Journal of Memory and Language 95 (2017) 89–101

Contents lists available at ScienceDirect

Journal of Memory and Language

journal homepage: www.elsevier.com/locate/jml

Priming plural ambiguities

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ARTICLE INFO

Article history:
Received 8 February 2016
revision received 6 February 2017
Available online 6 March 2017

Keywords:
Plural ambiguities
Distributivity
Priming
Semantics

ABSTRACT

Sentences that involve two or more plural expressions, such as numerical expressions, give rise to systematic ambiguities. For example, the sentence *Two boys have three balloons* can either mean that there are two boys who, between them, have three balloons (*cumulative reading*) or that there are two boys who each have three balloons (*distributive reading*). In this paper, we report the results of three experiments which show that the distributive/cumulative ambiguity can give rise to *priming effects*. That is, when subjects perform a sentence-picture matching task which creates a strong bias towards one of the two types of readings, they are more likely to access the very same type of interpretation when subsequently presented with a different sentence-picture pair which does not create the same bias. This finding suggests that the abstract constructs that linguists posit to account for different types of readings describe some real features of mental representations.

Introduction: Plural ambiguities and priming effects

Sentences that involve two or more plural expressions, such as numerical expressions, can give rise to multiple readings. For example, a sentence like (1) has at least two different readings, paraphrased in (1a) and (1b). Situations illustrating each reading are depicted in Fig. 1.

(1) Two boys have three balloons.
   a. **Cumulative reading**: There are two boys who, between them, have three balloons (Fig. 1a).
   b. **Distributive reading**: Two boys have *each* three balloons (Fig. 1b).

The multiple readings to which plural expressions give rise in natural languages have been extensively studied in theoretical linguistics. Each of the two interpretations mentioned above for this sentence are assumed to instantiate different types of interpretation rules and possibly different syntactic structures, which play a role in many other sentences and sentence types. These rules and structures are, therefore, of an *abstract and general* nature, and it could be assumed that, when processing such sentences, interpreters access these abstract properties of sentences. The general goal of this paper is to investigate whether abstract semantic properties of these kinds of plural sentence are accessed during sentence comprehension, by means of a *priming paradigm*.

Before providing more details about our goals and methodology, we introduce some formal semantics background regarding the cumulative/distributive ambiguity and present some of the previous psycholinguistic literature on the processing of plural expressions, ambiguities and priming effects.

Formal approaches to distributive and cumulative readings

Formal semantics approaches to the cumulative-distributive contrast are based on the idea that the very same sentence (viewed as a phonological string) corresponds to (at least) two distinct logical forms. A common approach consists of assuming that the distributive interpretation is derived from the cumulative reading through the application of a so-called *distributivity operator*.

Under the *lexical cumulativity hypothesis* (Krifka, 1992; Landman, 2000, see also Kratzer (2007) for relevant discussions), the cumulative reading is in some sense primitive, since it encodes the most basic relation between two pluralities:

(2) Cumulative Interpretation of (1):
There is a plurality made up of two boys, call it *X*, and a plurality made up of three balloons, call it *Y*, such that every

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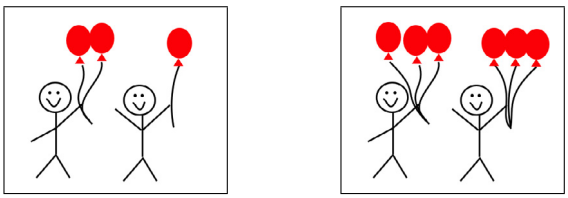
http://dx.doi.org/10.1016/j.jml.2017.02.002
0749-596X/



(a) Cumulative reading (b) Distributive reading

Fig. 1. Readings of sentences with plurals.

member of *X* owns at least one member of *Y*, and every member of *Y* is owned by at least one member of *Y*.

In its primary denotation, the predicate 'have' denotes a relation between *individuals* (cf. Link, 1983). However, when *have* is used in a sentence (e.g. 1), it receives a more complex meaning, which allows it to denote a relation between *sets of individuals* or *pluralities* (this is the aforementioned *lexical cumulativity hypothesis*). This relation, here represented by HAVE, is defined as follows: A plurality *X* can be said to HAVE a plurality *Y* just in case every individual in *X* is in the HAVE-relation to an individual in *Y*, and if for every individual in *Y*, there is an individual in *X* which is in the HAVE-relation to it.

In contrast with this, the distributive reading of (1) entails that there are two boys who each have three balloons. Following Link (1987) or Champollion (in press), we assume that this second reading is obtained by applying a distributivity operator, noted Δ, to the predicate *have three balloons* (but see Kratzer (2007) for an alternative view based on the star-operator). Under this view, while *have three balloons* is true of a plurality *X* if the members of *X* have between them three balloons *in total*, *Δ(have three balloons)* is true of a plurality *X* only if each atomic member *x* of *X* has three balloons in total. When the subject of *have three balloons* is an indefinite numerical phrase such as *two boys*, the resulting meaning is that there are two boys such that each of them has three balloons. To sum up, the cumulative and distributive interpretations of (1) correspond to two distinct Logical Forms (LFs), which we give in (3) in a simplified form:

(3) Two boys have three balloons.
   a. **LF for the cumulative reading:** [Two boys] [have [three balloons]]
   b. **LF for the distributive reading:** [Two boys] [Δ[have [three balloons]]]

We should finally notice that the cumulative interpretation of (1), as defined in (2), is true not only in cumulative situations of the type represented in Fig. 1a, but also in 'distributive' situations of the type represented in Fig. 1b: in a distributive situation where the boys have six balloons in total, it is always possible to single out a plurality of exactly three balloons such that the two boys jointly have these three balloons. However, the cumulative reading of sentences such as (1), which can be forced by adding the phrase *between them* (e.g. 'Two boys have three balloons between them'), tends to be strengthened with the pragmatic inference that the two boys who have three balloons between them do not have *more* than three balloons between them (see Landman (2000) for a discussion of such effects produced by numerals in cumulative sentences). That is, (1) can easily be interpreted with an *exact* meaning, i.e. as conveying that there are two boys who between them have *exactly* three balloons. Under this 'strengthened' cumulative reading, sentence (1) is false in the type of situations represented in Fig. 1b. In most of this paper, when we talk about the 'cumulative' interpretation, we intend to refer to this strengthened cumulative interpretation; we will discuss the *exact/at least* contrast and its potential implications regarding the interpretation of our results.

Understanding plural ambiguous sentences

In English, plurality can be expressed through a number of means, including the use of plural definites ("the boys"), numerical expressions ("two boys") and quantificational phrases ("each boy"). Many psycholinguistic approaches to plurality have attempted to define how these different plural expressions are interpreted (Kaup, Kelter, & Habel, 2002; Patson & Warren, 2010; Patson, George, & Warren, 2014; Patson, 2014; Sauerland, Anderssen, & Yatsushiro, 2005).

In a recent study, Patson et al. (2014) presented participants with a sentence together with a picture, and asked them to judge whether the elements named in the sentence appeared in the image. When the sentences contained numeric expressions ("two boys"), people were faster at making judgments about multiple than about singular referents in the picture. In contrast, no differences in time were found for plural definite descriptions. The authors interpret these results as evidence for the existence of different levels of plural representation: while plural definites are conceptualized in an "underspecified" way (i.e. the numerosity remains unresolved), numerically quantified expressions are interpreted as true pluralities. Specifically, numerals appear to be interpreted as referring to *exact* quantities by both adults and children (Huang, Spelke, & Snedeker, 2013; Marty, Chemla, & Spector, 2013; Patson et al., 2014): 'two boys' would refer to a plurality composed by *exactly* two boys. However, this does not necessarily imply that 'two'-quantified plurals cannot refer to *more than two* entities: weaker, *at least*, readings of numeric expressions, such as the ones proposed by certain accounts of bare numerals, are considered to be available during parsing (Bott & Chemla, 2016). A more extensive theory of how different plural expressions are conceptualized during parsing is provided in Patson (2014).

The study of how these plural expressions interact with each other, giving rise to ambiguities, has been focused on determining whether alternative interpretations (distributive, collective, and cumulative) differ in terms of preference or cognitive cost. Early on, it was observed that adults often prefer collective interpretations of plural ambiguous sentences. Several studies have shown that this pattern is consistent across sentences containing different plural expressions, ranging from numerically quantified phrases (e.g., as in Example 1) and plural definites, to personal pronouns and coordinate noun phrases (Brooks & Braine, 1996; Dotlacil, 2010; Kaup et al., 2002; Musolino, 2009; Syrett & Musolino, 2013; Ussery, 1998). This evidence suggests that interpretative differences among plural expressions (such as the ones described above, Patson, 2014) directly favor particular interpretations of ambiguous sentences.

Furthermore, adult preference seems to correlate with the cost associated with each reading (i.e. dispreferred readings are also slower or more costly). For instance, Frazier, Pacht, and Rayner (1999) used temporally ambiguous sentences (e.g."Mary and Paul won 100 dollars each/together") to investigate the dynamics of ambiguity resolution during online processing (see also Brasoveanu & Dotlačil, 2015). These experiments aimed to determine whether people make semantic commitments before disambiguation (e.g., location of 'each'/'together'). The authors found a slowdown in reading times (similar to garden-path effects) when sentences were disambiguated towards a distributive reading (but not towards a collective interpretation). These results suggest an early collective interpretation of the predicate, which may be guiding the slowdown in distributive sentences.