Children's Computation of Scalar Implicatures Induced by Universal Quantifiers in Negative Sentences

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This paper is concerned with children's computation of scalar implicatures (SIs) induced by universal quantifiers in negative sentences. Based on the results of an experiment, Terunuma (2008) has claimed that Japanese-speaking children assign non-adultlike interpretation to negative sentences containing a universal quantifier marked by the contrastive topic particle wa 'CTop' because they fail to compute SIs induced by universal quantifiers. Terunuma's (2008) SI-based account, together with Chierchia et al.'s (2001) claim on the acquisition of SIs, predicts that Japanese-speaking children would assign adult-like interpretation to the sentences in question when the processing load of computing SIs is small enough. Presenting the results of a new experiment that investigates whether this prediction is borne out, this paper shows that Terunuma's (2008) SI-based account (and Chierchia et al.'s (2001) claim) can be maintained because 4- or 5-year-old children's responses in the experiment do not contradict Terunuma's (2008) account.[*]

Keywords: language acquisition, scalar implicatures, universal quantifiers

1. Introduction

In adult Japanese, the negative sentence in (1), in which the universal quantifier is marked by the contrastive topic particle *wa* 'CTop,' implies as a scalar implicature (SI) that (2) is false.[1,2]

(1)	Mickey-wa	ringo-o	zenbu-wa	tabe-nakat-ta	yo.
	Mickey-TTop	apple-Acc	all-CTop	eat-Neg-Past	SFP
	'It is not the case that Mickey ate all the apples.'				
(2)	Mickey-wa	ringo-o	dore-mo	tabe-nakat-ta	yo.
	Mickey-TTop	apple-Acc	which-mo	eat-Neg-Past	SFP
	'Mickey didn't eat any apples.'				

SIs, which are triggered by scalar terms such as quantifiers, are computed on the basis of the Cooperative Principle (Grice (1975)), in particular, the maxim of quantity. In (1), the presence of the universal quantifier and the knowledge of the pragmatic principle lead Japanese-speaking adults to compute the SI.

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[1] In this paper, the following abbreviations are used: TTop = thematic topic particle, CTop = contrastive topic particle, Nom = nominative, Acc = accusative, Gen = genitive, CL = classifier, Past = past tense morpheme, Neg = negative morpheme, SFP = sentence-final particle.

[2] The particle *wa* in Japanese functions as either marking a theme (thematic *wa* 'TTop') or marking a contrasted element (contrastive *wa* 'CTop') (Kuno (1973)). The two types of *wa* differ both prosodically and syntactically. As mentioned in Kuno (1973), while the element marked by thematic *wa* 'TTop' does not receive prominent intonation, the one marked by contrastive *wa* 'CTop' can. Nakanishi (2002, 2007) confirms the difference in prosody between the two types of *wa* by conducting an experiment on adult native speakers of Japanese. The two types of *wa* are also different in the element that they can attach to, as McGloin (1987) claims. While thematic *wa* 'TTop' can mark only nominal elements, contrastive *wa* 'CTop' can mark not only nominal elements but also non-nominal elements such as verbs, adverbs and quantifiers.

Conducting an experiment on 3- to 5-year-old Japanese-speaking children, Terunuma (2008) found that they differed from Japanese-speaking adults in the interpretation of sentences like (1). Terunuma (2008) claims that this difference results from children's failure to compute SIs induced by universal quantifiers.

Investigating further into Japanese-speaking children's computation of SIs, this paper examines whether Terunuma's (2008) SI-based account for children's non-adultlike interpretation of sentences like (1) is tenable. In previous studies, several experiments have been conducted in English and Greek to examine whether children can compute SIs. The results of Chierchia et al.'s (2001) experiments demonstrate that 3- to 6-year-old English-speaking children generally fail to compute SIs induced by *or*, but are able to do so in a particular situation. In order to explain the results of their experiments, Chierchia et al. (2001) claim that children have the knowledge of SIs, but cannot compute SIs unless the computation of SIs involves a small enough processing load. The results of experiments in Greek also provide evidence that children have the knowledge of SIs. According to Papafragou (2002, 2003), Papafragou and Musolino (2003) and Papafragou and Tantalou (2004), Greek-speaking children at the age of 4 to 6 can compute SIs induced by *miso* 'half,' *meriki* 'some' and *dio* 'two' (to some extent). Based on these previous studies, we can assume that children are endowed with the pragmatic principle that governs the computation of SIs, although they sometimes fail to use the knowledge of the pragmatic principle. Under this assumption, we can argue that one conceivable factor in Japanese-speaking children's failure to compute SIs in sentences like (1) is their insufficient processing ability. Given Chierchia et al. (2001) and Terunuma (2008), it follows that Japanese-speaking children would interpret sentences like (1) as Japanese-speaking adults do when the processing load of computing SIs is small enough. If this prediction is confirmed, Terunuma's (2008) SI-based account (as well as Chierchia et al.'s (2001) claim) will be corroborated.

The organization of this paper is as follows: Section 2 overviews Chierchia et al.'s (2001) study on SIs and Terunuma's (2008) study on children's interpretation of sentences like (1). Section 3 presents the design and results of a new experiment that investigates how Japanese-speaking children interpret sentences like (1) in the situation where the computation of SIs costs a small processing load. Taking into account the results of the experiment in section 3, section 4 considers whether Terunuma's (2008) SI-based account can be maintained. Section 5 concludes the paper.

2. Previous Studies

This section overviews two previous studies. Section 2.1 reviews Chierchia et al.'s (2001) study on English-speaking children's computation of SIs induced by *or*. Section 2.2 summarizes Terunuma's (2008) study on Japanese-speaking children's interpretation of negative sentences containing *zenbu-wa* 'all-CTop.'

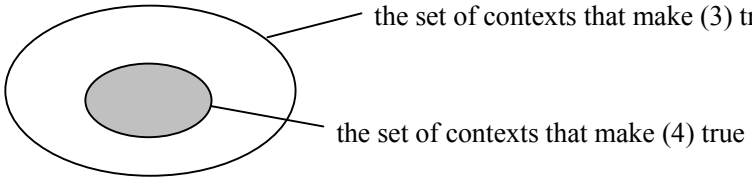
2.1 Chierchia et al.'s (2001) Study on Scalar Implicatures

In adult English, the sentence in (3) implies as a SI that the statement in (4) is false.

(3) John ordered pizza or pasta.
(4) John ordered pizza and pasta.

The SI in the sentence in (3), which is triggered by the scalar term *or*, is computed on the basis of the Cooperative Principle as follows: (3) is entailed by (4), but not vice versa. That is, the set of contexts that make (3) true includes the set of contexts that make (4) true, as Figure 1 shows.

Figure 1



(4) is more felicitous than (3) as a description of contexts included in the shaded part of Figure 1 because (4) is more informative. In this situation, assuming that the speaker is cooperative, the hearer concludes that the speaker will utter (4) rather than (3) to describe contexts included in the shaded part. The hearer then reasons that when the speaker utters (3), the described situation is not included in the shaded part. Thus, uttering (3) leads to the implicature that (4) does not hold.

As illustrated immediately above, the computation of SIs involves comparing propositions that are in an entailment relation. Out of such propositions, the more informative one is called a stronger statement, and the less informative one is called a weaker statement. When weaker statements are uttered, it is implied as SIs that stronger statements are false.

Because of SIs induced by *or*, English-speaking adults judge sentences containing *or* such as (3) to be unacceptable in contexts in which sentences containing *and* such as (4) are true. Chierchia et al. (2001) carried out two experiments to examine whether English-speaking children as well could compute SIs induced by *or*. In one experiment, the truth value judgment task (TVJT) methodology (Crain and Thornton (1998)) was used. Sentences containing *or* were judged against contexts where sentences containing *and* were true (inclusive contexts). (5) instantiates a test sentence, and (6) is the outline of the inclusive context for (5).

(5) Every boy chose a skate-board or a bike.
(6) Four boys are at a summer camp. They are choosing which toys they will play with. There are some skate-boards, some bikes, a boat and a truck. After a while, the four boys take both a skate-board and a bike.

Sentences like (5) were given in inclusive contexts four times. The sentences should be rejected in given contexts if SIs are computed. Fifteen English-speaking children (3;5–6;2) and eight English-speaking adults were tested. The results of this experiment are that while the adults rejected the sentences 100% of the time, the children accepted the sentences 50% of the time.

In the other experiment, the felicity judgment task methodology was adopted. Both a sentence containing *or* and a sentence containing *and* were presented in one inclusive context, and children were asked which sentence was a better description of the context. For example, the sentences in (7) and (8) were given in the context outlined in (9).

(7) Every farmer cleaned a horse or a rabbit.
(8) Every farmer cleaned a horse and a rabbit.
(9) Some farmers are going to clean their animals. After looking at all of the animals, each farmer cleans a horse and a rabbit.

Sentences containing *and* should be judged better than those containing *or* in given contexts if SIs are computed in sentences containing *or*. Fifteen English-speaking children (3;2–6;0) different from those participated in the other experiment were tested in four trials. They responded 93.3% of the time that sentences containing *and* were more felicitous than sentences containing *or*.

What was found in the two experiments by Chierchia et al.'s (2001) is that English-speaking children have difficulty in computing SIs when they are given only sentences containing *or*, but that they can compute SIs when they are given both sentences containing *or* and those containing *and*. Based on this, Chierchia et al. (2001) claim that children fail to compute SIs not because they lack the knowledge of SIs but because the computation of SIs is sometimes beyond their processing ability. As noted above, SIs are computed by comparing two propositions in terms of informativeness. On Chierchia et al.'s (2001) view, which is based on Reinhart (1999), it is difficult for children with insufficient processing ability to maintain two propositions in memory for comparison. Consequently, they cannot compute SIs in weaker statements unless they are given the corresponding stronger statements explicitly.

2.2 Terunuma's (2008) Study on Japanese Negative Sentences Containing Zenbu-wa 'All-CTop'

In adult Japanese, the negative sentence containing *zenbu-wa* 'all-CTop' in (10) is unambiguous with respect to the relative scope of the quantifier and negation.

(10) Mickey-wa ringo-o zenbu-wa tabe-nakat-ta yo.
Mickey-TTop apple-Acc all-CTop eat-Neg-Past SFP
'It is not the case that Mickey ate all the apples.'

The reading in which negation takes scope over the universal quantifier (the NEG > ∀ reading) is allowed, but the reading in which the universal quantifier takes scope over negation (the ∀ > NEG reading) is blocked due to the contrastive implicature induced by *wa* 'CTop' (Hirose and Kaga (1997), Terunuma (2005a, b)). That is, (10) is interpreted as in (11) but not as in (12).

(11) Not all the apples were eaten by Mickey.
(12) None of the apples were eaten by Mickey.

Because (10) has the NEG > ∀ reading paraphrased in (11), (10) is true in contexts like (13), where (11) holds.

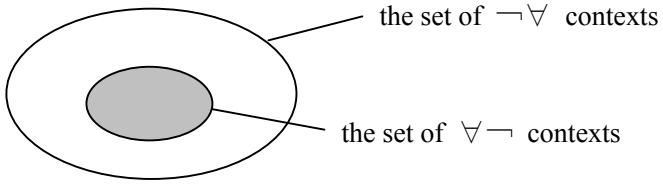
(13) There are three apples. Mickey Mouse ate two of them, but didn't eat the remaining one.

Logically, (10) is also true in contexts like (14), where (12) holds, although it does not have the ∀ > NEG reading paraphrased in (12).

(14) There are three apples. Mickey Mouse ate none of them.

This is because the NEG > ∀ reading, which (10) has, is entailed by the ∀ > NEG reading, which (10) actually does not have. As illustrated in Figure 2, the set of ¬∀ contexts, namely the set of contexts that make the NEG > ∀ reading true, includes the set of ∀¬ contexts, namely the set of contexts that make the ∀ > NEG reading true.

Figure 2



Having the NEG > ∀ reading, (10) is true in all the contexts included in the outer circle of Figure 2. (10) is therefore true both in contexts like (13), which is included in the unshaded part, and in contexts like (14), which is included in the shaded part. Accordingly, (10) should be accepted not only in ¬∀ contexts but also in ∀¬ contexts, if interpreted logically.[3]

Japanese-speaking adults do not assign logical interpretation to the sentence in (10), however, because they compute the SI induced by the universal quantifier. Compare (10) with (15).

[3] As Figure 2 in the text shows, some of the ¬∀ contexts are also ∀¬ contexts. In the remainder of this paper, however, only the contexts that are included in the unshaded part of Figure 2 are referred to as ¬∀ contexts.

(15) Mickey-wa ringo-o dore-mo tabe-nakat-ta yo.
Mickey-TTop apple-Acc which-mo eat-Neg-Past SFP
'Mickey didn't eat any apples.'

While (10) is true in contexts included in the outer circle of Figure 2, (15) is true only in contexts included in the inner circle. That is, (10) is a weaker statement, and (15) is a stronger statement. (10) hence implies as a SI that (15) is false. Such a SI makes (10) incompatible with ∀¬ contexts because (15) is true in ∀¬ contexts. As a result, (10) is acceptable only in ¬∀ contexts in adult Japanese.

Terunuma (2008) conducted an experiment with the TVJT methodology to investigate how Japanese-speaking children interpret sentences like (10). In her experiment, sentences like (10) were presented in ¬∀ contexts and ∀¬ contexts on two trials each. Thirty Japanese-speaking children ranging in age from 3;10 to 5;3 and fifteen Japanese-speaking adults were tested. They were classified into four age groups: C1 (the group of children under 4;6), C2 (the group of children of and over 4;6 but under 5;0), C3 (the group of children of and over 5;0), and A (the group of adults). Of the thirty children, eight were in C1, seventeen were in C2, and five were in C3. The two figures below indicate the rates at which each age group accepted sentences like (10) in ¬∀ and ∀¬ contexts.

Figure 3: The acceptance rate for sentences like (10) in ¬∀ contexts

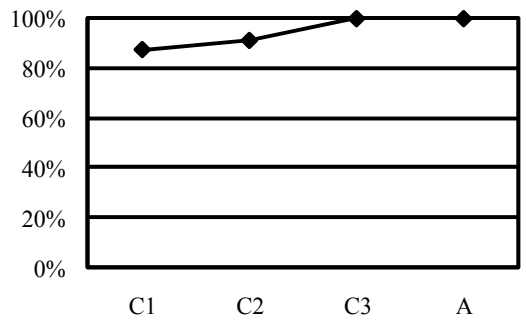
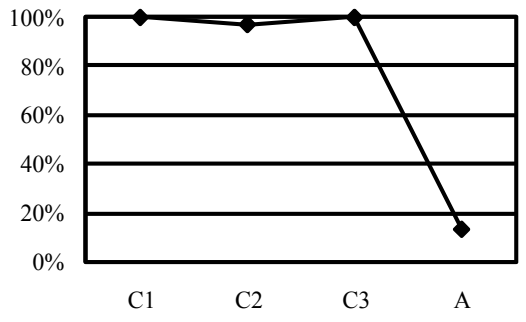


Figure 4: The acceptance rate for sentences like (10) in ∀¬ contexts



According to Terunuma (2008), statistical analyses show that no effect for age is found in Figure 3, but that the difference in response between each of the three child groups on the one hand and A on the other is significant in Figure 4. The results of Terunuma's (2008) experiment demonstrate that Japanese-speaking children are adult-like in accepting negative sentences containing *zenbu-wa* 'all-CTop' in ¬∀ contexts, but are different from adults in accepting the sentences in ∀¬ contexts as well.

Terunuma (2008) accounts for this difference between children and adults as follows: Japanese-speaking

children, like adults, can compute contrastive implicatures in negative sentences containing *zenbu-wa* 'all-CTop.' Accordingly, in child Japanese as well as in adult Japanese, the ∀ > NEG reading is blocked and only the NEG > ∀ reading is allowed in the sentences. However, children, unlike adults, fail to compute SIs in the sentences. The sentences are hence interpreted logically and are accepted not only in ¬∀ contexts but also in ∀¬ contexts in child Japanese. On this account, children's non-adultlike interpretation of negative sentences containing *zenbu-wa* 'all-CTop' results not from their peculiar scope reading but from their failure to compute SIs.

3. The Experiment

In Terunuma's (2008) experiment, negative sentences containing *zenbu-wa* 'all-CTop,' which are weaker statements, alone were presented. Given Chierchia et al's (2001) claim on children's computation of SIs, Terunuma (2008) makes the following prediction.

(16) Japanese-speaking children will interpret negative sentences containing *zenbu-wa* 'all-CTop' as Japanese-speaking adults do when the corresponding stronger statements are explicit.

In order to examine whether this prediction is borne out, an experiment was conducted. The following subsections describe the experiment and present the results.

3.1 Design

The experiment consisted of two sessions: the control session and the test session. Each session is described bellow in turn.

Adopting the TVJT methodology, the control session was designed to examine whether children would understand the basic meaning of negation and three quantifiers that would be used in the test session. The following four types of control sentences were used in the control items: negative sentences containing no quantifiers such as (17), affirmative sentences containing *zenbu* 'all' such as (18), negative sentences containing *dore-mo* 'which-mo' such as (19) and negative sentences containing *hitotsu-mo* 'one-mo' such as (20).

(17) Mickey-wa supuun-o arawa-nakat-ta yo.
Mickey-TTop spoon-Acc wash-Neg-Past SFP
'Mickey didn't wash spoons.'

(18) Mickey-wa budoo-o zenbu tot-ta yo.
Mickey-TTop grape-Acc all pick-Past SFP
'Mickey picked all the bunches of grapes.'

(19) Mickey-wa banana-o dore-mo kawa-nakat-ta yo.
Mickey-TTop banana-Acc which-mo buy-Neg-Past SFP
'Mickey didn't buy any bananas.'

(20) Mickey-wa banana-o hitotsu-mo kawa-nakat-ta yo.
Mickey-TTop banana-Acc one-mo buy-Neg-Past SFP
'Mickey didn't buy even one banana.'

Each type of control sentence was presented in two contexts: the context where the sentence is false (the mismatch context) and the context where the sentence is true (the match context). For instance, the control items of negation are given in (21) and (22).

(21) The control item of negation in the mismatch context

Outline of the context story:

Mickey Mouse is washing up after dinner. There are three forks and three spoons. First he considers washing the forks, but does not wash any of them after all. Next he considers washing the spoons, and indeed washes them.

Control sentence:

Mickey-wa	spuun-o	arawa-nakat-ta	yo.
Mickey-TTop	spoon-Acc	wash-Neg-Past	SFP

'Mickey didn't wash spoons.'

(22) The control item of negation in the match context

Outline of the context story:

Mickey Mouse goes to a flower shop, where he finds three sunflowers and three tulips. He first considers buying a sunflower, and indeed buys one. He considers buying a tulip too, but does not buy any tulips after all.

Control sentence:

Mickey-wa	chuurippu-o	kawa-nakat-ta	yo.
Mickey-TTop	tulip-Acc	buy-Neg-Past	SFP

'Mickey didn't buy a tulip.'

The control session also included some filler items. Filler sentences were all affirmative sentences that did not contain any of *zenbu* 'all,' *dore-mo* 'which-mo' and *hitotsu-mo* 'one-mo.' (23) and (24) exemplify the filler items.

(23) A filler item in the mismatch context

Outline of the context story:

In a forest, Mickey Mouse finds four apples on a tree and three carrots in the ground. He picks three of the apples and all the three carrots.

Filler sentence:

Mickey-wa	ringo-o	yon-ko	tot-ta	yo.
Mickey-TTop	apple-Acc	four-CL	pick-Past	SFP

'Mickey picked four apples.'

(24) A filler item in the match context

Outline of the context story:

Mickey Mouse goes to his friend's house. His friend has prepared a lot of food on a table. There are a banana, a bunch of grapes, a green pepper and two cups of orange juice.

Filler sentence:

Tsukue-no	ue-ni	banana-ga	aru	yo.
table-Gen	top-at	banana-Nom	exist	SFP

'There is a banana on the table.'

As can be seen in (23) and (24), filler sentences were presented either in the mismatch context or in the match context.

Let us now turn to the test session, which was designed to examine whether children could compute SIs in negative sentences containing *zenbu-wa* 'all-CTop' under the circumstances where the corresponding stronger statements were given explicitly. In the test items, the felicity judgment task methodology was adopted. A negative sentence containing *zenbu-wa* 'all-CTop,' which is a weaker statement, was presented with the corresponding stronger statement in a $\forall\neg$ context. Children were asked to judge which sentence had described the given context better. (25) exemplifies negative sentences containing *zenbu-wa* 'all-CTop' used in the test items. (26) and

(27) are two types of stronger statements corresponding to (25).

(25) Mickey-wa suika-o zenbu-wa tabe-nakat-ta yo.
Mickey-TTop watermelon-Acc all-CTop eat-Neg-Past SFP
'It is not the case that Mickey ate all the slices of watermelon.'

(26) Mickey-wa suika-o dore-mo tabe-nakat-ta yo.
Mickey-TTop watermelon-Acc which-mo eat-Neg-Past SFP
'Mickey didn't eat any slices of watermelon.'

(27) Mickey-wa suika-o hitotsu-mo tabe-nakat-ta yo.
Mickey-TTop watermelon-Acc one-mo eat-Neg-Past SFP
'Mickey didn't eat even one slice of watermelon.'

A test sentence of *zenbu-wa* 'all-CTop' was paired with a test sentence of either *dore-mo* 'which-mo' or *hitotsu-mo* 'one-mo.' (28) instantiates a test item.

(28) A test item
Outline of the context story:
Pooh serves Mickey Mouse three bunches of grapes and three slices of watermelon for lunch. Mickey Mouse first considers eating the bunches of grapes, and eats two of them. He does not eat the other bunch. Next he turns to the slices of watermelon and considers eating them, but eats none of them after all.
Test sentences:
Mickey-wa suika-o zenbu-wa tabe-nakat-ta yo.
Mickey-TTop watermelon-Acc all-CTop eat-Neg-Past SFP
'It is not the case that Mickey ate all the slices of watermelon.'
Mickey-wa suika-o dore-mo tabe-nakat-ta yo.
Mickey-TTop watermelon-Acc which-mo eat-Neg-Past SFP
'Mickey didn't eat any slices of watermelon.'

Test sentences of *dore-mo* 'which-mo' and *hitotsu-mo* 'one-mo' are acceptable in $\forall\neg$ contexts. In contrast, test sentences of *zenbu-wa* 'all-CTop' are not acceptable in $\forall\neg$ contexts due to SIs. Accordingly, test sentences of *dore-mo* 'which-mo' and *hitotsu-mo* 'one-mo' should be considered better than test sentences of *zenbu-wa* 'all-CTop' as descriptions of $\forall\neg$ contexts if SIs are taken into account.

The test session included some filler items as well. Filler sentences were affirmative sentences that did not contain any quantifiers. (29) is an example of the filler items.

(29) A filler item
Outline of the context story:
There are two pieces of cakes and two hamburgers on the table. Pooh is going to eat them. Then, there comes a crow. The crow takes a piece of cake away.
Filler sentences:
Karasu-wa hanbaagaa-o kuwaeteiru yo.
crow-TTop hamburger-Acc holding SFP
'A crow is holding a hamburger.'
Karasu-wa keeki-o kuwaeteiru yo.
crow-TTop cake-Acc holding SFP
'A crow is holding a piece of cake.'

The filler items of the test session are the same as the test items in presenting two sentences in one context.

However, they differ from the test items in the truth value of the two sentences in the given context. In the test items, two sentences presented at a time are both true in the given context although one of them is infelicitous as a description of the context. In the filler items, on the other hand, one of the two sentences is true and the other is false in the given context. In this sense, what subjects do in the filler items of the test session is more like a truth value judgment task than a typical felicity judgment task. The filler items in the test session were designed in this way in order to confirm clearly whether children still were engaged in the experiment.

3.2 Procedure

In the control session, each of the four types of control sentences was presented twice: once in the mismatch context and once in the match context. These eight trials for control items were interspersed with five trials for filler items. The procedure of each trial was the same as that in Terunuma's (2008) experiment. Specifically, the experimenter read a context story to a child while showing several pictures in sequence, and played back a sentence recorded in advance on an MD pretending that a puppet was uttering it. The child was then asked to judge whether the puppet's utterance was right or wrong as a description of what had happened in the story. Sentences were presented to children with care so as not to give the same type of sentences in a row. The control session took about fifteen minutes to complete.

The test session of the experiment contained three trials for test items, interspersed with two trials for filler items. Each trial proceeded as follows: First, the experimenter read a story to a child while showing a sequence of pictures, and played back two sentences recorded in advance on an MD pretending that two puppets were uttering them in turn. The child was then asked to judge which puppet described better what had happened in the story.[4] The test session took about fifteen minutes to complete.

Except for two cases in which children finished both sessions on the same day after some interval, the two sessions were finished on different days. Children were tested individually in a quiet room after they played with and felt comfortable with the experimenter.

3.3 Subjects

Thirty-two monolingual Japanese-speaking children took part in the experiment. They ranged in age from 4;2.14 to 5;2.3. Twenty Japanese-speaking adults were also tested.[5] The subjects were classified into four age groups: C1 (the group of children under 4;6), C2 (the group of children of and over 4;6 but under 5;0), C3 (the group of children of and over 5;0), and A (the group of adults).

3.4 Results

In the control session, twenty-one children passed the control test of both negation and *zenbu* 'all.' Among them, twenty children passed the control test of at least either *dore-mo* 'which-one' or *hitotsu-mo* 'one-mo.' In the test session, these twenty children were tested. The twenty children ranged in age between 4;2.15 and 5;1.23 when they participated in the test session of the experiment. Nineteen of the twenty children passed the control test of *dore-mo* 'which-mo' (and the control test of *hitotsu-mo* 'one-mo' as well in some cases). They were given test sentences of *zenbu-wa* 'all-CTop' and *dore-mo* 'which-mo' in test items. The remaining one child (4;8.27) failed

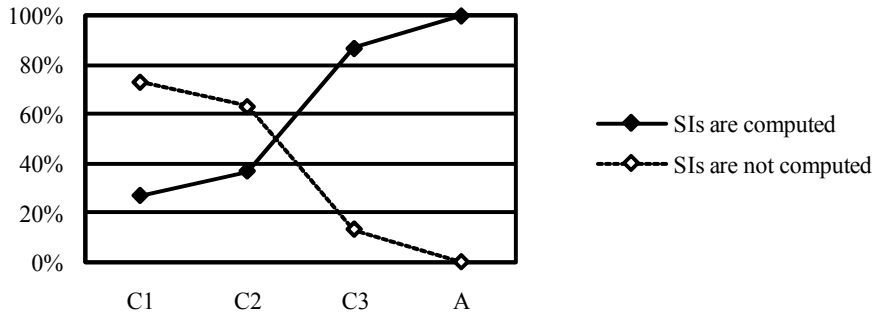
[4] In one of the three trials for test items, the test sentence of *zenbu-wa* 'all-CTop' was presented before the test sentence of *dore-mo* 'which-mo' or *hitotsu-mo* 'one-mo.' In the remaining two trials for test items, the test sentence of *zenbu-wa* 'all-CTop' was presented after the other test sentence. In one of the two trials for filler items, the filler sentence that was true in the context was presented before the filler sentence that was false in the context. In the other trial for filler items, the two filler sentences were presented in the opposite order.

[5] Adult subjects were tested all at once for two sessions running. They were required to write down their judgments on their answer sheets.

the control test of *dore-mo* 'which-mo' but passed the control test of *hitotsu-mo* 'one-mo.' This child was given test sentences of *zenbu-wa* 'all-CTop' and *hitotsu-mo* 'one-mo' in test items. Of the twenty children, five were in C1, ten were in C2, and five were in C3.

In test items, two patterns of response were found. One pattern was that test sentences of *dore-mo* 'which-mo' or *hitotsu-mo* 'one-mo' were judged to be better than test sentences of *zenbu-wa* 'all-CTop' as descriptions of $\forall\neg$ contexts. This response indicates that subjects computed SIs in test sentences of *zenbu-wa* 'all-CTop.' This response was observed 26.7 % of the time (4/15 trials) in C1, 36.7% of the time (11/30 trials) in C2, 86.7% of the time (13/15 trials) in C3, and 100% of the time (60/60 trials) in A. In the other pattern of response, test sentences of *zenbu-wa* 'all-CTop' and test sentences of *dore-mo* 'which-mo' or *hitotsu-mo* 'one-mo' were judged to be equally good as description of $\forall\neg$ contexts. This response indicates that subjects did not compute SIs in test sentences of *zenbu-wa* 'all-CTop.' Such response was observed 73.3 % of the time (11/15 trials) in C1, 63.3% of the time (19/30 trials) in C2, 13.3% of the time (2/15 trials) in C3, and 0% of the time (0/60 trials) in A. The rates at which each age group did or did not compute SIs in test sentences of *zenbu-wa* 'all-CTop' are illustrated in Figure 5.

Figure 5: The interpretation of test sentences of *zenbu-wa* 'all-CTop'



For the results above, χ^2 analysis was conducted at the $p < .05$ level of significance to see whether the difference between children's and adults' responses was significant or not. In the analysis, Yates' correction factor was undertaken.[6] The statistical analysis showed that the difference between each of the three child groups on the one hand and A on the other was significant ($\chi^2 = 45.87$, $p < .05$ for C1 and A, $\chi^2 = 44.44$, $p < .05$ for C2 and A, and $\chi^2 = 3.88$, $p < .05$ for C3 and A), although the response of C3 seems to be more adult-like than those of C1 and C2.

4. Discussion

The experimental studies of Chierchia et al. (2001), Papafragou (2002, 2003), Papafragou and Musolino (2003) and Papafragou and Tantalou (2004) have demonstrated that English-speaking children at the age of 3 to 6 and Greek-speaking children at the age of 4 to 6 can compute SIs in certain circumstances. Taking these cross-linguistic studies into consideration, we can assume that children are endowed with the knowledge of the pragmatic principle that governs the computation of SIs. On this assumption, Terunuma's (2008) SI-based account for Japanese-speaking children's non-adultlike interpretation of negative sentences containing *zenbu-wa* 'all-CTop,' together with Chierchia et al.'s (2001) claim on children's computation of SIs, predicts (16), repeated here as (30).

[6] I am grateful to Chris Sheppard for statistical analysis.

(30) Japanese-speaking children will interpret negative sentences containing *zenbu-wa* 'all-CTop' as Japanese-speaking adults do when the corresponding stronger statements are explicit.

The experiment in section 3 was conducted to check if the prediction in (30) is borne out.

The results of the experiment in section 3 do not offer a straightforward confirmation of the prediction in (30). According to statistical analysis, the difference between children and adults in the interpretation of the sentences is significant in the experiment. Even if we admit that there is a significant difference between the responses of children and those of adults in the experiment in section 3, it is too early to conclude that Terunuma's (2008) SI-based account is not tenable. In the following discussion, it is shown that the results of the experiment in section 3 do not contradict Terunuma's (2008) SI-based account. First, the responses of children in C3 are considered (section 4.1). Then, the responses of children in C1 and C2 are then discussed (section 4.2).

4.1 The Responses of Children in C3

Compare the responses of children in C3 in the experiment in section 3 with those in Terunuma's (2008) experiment. Children in C3, namely children at the age of 5, interpreted negative sentences containing *zenbu-wa* 'all-CTop' in the adult-like manner at a much higher rate in the experiment in section 3 than in Terunuma's (2008) experiment. Specifically, in Terunuma's (2008) experiment, while adults accepted the sentences in $\forall\neg$ contexts only 13.3% of the time (4/30 trials), children in C3 did so 100% of the time (10/10 trials). In the experiment in section 3, by contrast, adults judged the sentences to be infelicitous in $\forall\neg$ contexts 100% of the time (60/60 trials), and children did so 86.7% of the time (13/15 trials). The difference between the responses of children in C3 in the two experiments suggests that 5-year-old children can compute SIs in negative sentences containing *zenbu-wa* 'all-CTop' and assign the adult-like interpretation to the sentences if the corresponding stronger statements are given explicitly and as a result the comparison of weaker and stronger statements is easy. This is what Terunuma (2008), together with Chierchia et al. (2001), predicts, as we have seen in (30) above. Therefore, Terunuma's (2008) SI-based account as well as Chierchia et al.'s (2001) claim on children's computation of SIs can be maintained with respect to 5-year-olds' responses.

4.2 The Responses of Children in C1 and C2

One might argue that the responses of children in C1 and C2 in the experiment in section 3 are problematic to Terunuma's (2008) SI-based account. Children in C1 and C2, namely children under the age of 5, did not interpret negative sentences containing *zenbu-wa* 'all-CTop' in the adult-like manner even when not only weaker statements but also stronger statements were presented to make the comparison between the two easier, contrary to the prediction in (30) above.

However, the responses of children in C1 and C2 do not necessarily falsify Terunuma's (2008) account because their non-adultlike interpretation of the sentences, namely their failure to compute SIs in the sentences, can be attributed to factors other than the difficulty of comparing a weaker statement and a stronger statement. There are two conceivable factors in younger children's failure to compute SIs. One factor has to do with the design of the experiment. In the test session, children were asked which of the two sentences was better as descriptions of given contexts. In the control session, which was held before the test session, by contrast, children were asked whether particular sentences were right or wrong in given contexts. Although the test session was generally given to children on a different day from the control session, younger children's judgments might be based on the truth value of the sentences in the test session as well as in the control session. In addition, the filler items included in the test session could also make children more aware of the truth value than of the felicity of the test sentences. In order to clearly ascertain whether children paid attention to the materials in the experiment, one of the two sentences that were presented at a time in the filler items of the test session was set true and the other was set false in a given context. In such filler items, children's attention is drawn to the truth value of the sentences.

It is then conceivable that in the test items included in the same session as well, younger children considered whether sentences were true or false in given contexts although they were required to consider the felicity of the sentences. Judging negative sentences containing *zenbu-wa* 'all-CTop' against $\forall\neg$ contexts in light of the truth value amounts to interpreting the sentences logically. The design of the experiment in section 3 could therefore lead younger children to ignore SIs and assign the logical interpretation to negative sentences containing *zenbu-wa* 'all-CTop.'

Another possible factor in young children's failure to compute SIs in negative sentences containing *zenbu-wa* 'all-CTop' is concerned with the environment in which SIs arise. Chierchia (2004) calls SIs arising in downward entailing environments indirect implicatures, distinguishing them from SIs arising in non-downward entailing environments. As an example of indirect SIs, consider (31).

(31) Every girl who picked a turtle and a bunch of flowers received a bottle of water.

Due to *and* in the restrictive clause of *every*, (31) implies as a SI that (32) is false.

(32) Every girl who picked a turtle or a bunch of flowers received a bottle of water.

This SI is an indirect one because the restrictive clause of *every*, in which *and* occurs, is a downward entailing environment.[7] Investigating whether children can compute SIs in sentences like (31), Gualmini et al. (2001) claim that children have difficulty in computing indirect SIs even if they are given both weaker and stronger statements. In Gualmini et al.'s (2001) experiment, in which the felicity judgment task methodology was adopted, sentences like (31) were presented with stronger statements like (32) in contexts where stronger statements were true. Fifteen English-speaking children (4;6–6;1) were tested. If they compute SIs in sentences like (31), they should judge that sentences like (32) are more felicitous as descriptions of given contexts. The result of this experiment is that the children judged sentences like (32) to be more felicitous than sentences like (31) in 36 out of 60 trials. Although the children tested in Gualmini et al.'s (2001) experiment could compute SIs in sentences like (31) in more than half of the trials, they still failed to do so in many cases even in the situation in which it was easy to compare the sentences with their corresponding stronger statements.

It has also been reported in Gualmini's (2001) experimental study that even adults sometimes fail to compute indirect SIs. Gualmini (2001) investigates how English-speaking adults interpret sentences like (33).

(33) None of the dolphins carried the penguin and the panda bear.

Due to *and*, sentences like (33) imply as SIs that sentences like (34) are false.

(34) None of the dolphins carried the penguin or the panda bear.

Because *and* in sentences like (33) is contained in the nuclear scope of *none of the Ns*, which is another downward entailing environment, SIs induced in sentences like (33) are indirect ones. Adopting the felicity judgment task methodology, Gualmini (2001) conducted an experiment on sixteen English-speaking adults to investigate whether they could compute indirect SIs in sentences like (33). In the experiment, sentences like (33) and stronger statements like (34) were given in contexts where stronger statements were true. Those who compute SIs in sentences like (33) should judge sentences like (34) as more felicitous in given contexts. What Gualmini (2001) found in his experiment is, however, that the adults could compute SIs in sentences like (33) only 28 out of 64

[7] One property of downward entailing environments is to license the negative polarity item *any*. Because *any* can occur in the restrictive clause of *every*, as shown below, the restrictive clause of *every* is a downward entailing environment.

(i) Every student who learned any Romance language is welcome. (Gualmini et al. (2001))

trials.

The results of Gualmini et al.'s (2001) and Gualmini's (2001) experiments suggest that indirect SIs are especially difficult to compute. Because the scope of negation is a downward entailing environment, SIs induced in negative sentences containing *zenbu-wa* 'all-CTop' are indirect ones. This might also be a reason for children's failure to compute SIs in the sentences in question.

The non-adultlike responses that children in C1 and C2 displayed in the experiment in section 3 are then compatible with Terunuma's (2008) SI-based account. In the experiment in section 3, the processing load of computing SIs is smaller as compared with Terunuma's (2008) experiment because stronger statements were explicit. However, it is still difficult for younger children to compute SIs in the experiment in section 3 due to its experimental design and/or the environment in which the scalar term occurs.

5. Conclusion

This paper has experimentally investigated Japanese-speaking children's computation of SIs in negative sentences containing *zenbu-wa* 'all-CTop.' Analyzing the results of the experiment, I have claimed that Terunuma's (2008) SI-based account on children's non-adultlike interpretation of the sentences in question can be maintained. I have also argued that one factor in children's failure to compute SIs is, as claimed in Chierchia et al. (2001), the difficulty of comparing a weaker statement with an implicit stronger statement, and that the experimental design and the environment in which SIs arise might also be responsible for their failure to compute SIs.

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