Syntactic Cues Help Disambiguate Objects Referred to With Count Nouns: Illustration With Malay Children

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Children employ multiple cues to identify the referent of a novel word. Novel words are often embedded in sentences and children have been shown to use syntactic cues to differentiate between types of words (adjective vs. nouns) and between types of nouns (count vs. mass nouns). In this study, we show that children learning Malay ($N = 67$), a numeral classifier language, can use syntactic cues to perform even finer-grained disambiguation–between count nouns. The manipulation of congruence between lexical and syntactic cues reveals a clear developmental trajectory: while 5-year-olds use predominantly lexical cues, older children increasingly rely on syntactic cues, such that by 7 years of age, they disambiguate between objects referred to with count nouns using syntactic rather than lexical cues.

Children commonly hear novel words in the presence of numerous objects. These objects can all, potentially, be referents for the novel word, thus creating a situation known as a referential problem (Quine, 1960). Children employ several strategies to solve this referential problem and learn the meanings of new words. For example, children can reduce referential ambiguity by applying *lexical* biases (Markman, 1990). One such bias, called the Mutual Exclusivity constraint (thereafter referred to as ME; Markman & Wachtel, 1988), suggests that children map novel labels to novel objects through the assumption that each object is given just one basic-level label. The application of ME therefore limits the number of possible referents when children hear a novel label, by excluding familiar, name-known, objects from the set of potential referents.

Yet, frequently, children do not hear novel words in isolation. Novel words are typically embedded in sentences, such that children can make use of grammatical cues to refine the meanings of these words, an ability termed *syntactic bootstrapping*

(Gleitman, 1990; Landau & Gleitman, 1985). For example, 2-year-old children infer aspects of a new verb's meaning depending on the transitivity of the sentence (*The duck is glorping the bunny* vs. *the duck and the bunny are glorping*; Naigles, 1990; and from 15 months of age, Jin & Fisher, 2014), and 14-month-old toddlers rely on grammatical form to identify nouns from other grammatical categories (e.g., *This is a blicket* vs. *This is blickish*; Booth & Waxman, 2003).

Although considerable effort has refined the age and conditions under which syntactic bootstrapping operates to decode *verb* meaning (e.g., Arunachalam & Waxman, 2010; Fisher, 1996; Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005; Naigles, 1990, 1996; Yuan & Fisher, 2009; Yuan, Fisher, & Snedeker, 2012), the effort to evaluate the use of syntactic cues to infer the meaning of *nouns* has been relatively modest, with the notable exception of the singular-plural distinction (with 4- to 5-year-olds; Bloom & Kelemen, 1995) and of the mass-count noun distinction (3- to 4-year-olds, Barner & McKeown, 2005; 3-year-olds, Barner & Snedeker, 2006; 2-year-olds, Soja, Carey, & Spelke, 1991). Disambiguation within count nouns (i.e., objects where the boundary of one exemplar from another

is clear cut, allowing each individual object to be counted, e.g., horses and books) has been assumed not to be solvable by relying on syntactic cues (Sloutsky, Yim, Yao, & Dennis, 2017). This is indeed the case for nonclassifier-based languages such as English, as the determiner of a count noun (i.e., *a* or *an*) does not provide additional information about the noun, hence, does not allow disambiguation between count nouns.

Yet several languages, in particular in South-East Asia (Gil, 2013), possess numeral classifiers as an obligatory category in their linguistic structure. The closest English equivalent would be limited to mass nouns ("a cup of tea," "a liter of milk"), whereas numeral classifiers extend to count nouns. Numeral classifiers are numeratives and specify characteristics of objects (Allan, 1977). They typically enter the sentence construction between the numerosity and the object. Li, Huang, and Hsiao (2010) found that Mandarin-speaking children are able to extend the specifications of classifiers to novel objects. We thus conjectured that, in contrast to nonclassifier-based languages, disambiguation of count nouns in numeral-classifier-based languages can be achieved using syntactic cues. For instance, as the Malay classifier *batang* refers to a class of objects that are long, a child who hears *sebatang blicket* would disambiguate count nouns by mapping the novel label *blicket* to a long object.

Malay, an Austronesian language, uses over two dozen numeral classifiers, which, like sortal classifiers, categorize objects based on factors such as animacy, shape (then subcategorized along dimension, size and rigidity) and specific categories (e.g., flowers, sharp objects; Salehuddin & Winskel, 2008). Salehuddin and Winskel (2011) showed that Malay children from 6 years of age are able to use classifiers appropriately. Compared to speakers of other languages (e.g., 4-year-olds for Mandarin speakers; Li et al., 2010, although the acquisition of Mandarin classifiers continues beyond 6 years of age; Cheung, Li, & Barner, 2010), Malay children acquire classifiers at a later age and continue to learn about classifiers up to adolescence (Salehuddin, 2014). One reason for this notable age difference is that Malay's spoken and written versions differ markedly. The usage of classifiers provides a good illustration of such differences; while it is ungrammatical to omit classifiers in written Malay, classifiers can be omitted in spoken Malay. In fact, Salehuddin (2014) found that caregivers seldom use classifiers when conversing with young children. We thus hypothesized that Malay-speaking children from 6 years of age (i.e., exposure to formal Malay through kindergarten) will be able to use classifier information to disambiguate between objects referred to with count nouns.

Indeed, although children from as early as 14 months of age start applying elements of syntactic bootstrapping to identify the syntactic class of a novel word (Booth & Waxman, 2003), subtler syntactic distinctions are typically only resolved by older children (e.g., Papafragou, Cassidy, & Gleitman, 2007). Children improve steadily when it comes to mastering increasingly complex syntactic structures. For instance, Entwisle and Frasure (1974) found that children improve gradually from 6 to 9 years of age in repeating sentences that are syntactically correct, but semantically meaningless (e.g., little Indians eat nearby elevators), and further progress is observed between 9 and 12 years of age, for example, when processing passive sentences (Dick, Wulfeck, Krupa-Kwiatkowski, & Bates, 2004; Montgomery, Evans, Gillam, Sergeev, & Finney, 2016). While syntactic bootstrapping and ME are crucial when infants possess limited vocabularies, language learning continues at a fast pace throughout childhood, such that between 5 and 10 years of age children still learn several new words each day (7.3 new lemmas per day according to Brysbaert, Stevens, Mandera, & Keuleers, 2016; 3.4 new words per day according to large-scale informal data collection efforts, Baldwin, 2013). By then, children possess an arsenal of word learning strategies at their disposal—sociopragmatic cues, hypothesis-testing strategies (Aravind et al., 2018), cross-situational statistical learning capacities (Fitneva & Christiansen, 2017), among many others. We expect that further, and subtler, improvements in syntactic processing can affect noun learning such that disambiguation of count nouns—in turn noun learning—can be achieved using syntactic cues, in contrast with claims made by Sloutsky et al. (2017).

To evaluate whether Malay-speaking children can disambiguate between objects referred to with count nouns using classifier information, we adopted a classical ME design in which children typically look at a novel object when hearing a novel name ("look at the meb!")—via the application of a *lexical* bias. We manipulated the carrier sentence such that the numeral classifier—a *syntactic* cue—used before the novel name can be either (a) suitable for the novel object but not the name-known object (trials referred to as *congruent* trials, as both lexical and syntactic cues predict children's selection of the novel object, see first row of Figure 1), (b) suitable for the name-known object but
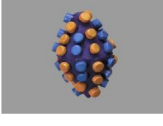
Condition	Novel Object	Familiar Object	Auditory stimuli	Predicted Outcomes
Congruent			*Carikan Sebatang buhi!* (Find a [classifier] buhi!)	Lexical cue: novel object Syntactic Cue: Novel Object
Incongruent			*Carikan Sebatang wukca!* (Find a [classifier] wukca!)	Lexical Cue: Novel Object Syntactic Cue: Familiar Object
Syntax- Neutral- Match -both			*Carikan Sebatang himdek!* (Find a [classifier] himdek!)	Lexical Cue: Novel Object Syntactic Cue: Either Object
Syntax- Neutral- Mismatch - Both			*Carikan Sebatang sungkil!* (Find a [classifier] sungkil!)	Lexical Cue: Novel Object Syntactic Cue: Neither Object

Figure 1. Examples of the four conditions used for the classifier *batang* (used for objects that are long). [Color figure can be viewed at wileyonlinelibrary.com]

not for the novel object (referred to as *incongruent* trials, as children would select the novel object if respecting lexical cues and the familiar object if following syntactic cues, see second row of Figure 1), (c) suitable for both objects (referred to as *syntax-neutral-match-both* trials, as syntactic cues do not provide any disambiguating information, see third row of Figure 1) and (d) suitable for neither object (referred to as *syntax-neutral-mismatch-both* trials, see fourth row of Figure 1). Differential behavior in object selection, in particular between congruent and incongruent trials would reveal that children can employ syntactic cues to disambiguate between objects referred to with count nouns and that syntactic cues can override novelty-preference induced by the application of ME.

Indeed, we know that ME can be overruled using syntactic information. Hall, Quantz, and Persoage (2000) and Hall, Lee, and Bélanger (2001) demonstrated that English-speaking children were able to overrule ME using form class cues (i.e., syntactic cues). Hall et al. (2000) revealed that when ME and syntactic cue were in conflict, 3- to 5-year-old children mapped a novel label embedded in an adjectival structure (e.g., a *dax* one) to a novel property of an object (as suggested by form class cues) instead of to a novel object (as hypothesized by ME). Our study goes further in assessing whether children will map a novel label to an object (e.g., following classifier information) even if the object is *not* novel.

This study thus aimed at testing the following hypotheses:

1. Children learning numeral classifier-based languages can exploit syntactic cues (in the form of classifier information) to disambiguate between count nouns of the same numerosity.

2. Older children, capitalizing on their more extensive experience with classifiers, will increasingly favor syntactic cues (i.e., classifier information) over lexical ones (in our case, ME). Younger children will rely more on ME when disambiguating between objects.

3. Children will follow syntactic cues (i.e., classifier information) over lexical ones (ME) when in conflict (in line with Hall et al., 2000).

By testing these three hypotheses, this study aims at addressing the theoretical question posed by Sloutsky et al. (2017) on the role of syntactic cues in noun learning.

Method

Participants

Sixty-seven Malay-ethnic children were recruited from a Malay government primary school in Kuala Lumpur, Malaysia, which uses Malay as a medium of instruction. The children (30 boys, 37 girls) were all dominant Malay speakers, learning English in school (5 hr per week). Their ages ranged from 5 to 9 years ($M = 7.21$ years, $SD = 1.29$). Ethics approval was granted by The University of Nottingham Institutional Ethics board (JM190315).

Design

A within-participant design was used in the current tablet-based study. Each trial was built around a classical ME design (see Figure 1); two objects were depicted on the screen—one novel and the other name-known—while a novel label was uttered, embedded into a sentence including a classifier (*Carikan se-*[classifier] [novel label]! Literally, "*find one-*[classifier] [novel label]"). There were four conditions in the study;

1. A *congruent* condition; the classifier is suitable for the novel object but not the familiar object. In other words, both lexical (ME) and syntactic (classifier information) cues favor the same, novel object (see first row of Figure 1).
2. An *incongruent* condition; the classifier is suitable for the familiar object but not the novel object. Lexical cues (ME) favor the novel object, whereas syntactic cues (classifier information)

support the familiar object (see second row of Figure 1).
3. A *syntax-neutral-match-both* condition; the classifier is suitable for both objects (see third row of Figure 1).
4. A *syntax-neutral-mismatch-both* condition; the classifier is not suitable for either object (see fourth row of Figure 1).

Eight classifiers, typically learnt in primary school (Salehuddin & Winskel, 2011), were used in each condition: *batang* (for objects that are long), *biji* (for small objects), *ekor* (for animals), *helai* (for objects that are thin), *keping* (for something that is flat and thin), *ketul* (for chunky objects), *orang* (for human beings), and *utas* (for objects made up of individual units; see Appendix B for the meanings and usage of these classifiers).

Stimuli

The study was carried out using an iPad Pro with a web-application based on Frank, Sugarman, Horowitz, Lewis, and Yurovsky (2016). Each trial consisted of a pair of objects, one novel and one name-known, presented on the left and the right of the iPad screen. To ensure that children saw each object only once, there were 32 pairs of objects. Novel objects appeared equally on the left and the right. Images of objects had a resolution of 640×480 pixels and were depicted against a light-gray background. These images were obtained from various internet sources and Frank et al. (2016). Stimuli can be accessed on: https://osf.io/3b4zk/?view_only=94788185be2f4b9ab09fb8ab90db1f27.

Novel labels followed phonotactic rules of Malay and sentences were recorded by a female native speaker of Malay in a child-directed manner.

Manipulation Check

A manipulation check assessed the suitability of the classifiers for the different objects. Ten young adults, native Malay speakers, evaluated the suitability of the classifiers for each object on a 5-point rating scale, from 1 (*not at all suitable*) to 5 (*very suitable*).

One-sample t-tests were conducted to compare suitability ratings against an average rating of 2.5 (i.e., neither suitable nor unsuitable). The mean rating of classifiers *mismatching* the objects was 1.20 ($SD = 0.23$), significantly lower than the average rating of 2.50, $t(9) = -11.98$, $p < .001$, whereas the mean suitability rating for the *matching* classifiers was 4.21 ($SD = 0.64$), significantly higher than 2.50,

$t(9) = 13.39$, $p < .001$. Thus, according to Malay-speaking adults, classifiers used in the study achieve their role of matching selectively some objects and not others.

Procedure

Children were first presented with a warm-up task in which they were instructed to tap on colored dots and smiley faces that appeared in random locations on the iPad screen. This task familiarized the children with the iPad. Then, children were instructed in Malay: "Untuk *game* ini, adik akan tengok dua gambar, satu di sini dan satu di sini. Adik juga akan dengar perkataan-perkataan yang adik tidak pernah dengar. Adik tekan gambar yang adik rasa betul." ("In this game, you will see two pictures, one here (with the researcher pointing to the left side of the iPad) and another here (pointing to the right side of the iPad). You will hear new words that you have not heard before. You will have to tap on one of these pictures (pointing to both sides of the iPad) that you think matches the words you hear.") After children indicated that they understood the task, the experiment started. Trial order was fully randomized.

Coding and Data Analysis

For each trial, novel object selections were attributed a score of 1, whereas selections of the familiar object were coded as 0. To identify which variables affected children's responses, a binomial mixed-effect logistic regression using the lme4 package (Bates, Mächler, Bolker, & Walker, 2015) was conducted with participants and items as random effects and fixed effects for condition (congruent, incongruent, syntax-neutral-match-both, and syntax-neutral-mismatch-both), age, and interaction between condition and age. This approach is better suited than analyses of variance as it factors the sampling variability in conditions (Boisgontier & Cheval, 2016) and thus provides better reliability (Baayen, Davidson, & Bates, 2008).

Significant main effects were subsequently explored using one-sample proportions tests on mean values (compared to a chance level of 0.5; similar to one-sample *t*-tests) to identify object preference in different conditions.

Results

Table 1 shows the mean proportion of novel responses in each condition and in each age group.

The mixed-effect logistic regression revealed that condition, and interaction between condition and age, contributed significantly to the fit. Table 2 shows the estimates of each parameter, using the glmer function. Tukey post hoc pairwise comparisons (adjusted for multiple comparisons) between conditions revealed that children selected the novel object significantly more in the congruent condition (when syntactic and lexical cues both favor the novel object) than in all other conditions (syntax-neutral-match condition ($p = .019$), syntax-neutral-mismatch condition ($p = .034$), and incongruent condition ($p < .001$)). All other differences were nonsignificant (all $p > .10$).

Since conditions only differ in terms of the congruence between syntactic and lexical cues, any differences across conditions can only be attributed to children's processing syntactic information when disambiguating objects. The main effect of condition therefore validates our first hypothesis—that children use syntactic cues to disambiguate between count nouns. One-sample proportions tests were run to test the proportion of novel object selection in each condition against a baseline of random object selection (proportion of 0.5). Participants selected novel objects significantly above chance in

Table 1

Mean Proportion of Novel Responses, and Standard Deviations, for Each Age Group and Each Condition. Proportions Above 0.50 Show Novelty Bias Whereas Proportions Below 0.50 Indicate That the Familiar Object is Selected More Often That the Novel One

Age (years)	Congruent	Incongruent	Syntax-neutral match-both	Syntax-neutral mismatch-both
5 ($n = 6$)	.63 (.11)	.42 (.13)	.71 (.13)	.58 (.15)
6 ($n = 17$)	.76 (.15)	.60 (.20)	.60 (.14)	.62 (.17)
7 ($n = 15$)	.78 (.14)	.35 (.31)	.56 (.24)	.61 (.18)
8 ($n = 15$)	.91 (.10)	.40 (.24)	.63 (.20)	.56 (.19)
9 ($n = 14$)	.81 (.17)	.20 (.21)	.46 (.18)	.58 (.17)
M	.80 (.16)	.39 (.27)	.58 (.20)	.59 (.17)

Table 2

Estimate, Standard Error, z-Score, and p-Value of Each Fixed Effect. The Full Model Was Response ~ (1|Participant) + (1|Item) + Age* Condition

Parameter	Estimate	SE	z-Score	p-Value
Intercept	1.01	.53	1.91	.056
Condition	−1.45	.67	−2.17	.030
Age	−0.55	.47	−1.17	.240
Interaction (Age × Condition)	1.41	.53	2.65	.008

the congruent condition—in which both lexical and syntactic cues favor the novel object ($\chi^2(1) = 187.48$, $p < .001$, $h = .64$); in the syntax-neutral-match-both condition ($\chi^2(1) = 11.64$, $p < .001$, $h = .15$); and the syntax-neutral-mismatch-both condition ($\chi^2(1) = 17.55$, $p < .001$, $h = .18$)—two conditions in which syntactic cues do not provide any disambiguating information. In the incongruent condition—in which lexical cues favor the novel object, whereas syntactic cues favor the familiar object—participants selected the *familiar* object significantly above chance ($\chi^2(1) = 25.54$, $p < .001$, $h = .22$). In other words, syntactic cues modulate children's object selection. Furthermore, when lexical and syntactic cues are in conflict (as in the incongruent condition), children rely more prominently on syntactic cues and override novelty preference induced by the ME lexical bias, in line with our third hypothesis.

Our second hypothesis was that children would be increasingly relying on syntactic cues, as they gain experience with numeral classifiers. To this end, we illustrate the significant interaction between age and condition in Figure 2. As illustrated in Figure 2, the interaction is primarily driven by the divergence between the congruent and incongruent conditions—such that older children rely more
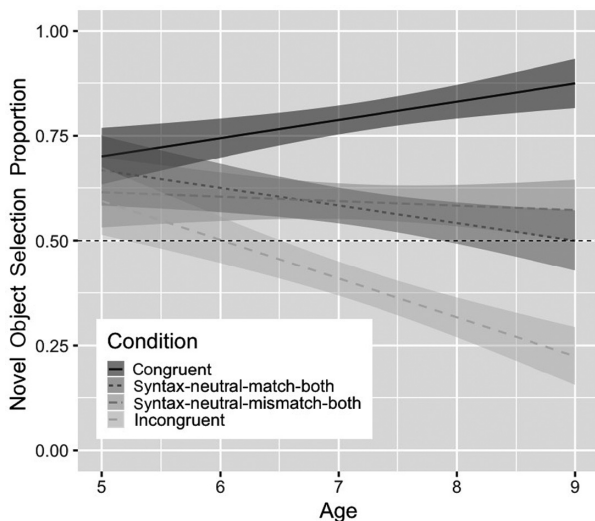

Figure 2. Illustration of the interaction between condition and age. Shaded areas depict the 95% confidence interval around the mean. Children rely progressively less on lexical cues with age (as illustrated by the decrease in novel-object selection in both syntax-neutral conditions). In contrast, syntactic cues play an increasing role with age, such that when syntactic and lexical cues align (congruent condition) children select the novel object more robustly than when syntactic and lexical cues favor distinct objects (in the incongruent condition).

predominantly on syntactic cues when disambiguating between objects, in line with our second hypothesis.

Novelty-preference was similar across both syntax-neutral conditions. Furthermore, using two-sample proportional tests, a comparison between children who started the experiment with trials in which classifiers did not match either object (syntax-neutral-mismatch-both) with that of other children failed to reveal any difference in their response (all $p > .10$). In other words, children did not appear to be confused by being exposed to trials in which neither of the object-matched classifier information.

Our third hypothesis was that children would rely on syntactic cues when lexical and syntactic cues are in conflict with each other. We evaluated this hypothesis by performing Tukey post hoc pairwise comparisons (adjusted for multiple comparisons) between congruent and incongruent conditions in each age group. Differences between congruent and incongruent conditions can only be accounted if children process syntactic information when disambiguating between objects referred to with count nouns. As displayed in Table 3, syntactic cues significantly modulate object disambiguation from 7 years of age and become increasingly robust.

Figure 3 displays children's reliance on lexical cues, a novelty-preference induced by the application of ME (top panel), as well their reliance on syntactic cues (obtained by computing the difference between the congruent and incongruent conditions, see bottom panel), for different ages. Overall, children rely progressively less on lexical cues, such that by 9 years of age, the do not display preference for the novel object in syntax-neutral conditions (Figure 3, top panel). In parallel, older children increasingly rely on syntactic cues when disambiguating between objects referred to with count nouns (Figure 3, bottom panel).

An exploratory analysis per classifier suggests that different numeral classifiers impact object selection at different ages (see Appendix C). While children's classifier knowledge was not tested directly, differences between conditions can only be explained if children process syntactic information in the first place. Differential trajectories across classifiers suggest that there is no single age at which an inferential insight emerges—that classifier information can be employed to disambiguate among count nouns. Rather, classifiers can only help disambiguating objects when mastered by children, and the age at which any given classifier will help

Table 3

Post Hoc Tukey Comparisons Between Congruent and Incongruent Conditions. Log Odds Ratio, z-Score, and p-Value of Each Fixed Effect

Age (in years)	Log-odds ratio	SE	z-Score	p-Value
5	−1.04	.67	−1.55	.410
6	−1.13	.57	−2.17	.201
7	−2.42	.59	−4.11	< .001
8	−3.54	.64	−5.51	< .0001
9	−3.88	.63	−6.18	< .0001

the child disambiguate count nouns will be modulated by the age of acquisition of that classifier. For example, children already possess sufficient knowledge about the numeral classifier *orang* (referring to human beings) to disambiguate between count nouns by 5 years of age (see Appendix C, top panel). However, other numeral classifiers only modulate object selection from 8 or 9 years of age (e.g., *helai*—used for thin, nonrigid, two-dimensional objects), if at all (e.g., *ketul*, used for three-dimensional chunky objects of medium size).

Discussion

This study examined whether children disambiguate between objects referred to with count nouns of the same numerosity, using syntactic cues. By manipulating the congruence between lexical and syntactic cues, we investigated the developmental trajectory of children's reliance on lexical (ME) and syntactic (classifier) cues between 5 and 9 years of age. Incidentally, as most research have focused on English, this study—with Malay-speaking children—adds to a growing body of research investigating the universality of syntactic bootstrapping in language acquisition (e.g., Dautriche et al., 2014; Göksun, Küntay, & Naigles, 2008; Lee & Naigles, 2008; Lidz, Gleitman, & Gleitman, 2003; Trueswell, Kaufman, Hafri, & Lidz, 2012).

Our results revealed that syntactic cues modulate object disambiguation. Moreover, reliance on classifier information increased with age. Whereas younger children in our sample (at 5 and 6 years of age) barely processes classifier information when disambiguating between objects, older children relied increasingly on syntactic cues while becoming less reliant on ME. Malay classifiers consist of multiple category attributes; animacy, shape, size, rigidity, dimensionality (one- vs. two- vs. three-dimensional objects), whereas other classifiers have specific use; for example, for knifes, flowers,

firearms (Salehuddin & Winskel, 2008). These categories, although complex, enable children to rely on syntactic cues when disambiguating between count nouns at a finer level of differentiation that has been described before. This complexity comes at a cost, and Malay children need many years to master their use appropriately. For instance, while animacy cues are already mastered by 5-year-old children, classifiers applied to objects without a fixed shape, such as a rope (i.e., can be laid straight or coiled round), pose a greater challenge to children and will be acquired at a later age (see Appendix A for a discussion of the contribution of classifier information in syntactic vs. semantic processing). Sloutsky et al. (2017) argued that syntactic bootstrapping can only be used for broad differentiations in English and "do not help distinguish among candidate mappings or generalizations of the count noun" (p. 5). This study demonstrates that syntactic cues—Malay classifiers in this study—can be used to differentiate between objects that are referred to with count nouns.

Several aspects of this developmental trajectory are noteworthy. First, to be able to process classifier information, children need to have gained sufficient knowledge about their use. Many studies on syntactic bootstrapping reveal that many elements of syntactic processing may be in place at younger ages; English-learning infants can distinguish between nouns and verbs at 18 months of age (Echols & Marti, 2004). At 2 years of age, they are able to differentiate proper nouns from count nouns (Katz, Baker, & Macnamara, 1974), count nouns from mass nouns (Soja et al., 1991) and map novel labels embedded in an adjectival structure to object properties (Mintz & Gleitman, 2002). At 4 years of age, they can use form class cues (Hall, Waxman, Brédart, & Nicolay, 2003). In contrast, reliance on more complex Malay classifier such as those that depict objects with flexible characteristics (e.g., *helai* for two-dimensional, flexible objects such as a piece of cloth) only emerges when children are older, around 7 years of age, in agreement with the claim that Malay-speaking preschool children are inexperienced with classifiers until they enter formal education (Salehuddin & Winskel, 2011).

We expect that children learning other numeral classifier-based languages (e.g., Mandarin, Japanese) would similarly use syntactic cues to perform object disambiguation at a finer scale, despite the observation that Japanese children do not *need* syntactic cues to differentiate count nouns from mass nouns (Imai & Haryu, 2001). The observation that Malay children use numeral classifiers to disambiguate
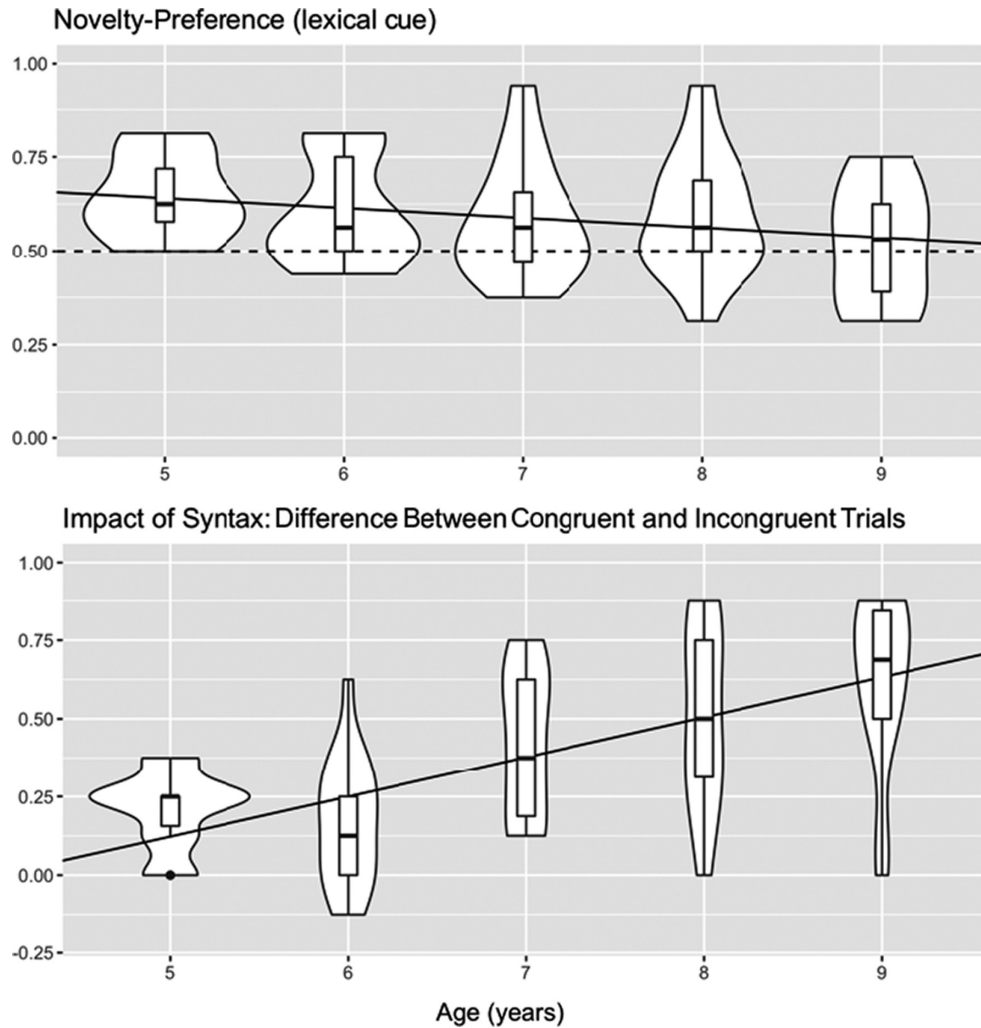
Novelty-Preference (lexical cue)

Impact of Syntax: Difference Between Congruent and Incongruent Trials

Age (years)

Figure 3. Violin plots illustrating the effect of age on the reliance of lexical (Mutual Exclusivity [ME]) and syntactic (classifier) cues. The shape of the violin plot shows the distribution of responses, the thick horizontal bar displays the median, and the top and bottom horizontal bars define the upper and lower quartiles. Solid lines represent linear regressions with age. The top panel displays novelty preference in syntax-neutral conditions, that is, using only lexical cues (ME effect) as a function of age (values above 0.5 indicate a novelty-preference). The bottom panel displays syntax use as a function of age, as computed via the difference between congruent and incongruent trials. Larger value indicating stronger reliance on syntax, whereas a value of zero indicates that children do not process syntactic information when disambiguating between objects.

Note. For each trial, children scored either a 0 (familiar object) or 1 (novel object). The different score between congruent and incongruent conditions consequently ranges between +1 to −1. In the congruent condition, children are hypothesized to select the novel object (see first row of Figure 1). However, in the incongruent condition, children could either select the novel object or the familiar object (see second row of Figure 1). Thus, a score of 0 suggests that children fail to consider syntactic cues when disambiguating between objects, whereas a score of 1 suggests that disambiguation is entirely driven by the application of syntactic cues.

between objects of the same numerosity provides additional evidence to the claim that, beyond differences in syntax across languages, young learners will exploit syntactic information when available (Lee & Naigles, 2008). The case of Malay suggests that children learning languages with a richer set of classifiers may be able to use syntactic cues at a finer scale when learning new words.

Finally, older children in our study relied more heavily on syntactic information than on ME when

disambiguating between objects. Our study adds to a considerable body of evidence that ME should be considered as a probabilistic bias, providing a disambiguating cue when multiple object may act as potential referents (e.g., Kalashnikova, Mattock, & Monaghan, 2016; Woodward & Markman, 1991), rather than a strict interpretation of enforcing a one-to-one mapping between an object and its label (Markman & Wachtel, 1988). Malay children use multiple cues when identifying potential referents

for a novel word, both at lexical and syntactic levels. The relative strength of these cues suggests that syntactic information is given more weight than lexical cues over time, and that by 9 years of age Malay children do not apply ME anymore. Our findings also add to the discussion by Naigles and Swensen (2007) on the relative weight of syntactic information in word learning. While Naigles and Swensen (2007) suggested that syntactic bootstrapping may play a lesser role in noun learning than in verb learning, this study demonstrated that children will exploit syntactic information in noun learning if such information is available.

The increasing reliance on syntactic information is likely driven by several factors; it may be reflecting on the accumulated experience children have with longer and more complex sentences, or that children may be discovering the stronger discriminative power classifiers have over novelty-based cues (e.g., by allowing children to disambiguate between items that are equally novel, but that differ in terms of shape, solidity, or size). Arguably, distinct languages possess distinct syntactic constructions and hence the relative reliance, use and weight of these multiple disambiguating cues—or their hierarchy—should be expected to reflect these differences.

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Appendix A

Use of Classifiers—Semantic or Syntactic Information?

In the introduction section, we argue that selecting an object that matches the classifier is evidence that children apply syntactic cues in noun learning situations. In Malay, some classifiers also exist as nouns or verbs. For instance, *batang* is a classifier for long objects, but it means *stem* when used as a noun, whereas *biji*, a classifier for small objects, means *seed* as a noun (Salehuddin & Winskel, 2008). In order to differentiate between these meanings, children need to know whether the word is used as a classifier or a noun. When used in a noun phrase (i.e., numeral + classifier + noun; e.g., *dua batang sungai*, two rivers), the word acts as a classifier and the meaning of the classifier should be accessed, instead of the meaning of the noun. Thus, appropriate selection of the classifier-matching object suggests that children rely on the function word (a classifier, i.e., a syntactic cue) rather than on the word's meaning *per se* (semantic cue).

In the discussion section, we observe that classifiers for animate objects are learned early in life whereas classifiers for flexible objects are mastered at a later age. Differences in word meaning between

the classifier scope and its meaning when used as a standalone word may offer a challenge to children. Some classifiers, such as *orang* (*human* when used as a noun), the classifier used for human beings, and *ekor* (*tail* when used as a noun), a classifier used for animals, have very close meaning when used as a classifier or a noun. In contrast, others have word meanings markedly distinct from their classifier specification; *buah* is a classifier for large objects (e.g., a book, a car or a house), yet it means *fruit* as a noun while *pasang* is a classifier for objects that come in pairs (e.g., earrings), but it is also used as a verb to mean *switch on*. It is plausible that differences between the scope of the classifier and its meaning as a standalone word modulate the age at which children master its use.

Appendix B

Table B1

Meanings and Examples of Classifiers Used in This Study

Classifiers	Meanings	Examples
Batang	For objects that are long	*Sebatang jalan* (a [classifier] road)
Biji	For small objects	*Sebiji telur* (an [classifier] egg)
Ekor	For animals	*Empat ekor lembu* (four [classifier] cows)
Helai	For objects that are thin	*Sehelai daun* (a [classifier] leaf)
Keping	For something that is flat and thin	*Dua keping kertas* (two sheets of paper)
Ketul	For chunky objects	*Seketul tulang* (a [classifier] bone)
Orang	For humans	*Lima orang guru* (five [classifier] teachers)
Utas	For objects that consist of individual units	*Seutas rantai* (a [classifier] necklace)

Note. Meanings and examples of classifiers are translated from Kamus Dewan (the dictionary published by Malaysia's board for Language and Literature).

Appendix C

Analysis Per Classifier

Table C1 provides a summary of the developmental trajectory associated with each classifier used in the study (as measured by computing the difference between the congruent and the incongruent conditions). A difference score of 0 suggests that syntactic information was not processed when disambiguating between objects, whereas larger

Table C1

Violin Plot Showing the Difference in Score Between Congruent and Incongruent Conditions for Each Classifier and Each Age Group
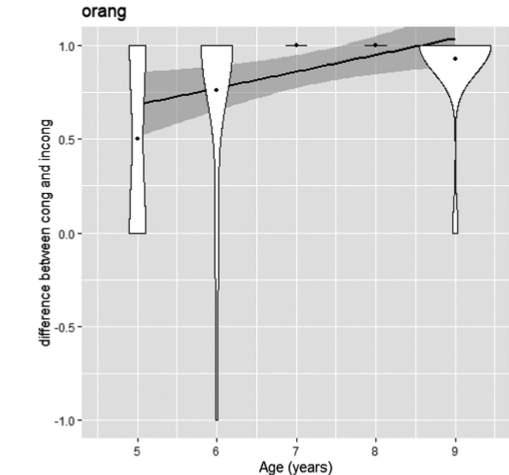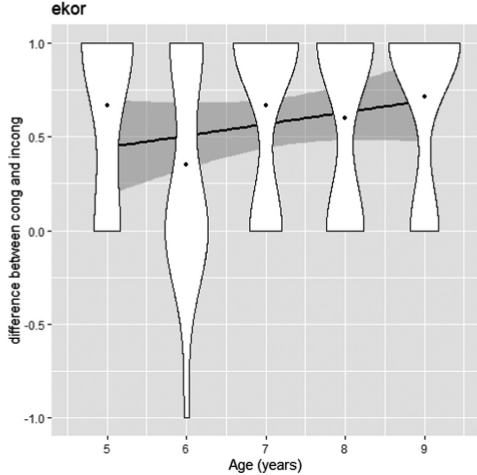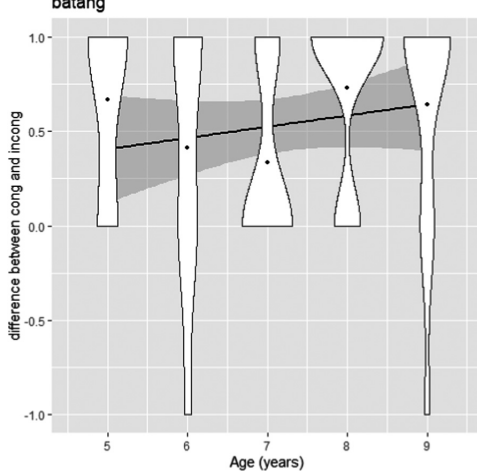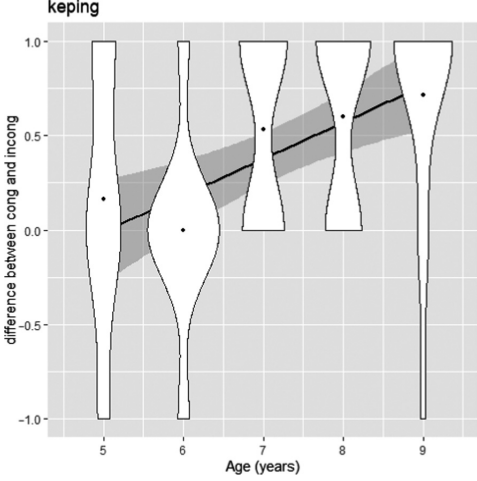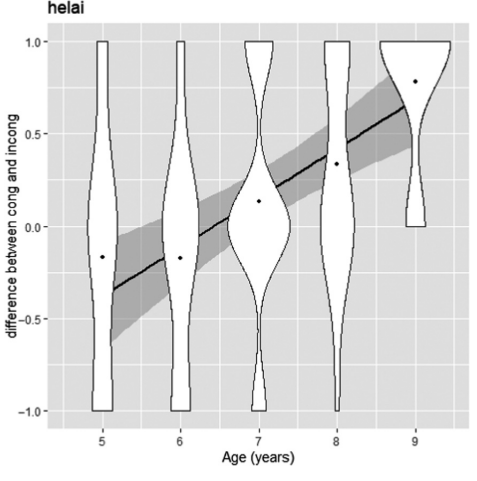
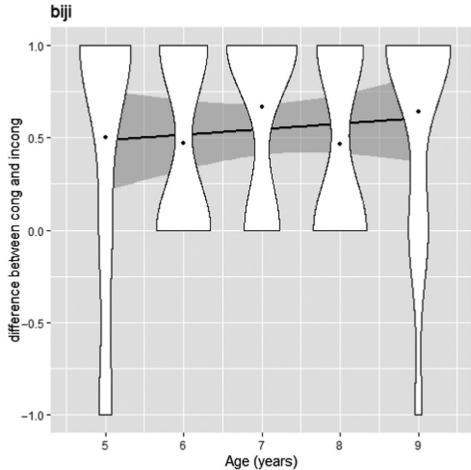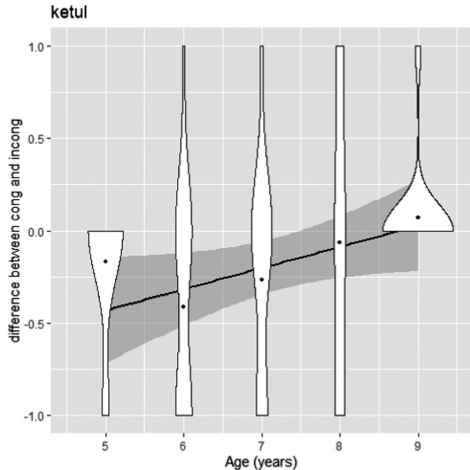| Classifier	Meaning	Salehuddin and Winskel's (2008) categorization of the classifiers	Difference between congruent and incongruent conditions as a function of age
Orang	For humans	Animate	
Ekor	For animals	Animate	
Batang	For long objects	1-D, rigid	

Table C1
Continued
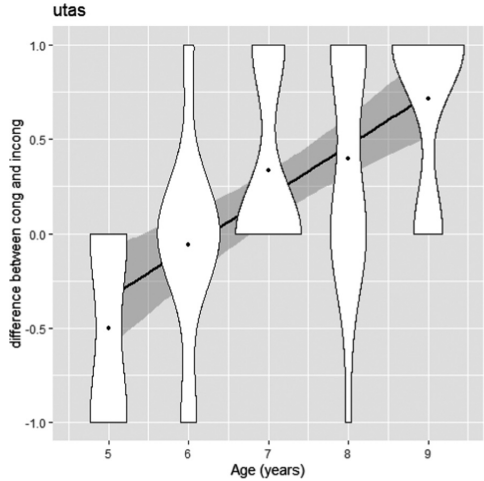
Classifier	Meaning	Salehuddin and Winskel's (2008) categorization of the classifiers	Difference between congruent and incongruent conditions as a function of age
Utas	For objects that consist of individual units	1-D, flexible	
Keping	For something that is flat and thin	2-D, rigid	
Helai	For objects that are thin	2-D, flexible	

utas

keping

helai

Table C1
Continued

Classifier	Meaning	Salehuddin and Winskel's (2008) categorization of the classifiers	Difference between congruent and incongruent conditions as a function of age
Biji	For small objects	3-D, small (size)	
Ketul	For chunky objects	3-D, medium (size)	

Note. Shaded areas depict 95% confidence intervals, whereas the solid line a linear regression of the difference score with age. The black dot within each violin plot refers to the mean of the difference.

scores suggest that syntactic cues strongly modulate object selection.

A comparison of regression lines (the solid lines) suggests that animate classifiers are learned before other classifiers, that one-dimensional classifiers are relatively easier than two-dimensional (and three-dimension) classifiers, and that rigid classifiers are acquired earlier than nonrigid ones.