Title

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Abstract

When faced with a sentence like, "some of the toys are on the table", adults, but not preschoolers, compute a scalar implicature, taking the sentence to suggest that not all the toys are on the table. Although this difference is sometimes attributed to children's difficulties in processing and pragmatic understanding, this paper explores the hypothesis that children fail to compute scalar implicatures because they lack knowledge about relevant lexical alternatives to words like "some". Four-year-olds were shown pictures in which two objects fit a description and a third object did not, and were asked to judge the truth value of statements that relied on context-independent alternatives (e.g. *only some of the toys are on the table*) or contextual alternatives (e.g. *only the drum and the ball are on the table*). Children computed scalar implicatures only in the case of contextual alternatives, and only when the statements were grammatically strengthened, supporting the hypothesis that children's difficulties with scalar implicature result from a lack of knowledge of the relevant alternatives.

Keywords: scalar implicature; pragmatic reasoning; processing limitations; contextual alternatives

Introduction

As children acquire language, their task is complicated by the fact that speakers' intended meanings go beyond the literal meanings of their utterances. Word learning is not simply a process of mapping strings of words to speaker intentions. Instead, children must infer the core lexical meanings of words by distinguishing what is logically entailed from that which is merely implied. For example, given a dialogue like (1), John is likely to infer that Mary did not eat all of his cake.

(1) John: Did you eat my cake?
Mary: I ate some of it.

Although Mary's statement would be literally true if she had eaten the whole cake (eating *all* entails eating *some*), her utterance implies that she did not. This inference relies on the assumption that, if Mary had eaten the whole cake, and was communicating cooperatively, she would have uttered a more informative statement like "I ate *all* of it" (Grice, 1989).

The language acquisition literature is filled with examples of children learning words by making inferences about speaker intentions. A classic demonstration of this comes from experiments investigating mutual exclusivity. When a child is shown two objects, one of which has a known label (e.g., a car), they infer without difficulty that a novel label (e.g., *dax*) refers to the previously unlabeled object. Such an inference follows from the assumption that the speaker would not use two words to denote one kind of object (i.e., words exhibit *mutual exclusivity*, or *contrast*; Markman, 1989; Clark 1987). Children apply such strategies not only when learning nouns, but also when interpreting other classes of words, such as numerals. For example, when 2-year-olds who know the meaning of the word *one* (but no higher number) are shown two sets – e.g., 1 balloon and 5 balloons – they readily infer that *five* refers to the set of five objects (Wynn, 1992; Condry & Spelke, 2008).

Amidst such evidence, and further studies which find that children are sensitive to subtle intentional cues like eye gaze, speaker desires, etc. (Baldwin, 1993; Tomasello, 1992) children also exhibit striking failures in computing some simple inferences, including the inference in (1), which is a type of *scalar implicature*. Following Horn (1989), it is typically assumed that the quantifier *some* belongs to a larger class of terms called "scalar items". Scales are used to generate sets of alternative meanings, which are ordered according to their informativeness, and are implicitly contrasted during interpretation. In the case of *some*, the relevant scale includes other quantifiers – e.g., *a, some, many, most, all*. Examples of such scales are shown in (2):

(2) a. <*some, many, most, all*, etc.>
b. <*warm, hot, boiling*, etc.>
c. <*one, two, three*, etc.>

By most accounts, deriving a scalar implicature involves at least four steps, summarized in I - IV. First, the listener computes the basic, *literal*, meaning of the expression (Step I). Second, she considers the alternative sentences that might have been uttered (by substitution of scalar alternatives; Step II). Third, she restricts these alternatives by removing those that are less informative (Step III). Finally, she "strengthens" the interpretation of the sentence by negating the remaining alternatives – e.g., "I ate some (but not all) of the cake" (Step IV).

I. Compute basic meaning of a sentence S containing L, a scalar item.

II. Generate a set of alternatives ($a_1, a_2, \ldots, a_n$) to S, called S_{alt}. These are all the sentences that can be generated by replacing L with its scalar alternatives.

III. Restrict the alternatives in S_{alt} by removing any alternative that is entailed by the original utterance S. Call this restricted set S*.

IV. Strengthen the basic meaning of S (containing L) with the negation of all of the members of S*.

A large number of studies have found that children fail to derive such implicatures. This has been shown for many scalar contrasts, including *might* vs. *must* (Noveck, 2001), *a* vs. *some* (Barner, Chow, & Yang, 2009), *some* vs. *all* (Huang & Snedeker, 2009; Papafragou & Musolino, 2003; Noveck, 2001), and *or* vs. *and* (Chierchia et al., 2001). For example, in a study by Papafragou and Musolino (2003), 5-year-old children were shown a scene including three horses, in which all three jumped over a log. When asked whether the sentence, "Some of the horses jumped over the log" was a good description of the event, most children said yes. Adults, in contrast, denied that this was a good description, since *all* of the horses jumped over the log. Adults, unlike children, computed a scalar implicature. Children do not always lack a so-called *strengthened* meaning. Papafragou and Musolino found that children provided adult-like responses when tested with numerals. Children denied that "Two of the horses jumped over the log" when three horses did. Thus, although children failed to have adult-like response with *some* and *all*, they interpret numerals with an *exact*-meaning just like the adult controls.

Previous studies have suggested factors that could affect children's derivation of implicatures, including limitations on working memory, limited understanding of context and meta-linguistic tasks, and the salience or availability of relevant scalar alternatives (see Chierchia et al., 2001; Papafragou & Tantalou, 2002; Pouscoulous et al, 2007; Reinhart, 2004). According to Papafragou and Musolino (2003), since each of these factors might limit children's computation of implicatures, and since children readily assign exact interpretations to numerals, children must not be using implicatures to derive exact meanings of numerals. Instead, by their view, the difference between quantifiers and numerals is due to the fact that numerals have lexically strengthened, exact meanings (see also Huang, Snedeker, & Spelke, under review).

Context clearly affects whether children (and adults) will compute implicatures (e.g., Papafragou & Musolino, 2002). It is also well established that working memory capacity grows over the course of development (e.g., Gathercole & Baddley, 1990). Nevertheless, the role of these factors in children's pragmatic difficulties has not been empirically established. First, although previous studies find that implicatures are more likely in some contexts than others (e.g., Papafragou & Musolino, 2002), the fact that strong contextual cues can push children towards one interpretation over another does not demonstrate that their difficulties are due to contextual misunderstanding. For example, strong contextual cues may compensate for difficulties that originate elsewhere in the process of deriving implicatures.

Second, there is currently no direct evidence that processing constraints are responsible for limiting children's implicatures. Studies that attribute their problems to processing limitations (Chierchia et al., 2001; Pouscoulous et al., 2007; Reinhart, 2004) do not actually assess working memory, nor do they demonstrate that individual differences in processing capacity predict differences in pragmatic abilities. For example, Chierchia et al. (2001) tested 3- to 6-year-old children's interpretation of *or*. Unlike adults, when children were told, "Every boy chose a skateboard or a bike," they accepted situations in which a boy chose both objects. Thus, they accepted the weak inclusive interpretation of *or*, when adults did not. However, when explicitly presented with a sentence containing *and* as an alternative, children strongly preferred it over a sentence containing *or*. This study shows that when children are presented with explicit scalar alternatives, they know when to use the stronger statement. However, it does not single out working memory as the source of children's difficulty. Instead, we suggest that it is also consistent with the idea that children lack knowledge of scales, and which words are activated as relevant alternatives during interpretation (Step II, see also Papafragou & Tantalou, 2004). An inability to generate relevant scale-mates could explain numerous failures in the literature, as well as the apparent discrepancy between children's difficulty with implicatures and their relatively sophisticated use of pragmatic cues elsewhere in language acquisition. Further, this account, as noted by Barner and Bachrach (2010), could explain children's ability to assign exact interpretations to numerals, which belong to an explicitly memorized set of alternatives – the count list.

Barner and Bachrach (2010) argued that young children routinely make inferences that are similar in structure to scalar implicatures when interpreting unknown numerals. As noted earlier, when a child who knows the meaning of *one* is shown two sets – e.g., one containing one balloon, and the other containing five – they systematically point to the larger set when asked to find *five balloons*. However, they do not do so when asked to find *blicket balloons*. According to Wynn (1992), "Since all the children knew that the word 'one' refers to a single item, then if they knew that, for example, the word 'five' refers to a numerosity, they should infer that it does not refer to a single item since they already have a word for the numerosity one." (p. 229).

This inference – that *five* refers to the larger set by virtue of *not* referring to *one* – requires all of the processing resources that an implicature would require, as well as several of the same steps. The child must generate a weak meaning for *five* (Step I), generate *one* as an alternative (Step II), and strengthen the interpretation of *five* by negating *one* (Step IV). The only missing component of implicature is that weaker items are not exhaustified by appeal to stronger ones (this would be impossible here, since stronger numeral words have not yet been acquired). Still, once children acquire a meaning for *two*, they should be in a position to compute an implicature for *one*, meaning that even 2-year-olds could compute implicatures to derive exact meanings for numerals.

Children do not have difficulty accessing *one* as a relevant alternative to *five*. Also, once children have accessed *one* as an alternative, they appear capable of inferences not far from a full-fledged scalar implicature. These facts suggest that children's failure to compute implicatures for other scales may be due to a failure to generate relevant scalar alternatives. While children begin to explicitly memorize a count list well before they learn any numeral meanings (see Fuson, 1988), no child is taught to recite a list of quantifiers.

The present study tested the hypothesis that children's difficulty computing implicatures is caused by a failure to generate relevant alternatives. We asked whether children could strengthen their interpretation of utterances containing the quantifier *some* when used with the focus word *only*. In English, the algorithm for calculating scalar implicatures is grammatically mirrored by the semantics of *only*, a fact that allows us to isolate the role of access to alternatives in implicature. As with implicatures, *only* triggers the negation of alternative sentences. For example, consider the sentence in (5).

(5) I ate only some of the cake.

This sentence indicates that the speaker did not eat all of the cake, like Mary's statement in (1). The difference between the sentences in (1) and (5) is that in (5) the denial of the alternative "*I ate all of the cake*" is logically entailed by the sentence's core, literal meaning (it is not merely implied). Still, in order for this entailment relation to be realized, the listener must access *all* as a relevant alternative and negate it. Therefore, evidence that children comprehend *only* but fail to strengthen sentences containing *only some* would suggest that their difficulty is caused by a failure to access scalar alternatives.

To manipulate the accessibility of alternatives, we contrasted children's interpretation of *some*, whose scale members are specified in a context-independent way, with their interpretation of words that have contextually specified alternatives (for discussion, see Hirschberg, 1985). Previous studies find that young children are able to strengthen utterances that rely on contextual alternatives. For example, Goro, Minai & Crain (2006) found that children rejected sentences like "Only Bunny Rabbit will eat a carrot or a pepper" in contexts where another character ate a pepper.

We tested the hypothesis that children's difficulty is due to difficulty generating relevant alternatives by (1) manipulating the availability of alternatives by contrasting utterances that involve context-independent scales like <*some*/*all*> to utterances that draw on contextually specified sets of alternatives, and (2) forcing the exhaustification of utterances by including the focus element *only* in sentences. Critical trials in the experiment presented situations involving three things (e.g., three animals sleeping), and asked children to evaluate one of the questions in (6):

(6) a. Are some of the animals reading?
b. Are only some of the animals reading?
c. Are the cat and the dog reading?
d. Are only the dog and the cat reading?

If children's difficulty computing implicatures for context-independent scales is due to a failure to access alternatives, then they should accept statements like (6a) and (6b) regardless of whether *only* is present. They should fail to construct an alternative sentence containing *all*, and therefore be unable to strengthen either sentence. In contrast, children should have no difficulty strengthening a sentence like (6d), since the alternative contrast set is contextually specified and therefore readily available.

Method

Participants

Sixty 4-year-olds (*M*=53.94 months, age range: 48.7–59.8 months) participated in this experiment. Two additional children were excluded due to failure to complete the task.

Stimuli

Stimuli were twelve picture cards, each depicting a scene of three items. Four cards were used in a familiarization phase, and eight in the test phase. Familiarization cards depicted sets of animals with distinct characteristics, such as color or clothing. The test cards depicted four scenes (in 1 – 4).

(1) Cookie Monster holding fruit (an orange, an apple, and a banana)
(2) Animals sleeping (a dog, a cat, and a cow)
(3) Animals reading (a dog, a cat, and a rabbit)
(4) Toys on a table (a ball, a drum, and a train)

Two versions of each scene were created: one in which all three items shared a property (e.g., Cookie Monster is holding all three fruits), and one in which two of the three items shared the property (e.g., Cookie Monster is holding two fruits, and one is on the floor). An example is provided in Figure 1.

Figure 1: Example test stimulus card.

Procedure

Children were first shown the familiarization cards one at a time and asked to identify each animal ("What's this? That's right, it's a cow!"). If the child labeled an animal incorrectly, they were given the correct label and encouraged to repeat it ("That's a cow, can you say 'cow?").

Children were then asked a question about the scene (e.g., "Is the cow wearing a hat?" when the *fish* is wearing a hat). This exercise was designed to accustom children to answering both yes and no to questions. If a child answered any question incorrectly, the experimenter moved on to the next familiarization card, but returned to the problematic card after completing the remaining familiarization trials. If a child failed twice on any single familiarization trial, the experimenter ended the testing session.

At test, children were given nine trials using the test cards, presented in one of two counterbalanced orders. Again, children were asked to identify all of the items in the picture, and then to evaluate the truth-value of a statement.

Each child participated in one of four conditions. In Conditions 1 and 3 (*Context-Independent Alternatives)*, children were asked questions that required them to evaluate the meanings of the quantifiers *some* and *all*, e.g. *Is Cookie Monster holding some / all of the fruits?* In Conditions 2 and 4 (*Contextual Alternatives*), the individual animals, fruits, etc. were labeled separately, e.g., *Is Cookie Monster holding the banana, the apple and the orange?* The questions in each condition were identical, except that in Conditions 3 and 4 (*Grammatically Exhaustified* conditions) the word *only* was inserted– e.g., *Are only some of the animals reading?* or *Are only the dog and the rabbit reading?*

There were 9 questions in each condition. On "2-item, False" questions, children were shown a picture in which only two of the three items fit a description, and were asked whether the description was true for all the items (e.g., *Is Cookie Monster holding all of the fruits?* or *Is Cookie Monster holding the apple, the orange, and the banana?*). These were used as control trials, to be sure that children were attending to the task, and were presented identically in conditions 1 and 2 and conditions 3 and 4. On "2-item, True" questions, children saw pictures where two of the three items fit a description, and were asked whether the description was true for a subset of the items (e.g. *Are (only) some of the animals reading?* or *Are (only) the rabbit and the dog reading?*). Lastly, on "3-item, Test" questions, children were shown pictures in which all three items fit the description, and asked whether the description was true for a subset of the items (questions were identical in the 2-item, True and 3-item, Test trials).

Neither the word *only* nor the quantifier was emphasized by the experimenter's prosody.

Results

The use of the word *only* had a significant effect on how children interpreted sentences involving contextual alternatives, but had no effect on their interpretation of sentences involving context-independent alternatives (*some* and *all*). A 2x2x2 repeated measures ANOVA was conducted with Trial Type ("2-Item True" vs. "3-Item Test") as a within-subjects variable and Scale Type (context-independent vs. contextual) and Grammatical Exhaustification (*only* vs., *no-only*) as between-subjects variables. Two-Item False Trials were excluded from this analysis as children were expected to reject these sentences (results for these trials are described below).

Overall, children were significantly more likely to accept sentences on 2-Item True Trials (87.9%), than on 3-Item Test Trials (59.6%), $F(1,56)=37.05$, $p<.001$. They were also less likely, overall, to accept sentences with *only*, such as "only the drum and the ball are on the table" (84.8% of trials) than those that did not contain *only* (62.7% of trials, $F(1,56)=672.2$, $p<.001$). There was no main effect of Alternative Type ($p>0.05$). Crucially, there were two-way interactions between Alternative Type and Grammatical Exhaustification ($F(1,56)=13.74$, $p<.001$), Trial Type and Grammatical Exhaustification ($F(1,56)=15.08$, $p<.001$),Trial Type and Alternative Type ($F(1,56)=8.87$, $p<.01$), and a three-way interaction between Trial Type, Alternative Type, and Grammatical Exhaustification ($F(1,56)=13.28$, $p<.001$). These interactions were due to the fact that *only* had a significant effect on children's judgments only for contextual alternatives, and only on 3-item Test trials.

Figure 2 shows the percentage of children who said "yes" to questions in the contextual alternatives conditions. In contexts involving 2 items (e.g., Cookie Monster holding an apple and a banana), children correctly agreed to sentences like, "Is cookie monster holding the apple and the banana?" on 95.8% of trials, and correctly denied that he was holding "the apple, the banana, and the orange" on 80.5% of trials. As expected, adding the word *only* had no effect on either trial type ($ps>.05$). In contrast, on critical 3-item Test trials, children tested with contextual alternatives were highly sensitive to the presence of *only*. These children said "yes" when asked, "Is cookie monster holding the apple and the banana?" on 92.9% of trials, but rarely said "yes" when *only* was added: "Is cookie monster holding only the apple and the banana?" (14% of trials; $t(28)=8.98$, $p<.001$).

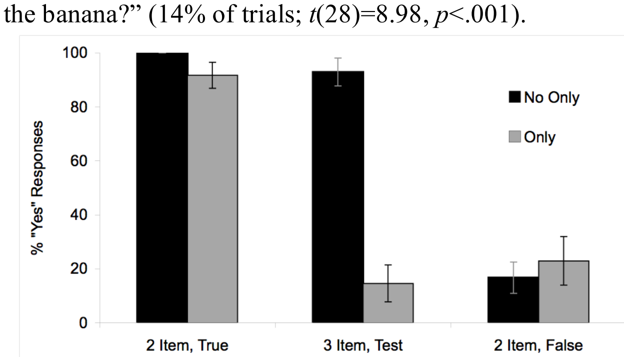

Figure 2: Percentage of children who said "yes" to sentences in contextual alternatives conditions.

When children were tested with the word *some* (Context-Independent Alternatives conditions), they also correctly said "yes" on 2-item true trials (80.0% of trials), and correctly said "no" 2-item false trials (87.2% of trials). The insertion of *only* again had no effect on children's responses for these trial types ($ps>0.05$). As in other studies, children did not strengthen utterances containing *some* in absence of *only*. There was no significant difference in children's response for 2-item True trials and 3-item Test trials

($t(14)=1.0$, $p>.3$). For example, children were equally likely to agree that *some* animals were reading when all three of them were, relative to when only two were. The insertion of *only* did not improve matters and had no effect on the 3-item test trials ($t(28)=.16$, $p>.8$). For example, when three animals were reading, children were equally likely to say "yes" when asked, "Are some of the animals reading" and "Are only some of the animals reading". Thus, whereas *only* had a huge impact on children's interpretation of utterances including contextual alternatives, it had no effect at all when children interpreted utterances containing the word *some*.

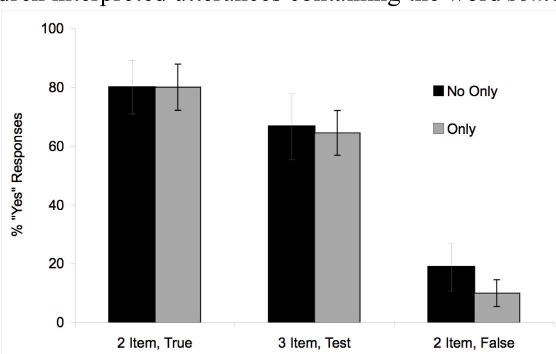

Figure 3. Percentage of children who said "yes" to questions in context-independent conditions.

Discussion

Children's ability to generate scalar alternatives places a significant constraint on their ability to compute scalar implicatures. In this study, children assigned strengthened interpretations to utterances when they included the focus element *only*, if alternatives were provided contextually. For context-independent scales (e.g., *some/all*) children failed to compute implicatures, even when *only* was added. Since *only* forces exhaustification grammatically (and did so for contextual alternatives), children's failure to derive strengthened readings for *some* must be attributed to a failure to generate relevant scalar alternatives – in this case the quantifier *all*.

These data also suggest, contrary to speculation in the literature (e.g., Chierchia et al, 2001; Pouscoulous et al., 2007) that children's difficulties are not purely attributable to processing constraints. Children were perfectly capable of deriving strengthened interpretations for utterances that involved contextual alternatives, but failed for identical sentences that involved *some*. This result is not predicted by theories that posit processing limitations, since the sentences in these conditions did not differ in grammatical complexity. They only differed with respect to the type of scale that they implicated. The possibility that there are differences in processing difficulty between these conditions cannot be completely ruled out. However, no previous study has provided direct evidence that children's failures are related to processing limits or working memory. Also, as they are presented, the previous accounts of processing limits are too vague to explain why they would affect Horn scales but not context dependent scales. Thus, we see no compelling reason to conclude that processing limits are at the root of children's difficulties on this task or with scalar implicature generally. Instead, we submit, children lack *knowledge* that is scale-specific – i.e., they lack the knowledge that *all* is a relevant alternative when interpreting *some*.

Our hypothesis – that children interpret "only" like adults but fail to compute scalar implicatures because they lack knowledge of specific scales – allows us to explain a much wider array of data than previous accounts, while explaining why children appear pragmatically sophisticated in some domains but not in others. As noted in the introduction, previous studies of children's number word acquisition find that children can make inferences that resemble scalar implicature from a very early age (Wynn, 1992; Condry & Spelke, 2008). These inferences – e.g., that *five* cannot refer to sets of one, because *one* does –involve processes similar to those needed for scalar implicature. (see Barner & Bachrach, 2010).

Children's ability to make such inferences for numerals and contextual scales, but not for scales like <*some, all*>, points to differences in scale-specific knowledge. In the case of contextual scales, no scale-specific learning is required since these scales are constructed on the fly in context. In the case of number words, children begin acquisition by learning numerals as an ordered list of alternatives. They acquire a partial count list *before* learning any individual numeral meanings (for review, see Carey, 2009). Thus, the first thing that children learn about the numeral *five* is that it is a member of the count list. In contrast, normal children never learn to recite a sequence of quantifiers like *some, many, most, all*, etc. This view of acquisition suggests, contrary to previous reports (e.g., Papafragou & Musolino, 2003; Huang, Snedeker, & Spelke, under review) that children may derive exact meanings of early numerals via scalar inference (by contrasting numerals with one another).

The idea that children's difficulties are scale-specific, rather than due to pragmatic immaturity, is also consistent with reports of pragmatic sophistication in other domains, such as noun learning (see Baldwin, 1993; Clark, 1987, 1988; Markman, 1989; Tomasello, 1992). For example, when shown a novel object next to an alternative with a known label – e.g., a shoe – children readily infer that a novel label like *blicket* must refer to the new object (Clark, 1987, 1988; Markman, 1989). Similarly, children infer that a novel color word, like *chromium*, must refer to a novel color, and not to known colors like *red* or *blue* (Carey & Bartlett, 1978). Children fail to respect mutual exclusivity if they believe the novel word is not at the same level of description as the label for the known object, or if they are told the word is from another language (Au & Glusman, 1990). In these cases, the known label is not considered a relevant alternative to the novel label. These simple inferences, though distinct from implicatures in many ways, nonetheless require both pragmatic understanding (including ascription of speaker intent), and the processing abilities needed to entertain and restrict possible alternatives. These abilities would be difficult to explain if children's difficulties with scalar implicature were due to processing limits or a general insensitivity to pragmatics.

What must children learn about scales to use them for implicature? Clearly children must learn the meanings of scale mates, and how these meanings differ in informational strength in different contexts. At 4 years of age, children easily differentiate meanings like *some* and *all*, and are able to correctly choose stronger descriptions over weaker ones when provided with a forced choice (e.g., Chierchia et al., 2001). Children's difficulty, it seems, is in recognizing that, for communicative purposes, these scale mates are alternatives to one another – i.e., that using one implies that the others are not true. Thus, a failure to generate words as alternatives does not mean that children have difficulties with lexical retrieval. Rather, our claim is that even when children can retrieve *all* when interpreting *some*, they do not access it *as a relevant alternative* to *some*.

A remaining puzzle, and one that is not addressed by the current study, is how children eventually come to acquire such scales. Our results, and others from the literature, suggest that children are capable of strengthening utterances by appeal to alternatives, so long as these alternatives are contextually specified or memorized explicitly as a list. It is not clear children they come to associate scale mates, such as quantifiers, that they do not learn as a list. We suggest that the association of these lexical items may take place by trial and error learning – by hearing words used contrastively in context, or via explicit cancellations of implicature in the speech of adults. Future studies should explore the effects that such input has on children's pragmatic reasoning, and how experience with different scales affects their ability to compute implicatures.

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