Language Learning from Inconsistent Input: Bilingual and Monolingual Toddlers Compared

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Abstract:	This study examines novel language learning from inconsistent input in monolingual and bilingual toddlers. We predicted an advantage for the bilingual toddlers on the basis of the structural sensitivity hypothesis (Kuo & Anderson, 2010, 2012). Monolingual and bilingual 24-month-olds performed two novel language learning experiments. The first contained consistent input, the second occasionally contained inconsistent input (i.e., 'errors'). Neither group showed learning of the novel pattern in the consistent experiment. The bilingual toddlers, but not the monolinguals, showed learning in the inconsistent experiment, which suggests they are better at detecting regularities from inconsistent input than monolinguals.

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Quantity of language input is one of the factors contributing to children's language acquisition, with increased amounts of exposure generally leading to faster language learning (e.g., Hart & Risley, 1995; Hoff, 2006; Huttenlocher, Haight, Bryk, Selzer, & Lyons, 1991). However, input is not always consistent, as it can contain (grammatical) errors. This may be due to the stops and starts characteristic of natural language and/or input from less proficient speakers. To date, possible effects of such inconsistency in language input have received little attention. In the present study, we assess whether monolingual and bilingual toddlers are able to learn a novel language on the basis of inconsistent input. Our expectation is that, although both monolingual and bilingual toddlers will be able to acquire a novel pattern on the basis of consistent input, bilinguals may outperform monolinguals when learning from inconsistent input, as a result of increased sensitivity to the input by virtue of being exposed to more than one language.

Over the past decade, a number of studies examining a range of bilingual populations and language combinations have shown that experience with two languages may change children's cognitive development, with bilinguals often (but not always) outperforming their monolingual peers (see Adesope, Lavin, Thompson, & Ungerleider, 2010; Barac, Bialystok, Castro, & Sanchez, 2014 for reviews). Specifically, earlier studies have found that bilingual children may outperform their monolingual peers on tasks assessing working memory (Blom, Küntay, Messer, Verhagen, & Leseman, 2014), and inhibitory control, or the ability to attend to relevant information and ignore irrelevant or distracting information (Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008). Such bilingual advantages in memory and inhibitory control have been found at an early age, in children as young as one or two years of age (Brito & Barr, 2012; Poulin-Dubois,

Blaye, Coutya, & Bialystok, 2011), and even in infants (Kovács & Mehler, 2009). Brito and Barr (2012), for instance, showed that 18-month-old bilingual infants were better able at generalizing observed actions across cues than their monolingual peers and Singh et al. (2015) found improved recognition memory of visual stimuli in 7-month-old bilinguals compared to their monolingual peers.

These reported domain-general cognitive advantages in bilinguals have been invoked in relation to language learning in the *structural sensitivity hypothesis* (Kuo & Anderson, 2010, 2012; Kuo & Kim, 2014). According to the structural sensitivity hypothesis, bilinguals are better able to reorganize linguistic input and impute linguistic structure than monolinguals. Bilinguals' increased sensitivity to linguistic structure is assumed to stem from two sources. First, in order to overcome interlingual interference, bilinguals develop enhanced abilities to attend to structural properties of language and inhibit attention to other less relevant aspects of language. Second, exposure to two languages may render similarities and differences between languages more salient, boosting bilinguals' ability to extract structure. Support for the structural sensitivity hypothesis comes from several studies. Kuo and Anderson (2012) showed that, compared to monolingual peers, bilingual children from kindergarten-age to second grade had an advantage in implicit learning of phonological patterns in a novel language. Similarly, Kuo and Kim (2014) found that bilingual Chinese-English 8- to 10-year-old children were better able to acquire word order relations in an artificial language than monolingual English-speaking peers. Cross-language transfer could not account for these findings, as the syntactic relations to be acquired did not conform to either Chinese or English.

The structural sensitivity hypothesis aligns with earlier research showing that balanced bilingual children accept grammatically correct but semantically anomalous sentences, such as 'Apples grow on noses', more readily than their monolingual peers

(e.g., Bialystok, 1986; Cromdal, 1999; Foursha-Stevenson & Nicoladis, 2011), which suggests that bilingual children are better able to focus on structural properties of language rather than on meaning. Findings by Nation and McLaughlin (1986) are less conclusive: these authors found that adult multilingual learners were better able to learn an implicit artificial grammar consisting of visually presented strings of letters compared to monolingual and bilingual learners. On the basis of the above-mentioned interpretations, it is surprising that the bilingual adults in Nation and McLaughlin's study performed at a similar level as the monolingual subjects. However, the authors included a heterogeneous group of both simultaneous and sequential bilinguals, which may have masked effects of specific types of bilingualism. The multilingual learners did outperform the other groups, which suggests that experience with learning additional languages leads to enhanced performance on a complex learning task.

A study by Kovács and Mehler (2009) suggests that exposure to bilingual language input can enhance children's ability to learn multiple linguistic structures already at a very young age. In this study, bilingual 12-month-olds learned two linguistic structures (i.e., three-syllable strings with an AAB or ABA structure), whereas monolingual infants learned only one (AAB). Kovács and Mehler propose that this bilingual advantage is due to increased cognitive flexibility in the bilingual infants. They argue, moreover, that bilingual infants' enhanced ability to extract structural regularities may be related to their precocious development of inhibitory control, which may help them to become more efficient language learners.

Taken together, these earlier studies comparing monolingual and bilingual speakers' ability to judge grammatical structures (Bialystok, 1986; Cromdal, 1999; Foursha-Stevenson & Nicoladis, 2011) and to learn novel structures (Kovács & Mehler, 2009; Kuo & Anderson 2012; Kuo & Kim, 2014; Nation & MacLaughlin,

1986) indicate that individuals with exposure to more than one language may show a greater readiness to impute linguistic structure. As outlined above, according to the structural sensitivity hypothesis, this bilingual advantage is likely to stem from two sources: (i) an advantage related to executive functioning, leading to enhanced cognitive flexibility and inhibitory control, and/or (ii) increased salience of the structural properties of languages as a result of being exposed to two languages.

Interestingly, all previous studies have looked at bilinguals' response to language input that is consistent. However, if bilinguals' advanced learning is indeed due to enhanced cognitive flexibility, or specifically, their ability to selectively attend to relevant properties of language and suppress less relevant information (Kovács & Mehler, 2009; Kuo & Anderson, 2010), we may expect the advantage to be particularly prominent in a situation of non-uniform input, where part of the input provides conflicting information, which has to be suppressed. Thus, the question at stake is whether bilinguals might fare better than monolingual children at learning from *inconsistent* input, too.

Bilingual children grow up in varying circumstances, with language exposure from a range of sources and in some cases, of variable quality: family members may be monolingual or bilingual, they may speak their native language only or they may use both languages, sometimes despite limited linguistic proficiency (Byers-Heinlein & Fennell, 2014). Across this range of input patterns, bilingual children have to detect the regularities of their two languages using, in most cases, less input per language than their monolingual peers and, in some cases, input which contains non-native errors. In cases of inconsistent, 'noisy' input, learning the language successfully involves focusing on the relevant pattern and ignoring the irrelevant (and typically infrequent) patterns in the signal.

Whilst there are a number of studies which have investigated whether monolingual adults and children regularize inconsistent input, there are – to the best of our knowledge – no studies comparing language learning from inconsistent input between monolingual and bilingual children. Earlier work examining how monolinguals deal with inconsistent input has shown that adults do not regularize inconsistencies, unless complexity and variation increase (Hudson Kam & Newport, 2009). In contrast, children regularize inconsistencies also at lower levels of complexity, at least in production studies (Hudson Kam & Newport, 2005, 2009; Wonnacott & Newport, 2005). In these studies, probabilistically occurring determiners were used to construct inconsistent input (e.g., presence of determiners in 60% vs. 100% of the cases) to mimic the variation present in non-native speech. Results from monolingual children suggest that they regularize the input according to the dominant pattern. Studies with young monolingual infants have shown, moreover, that monolingual 12-month-olds can cope with a certain amount of inconsistency when acquiring a linguistic pattern. Specifically, Gómez and Lakusta (2004) found that monolingual 12-month-olds could generalize aX bY rules when 17% of the input supported opposite rules (aY bX), but not when 33% did. Similarly, Gónzales, Gerken, and Gómez (2015) found that monolingual 12-month-olds could generalize aX bY rules with 38% strings supporting the opposite rules, depending on the distribution of the two sets of rules during stimuli presentation. In both studies, however, the inconsistency was created by having opposing rules, one of which was more frequent than the other. This resembles the presentation of two different rule systems, or languages. The different set-up of our study, in which a predominant pattern had to be learned over a non-predominant, partially overlapping pattern, resembles earlier experiments in monolingual adults on statistical learning (Gebhart, Aslin, & Newport, 2009; Weiss,

Gerfen, & Mitchel, 2009), neither of which found evidence of learning, unless a contextual cue (e.g., speaker voice) was present.

Variability is rather frequent, not only across languages in bilingual situations, but also *within* a language: this may be caused by incidental errors, or it may be part and parcel of specific dialectal variants. For example, in Chilean Spanish, the plural marker /-s/ is variably omitted, and in certain dialects of English, non-agreeing *don't* alternates with its standard agreeing form *doesn't* (e.g., 'She don't/doesn't like him'). This variability has been found to have a negative impact on (monolingual) children's rate of acquisition and the types of errors they make (Miller, 2012).

In the current study, we ask whether bilingual children are better able to deal with such inconsistency than monolingual children. Specifically, we ask whether they are more apt to learn the 'correct' predominant pattern in the presence of a non-predominant pattern. Note that this is a different question from the one addressed in earlier studies, including the study by Kovács and Mehler (2009) who investigated whether 12-month-olds could track two equally frequent structures simultaneously, rather than learn a predominant structure despite the presence of a non-predominant structure. In their experiment, one of the structures may have interfered with the other, leading the monolingual infants to focus on one rather than both. In the current study, there is one target pattern. The inconsistent 'noise', i.e., targets deviating from the pattern, should be ignored (rather than treated as a different pattern), due to its much lower frequency of occurrence. Hence, we define an inconsistent pattern as a partially overlapping pattern that violates the word order of the more frequent pattern.

In sum, earlier work suggests that bilingual children may have an advantage in tracking linguistic structure from novel linguistic input. However, previous studies have looked at consistent input rather than input that more closely reflects natural speech,

which is typically not error-free. The few existing studies that have looked at learning from inconsistent input in young children have tested how monolingual infants deal with larger amounts of inconsistent patterns, involving opposing rules that might be processed as two different language systems (Gómez & Lakusta, 2004; Gónzales, Gerken, & Gómez, 2015). To the best of our knowledge, no study has yet investigated whether monolingual and bilingual children can learn a predominant pattern in the presence of occasional 'noise', and whether bilingual children have an advantage in doing so as compared to monolingual children.

Present Study

In this study, we investigate how monolingual and bilingual toddlers cope with learning from consistent and inconsistent input, employing two artificial grammar learning experiments. The grammatical pattern presented in these experiments was a non-adjacent dependency, that is, a co-occurrence of two elements separated by an intervening element. Non-adjacent dependencies frequently occur as (morpho-)syntactic patterns in real languages, as, for instance, in English 'is X-ing': *is* and *–ing* are dependent elements that are separated by a variable verb stem (e.g., *is singing*). Monolingual infants have been found to be sensitive to such non-adjacent dependencies around 18 or 19 months of age in English (Santelmann & Jusczyk, 1998), German (Höhle, Schmitz, Santelmann, & Weissenborn, 2006) as well as in Dutch (van Heugten & Johnson, 2010; Wilsenach & Wijnen, 2004).

In the present study, 24-month-old toddlers were presented with a miniature artificial language consisting of non-adjacent dependencies, that is., a relationship between the first and third element in a string of three pseudowords. We opted for older children than in previous studies because we included a background measure (see below) that was not suitable for younger children. In the first experiment, all non-adjacent

dependencies were consistent, that is, 'error-free'. Thus, only one pattern had to be learnt. In the second experiment, the dependencies were inconsistent, as they occasionally contained 'errors' (see below for more details). This means that a predominant pattern had to be learnt and an error (a non-predominant pattern) had to be ignored. Our consistent input experiment was adapted from previous non-adjacent dependency learning experiments with English 17-month-old infants (Gómez, 2002) and Dutch 18-month-old infants (Kerkhoff, de Bree, de Klerk, & Wijnen, 2013), which found that typically developing infants were sensitive to (consistently presented) non-adjacent dependencies.

On the basis of these previous findings, we formulated a number of hypotheses. First, given earlier research showing that young monolingual children can successfully learn non-adjacent dependencies (Gómez, 2002; Kerkhoff et al., 2013), we hypothesized that both monolingual and bilingual toddlers would be sensitive to non-adjacent dependencies when presented with consistent input.

Second, regarding the experiment containing inconsistent input, following the structural sensitivity hypothesis (Kuo & Anderson, 2010, 2012; Kuo & Kim, 2014), we hypothesized that the bilingual group would be better able to learn the predominant pattern than the monolingual group, as the bilingual children were expected to focus on the predominant pattern and suppress interference from the non-predominant pattern more than monolingual children. However, given the earlier work showing that monolingual infants can track structural relationships despite a certain degree of inconsistency in the input (Gómez & Lakusta, 2014; Gonzales, Gerken, & Gómez (2015), we did not make a strong prediction regarding the monolingual children, as they might also be able to learn the predominant pattern despite the presence of (relatively few) inconsistent items. The only outcome we did not anticipate was that only the monolingual group, and not the bilingual group, would be able to learn the dominant pattern in the inconsistent input

experiment. So, if any group difference was found, this was predicted to be in favour of the bilingual children.

Finally, we included measures of vocabulary and verbal short-term memory for two reasons. The first was to see whether the two groups differed on these aspects, both of which might be related to non-adjacent dependency learning, and thus be confounding factors in our study. The second was to establish whether the vocabulary and verbal short-term memory measures related to toddlers' performance on the two experiments, as has been found for older children and adults (Bartoletti et al., 2011; Kappa & Colombo, 2014).

Method

Participants

Monolingual and bilingual infants who were almost or just 24 months old participated. Toddlers all had normal birth weight (range 2700-4600 grams), gestation time (range 37-42 weeks), hearing and vision, and no known neurological problems. All parents had completed higher tertiary education and they had no diagnosed language difficulties.

The monolingual toddler group consisted of 24 children (eight females) with an average age of 23;8 months (SD = 12 days) and the bilingual toddler group consisted of 14 toddlers (seven females) with an average age of 24;0 months (SD = 12 days). Monolingual toddlers came from monolingual Dutch families and did not receive regular exposure to languages other than Dutch. Bilingual toddlers came from families in which both Dutch and another language were spoken. The other languages were English (n = 5), German (n = 2), Frisian (n = 1), Spanish (n = 1), Norwegian (n = 1), Dari (n = 1), Czech (n = 1), Indonesian (n = 1) and Italian (n = 1). Toddlers were considered bilingual if they had been exposed to two languages from birth and if they had been exposed to one

language at least 15% of the time. Except for one child, they all heard Dutch from one of their parents. The exception was a child who only heard Dutch at daycare and from her grandparents who babysat the child at home every week. For ten out of fourteen bilingual children, the dominant language was Dutch, as determined by the language background questionnaire UBiLEC (Unsworth, 2013, see below).

Information about parents' highest attained educational level was collected as a proxy for socio-economic status. Specifically, educational level was coded on a 5-point scale ranging from 1 (primary education only) to 5 (university education completed) for both parents separately. Our data showed that all children came from highly educated families. There were no differences in parental educational levels between the bilingual and monolingual children in terms of their mothers' level of education (monolinguals: M = 5.0, SD = 0, bilinguals: M = 4.8, SD = SD 0.5, $t(1,35) = -1.74$, $p = .10$) or fathers' level of education (monolinguals: M = 4.7, SD = 0.6, bilinguals: M = 5.0, SD = 0, $t(1,36) = 1.0$, $p = .34$).

An additional 26 monolingual and 16 bilingual toddlers were tested but not included in the final sample (39/80 = 49%), with most exclusions due to not showing up at one of the sessions ($n = 8$ monolingual, $n = 6$ bilingual). Other reasons for exclusion were excessive fussiness or crying in either of the language learning experiments ($n = 6$ monolingual, $n = 3$ bilingual), completing fewer than three valid trained and three valid untrained trials in the test phase in either of the language learning experiments ($n = 2$ monolingual, $n = 2$ bilingual), technical difficulties in either of the language learning experiments ($n = 7$ monolingual, $n = 3$ bilingual), or parental interference in either of the language learning experiments ($n = 3$ monolingual, $n = 2$ bilingual). The percentage of exclusions across the groups was equal and so was the main cause for exclusion. Importantly, drop-out numbers may seem high, but these are based on two experiments

rather than one, and as such, comparable to earlier reports in the literature (cf. 32% drop-out rate in Kerkhoff et al. (2013) for just one non-adjacent dependency learning experiment).

Materials

Language background. Language background characteristics were measured through two questionnaires, *UBiLEC* (*Utrecht Bilingual Language Exposure Calculator,* Unsworth, 2013) and the *Daily Communication Questionnaire* (Mayo & Leseman, 2008). *UBiLEC* was presented only to parents of the bilingual children. It assesses, among others, the amount of exposure to a given language at the time of testing as a proportion of the total language input. It also assesses the quality of exposure by all caregivers, siblings, and other important input providers in the child's environment. Quality was operationalized as self-reported proficiency on a 6-point scale, ranging from 0 (no fluency) to 5 (native-like fluency). Mean scores were calculated for Dutch and the other language separately. The *Daily Communication Questionnaire* assesses how often parents undertake language and literacy activities with their child such as personal conversations, shared book reading, singing and storytelling. Answers are provided on a 5-point scale, ranging from 1 (never) to 5 (daily). Mean scores were calculated.

Language outcomes. To measure lexical development, children's parents completed the Dutch *McArthur Bates Communicative Developmental Trajectory* (N-CDI, Zink & Lejaegere, 2002) by indicating whether their child 'understood' or 'understood and said' 702 words from a fixed list. Parents of bilingual toddlers also filled in the CDI form for the other language. Presenting all parents with the same CDI version rather than different CDI versions for each language allowed us to compare vocabulary across the two languages. Raw scores were used to be able to compare scores across languages. On the basis of this procedure, percentile scores were not calculated, as these could not be

computed for the form filled in for children's language other than Dutch. A total conceptual vocabulary score is reported for the monolingual (N-CDI total score) and bilingual children (N-CDI and CDI other language summed), as a fair comparison between monolingual and bilingual children's vocabularies requires collapsing bilingual children's vocabularies (Hoff, Core, Place, Rumiche, Señor, & Parra, 2012; Patterson & Pearson, 2004; Pearson, Fernandez, & Oller, 1993).

The grammatical categories of the Dutch N-CDI were used to obtain information on children's grammatical proficiency. Answer options (not yet, sometimes, and often), were converted to a 3-point scale. The maximum score for the questions concerning plurals, possessives, past tenses, and word combinations was 12 points.

Verbal short-term memory. Verbal short-term memory was assessed through a twelve-item nonword repetition task (Verhagen, De Bree, Mulder, & Leseman, 2014) containing monosyllabic and bisyllabic nonwords. Percentages of phonemes correct were calculated on the basis of offline transcriptions by a Dutch native speaker. Ten percent of the data was transcribed and scored by an additional researcher. Interrater-reliability was good (transcription: 86%, scoring: 92%). Consensus was reached on the items that had been transcribed or scored differently.

Consistent input language learning experiment. This experiment was highly similar to the experiment reported in Kerkhoff et al. (2013), containing stimuli which resembled the original stimuli from Gómez (2002) but were made to adhere to Dutch phonotactics. Toddlers listened to one of two artificial languages, Language1 or Language2, consisting of strings of three pseudowords. Language1 strings contained the dependencies a-X-c and b-X-d and Language2 strings took the form a-X-d and b-X-c. In both languages, the 24 X-elements were identical. The elements a and c were *rak* and *toef*, the elements b and d were *sot* and *lut* (see Table 1). Stimuli had been pre-recorded

by the same female speaker as in Kerkhoff et al. (2013), using a high-pitched, child-friendly voice. The a-b-c-d elements in the dependencies all had a CVC syllable structure; the X-items a CV.CVC structure, in which stress was on the first syllable. As such, the stimuli were composed of syllables that are acquired early (Levelt, Schiller, & Levelt, 1999/2000).

As typical of head-turn preference experiments (see Kemler-Nelson et al., 1995) the current experiment included a familiarization phase (3.5 minutes), immediately followed by a test phase. During the entire experiment, children were seated on their caregiver's lap in an experimental booth fitted with a centre light and two side lights. Caregivers listened to music via headphones such that they could not hear the stimuli presented to the child. Children's looking behavior was monitored and reacted upon by an experimenter outside the test booth, using a button box. A custom-made experiment control application initiated trials and registered head-turn responses (see blinded). The experimenter was blind to the condition of the experiment and could not hear the stimuli being played.

During the familiarization phase, children heard 56 strings of Language1 or Language2; each of the two non-adjacent dependencies in a language were presented with the 24 X-items once (rendering 48 strings). Eight pseudorandom strings (four of each dependency) were presented in addition to the experiment used in Kerkhoff et al. (2013) to make the consistent and inconsistent experiments equally long. These pseudorandom strings were 4 a-X-b and 4 c-X-d trials in Language 1 and 4 a-X-d and 4 c-X-b trials in Language 2. They thus always adhered to the predominant pattern. The X-items in these trials were different for each string and were never $X_{1\text{-}3}$, i.e., those used in the test phase (*wadim*, *kasi*, *domo*). During familiarization, there was no correspondence between the lights and the stimuli, as the sentences played continuously from both sides of the booth.

However, the lights would switch on and off according to the child's head turns, as described for the test phase (similar to Gómez, 2002).

The test phase contained eight trials. Each trial consisted of passages of non-adjacent dependencies of one of the languages, either Language 1 or Language 2. Half of the eight test trials came from Language1 and half from Language2, corresponding to the dependencies that had been presented during the familiarization phase (trained trials) and dependencies that had not (untrained trials), see Table 2. The test trials included only X-items that had already been presented during familiarization. The order of test strings within each trial was randomized for each participant. A trial was started by a blinking middle light. Upon fixating to this light, the experimenter pressed a button. As a consequence, the center light would be switched off and one of the two side lights started to blink. When the child directed his or her head towards the light, the experimenter subsequently started the presentation of the stimulus from the loudspeaker below the light. This presentation stopped automatically when the toddler looked away for two seconds or until the trial had played out. Looking times were tracked automatically.

<Insert Table 2 and 3 about here>

Looking time data were recoded offline (fourth author) using PsyCode software for head-turn preference procedure data (http://psy.ck.sissa.it/PsyCode/PsyCode.html). The coder was blind to the condition or group that the child was in. Trials in which the total looking time was below 1600ms (i.e., the duration of one string) were discarded, as an infant needed to hear at least one string of a test trial to determine whether the stimulus was grammatical or not. If fewer than three valid trials out of four test trials per condition remained, the data for that child were excluded, to avoid calculating scores on few data points per participant. Offline coded data were used for analysis.

Inconsistent input language learning experiment. This experiment was the same as the consistent experiment, except that the stimuli in the familiarization phase included eight 'errors' in one of the non-adjacent dependencies. Specifically, if toddlers were trained on Language1, containing the strings *rak*-X-*toef* (i.e., a-X-b) and *sot*-X-*lut* (i.e., c-X-d), they would hear eight instances of incorrect **rak*-X-*lut* (i.e., a-X-d), in the training phase, next to 24 correct instances of *rak*-X-*toef* and 24 instances of correct *sot*-X-*lut*. Likewise, if they were trained on Language2, containing the strings *rak*-X-*lut* (i.e., a-X-d) and *sot*-X-*toef* (i.e., c-X-b), they would hear eight instances of incorrect **rak*-X-*toef* (i.e., a-X-b) in the training phase, next to 24 grammatical *sot*-X-*toef* and 24 *rak*-X-*lut* strings (see Table 1). The percentage of incorrect strings was 14% (8/56). The incorrect strings presented in the training phase were never those with the three X-items (*wadim*, *kasi*, *domo*) that also occurred in the test phase.

Errors only occurred with the a-element in the a-X-c and b-X-d strings (rather than both a- and b-elements), to allow for an investigation of relatively subtle disturbances of the uniformity of input. Furthermore, having an 'error' in only one out of the two dependencies in a language mimics a common real-life error in non-native Dutch. Specifically, non-native speakers of Dutch regularly make errors with the Dutch definite determiners *de* and *het*, generally replacing *het* with *de*, as in **de mooie meisje* for *het mooie meisje* ('the beautiful girl'), but not the other way around (i.e., *de* is not replaced with *het*) (Blom, Polišenska, & Weerman, 2008).

In the inconsistent input experiment, the 'incorrect' strings were randomly taken from a list and inserted at fixed, pseudorandomized positions within the training phase. The pseudorandom strings were always 8 a-X-d trials in Language1, i.e., *rak*-X-*jik* trials (instead of the dominant *rak*-X-*toef* trials) and 8 a-X-b trials in Language 2 i.e., *rak*-X-*toef* trials (instead of the dominant *rak*-X-*jik* trials). The X-elements in these trials

differed for each string and were never $X_{1\text{-}3}$, i.e., those used in the test phase (*wadim*, *kasi*, *domo*). These strings occurred in positions 7, 12, 19, 25, 32, 39, 46, and 51 within the familiarization list.

Importantly, the test phase of the inconsistent input experiment was exactly the same as in the consistent input experiment. Thus, whereas the test phase in the consistent input experiment consisted of strings the toddlers had heard (trained strings) and had not heard (untrained strings), the test phase in the inconsistent input experiment consisted of strings that they had heard (trained strings) and mixed strings, containing both untrained strings and incorrect strings they had heard in the familiarization.

General procedure

Parents and children visited the lab twice. The two visits were one week apart, with a minimum of one week and a maximum of one week and two days. The consistent experiment was always conducted in the first session. In this session, the experimenter also filled in the UBiLEC with the parent and the parent handed in the Daily Communications Questionnaire. In the second session, the inconsistent experiment was presented as well as the nonword repetition task. The inconsistent input experiment always contained the same familiarization Language (Language1 or Language2) as the consistent experiment. Participants were thus exposed to the same general pattern twice, once in the consistent input experiment and once in the inconsistent experiment. Both test sessions lasted approximately half an hour, as they also contained tasks for a larger project.

For nonword repetition, data was available for 19 monolingual children (i.e., five missing), and 12 bilingual children (i.e., two missing). Data from the Daily Communication Questionnaire was available for 21/24 monolingual and 12/14 bilingual toddlers.

Analyses

Independent samples t-test analyses were conducted to compare the two participant groups on the language-related measures: vocabulary, grammar, verbal short-term memory, and amount of language and literacy activities.

With respect to the language learning experiment, looking time, which has been assumed to be indicative of listening time in head-turn preference studies, was the dependent variable. Repeated-measures ANOVAs with group (monolingual/ bilingual) as between-subjects factor and trial type (trained/untrained in the consistent input experiment, trained/mixed in the inconsistent input experiment) as within-subjects factor were run to test for differences in looking time between the groups. As the groups trained on Language1 and Language 2 did not differ in looking time trained minus untrained for the consistent input ($t(36) = -0.308$, $p = .759$) and inconsistent input experiment ($t(36) = -1.308$, $p = .200$), data of both languages was collapsed.

Additionally, the difference in looking times between trained and untrained trials (i.e., mean looking time to trained trials minus mean looking time untrained trials) was calculated. These outcomes were correlated with children's scores on the vocabulary (N-CDI) and verbal short-term memory (nonword repetition) measures.

Results

Descriptive statistics for the language input measures and verbal short-term memory abilities of the two groups are presented in Table 3. The findings indicate that parents self-reported quality of speech input to their bilingual children in Dutch and the other language was relatively high. With respect to the language-based measures, the groups only differed significantly in the proportion of Dutch input, but not in vocabulary, grammar, verbal short-term memory, or the mean frequency of language and literacy activities employed at home.

Descriptive statistics for the consistent and inconsistent input experiments are reported in Tables 4 and 5. A repeated-measures ANOVA for the consistent input experiment did not render a main effect of trial type $F(1,36) = 0.153$, $p = .698$, group $F(1,36) = 0.087$, $p = .770$, or an interaction between the two $F(1,36) = 0.344$, $p = .561$. Of the 38 participants, 16 looked longer to the trials containing untrained strings (42%).

There were no significant correlations between looking time differences between trained and untrained trials of the consistent input experiment and total receptive vocabulary, $r(38) = .179$, $p = .283$, or productive vocabulary, $r(38) = .238$, $p = .150$. However, there was a significant moderate positive correlation between the difference in looking time to trained and untrained trials and nonword repetition, $r(32) = .400$, $p = .023$.

Unlike for the consistent input experiment, a repeated-measures ANOVA for the inconsistent input experiment yielded a main effect of trial type, $F(1,36) = 7.820$, $p = .008$, $\eta 2p = .178$, indicating that looking times were longer to mixed trials than to trained trials. There was no effect of group $F(1,36) = 0.018$, $p = .893$. There was an interaction effect between trial type and group $F(1,36) = 4.169$, $p = .049$, $\eta 2p = .104$, indicating that the bilingual group showed a more pronounced difference in looking time between trained and untrained trials than the monolinguals. Paired sample t-tests with looking time to trained and mixed trials for each group as the dependent variable showed an effect of trial type for the bilingual group ($t(13) = -2.749$, $p = .017$, Cohen's $d = -0.85$), but not for the monolingual group ($t(23) = -0.666$, $p = .51$, Cohen's $d = -0.14$). These findings indicate that, in the inconsistent input experiment, the bilingual toddlers discriminated between the non-adjacent dependencies they had been trained on and the mixed dependencies (i.e., both untrained and inconsistent dependencies), whereas the monolinguals did not.

<Insert Table 4 and 5 about here>

Correlation analyses did not show significant relations between children's looking times in the inconsistent input experiment and their receptive $r(38) = .202$, $p = .223$ or productive vocabulary outcomes $r(38) = .179$, $p = .281$, or nonword repetition outcomes $r(32) = .095$, $p = .609$. Thus, higher receptive or productive vocabulary outcomes or nonword repetition performance did not go hand in hand with larger looking time differences between trained and untrained trials in the inconsistent input experiment.

Discussion

In this study, we tested whether monolingual and bilingual toddlers were able to learn a novel grammatical pattern on the basis of consistent and inconsistent input. To the best of our knowledge, this is the first study that compares young monolingual and bilingual children's implicit learning of a novel language containing inconsistent input, operationalized as input containing a predominant structure as well as a (partially overlapping) non-predominant structure. We had two hypotheses. The first was that both the monolingual and bilingual group would learn the novel structure on the basis of consistent input. The second hypothesis was that, on the basis of the structural sensitivity hypothesis (Kuo & Anderson, 2010, 2012; Kuo & Kim, 2014), an advantage for the bilingual group may be found for learning a predominant structure from inconsistent input. We included measures of vocabulary and verbal short-term memory to see if there were any a priori differences between the groups and if these measures showed positive correlations with children's performance in the language learning experiments.

Unexpectedly, neither group showed learning of the novel language pattern in the first experiment they were exposed to, which contained consistent language input. That is, neither of the groups discriminated between trained and untrained trials in this experiment. In the inconsistent input experiment, in contrast, the bilingual group showed

significant differences in looking time between the two types of test trials. The monolingual group did not show this difference. These findings were interpreted to reflect learning of the language pattern by the bilingual group, but not by the monolingual group.

Finally, the study showed that there were no clear associations between vocabulary and verbal short-term memory, on the one hand, and performance in the language learning experiments, on the other, with the exception of a significant moderate positive correlation between the difference in looking times to trained and untrained trials in the consistent experiment and verbal short term memory, as assessed with nonword repetition. Because of the lack of a clear correlation between verbal short-term memory and performance in the inconsistent input experiment as well as very similar performance on this measure across groups, the bilingual children's enhanced performance in the inconsistent input experiment is not likely due to an advantage in verbal short-term memory, as has been suggested to explain bilingual adults' enhanced performance in statistical learning (Bartolotti, Marian, Schroeder, & Shook, 2011).

The finding that neither of the groups showed sensitivity to the non-adjacent dependencies in the consistent input experiment is surprising in light of the finding that American English 18-month-olds (Gómez, 2002) and Dutch 18-month-olds (Kerkhoff et al., 2013) were able to learn such dependencies in highly similar experiments. The main difference between the current study and these previous studies seems to be the older age group tested in the current study. In our study, testing children at a younger age was not possible, because the verbal short-term memory measure that we included to make sure that there were no a priori differences between the groups, could not be used with children younger than 24 months.

Previous work has shown that the same stimuli may elicit a familiarity preference, a novelty preference or even no preference from young children in head turn preference

studies, depending on children's age (Rose, Gottfried, Melloy-Carminar, & Bridger, 1982). Such effects of age have also been found for non-adjacent dependency learning. Specifically, work by Gómez and Maye (2005) demonstrated that 15-month-olds showed a familiarity preference (i.e., longer looking times to trained trials), whereas 17-month-olds (and 18-month-olds in Gómez, 2002 and Kerkhoff et al., 2013) showed a novelty preference. Perhaps, 24-month-old toddlers do not recruit the same attentional or linguistic mechanisms as younger children when administered an experiment such as the current one, containing relatively simple and repetitive auditory stimuli and only very basic visual stimuli (blinking lights), explaining, perhaps, the lack of a learning effect. Future studies could include different age groups as well as more detailed measures of looking times (such as eye-tracking) to obtain a more fine-grained picture of children's tracking of grammatical structure involving consistent versus inconsistent input and include measures of attention within the experiment, to see whether the partial null result in the current study can indeed be attributed to children's age and/or lack of attention.

In contrast to the consistent input experiment, results on the inconsistent input experiment did show a learning effect. In the latter experiment, 'incorrect' dependencies were presented in a 1:7 ratio. Only the bilingual toddlers showed a difference in looking times to the trained versus mixed trials (containing both untrained and 'incorrect' dependencies). This finding suggests that the bilingual infants were able to detect the predominant pattern despite the inconsistencies. This finding is in line with the hypothesis that bilingual children show heightened sensitivity to structural properties of language (Kuo & Anderson, 2010, 2012; Kuo & Kim, 2014). According to this structural sensitivity hypothesis, bilinguals' enhanced sensitivity is due to their linguistic environment (availability of two languages) leading to increased salience of the structural

properties of languages as well as bilingual children's enhanced cognitive flexibility and inhibitory control abilities (see Kovács & Mehler, 2009 for very similar claims).

While these findings are taken to reflect better learning in the second 'inconsistent' experiment, it is also possible that the bilingual infants had better memory consolidation of the dominant pattern learned in the first experiment. In a previous non-adjacent dependency learning experiment with 15-month-olds, Gómez, Bootzin and Nadel (2006) found different learning outcomes for infants who had taken a nap during a four-hour interval between familiarization and test (compared to infants who had not slept). Gómez et al. argued that sleep may have promoted the abstraction of a pattern, because the infants who slept did not show the classic learning effect (i.e., a difference in preferences between familiar and novel test sentences), but instead showed a preference for strings that were consistent with the first test trial (regardless of whether they corresponded to the familiarization language). It is possible that, in the current study, monolingual and bilingual infants differed in their ability to consolidate and retain knowledge of the pattern across a period of one week. In that case, a difference between the groups would also have surfaced if the second experiment had just contained a test phase and no familiarization.

The finding that the bilingual, but not the monolingual group, was able to learn the pattern in the inconsistent input experiment is important, as it extends earlier research in two ways. First, it shows that bilingual speakers' enhanced learning from linguistic input that has been attested in earlier work (Kuo & Anderson 2012; Kuo & Kim, 2014; Nation & MacLaughlin, 1986) extends to a much younger age group than studied in most previous work, which suggests that a relatively short period of dual language input is sufficient for the effect to emerge (see also Kovács & Mehler, 2009). Second, the current work shows that the bilingual advantage in learning from linguistic structure extends to

situations in which the input is not completely uniform and, as such, is representative of naturally occurring errors within one language system. In the current study, learning from inconsistent input may have required children to attend to a predominant pattern over less-frequent, interfering information. Presumably, performing this task relies for an important part on inhibitory control. As such, the bilingual advantage in learning from inconsistent input we found in the current study extends earlier work on bilingual advantages found in non-linguistic tasks assessing inhibitory control (Bialystok, 2001; Poulin-Dubois et al., 2011), and suggests that young bilingual children do not only have an advantage when being confronted with the type of speech typically encountered in bilingual situations (as suggested by the results in Kovács & Mehler, 2009), but also when encountering 'noisy' linguistic input, which may be representative of both monolingual and bilingual settings. This interpretation is, however, speculative, and needs to be tested in further research.

Another explanation of our results than enhanced language learning and inhibitory control skills – two advantages that may actually work in parallel, is that the bilingual children had simply had more experience with inconsistent (non-native) input, and therefore, outperformed the monolingual children on the inconsistent input experiment. Parental reports indicated, however, that most parents spoke their native language to their children, which suggests that non-native speech was not frequent in children's language input. However, in the questionnaire we used (UBiLEC), parents were also asked to evaluate the nativelikeness of other input providers, which might have led to an overestimation (or underestimation) of other input providers' proficiency levels, and hence, of the quality of the input children were exposed to. However, given that virtually all children's parents were native speakers of the languages they spoke to their children, and parents are by far the most important input providers for most 24-month-olds, we do

not think it is likely that increased experience with errors through non-native speech played a major role in explaining our results.

Future research could investigate the relationship between bilingual children's quality of input and their ability to learn from 'noisy' input further. This could be done by repeating the present experiments with a larger sample of toddlers whose bilingual backgrounds are more similar. Importantly, moreover, future studies could relate monolingual and bilingual children's ability to learn novel language patterns from 'noisy', inconsistent input to measures of inhibitory control. Specifically, such studies could investigate relationships between artificial language learning outcomes and cognitive outcomes in toddlers as well as older children and adults, to see if general cognitive skills and bilingualism have differential effects on statistical learning across the life-span. Whereas in our study bilingual children's advantage could not be explained by differences in verbal short-term memory, Bartolotti et al. (2011) proposed that bilingual adults' advantage in statistical learning could be explained by enhanced verbal short-term memory skills (see also Kappa & Colombo, 2014 who found a positive relationship between verbal memory and statistical learning in monolingual school-aged children and adults).

In sum, then, the current findings show that bilingual – but not monolingual – toddlers, are able to learn from inconsistent input, which likely better reflects real-life exposure than input which is entirely error-free. These findings are in line with the structural sensitivity hypothesis (Kuo & Anderson, 2010, 2012; Kuo & Kim, 2014), although more research is warranted to further investigate the factors contributing to this bilingual advantage.

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Table 1

Experimental Design of the Consistent and Inconsistent Input Experiments

Experiment	Nr. of strings	Language1		Language2	
		Non-adjacent dependencies		Non-adjacent dependencies	
Consistent input	24 of each dependency	a-$X_{(1-24)}$-b	c-$X_{(1-24)}$-d	a-$X_{(1-24)}$-d	c-$X_{(1-24)}$-b
	4 of each dependency	a-$X_{(4-24)}$-b	c-$X_{(4-24)}$-d	a-$X_{(4-24)}$-d	c-$X_{(4-24)}$-b
		(rak X toef)	(sot X lut)	(rak X lut)	(sot X toef)
Inconsistent input	24 of each dependency	a-$X_{(1-24)}$-b	c-$X_{(1-24)}$-d	a-$X_{(1-24)}$-d	c-$X_{(1-24)}$-b
		(rak X toef)	(sot X lut)	(rak X lut)	(sot X toef)
	8 of one dependency	a-$X_{(4-24)}$-d*		a-$X_{(4-24)}$-b*	
		(rak X lut)*		(rak X toef)*	

Note. * refers to ungrammatical strings in familiarization; $X_{(\text{with subscript numbers})}$ refers to the different X-items used in each phase of the experiment

Table 2

Test Trials of the Consistent and Inconsistent Experiments

Language1		Language2	
a-$X_{(1,2,3)}$-b	c-$X_{(1,2,3)}$-d	a-$X_{(1,2,3)}$-d	c-$X_{(1,2,3)}$-b
rak wadim toef	sot wadim lut	rak wadim lut	sot wadim toef
rak kasi toef	sot kasi lut	rak kasi lut	sot kasi toef
rak domo toef	sot domo lut	rak domo lut	sot domo toef

Note. $X_{(\text{with subscript numbers})}$ refers to the different X-items used in each phase of the experiment

Table 3

Means and Standard Deviations for Language Input and Language Outcomes per Group and Statistical Outcomes

	Monolingual		Bilingual		*t* statistic	Cohen's *d*
Measure	*M*	*SD*	*M*	*SD*		
Language input						
Proportion language input Dutch	1.0	0.0	.58	.19	8.224**	3.12
Language and literacy activities at home	2.70	.47	2.83	.42	-.761	-0.22
Quality of language input Dutch (Ubilec)	-		4.52	.84		
Quality of language input other language (Ubilec)	-		4.42	.80		
Language outcomes						
CDI Dutch Understanding and Saying (raw score)	275.21	136.42	169.36	114.94	2.438	0.84
Total CDI Understanding and Saying[1]	275.21	136.42	337.36	157.44	-1.280	-0.42
CDI grammatical categories (max 12)	6.51	1.41	6.21	1.61	.634	0.20
Nonword repetition percentage phonemes correct	72.12	22.76	56.78	34.38	1.368	0.52

Note. ** $p < .001$. [1] monolingual children: maximum = 702; bilingual children: maximum = 1404

Table 4

Mean Looking Times in Milliseconds (Standard Deviations) for the Consistent Input Experiment per Language Group

	Trained trials		Untrained trials		Difference in looking time	Nr. toddlers looking longer towards untrained trials
	M	*SD*	*M*	*SD*		
Monolingual	10303.19	5889.65	9283.05	5754.92	4640.69	11/24
Bilingual	9207.38	5224.15	9410.71	6216.50	4077.14	5/14

Table 5

Mean Looking Times in Milliseconds (Standard Deviations) for the Inconsistent Input Experiment per Language Group

	Trained trials		Mixed trials		Difference in looking time	Nr toddlers looking longer towards mixed trials
	M	*SD*	*M*	*SD*		
Monolingual	6643.74	4091.94	7251.94	4249.10	2982.08	12/24
Bilingual	5158.81	2863.15	9057.86	5792.13	5032.85	9/14