sup>.

The experimental sentence “*We saw her duck.*” actually has three valid parses<sup>4</sup>, one of which has been omitted from this investigation – “*We cut her duck using a saw.*” While it might seem trivial to remedy this by the addition of another entry for the verb “saw” to the lexicon, it is already present tagged as a verb of perception. While a solution for this would lie outside the scope of this investigation, this would be an ideal starting point for further experimentation.

<sup>3</sup> Boye, K. (2010) ‘Reference and clausal perception-verb complements’, *Linguistics*, 48(2). doi: 10.1515/ling.2010.013.

<sup>4</sup> Byrd, I. (2009) Ambiguous sentences. Available at: <http://www.byrdseed.com/ambiguous-sentences/> (Accessed: 16 May 2016).