Journal of Child Language (2025), **52,** 648–674
doi:10.1017/S0305000924000461

CAMBRIDGE UNIVERSITY PRESS

ARTICLE

Children's reliance on pointing and mutual exclusivity in word-referent mapping: The role of vocabulary and language exposure

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(Received 22 December 2022; revised 09 February 2024; accepted 21 April 2024)

Abstract

This study explored monolingual and multilingual two- to five-year-olds' reliance on a non-verbal and a verbal cue during word-referent mapping, in relation to vocabulary knowledge and, for the multilinguals, Dutch language exposure. Ninety monolingual and sixty-seven multilingual children performed a referential conflict experiment that pitted a non-verbal (pointing) cue and a verbal (mutual exclusivity) cue. Mixed-effect regressions showed no main effects of vocabulary and language exposure. An interaction between vocabulary and group showed that lower vocabulary scores were associated with a stronger reliance on pointing over mutual exclusivity for multilinguals (but not monolinguals). Furthermore, an interaction between vocabulary, language exposure, and cue word (novel vs. familiar label) indicated that multilinguals with lower exposure and lower vocabulary showed a stronger reliance on pointing over mutual exclusivity when a novel rather than familiar word was used. These findings suggest that multilingual and monolingual children go through different trajectories when learning to map words to referents.

Keywords: multilingualism; non-verbal cues; mutual exclusivity; vocabulary; language exposure

Introduction

The relative importance of children's use of the verbal versus non-verbal context in early vocabulary acquisition has been long debated. Studies focusing on verbal context maintain that children develop assumptions concerning the way words relate to meaning (Golinkoff et al., 1994; Hansen & Markman, 2009; Jaswal, 2010; Markman & Wachtel, 1988; Merriman et al., 1989). For example, the mutual exclusivity assumption refers to children's tendency to assume there is only one word for a referent (Markman & Wachtel, 1988; Merriman et al., 1989). However, children would need to overcome this assumption to acquire synonyms or labels for parts and properties of objects (Ambridge & Lieven, 2011). Conversely, studies addressing the social contexts of language development have argued that children rely on speakers' non-verbal behaviors, such as pointing gestures and eye gaze, and relate these to their own world knowledge to acquire the meanings of new

words (Clark, 1990, 2014; Baldwin & Moses, 2001; Booth et al., 2008; Tomasello, 2000). For instance, young children tend to follow a speaker's eye gaze and hand gestures to infer what the speaker is talking about when using a new word (Carpenter et al., 1998; Hirotani et al., 2009). However, although such non-verbal cues undoubtedly enable word learning, studies have shown that children can learn words without social interaction (Akhtar & Gernsbacher, 2007; Houston-Price et al., 2005; Scofield & Behrend, 2011; Werker et al., 1998). Thus, neither assumptions based on verbal and lexical context, such as mutual exclusivity, nor non-verbal behaviors provided in a social context alone can fully explain children's word learning: Rather, children draw on multiple strategies to acquire new vocabulary (Hirsh-Pasek et al., 2004; Hollich et al., 2000).

Concerning non-verbal cues to word learning, previous evidence suggests that multilinguals tend to pay heightened attention to such cues compared to monolinguals. Yow (2014), for example, found that four-year-old multilingual children relied on a speaker's hand gesture to determine the referent of ambiguous pronouns significantly more often than monolingual peers. Brojde et al. (2012) found that two- to three-year-old multilingual children showed a stronger reliance on a speaker's eye gaze than monolingual peers, whereas monolingual children showed a stronger reliance on an object property cue, when these two types of cues competed in a word-referent mapping task. As a possible explanation for this finding, the authors propose that multilingual children experience more challenging communicative contexts in which they must monitor which language a speaker is using and to switch languages accordingly, which strengthens their vigilance to their interlocutor's non-verbal behaviors. However, the evidence is not straightforward. First, in Brojde et al. (2012), both groups relied on the object property and eye gaze cues to a similar extent when only one cue was provided rather than a conflict between the two types of cues. Moreover, Gangopadhyay and Kaushanskaya (2021) found that four- and five-year-old multilinguals and monolinguals did not differ in their ability to disambiguate referents based on a speaker's eye gaze. However, in this study, multilinguals established the novel word-referent relations faster than monolinguals in a condition with fewer gaze cues, suggesting that they paid increased attention to the speaker's eye gaze during word-referent mapping (Gangopadhyay & Kaushanskaya, 2021). Taken together, these earlier findings suggest that multilingual children may be more attentive to non-verbal cues to word learning (Brojde et al., 2012; Yow, 2014; Gangopadhyay & Kaushanskaya, 2021), which may benefit their word-referent mappings (but not necessarily their subsequent retention of these mappings, cf. Gangopadhyay & Kaushanskaya, 2021). Moreover, the evidence across studies is mixed, with some, but not all, studies finding enhanced reliance on non-verbal cues in multilingual children (for a review, see Van Wonderen et al., 2023).

Regarding mutual exclusivity, some earlier studies have found differences in the degree to which monolingual and multilingual children develop a mutual exclusivity assumption in word learning, although the evidence is mixed. Houston-Price et al. (2010) concluded that 17- to 22-month-old monolingual toddlers relied on mutual exclusivity to infer that a new word referred to an unfamiliar, novel object, but multilinguals of the same age did not. Similarly, Byers-Heinlein and Werker (2009) found that 17- to 18-month-old monolingual toddlers relied on mutual exclusivity to a stronger degree than bilinguals of the same age, who, in turn, relied on mutual exclusivity more strongly than trilingual peers. These differences were not related to the children's (English) vocabulary scores. In a subsequent study, Byers-Heinlein and Werker (2013) found that the more translation equivalents (or one-to-many mappings) were available in bilingual children's lexicons, the less likely they were to apply mutual exclusivity. However, Kalashnikova et al. (2015)

https://doi.org/10.1017/S0305000924000461 Published online by Cambridge University Press

found that while four-and-a-half to five-and-a-half-year-old monolinguals assumed mutual exclusivity to disambiguate word-referent pairs to a greater extent than multilingual peers, no significant differences were found between monolinguals and multilinguals younger than four-and-a-half years. Furthermore, in other studies on two- to three-year-old children (Frank & Poulin-Dubois, 2002) and five- to eight-year-old children (Merriman & Kutlesic, 1993), no differences were found in the extent to which monolinguals and multilinguals applied mutual exclusivity in word-referent mapping tasks. Overall, these earlier findings suggest that monolingual children consistently assume mutual exclusivity in word learning, while multilingual children show variability in their use of this strategy, demonstrating either a weaker assumption or an equally strong assumption compared to monolinguals.

Previous findings on children's relative weighting of non-verbal cues pitted against mutual exclusivity cues in word-referent mapping suggest that children tend to rely on the former, at least when pointing accompanied by supportive eye movements is used as a non-verbal cue (cf. Grassmann & Tomasello, 2010; Jaswal, 2010; Verhagen et al., 2017). Grassmann and Tomasello (2010) showed that when pointing was supported by eye gaze alternation between the child and the target referent, monolingual children aged two and four years overwhelmingly relied on this so-called ostensive pointing cue over a competing verbal cue congruent with mutual exclusivity. Furthermore, Verhagen et al. (2017) found that two- to four-year-old monolingual as well as multilingual children chiefly relied on ostensive pointing over verbal cues congruent with mutual exclusivity, though the multilinguals showed an even stronger reliance on pointing compared to monolinguals. Young children thus tend to give prominence to pointing over mutual exclusivity cues when these compete in word-referent mapping tasks, at least when pointing is ostensive.

To sum up, there is increasing evidence that the degree to which children rely on either non-verbal or mutual exclusivity cues to learn words is affected by whether they learn one or more languages (Brojde et al., 2012; Byers-Heinlein & Werker, 2009; Gangopadhyay & Kaushanskaya, 2020, 2021; Houston-Price et al., 2010; Kalashnikova et al., 2015; Verhagen et al., 2017; Yow, 2014). It is unclear, however, how these differences can be explained. As described above, earlier findings suggest that translation equivalents in multilingual children's vocabularies may make them rely less on mutual exclusivity, while the complex interactive (multilingual) contexts they face may make them pay closer attention to other speakers' non-verbal behaviors. However, another possible explanation for the effects of multilingualism on cue weighting relates to differences in existing language knowledge: It is well attested that young multilingual children generally have lower vocabulary knowledge than monolingual peers, at least within each of their languages (Hoff et al., 2012; Pearson et al., 1993; Thordardottir, 2019).

The idea that differences in language knowledge might explain earlier found differences between monolingual and multilingual children's reliance on mutual exclusivity receives support from a number of studies. First, for monolingual children, studies have shown that the mutual exclusivity assumption strengthens in parallel with vocabulary growth (Bion et al., 2013; Houston-Price et al., 2010; Law & Edwards, 2015; Lewis et al., 2020). This effect likely occurs because children initially acquire only the primary or most common words for objects and concepts, hence reinforcing their expectation that word-referent relations are mutually exclusive during initial stages of vocabulary acquisition. Second, for multilingual children, Verhagen et al. (2017) found that children relied more strongly on mutual exclusivity when a mutual exclusivity cue and a pointing cue were contrasted in a task conducted in their dominant language as opposed to their weaker

language. This finding suggests that, with increasing language knowledge, children develop a stronger tendency to rely on mutual exclusivity as opposed to pointing. It is important to note, however, that for multilingual children younger than two years, earlier research has shown that vocabulary size is unrelated to reliance on mutual exclusivity (Byers-Heinlein & Werker, 2013; Houston-Price et al., 2010).

A possible explanation of this discrepancy between monolingual and multilingual children is that the mutual exclusivity assumption develops later in multilinguals: since multilinguals are exposed to cross-language translation equivalents, their input contradicts the mutual exclusivity assumption from an early stage. Consequently, it may take multilingual children longer than monolinguals to learn that, within one language, word-referent relations are often mutually exclusive. Several previous findings are consistent with this idea. First, multilingual children older than two years (as opposed to younger children) have been found to assume mutual exclusivity to a similar extent compared to monolingual peers when learning words within a language (Frank & Poulin-Dubois, 2002; Kalashnikova et al., 2015; Merriman & Kutlesic, 1993). Second, Kalashnikova et al. (2015) found that three-and-a-half to five-and-a-half years old children with larger vocabulary sizes, regardless of whether they were acquiring one or two language(s), performed better at two word learning tasks asking them to either rely on mutual exclusivity or override mutual exclusivity (by accepting overlapping labels for a referent). Taken together, these findings suggest that, as children develop vocabulary knowledge within a language, their reliance on mutual exclusivity may increase for that language. This pattern seems to hold for both young monolingual and multilingual children, even though it may show a slower start in multilinguals, who have a weaker mutual exclusivity bias in very early phases of acquisition.

To the best of our knowledge, earlier studies comparing monolingual and multilingual children's behavior on tasks in which pointing was contrasted with mutual exclusivity have not tried to disentangle the effects of multilingualism and differences in language knowledge. Hence, it is currently unclear to what extent earlier attested effects of multilingualism are due to differences in language knowledge. The current study investigates the independent effects of multilingualism and language knowledge (i.e., vocabulary) on children's relative reliance on a pointing gesture versus mutual exclusivity while they interpret acts of reference. In addition, our study investigates to what extent, within the multilingual children, relative language exposure relates to children's cue weighting. Language exposure is positively correlated with proficiency in multilingual children, showing positive, moderate correlations with parental estimates of exposure per language for toddlers and preschool-aged children (e.g., Hoff et al., 2012; Unsworth et al., 2018). However, the two variables can of course not be equated, as variance in proficiency stems from many other factors as well, amongst them phonological memory (Verhagen et al., 2009), auditory attention (Boerma et al., 2017), and socio-emotional and personality factors, such as shyness (Prior et al., 2008). Moreover, relative exposure reflects factors such as familiarity with a language and is a strong correlate of language use (Bedore et al., 2012; Unsworth et al., 2018). This study will assess how differences in exposure to Dutch (i.e., the language of testing) relate to multilingual children's relative weighting of pointing and mutual exclusivity.

Apart from vocabulary knowledge and relative language exposure, age or experimental design may explain variability in children's reliance on different cues to word-referent mapping. The studies by Houston-Price et al. (2010) and Byers-Heinlein and Werker (2009), which found that bilinguals showed a weaker mutual exclusivity assumption than monolinguals, both involved children younger than two years and used preferential

https://doi.org/10.1017/S0305000924000461 Published online by Cambridge University Press

looking experiments with images instead of tangible objects and audio recordings rather than physically present speakers. In contrast, studies that found that bilinguals do make use of mutual exclusivity (Frank & Poulin-Dubois, 2002; Merriman & Kutlesic, 1993), even if to a lesser extent than monolinguals (Kalashnikova et al., 2015), focused on children older than two years and used behavioral tasks with physical objects and physically present interlocutors. Similarly, whereas Gangopadhyay and Kaushanskaya (2020) found that monolinguals – but not bilinguals – prioritized eye gaze over mutual exclusivity in a task that included digital images of objects and a digital speaker providing (part of) the instructions during the retention test phase, Brojde et al. (2012) and Verhagen et al. (2017) found that multilinguals relied more on non-verbal cues (respectively eye gaze and pointing cues) over a verbal cue in experiments with physical objects and physically present speakers providing the instructions. Therefore, previous studies leave open the possibility that experiments involving digital presentation rather than physical settings may alter the extent to which children rely on non-verbal and mutual exclusivity cues, and that bilingual children may start to apply mutual exclusivity more systematically only after the age of two, in contrast to monolinguals. In the current study, we used a physical task with children above two years, consistent with earlier studies in this line of research that pitted non-verbal and mutual exclusivity cues (Brojde et al., 2012; Grassmann & Tomasello, 2010; Verhagen et al., 2017).

Since the literature reviewed above suggests that differences in monolingual and multilingual children's attention to different cues during word-referent mapping are not absolute but a matter of degree (Brojde et al., 2012; Byers-Heinlein & Werker, 2009; Kalashnikova et al., 2015; Verhagen et al., 2017), we opted for a method that presented children with a conflict between two cues, to allow us to investigate children's relative cue weighting rather than their responses to one cue in isolation. Specifically, we used the same task as Grassmann and Tomasello (2010) and Verhagen et al. (2017) that was based on the task in Jaswal and Hansen (2006): a referential conflict task in which a pointing cue competed with a verbal cue consistent with mutual exclusivity. The pointing cue was supported by eye gaze direction, since previous work suggests that such 'ostensive pointing' is a more salient cue for children than pointing without supporting eye gaze (cf. Jaswal & Hansen, 2006; Grassmann & Tomasello, 2010). The mutual exclusivity cue consisted of a familiar or a novel object label that was spoken in a carrier phrase while children were presented with two objects, one familiar and one novel, as possible referents of the label.

Mutual exclusivity was interpreted in our study in the broad sense that each word is assumed to have one referent, such that we assessed both children's tendency to associate new words with referents for which they do not have a label yet as well as children's reluctance to accept that one word may refer to more than one referent, that is, when a familiar word was used in the task to refer to a new referent not conventionally associated with it. Although the conflict between cues in the experiment is artificial and unlikely to be encountered in real-life word learning situations, it might be less far-fetched than it may seem at first: language processing and acquisition involve a constant weighting of various cues, that is, pieces of information present in the linguistic input and the physical context, in relation to a language user's knowledge based on previous linguistic experience, enabling the language user to determine linguistic form-function relations (Bates & MacWhinney, 1987; Ellis, 2008; MacWhinney, 2008, 2012).

In our study, we examined monolingual children who acquired Dutch as well as multilingual children who acquired Dutch and one or two other language(s). The following research questions were addressed:

https://doi.org/10.1017/S0305000924000461 Published online by Cambridge University Press

1. How do differences in vocabulary knowledge relate to reliance on pointing versus mutual exclusivity in monolingual and multilingual two- to five-year-olds' word-referent mapping?
2. How do differences in relative exposure to Dutch relate to multilingual children's reliance on pointing versus mutual exclusivity during word-referent mapping?

Regarding the first research question, we predicted that both monolingual and multilingual children regardless of their Dutch vocabulary knowledge would show an overall preference for pointing over mutual exclusivity, based on the previous findings by Grassmann and Tomasello (2010) and Verhagen et al. (2017). Furthermore, we predicted that both monolingual and multilingual children with less well-developed Dutch vocabulary knowledge would rely on pointing over mutual exclusivity more often than children with better-developed Dutch vocabulary knowledge. This prediction was based on the positive relations between vocabulary knowledge and reliance on mutual exclusivity found by earlier studies on monolingual children (e.g., Houston-Price et al., 2010; Law & Edwards, 2015; Lewis et al., 2020) and multilingual children above two years of age (Kalashnikova et al., 2015; Verhagen et al., 2017). Specifically, given these earlier results, better-developed vocabulary knowledge was expected to correlate with a stronger reliance on mutual exclusivity, and hence, a weaker reliance on pointing in our task.

Concerning the second research question, we predicted that multilingual children who were less often exposed to Dutch would show a stronger preference for pointing over mutual exclusivity in our Dutch-based task than multilingual children with more exposure to Dutch. This prediction was based on the earlier finding that multilinguals relied on pointing over mutual exclusivity more often in their weaker language compared to their stronger language (Verhagen et al., 2017), perhaps due to a compensation mechanism whereby children rely more on non-verbal cues when they are not proficient in a language to make up for gaps in linguistic knowledge. Moreover, this prediction was based on the idea that exposure to a language – as a correlate of language proficiency – would be positively correlated with reliance on mutual exclusivity in children of this age range (Houston-Price et al., 2010; Law & Edwards, 2015; Lewis et al., 2020).

Method

The data for this study came from two previously collected datasets. One dataset was collected between 2013 and 2015 and reported on in Verhagen et al. (2017), targeting different research questions, as discussed above. The other dataset was collected in 2014 and 2015 and was not analyzed previously. Both datasets contained children's responses to a referential conflict experiment and a Dutch vocabulary test, as well as their parents' responses to a questionnaire on children's language background.

Participants

A total of 157 children participated: 90 monolingual children acquiring Dutch and 67 multilingual children acquiring Dutch and one (n = 49) or two (n = 18) other language(s). All children were residing in the Netherlands at the time of data collection. The monolingual group ranged in age between 26 to 59 months (M = 39 months; SD = 7 months) and contained 49 girls (54%). The multilingual group ranged between 29 to 58 months (M = 42 months; SD = 8 months) and included 33 girls (49%). Apart from

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Dutch, the multilingual children were acquiring various other languages, with English (n = 31) being most frequent, followed by German (n = 4), French (n = 3) and Italian (n = 3), and seven other languages occurring once or twice (i.e., Catalan, Moroccan, Norwegian, Polish, Portuguese, Spanish, Swedish). The trilingual children were all acquiring Dutch, English and another language. Note that, in our study, we use 'multilingual' as an umbrella term for both bilingual and trilingual children, thus referring to children acquiring more than one language.

Experiment Design and Materials

The experiment was a referential conflict task used by Verhagen et al. (2017), who had adapted the experimental design from Grassmann and Tomasello (2010). The materials consisted of a set of familiar objects (e.g., comb, pen, shoe, toy car) and a set of unfamiliar objects (e.g., closing clip, construction material, blank name tag, piece of a garden hose). The participants were assumed to know the Dutch labels for the familiar objects, given their age, their vocabulary scores and the commonness of these objects, while they were not expected to have a label for the unfamiliar objects. There were two experimental conditions, in both of which a non-verbal cue, namely a pointing gesture, and a verbal (mutual exclusivity) cue, namely a verbal label, were given in a conflicting manner. In the familiar label condition, the experimenter instructed the child to take the 'familiar label' (e.g., "Take the car"), while simultaneously pointing at the unfamiliar object (e.g., construction material), while a familiar object conventionally associated with the label was simultaneously presented (e.g., a toy car). In the novel label condition, the experimenter told the child to take the 'novel label' (e.g., "Take the toma"), while simultaneously pointing at the familiar object (e.g., a pen), while an unfamiliar object was simultaneously presented. The novel labels involved mono- and disyllabic nonwords that adhered to Dutch phonotactic constraints (e.g., *tieg*, *munk*, *dofu*, *modi*).

The aim of the experiment was to investigate whether children would assign more importance to the pointing gesture or the verbal label, by pitting these against each other. Assuming that social and non-verbal behaviors guide word learning, children should choose the object pointed at as the referent. Following the predictions of the lexical assumptions perspective, children should rely on mutual exclusivity and associate novel labels with unfamiliar objects and familiar labels with familiar objects. The two conditions assessed whether children would weigh the conflicting cues differently when a novel label referred to a familiar object, such that reliance on pointing would entail acceptance of a second label for a name-known object, versus when a familiar label referred to an unfamiliar object, such that reliance on pointing would involve the reinterpretation of a familiar label's meaning to extend to a new object (Grassmann & Tomasello, 2010).

There were some differences between the experimental materials and the number of trials used in each dataset. In the dataset from Verhagen et al. (2017), participants performed four referential conflict trials, two in each experimental condition, while in the other dataset participants resolved eight trials, four in each condition. Furthermore, there was partial overlap between the objects and labels occurring in the two component datasets. Specifically, four familiar and four unfamiliar objects were used in the experiment administered by Verhagen et al. (2017), while eight familiar and eight unfamiliar objects were used in the other experiment. The pairings of novel and familiar objects were counterbalanced, as was the order of presentation of the object pairs, the left-right positioning of the novel and familiar objects, and the assignments of the novel words to the novel objects.

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Experimental Procedure

Participants received all instructions in Dutch. The experimenter and the child sat opposite to each other at a table. In each trial, the experimenter held a familiar object in one hand and a novel object in the other hand, with both hands stretched out, about a shoulder width apart and at a height corresponding to the child's eye level. The experimenter said: 'Look!' (in Dutch). Then, using both hands, the experimenter placed both objects on the table, still at a shoulder width apart, and said the Dutch equivalent of 'Let's now play with the [familiar/novel label]. Take the [familiar/novel label]'. While articulating the instruction with the label, the experimenter started pointing at the object, which, according to mutual exclusivity, would be the least likely candidate for that label, as described in the previous section. The experimenter's pointing gesture involved her right arm, hand and index finger stretched out toward the object, while she directed her gaze to the object pointed at, then to the child, and back to the object. After five seconds, the experimenter stopped pointing and looked at the child with a neutral face expression until the child touched or pointed to an object. The experimenter never gave verbal or nonverbal feedback, to avoid influencing the child's choice on subsequent trials. Upon selecting an object, the child was allowed to play with this object for about one minute before the experimenter put both objects out of sight and the next trial was administered. The object pairs of subsequent trials were hidden, such that the child could only see the objects of the trial in progress.

Vocabulary Assessment

The Dutch version of the Peabody Picture Vocabulary Test (PPVT-III-NL, Dunn et al., 2005) was administered to assess children's Dutch receptive vocabulary knowledge. In this test, participants choose one of four pictures that best matches a target word. Raw PPVT scores were analyzed, since norm scores are not available for multilingual children. Multilingual participants' vocabulary knowledge of their other language(s) was not measured, as this was not feasible given the wide variety of languages in our sample.

Relative Exposure to Dutch

Multilingual children's relative language exposure was measured through a parental questionnaire that parents filled out in Dutch or English, depending on their preference. Identical questions were used in the two datasets. Specifically, the following question was used to evaluate multilingual children's relative language exposure: "During a conversation with your child, what language(s) do you and other family members speak?" Parents were instructed to indicate all the languages spoken; as well as, for each language, the percentage of time that they and possibly other household members (e.g., siblings) used each language during daily conversations with the child. Thus, parents' estimates of the percentages for each language added up to 100%, representing the sum of language input by the child's parents and sometimes additional household members. For instance, for a bilingual child, the estimated parental input percentages could be 70% English and 30% Dutch, while for a trilingual child, the percentages could be 30% Dutch, 50% English and 20% Spanish. The percentage parents estimated for exposure to Dutch was used for our analysis regarding the potential effect of relative exposure to Dutch on multilingual children's reliance on pointing versus mutual exclusivity.

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Procedure

Children were tested individually by trained research assistants at their daycare or in the lab of the Social Sciences Faculty of Utrecht University, the Netherlands. The current tasks were intermixed with other tasks not reported on in this paper. Concerning the data from Verhagen et al. (2017), children completed the receptive vocabulary task before the referential conflict task. Multilingual children performed the referential conflict task in both Dutch and in English, in separate sessions. Only their responses to the Dutch task were used for this study. Regarding the other dataset, children completed the referential conflict experiment before the receptive vocabulary task. During the conflict task, children were wearing a head-mounted eye-tracker. However, due to technical errors, their eye-tracking data were not analyzed. Children received a sticker after each task and a small gift at the end of the session.

Analyses

All data analyses were performed in the statistical software *R* (R Core Team, 2021). To assess how vocabulary knowledge and relative exposure to Dutch related to children's reliance on pointing versus mutual exclusivity, generalized linear mixed-effects regression analyses were performed using the *lme4* package (D. Bates et al., 2015). Separate models were run for each research question, since a model including all variables failed to converge. In both models, the dependent variable was operationalized as the binary outcome that represented whether the child followed the pointing cue (1 = yes, 0 = no). Trials in which the child selected both objects were excluded from the analyses due to their low occurrence (4%). Sum-to-zero contrast coding was applied to all categorical predictors, and all continuous numerical predictors were mean-centered. The maximal possible random-effects structure was used that allowed convergence of the models (Barr et al., 2013).

To answer the first research question whether vocabulary knowledge affected children's reliance on pointing versus mutual exclusivity, a generalized linear mixed-effects model was conducted with the outcome 'followed pointing' (1/0), the predictor 'group' (-½ monolingual, +½ multilingual), and the predictors 'vocabulary' (PPVT scores), 'condition' (-½ familiar label, + ½ novel label). 'Age' (in months) and 'trial number' were added as fixed-effect control factors. Age was added as a fixed-effect control factor because of the relatively wide age range of the participants (i.e., 29-59 months). The model contained by-item and by-participant random intercepts and a by-participant random slope for 'condition'. Data from two monolingual children were excluded because these children selected both objects on all trials.

The second research question on the potential effect of relative language exposure on multilingual children's reliance on pointing versus mutual exclusivity was addressed using a generalized linear mixed-effects model with the outcome 'followed pointing' (1/0), the predictor 'relative exposure' and the predictors 'condition' (-½ familiar label, +½ novel label), and 'vocabulary' (PPVT scores). 'Age' (in months) and 'trial number' were entered as fixed-effect control factors. The variable relative exposure to Dutch was rescaled to fix convergence issues. The model contained a by-participant random intercept. All code and data are available at OSF: https://osf.io/4thmj/?view_only=7ac6526d0ec045f2b92def030aca35c3.

Results

Mean proportions of children's 'point following' responses, overall and per group, are shown in Table 1. Note that the remaining proportions involved 'label following'

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Table 1. Mean Proportions (and Standard Deviations) of 'Followed Pointing' Responses out of all Trials by Group and Condition

		'Followed Pointing'	
Group	Condition	*M*	*(SD)*
Monolinguals	Familiar Label	0.65	(0.48)
	Novel Label	0.82	(0.38)
	Overall	0.74	(0.44)
Multilinguals	Familiar Label	0.69	(0.46)
	Novel Label	0.81	(0.40)
	Overall	0.75	(0.43)
Groups combined	Familiar Label	0.67	(0.47)
	Novel Label	0.82	(0.39)
	Overall	0.74	(0.44)

responses (in accordance with mutual exclusivity): for instance, the monolingual group's proportion of 0.65 'followed pointing' in the familiar label condition indicates that 0.35 of the responses involved label following. Table 1 shows that both the monolingual and multilingual groups relied on pointing more often than on verbal labels consistent with mutual exclusivity. Moreover, both groups followed pointing more frequently in the novel label than familiar label condition.

Vocabulary Knowledge and Children's Cue Reliance

The mean PPVT Dutch vocabulary score was 50.15 (SD = 11.91, range = 19-80) in the monolingual group and 44.61 (SD = 16.18, range = 11-79) in the multilingual group. A Welch two-sample t-test showed that these scores were significantly different (t = 5.30, 95% CI [7.58, 3.48], $p < .001$, d = 0.40).

Regarding our first research question, a generalized linear mixed-effects regression with children's vocabulary scores as one of the predictors was performed, the results of which are presented in Table 2. For the odds ratios and confidence intervals, see Table B1 in the Appendix.

These results show a significant intercept, which indicates that participants, averaged over groups and experimental conditions and with an average vocabulary score and age, were significantly more likely to follow pointing than verbal mutual exclusivity cues. Furthermore, a main effect of condition indicated that children overall followed pointing more often in the novel label than familiar label condition. A main effect of trial number indicated that children's point following responses decreased as the number of trials increased. No main effects of group, vocabulary or age were found. However, two significant interactions were obtained. First, there was a significant interaction between group and vocabulary, visualized in Figure 1. This figure presents mean proportions of point following for the two groups of children median-split on vocabulary. The data show that differences in vocabulary were related to cue reliance more strongly in the multilingual group than the monolingual group: multilinguals with lower vocabulary scores relied on pointing more

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Table 2. Results of the Mixed-Effects Regression with 'Followed Pointing' (1/0) as the Dependent Variable and the Predictors Vocabulary, Group, Condition, Trial Number and Age

	β	SE	*z*	*p*
Intercept	2.820	0.428	6.592	< .001
Group (−monolingual, +multilingual)	0.134	0.576	0.233	.816
Vocabulary	–0.018	0.024	–0.738	.460
Condition (–familiar label, +novel label)	1.589	0.533	2.981	.003
Age	–0.023	0.046	–0.489	.624
Trial number	–0.148	0.067	–2.196	.028
Group * Vocabulary	–0.099	0.039	–2.569	.010
Condition * Vocabulary	–0.048	0.024	–1.963	.050
Group * Condition	–0.310	0.631	–0.491	.623
Group * Condition * Vocabulary	0.039	0.050	0.790	.429

Note. The model included a random effect for item and a random effect for participant with a random slope for condition.

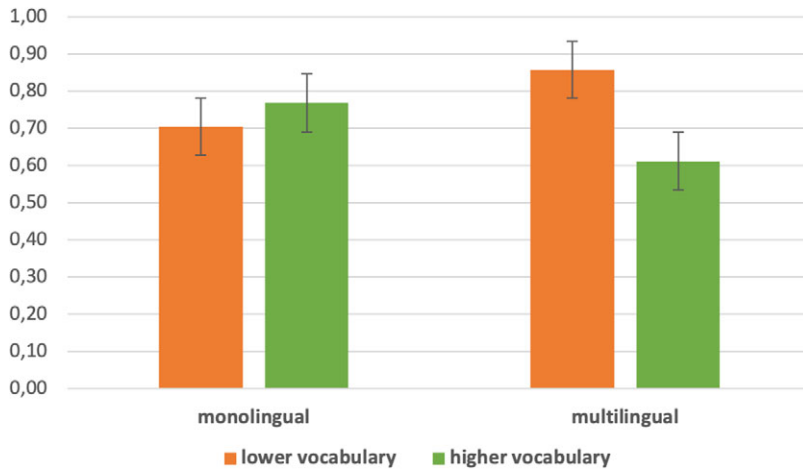

Figure 1. Point Following for the Monolinguals and Multilinguals with Lower Versus Higher Vocabulary Scores (as Determined by a Median-Split).
Note. Multilinguals: n = 42 Low, n = 25 High; Monolinguals: n = 37 Low, n = 51 High. Error Bars Present Standard Errors.

strongly than multilinguals with higher vocabulary scores, but this difference was smaller for monolinguals (and went in the opposite direction). Indeed, post-hoc mixed-effects regression models for each group separately indicated that vocabulary was a significant predictor of point following in the multilingual group (β = -0.075, SE = 0.036, z = -2.120, p = .034), but not in the monolingual group (β = 0.039, SE = 0.044, z = 0.880, p = .379). Thus, whereas children with lower vocabulary scores relied more on pointing over verbal mutual exclusivity cues than children with higher vocabulary scores in the multilingual group, no such differences depending on vocabulary were observed in the monolingual group. For the

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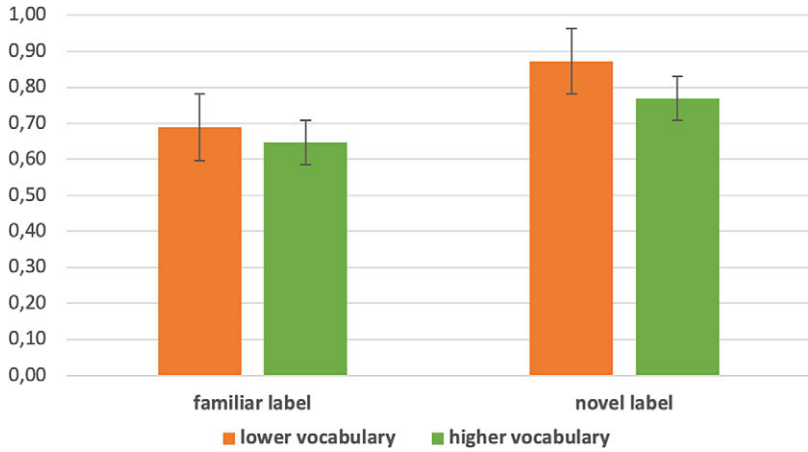

Figure 2. Point Following per Condition for Children with Lower vs. Higher Vocabulary Scores.
Note. Familiar Label: n = 57 Low, n = 56 High; Novel Label: n = 59 Low, n = 60 High. Error Bars Present Standard Errors.

full results of the post-hoc models see in the Appendix Tables A1 and A2 and Tables B3 and B4 for the odds ratios and confidence intervals.

The second interaction effect that was found involved a borderline significant interaction between condition and vocabulary ($p = .0496$), which signaled that the effect that children overall followed pointing over mutual exclusivity more often in the novel label than familiar label condition was stronger for children with lower (as opposed to higher) vocabulary scores. This interaction between condition and vocabulary is plotted in Figure 2, in which the lower versus higher vocabulary groups were based on a median split. Post-hoc mixed-effects models for each condition separately did not indicate an effect of vocabulary in either condition. However, just as in our main analysis, in the model with the familiar label trials, the interaction between group and vocabulary was significant ($\beta = -0.112$, SE = 0.046, $z = -2.416$, $p = .016$). In the model with the novel label trials, this interaction was not significant ($\beta = -0.099$, SE = 0.053, $z = -1.880$, $p = .060$). For the full results of the post-hoc models, see Tables A3 and A4 in the Appendix and Tables B5 and B6 for the odds ratios and confidence intervals.

Relative Exposure and Children's Cue Reliance

To investigate a potential effect of relative exposure to Dutch, the data of 61 out of the 67 multilingual children were analyzed, including 43 bilinguals and 18 trilinguals. Six bilinguals whose parents had not completed the exposure questionnaire were excluded. Mean relative exposure to Dutch in this group was 45.48 ($SD = 33.66$), with scores ranging from 0 (no family exposure in Dutch) to 100 (all family exposure in Dutch). A generalized linear mixed-effects regression with relative exposure to Dutch as a fixed-effect predictor yielded the results in Table 3. For the odds ratios and confidence intervals, see Table B2 in the Appendix.

As above, a significant intercept indicated that children, on average, relied on pointing more frequently than on mutual exclusivity. Furthermore, as in the first model, a main effect of condition showed that children followed pointing more often in the novel label than familiar label condition. Moreover, as above, a significant effect of vocabulary

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Table 3. Results of the Mixed-Effects Regression for the Multilingual Children with 'Followed Pointing' (1/0) as the Dependent Variable and Relative Exposure to Dutch, Condition, Vocabulary, Age and Trial Number as Predictors

	β	SE	*z*	*p*
Intercept	2.509	0.654	3.835	<.001
Relative exposure to Dutch	–0.266	0.152	–1.753	.080
Vocabulary	–0.085	0.041	–2.047	.041
Condition (–familiar label, +novel label)	1.591	0.681	2.336	.019
Age	–0.063	0.070	–0.902	.367
Trial number	0.021	0.102	0.206	.837
Vocabulary * Relative exposure to Dutch	0.022	0.012	1.939	.052
Condition * Relative exposure to Dutch	–0.323	0.259	–1.249	.212
Condition * Vocabulary	–0.047	0.045	–1.035	.301
Condition * Vocabulary * Relative exposure to Dutch	0.050	0.019	2.604	.009

Note. The model included a random effect for participants.

indicated that multilingual children with lower vocabulary scores relied on pointing over mutual exclusivity cues more often than multilingual children with higher vocabulary scores. The results showed no main effects of relative exposure to Dutch or age, and there were no significant two-way interactions, although the interaction between vocabulary and relative exposure to Dutch approached significance. However, the three-way interaction between condition, vocabulary and relative exposure to Dutch was significant. To unpack this interaction, exposure to Dutch scores were plotted against vocabulary scores in a scatterplot for the familiar label and novel label condition separately – see Figures 3 and 4. In these Figures, individual children are represented by dots, which differ in color depending on the proportion of point following responses (see the legend in the Figures below). Figure 3 suggests that in the familiar label condition, children with higher as opposed to lower vocabulary scores tended to follow pointing less often, irrespective of their relative exposure to Dutch. Figure 4 suggests that in the novel label condition, children with less exposure to Dutch relied more on pointing when they had lower as opposed to higher vocabulary scores, whereas children with relatively more exposure to Dutch showed no clear differences depending on their vocabulary scores. Post-hoc tests on the novel and familiar label trials separately confirmed this interpretation: while the interaction between vocabulary and exposure was not significant in the familiar label condition ($\beta = -0.001$, SE = 0.008, $z = -0.134$, $p = .893$), it was significant in the novel label condition ($\beta = 0.053$, SE = 0.024, $z = 2.187$, $p = .029$). For the full results see Tables A5 and A6 and Tables B7 and B8 in the Appendix. However, the patterns in Figures 3 and 4 are based on relatively few data points, so it is important to realize that the sample is too small to allow strong conclusions.

Finally, one may wonder to what extent Dutch vocabulary and exposure to Dutch scores could be considered separate constructs in our data, as they might be strongly correlated. To check this, a Pearson correlation was calculated with age in months partialed out, yielding a positive moderate correlation ($r(59) = 0.50$, $p = < .001$). This suggests that while the two

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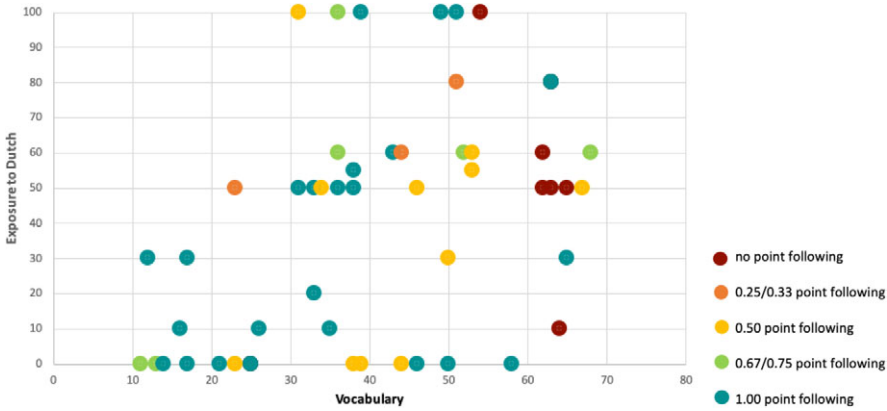

Figure 3. Proportion of Point Following of Individual Children as a Function of Vocabulary and Exposure to Dutch in the Familiar Label Condition.
Note. Due to trial exclusions and because some children did not complete both conditions, 52 multilingual children are represented in this plot. Note that the proportions 0.25 and 0.33 and the proportions 0.67 and 0.75 were collapsed into one category because there were only very few children who scored 0.25 and 0.67.

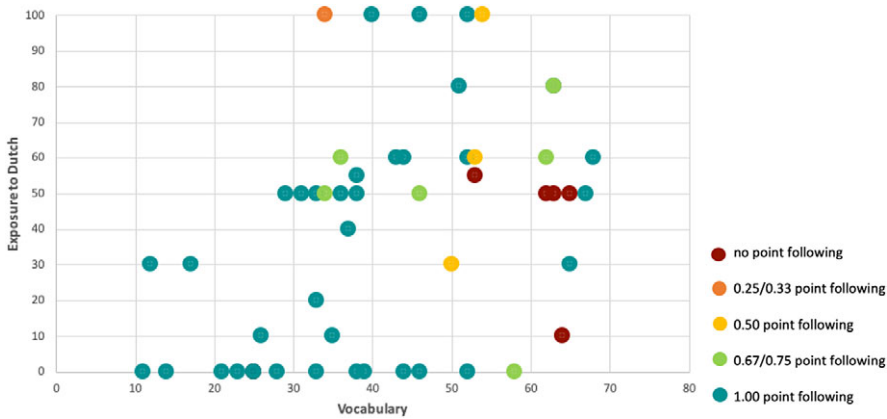

Figure 4. Proportion of Point Following of Individual Children as a Function of Vocabulary and Exposure to Dutch in the Novel Label Condition.
Note. Due to trial exclusions and because some children did not complete both conditions, 51 multilingual children are represented in this plot. Note that the proportions 0.25 and 0.33 and the proportions 0.67 and 0.75 were collapsed into one category because there were only very few children who scored 0.25 and 0.67.

variables were indeed correlated, they represented at least partially different constructs in our study.

Discussion

Previous research has shown that children's word learning processes are impacted by their linguistic experience, such that monolingual and multilingual children may differ in their reliance on non-verbal cues (Brojde et al., 2012; Kalashnikova et al., 2015; Yow,

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2014), mutual exclusivity (Byers-Heinlein & Werker, 2009; Houston-Price et al., 2010; Kalashnikova et al., 2015), and relative weighting of verbal versus non-verbal cues (Gangopadhyay & Kaushanskaya, 2020; Verhagen et al., 2017). However, earlier studies have yielded inconsistent findings, suggesting that such differences between monolingual and multilingual children are graded and subject to individual variation. This study explored whether individual differences in vocabulary knowledge and language exposure could help explain differences in children's relative cue weighting during word-referent mapping. To this end, children's responses in a referential conflict experiment, in which a non-verbal, pointing cue conflicted with a verbal cue congruent with mutual exclusivity, were related to their scores on a receptive vocabulary task and, for multilingual children, parent-reported estimates of their relative exposure to Dutch.

Vocabulary Knowledge and Children's Cue Reliance

Regarding potential effects of vocabulary knowledge, we predicted that both monolingual and multilingual children with lower vocabulary scores would rely on pointing over mutual exclusivity more often than children with higher vocabulary scores. Contrary to this prediction, however, our results for the monolingual and multilingual groups combined showed that Dutch vocabulary scores did not predict children's reliance on pointing versus mutual exclusivity. Rather, we found an interaction between Dutch vocabulary scores and the lingual groups. Post-hoc analyses for each group separately indicated that multilinguals with lower vocabulary scores relied relatively more on pointing over mutual exclusivity than multilinguals with higher vocabulary scores, while no effect of vocabulary was found for monolinguals. Thus, our prediction was borne out partially, for the multilingual group only. These findings are in line with earlier proposals that multilingual children may rely more on non-verbal cues as a compensatory mechanism, to mitigate gaps in their linguistic knowledge (Verhagen et al., 2017; Wermelinger et al., 2020). Moreover, our findings extend such previous proposals as they suggest that this mechanism may explain differences not only between monolinguals and multilinguals, but also within multilingual groups depending on differences in vocabulary knowledge.

Furthermore, our finding that vocabulary knowledge was related to multilingual children's reliance on pointing versus mutual exclusivity contrasts with findings by earlier studies involving children younger than two years (Byers-Heinlein & Werker, 2009, 2013; Houston-Price et al., 2010), which found no relation between multilingual toddlers' vocabulary size and their reliance on mutual exclusivity. However, our findings are not necessarily incompatible with these previous findings. Since our participants were two to five years old, our finding that better-developed vocabulary predicted increased reliance on mutual exclusivity cues over pointing cues in multilingual children supports the idea that multilingual children develop mutual exclusivity as a word learning strategy later than monolinguals due to differences in their vocabulary development. As discussed in our introduction, previous research has shown that multilingual children generally have smaller vocabulary sizes than monolingual peers (Hoff et al., 2012), given that their input is divided over more than one language. Our results indeed showed that multilingual children on average had lower Dutch vocabulary scores than monolingual peers. Moreover, multilingual children's language input likely contradicts mutual exclusivity as it contains cross-language translation equivalents. For these two reasons, it is plausible that multilingual children develop mutual exclusivity as a word learning strategy later than

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monolingual children because it takes them longer to acquire enough vocabulary within each of their languages to learn that, within a language, words and referents tend to be mutually exclusive. Support for this idea comes from our finding that multilingual children with higher Dutch vocabulary scores favored mutual exclusivity over pointing more often than children with lower Dutch vocabulary scores, relying on their knowledge of familiar object labels or associating novel labels with the novel object despite the experimenter's conflicting pointing gestures. However, our findings concern children's relative cue weighting, while many earlier studies have focused on the relation between multilingual toddlers' vocabulary and use of mutual exclusivity in isolation, without competing cues. More research is needed on whether vocabulary knowledge also predicts two-to-five-year-old multilingual children's reliance on mutual exclusivity during word learning in the absence of competing cues. Similarly, this study's focus on children's relative weighting of competing cues might explain why we did not find a relation between monolinguals' vocabulary size and their reliance on mutual exclusivity during word learning, as opposed to previous studies that did find such a relation when reliance on mutual exclusivity was measured in isolation (e.g., Houston-Price et al., 2010; Kalashnikova et al., 2016; Lewis et al., 2020).

Our results also showed an interaction between children's vocabulary scores and the experimental conditions, such that children's tendency to follow pointing over mutual exclusivity more often in the novel label than familiar label condition was stronger for children with lower vocabulary scores than children with higher vocabulary scores. This finding suggests that children with better-developed vocabulary knowledge may be more confident in their knowledge of familiar word-referent mappings, making them less inclined to accept novel labels for objects for which they already have a label. Furthermore, this finding corroborates earlier evidence that children follow pointing over mutual exclusivity more often when novel words are used as opposed to familiar words (Grassmann & Tomasello, 2010; Verhagen et al., 2017), although we also found that the strength of this effect was dependent on children's vocabulary knowledge.

Multilinguals' Cue Reliance and their Relative Exposure to Dutch

Concerning our second research question as to how differences in multilingual children's relative language exposure related to their reliance on pointing versus mutual exclusivity, we predicted that multilingual children with less exposure to Dutch would show a stronger preference to follow pointing over mutual exclusivity than children with more Dutch exposure in our Dutch-instructed task. Contrary to this prediction, we found no evidence that children's relative exposure to Dutch predicted their relative cue weighting. Thus, our results contrast with the finding by Verhagen et al. (2017) that bilingual children's relative language proficiency predicted their weighting of competing pointing versus mutual exclusivity cues, such that children with a lower proficiency in the experimental language relied on pointing more frequently than children with a higher proficiency in this language. However, since the current study focused on relative language exposure rather than relative language proficiency, it is possible that our measure of exposure was not sensitive enough to corroborate the result by Verhagen et al. (2017). We will return to this point in our discussion of the limitations of the present study.

However, a significant interaction between relative exposure to Dutch, vocabulary and experimental condition was found: Multilingual children with less Dutch exposure

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showed a stronger tendency to follow pointing over verbal mutual exclusivity more often in the novel than familiar label condition if they had low rather than high Dutch vocabulary scores, whereas there were no clear differences depending on vocabulary for children with more Dutch exposure. Multilinguals' responses in the familiar label condition did not show different patterns depending on relative exposure. Rather, children with lower vocabulary scores showed a stronger tendency to follow pointing over mutual exclusivity than children with higher vocabulary scores, irrespective of the amount of relative exposure to Dutch. A general explanation for this finding could be that, since both Dutch receptive vocabulary and exposure to Dutch give an indication of children's overall Dutch proficiency (and, in fact, were moderately correlated in our sample), the multilingual children who were less often exposed to Dutch and with less-developed Dutch vocabulary knowledge may have overwhelmingly relied on the non-verbal pointing gestures over verbal mutual exclusivity cues because they were less certain about their Dutch vocabulary knowledge and, hence, may have trusted the verbal information less. In line with this possible explanation, our results also showed that higher Dutch vocabulary scores had a significantly negative effect on multilinguals' reliance on pointing regardless of exposure and condition, and that the interaction between vocabulary and exposure approached significance. Moreover, such an explanation is in accordance with the hypothesis proposed by previous studies that multilingual children who have less knowledge of a language rely more strongly on speakers' non-verbal signals as a compensation mechanism for being less certain about their linguistic knowledge (Verhagen et al., 2017; Wermelinger et al., 2020).

However, if we assume the above explanation, we still need to account for the fact that the interaction between vocabulary and exposure applied to the novel label, but not the familiar label condition. This difference across conditions may be explained by the idea that it is easier to accept a novel label for a familiar object than it is to accept a familiar label for a novel object (Grassmann & Tomasello, 2010); the former involves accepting a second or synonymous word for a name-known object (e.g., *munk* for a shoe), while the latter involves extending the meaning of a familiar word to an object dissimilar to the referents typically associated with the familiar word (e.g., *car* for a piece of construction material). Thus, even children with less exposure to – and less vocabulary in – a language would likely be somewhat more confident about their knowledge of the meanings of familiar words than about their knowledge of synonyms or overlapping words for name-known familiar referents, which could explain why the interaction we found between vocabulary and exposure was significant in the novel label condition only.

Additional Results

Additional results of this study both support and contradict previous findings on the extent to which children rely on non-verbal cues in word-referent mapping. First, corroborating earlier evidence by Grassmann and Tomasello (2010), we found that children tend to give prominence to pointing cues over verbal cues congruent with mutual exclusivity when these compete in word-referent mapping, and that this tendency is stronger when new words are used in the referential conflict compared to familiar words. Second, in contrast to previous studies (Brojde et al., 2012; Verhagen et al., 2017; Yow, 2014), we did not find that multilingual children relied to a stronger degree on non-verbal cues than monolingual peers. Third, contrary to previous findings on younger children (Byers-Heinlein & Werker, 2009; Houston-Price et al., 2010), our findings did

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not demonstrate a stronger reliance on mutual exclusivity in monolinguals as compared to multilinguals.

As we suggested earlier, this study included older children than in most previous studies, such that the discrepancy between our findings and previous findings may be explained by the different ages of the participating children. By the time children reach the ages of three to five years, their word learning processes have likely expanded. Therefore, monolinguals' initial strong mutual exclusivity assumption may have become more flexible depending on context, such as the pointing gesture in our experiment, whereas multilingual children may gradually learn that mutual exclusivity can be used as a word learning strategy within a language. Our hypothesis that differences between monolingual and multilingual children's reliance on mutual exclusivity may reduce throughout childhood is consistent with the finding by Merriman and Kutlesic (1993) that five-to-eight-year-old monolinguals and multilinguals did not differ in the degree to which they maintained mutual exclusivity when extending novel labels to new referents. In contrast, Kalashnikova et al. (2015) found that multilinguals' acceptance of overlapping labels when two speakers used different labels for the same object and monolinguals' mutual exclusivity assumption both increased in strength after the age of four-and-a-half years, suggesting that as children grow older, their linguistic experience may also exert a stronger influence on their word learning processes, rather than a weaker influence.

Furthermore, our results for both groups combined showed that children's tendency to follow pointing over mutual exclusivity became weaker as they completed more trials, contrary to Grassmann and Tomasello's (2010) finding that German acquiring monolingual children's preference for pointing over mutual exclusivity patterned similarly in their first trial compared to their overall responses on four trials. However, in the experiments analyzed in the current study, approximately half of the participants completed eight trials instead of four. Therefore, the children in this study may have had more time to notice that they were not rewarded for compliance with the experimenter's pointing gesture and, hence, they may have been inclined to rely on mutual exclusivity on later trials to evoke a feedback response from the experimenter. Alternatively, in the absence of positive feedback for compliance with the pointing gesture, children may have become less motivated to comply and hence more likely to respond based on their own knowledge of familiar labels or their mutual exclusivity assumption.

Limitations

A limitation of the referential conflict experiment used in this study as well as previous studies is that although socio-pragmatic cues like pointing entail that one interlocutor is trying to direct another to form a particular interpretation, which naturally requires cooperation or compliance, some children may have complied with the experimenter's pointing gesture not out of social cooperation but out of fear for negative feedback or punishment. For instance, differences across cultures or parenting styles may lead to considerable variation in children's tendency to comply. Some evidence for this issue concerns verbal protest from children who commented on the experimenter's use of a label, for example: 'This is a comb' or 'It's not a bafo', while most protesting children nonetheless selected the object pointed at. However, the trials with verbal protest comprised only 6% of the data analyzed in this study. Therefore, it is unlikely that all children followed pointing out of fear of repercussions rather than their interpretation of the referential act.

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Furthermore, a disadvantage of the design with competing pointing and verbal mutual exclusivity cues is that it does not provide insight into children's reliance on these cues when occurring in isolation. As explained in our introduction, an advantage of this design is that it allowed us to compare differences in children's relative cue weighting, which, although tested in an artificial experimental context, nonetheless mimics the processing of various competing sources of information and the evaluation of their relative importance to determine a linguistic form-function relation, underlying everyday naturalistic language comprehension and learning. However, because of the conflict design, we cannot draw conclusions about children's reliance on a specific cue in general, as their reliance on each cue is related to their non-reliance on the other cue.

Another limitation is that we did not test whether all participants comprehended the Dutch labels for the familiar objects used in the experiment, while comprehension of the familiar labels was a crucial assumption of the experiment. However, all children comprehended words of a similar level of commonality during their Dutch vocabulary test, making it unlikely that participants did not know one or more of the familiar labels used.

Furthermore, there were some limitations to our measurement of relative language exposure. First, exposure scores were based on parental questionnaires assessing exposure by the child's household members, leaving out other sources of input to the child. A more extensive inquiry of language exposure, taking into account proportions of exposure at daycare or school, would have provided a more sensitive measurement of multilingual language exposure. Also, language exposure was measured through parents' self-evaluations of their language use toward their child, which could have been subject to over- or underestimates of the proportion of time they used each language with their child. Even though earlier research shows that parents can reliably estimate the exposure provided to their children to at least some extent (Unsworth, 2015; Unsworth et al., 2018), more objective data, such as observational data, would have been more reliable.

Conclusion

The present study aimed to contribute to further investigating variation in children's word learning processes and their relative weighting of two types of cues to map words to referents. We found initial evidence that individual differences in vocabulary knowledge have a different impact on monolingual and multilingual children's weighting of non-verbal pointing cues versus verbal mutual exclusivity cues. However, more research is necessary to understand how children's word learning processes evolve with age throughout childhood and how a variety of factors, including vocabulary knowledge, linguistic experiences of monolinguals versus multilinguals and variation in linguistic experiences among multilinguals, interact with this development.

Competing interest. The authors declare none.

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Appendix A

Table A1. Results of the Post-Hoc Mixed-Effects Regression for the Monolingual Children with 'Followed Pointing' (1/0) as the Dependent Variable

	β	SE	*z*	*p*
Intercept	3.185	0.757	4.207	< .001
Vocabulary	0.039	0.044	0.880	.379
Condition (–familiar label, +novel label)	1.192	1.135	1.051	.293
Age	–0.013	0.081	–0.160	.873
Condition * Vocabulary	–0.058	0.060	–0.964	.335
Vocabulary * Age	–0.011	0.005	–2.124	.034
Condition * Age	–0.048	0.102	–0.470	.638
Condition * Vocabulary * Age	–0.000	0.007	–0.019	.985

Note. The model included a random effect for items and a random effect for participants with a random slope for condition.

Table A2. Results of the Post-Hoc Mixed-Effects Regression for the Multilingual Children with 'Followed Pointing' (1/0) as the Dependent Variable

	β	SE	*z*	*p*
Intercept	2.923	0.707	4.135	< .001
Vocabulary	–0.075	0.036	–2.120	.034
Condition (–familiar label, +novel label)	2.272	1.040	2.185	.029
Age	0.020	0.067	0.299	.764
Trial number	–0.025	0.102	–0.244	.807
Condition * Vocabulary	–0.045	0.052	–0.872	.383
Vocabulary * Age	–0.002	0.003	–0.604	.546
Condition * Age	0.038	0.090	0.427	.669
Condition * Vocabulary * Age	–0.002	0.004	–0.526	.599

Note. The model included a random effect for participants with a random slope for condition.

Table A3. Results of the Post-Hoc Mixed-Effects Regression for the Familiar Label Trials with 'Followed Pointing' (1/0) as the Dependent Variable

	β	SE	*z*	*p*
Intercept	1.292	0.343	3.766	< .001
Group (-monolinguals, +multilinguals)	0.658	0.680	0.967	.333
Vocabulary	–0.001	0.029	–0.051	.960
Age	–0.021	0.053	–0.391	.696
Group * Vocabulary	–0.112	0.046	–2.416	.016

Note. The model included a random effect for participants but not for items, because of the low number of items in this model.

https://doi.org/10.1017/S0305000924000461 Published online by Cambridge University Press

Table A4. Results of the Post-Hoc Mixed-Effects Regression for the Novel Label Trials with 'Followed Pointing' (1/0) as the Dependent Variable

	β	SE	*z*	*p*
Intercept	3.150	0.607	5.190	< .001
Group (-monolinguals, +multilinguals)	–0.140	0.769	–0.182	.856
Vocabulary	–0.058	0.034	–1.693	.090
Age	0.002	0.061	0.039	.969
Group * Vocabulary	–0.099	0.053	–1.880	.060

Note. The model included a random effect for participants but not for items, because of the low number of items in this model.

Table A5. Results of the Post-Hoc Mixed-Effects Regression with Exposure Included for the Multilingual Children for the Familiar Label Trials with 'Followed Pointing' (1/0) as the Dependent Variable

	β	SE	*z*	p
Intercept	1.363	0.427	3.196	.001
Vocabulary	–0.050	0.032	–1.566	.117
Exposure	–0.110	0.118	–0.940	.347
Age	–0.052	0.059	–0.879	.380
Vocabulary * Exposure	–0.001	0.008	–0.134	.893

Note. The model included a random effect for participants.

Table A6. Results of the Post-Hoc Mixed-Effects Regression with Exposure for the Multilingual Children for the Novel Label Trials with 'Followed Pointing' (1/0) as the Dependent Variable

	β	SE	*z*	*p*
Intercept	3.790	1.131	3.353	< .001
Vocabulary	–0.150	0.081	–1.851	.064
Exposure	–0.470	0.284	–1.658	.097
Age	–0.096	0.117	–0.815	.415
Vocabulary * Exposure	0.053	0.024	2.187	.029

Note. The model included a random effect for participants.

https://doi.org/10.1017/S0305000924000461 Published online by Cambridge University Press

Appendix B

Table B1. Odds and 95% Confidence Intervals for the Regression Model with Group, Condition and Vocabulary as the Main Fixed-Effect Factors

	Estimate	SE	Odds	95% CI Odds
Intercept	2.820	0.428	16.78	7.128; 39.49
Group	0.134	0.576	1.143	0.361; 3.618
Vocabulary	–0.018	0.024	0.982	0.936; 1.030
Condition	1.589	0.533	4.899	1.687; 14.22
Age	–0.023	0.046	0.977	0.891; 1.071
Trial number	–0.148	0.067	0.862	0.754; 0.986
Group * Vocabulary	–0.099	0.039	0.906	0.838; 0.979
Condition * Vocabulary	–0.048	0.024	0.953	0.908; 1.000
Group * Condition	–0.310	0.631	0.733	0.208; 2.591
Group * Condition * Vocabulary	0.039	0.050	1.040	0.941; 1.149

Table B2. Odds and 95% Confidence Intervals for the Regression Model with Relative Exposure to Dutch, Condition and Vocabulary as Main Fixed-Effect Factors

	Estimate	SE	Odds	95% CI Odds
Intercept	2.509	0.654	12.29	3.323; 45.47
Relative exposure to Dutch	–0.266	0.152	0.766	0.565; 1.039
Vocabulary	–0.085	0.041	0.918	0.846; 0.997
Condition	1.591	0.681	4.909	1.257; 19.16
Age	–0.063	0.070	0.939	0.816; 1.080
Trial number	0.021	0.102	1.021	0.833; 1.252
Vocabulary * Relative exposure to Dutch	0.022	0.012	1.022	0.998; 1.047
Condition * Relative exposure to Dutch	–0.323	0.259	0.724	0.431; 1.215
Condition * Vocabulary	–0.047	0.045	0.954	0.872; 1.044
Condition * Vocabulary * Relative exposure to Dutch	0.050	0.019	1.051	1.012; 1.092

https://doi.org/10.1017/S0305000924000461 Published online by Cambridge University Press

Table B3. Odds and 95% Confidence Intervals for the Post-Hoc Regression Model for the Monolingual Group

	Estimate	SE	Odds	95% CI Odds
Intercept	3.185	0.757	24.17	5.317; 109.8
Vocabulary	0.039	0.044	1.040	0.952; 1.135
Condition	1.192	1.135	3.294	0.340; 31.88
Age	–0.013	0.081	0.987	0.839; 1.161
Condition * Vocabulary	–0.058	0.060	0.944	0.837; 1.064
Vocabulary * Age	–0.011	0.005	0.989	0.979; 0.999
Condition * Age	–0.048	0.102	0.953	0.777; 1.169
Condition * Vocabulary * Age	–0.000	0.007	1.000	0.986; 1.014

Table B4. Odds and 95% Confidence Intervals for the Post-Hoc Regression Model for the Multilingual Group

	Estimate	SE	Odds	95% CI Odds
Intercept	2.923	0.707	18.60	4.522; 76.48
Vocabulary	–0.075	0.036	0.928	0.863; 0.997
Condition	2.272	1.040	9.699	1.212; 77.63
Age	0.020	0.067	1.020	0.892; 1.166
Trial number	–0.025	0.102	0.975	0.795; 1.196
Condition * Vocabulary	–0.045	0.052	0.956	0.862; 1.061
Vocabulary * Age	–0.002	0.003	0.998	0.992; 1.004
Condition * Age	0.038	0.090	1.039	0.868; 1.244
Condition * Vocabulary * Age	–0.002	0.004	0.998	0.990; 1.006

Table B5. Odds and 95% Confidence Intervals for the Post-Hoc Regression Model for the Familiar Label Condition

	Estimate	SE	Odds	95% CI Odds
Intercept	1.292	0.343	3.640	1.833; 7.228
Group	0.658	0.680	1.931	0.496; 7.523
Vocabulary	–0.001	0.029	0.999	0.943; 1.059
Age	–0.021	0.053	0.979	0.880; 1.089
Group * Vocabulary	–0.112	0.046	0.894	0.815; 0.980

https://doi.org/10.1017/S0305000924000461 Published online by Cambridge University Press

Table B6. Odds and 95% Confidence Intervals for the Post-Hoc Regression Model for the Novel Label Condition

	Estimate	SE	Odds	95% CI Odds
Intercept	3.150	0.607	23.34	6.931; 78.57
Group	–0.140	0.769	0.869	0.187; 4.047
Vocabulary	–0.058	0.034	0.944	0.882; 1.010
Age	0.002	0.061	1.002	0.887; 1.132
Group * Vocabulary	–0.099	0.053	0.906	0.815; 1.007

Table B7. Odds and 95% Confidence Intervals for the Post-Hoc Regression Model with Exposure Included for the Multilingual Children for the Familiar Label Trials

	Estimate	SE	Odds	95% CI Odds
Intercept	1.363	0.427	3.908	1.664; 9.180
Vocabulary	–0.050	0.032	0.951	0.892; 1.014
Exposure	–0.110	0.118	0.896	0.708; 1.134
Age	–0.052	0.059	0.949	0.844; 1.068
Vocabulary * Exposure	–0.001	0.008	0.999	0.983; 1.015

Table B8. Odds and 95% Confidence Intervals for the Post-Hoc Regression Model with Exposure Included for the Multilingual Children for the Novel Label Trials

	Estimate	SE	Odds	95% CI Odds
Intercept	3.790	1.131	44.26	4.609; 425.0
Vocabulary	–0.150	0.081	0.861	0.732; 1.012
Exposure	–0.470	0.284	0.625	0.354; 1.103
Age	–0.096	0.117	0.908	0.719; 1.148
Vocabulary * Exposure	0.053	0.024	1.054	1.005; 1.106

Cite this article: Falkeisen, M., & Verhagen, J. (2025). Children's reliance on pointing and mutual exclusivity in word-referent mapping: The role of vocabulary and language exposure. *Journal of Child Language* **52,** 648–674, https://doi.org/10.1017/S0305000924000461