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Gesture Development in Infancy: Effects of Gender but not Bilingualism

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Keywords: Gesture, Infancy, Bilingualism, Gender, MCDI.

Abstract

Gesture is an important communication tool that provides insight into infants' early language and cognitive development and predicts later language skills (Iverson & Goldin-Meadow, 2005).

While bilingual school-age children have been reported to gesture more than monolinguals (Nicoladis et al., 2009), there is a lack of research examining gesture use in infants exposed to more than one language. In this pre-registered study, we compared three groups of 14-month-old infants ($N = 150$) learning French and/or English: bilinguals (hearing a second language at least 25% of the time), exposed (hearing a second language 10–24% of the time), and monolinguals (hearing one language 90% of the time or more). Parent-reported use of communicative gestures was gathered via the MacArthur-Bates Communicative Development Inventories (CDI). Results showed that the three language groups had similarly sized gesture repertoires, suggesting that language exposure did not affect gesture development at this age. However, a gender effect was found, where girls produced more types of gestures than boys. Overall, these results suggest that gender, but not language exposure, contributes to differences in gesture development in infancy.

Keywords: Gesture, Infancy, Bilingualism, Gender, MCDI

1. Introduction

Bilinguals have the capacity to express themselves in two languages. While this provides rich communication opportunities, it also comes at some cost: for example, bilingual infants and children have a smaller vocabulary size relative to monolinguals when each language is considered separately (Bialystok et al., 2010; Thordardottir et al., 2006), and bilingual adults have greater difficulty retrieving words than monolinguals (Bialystok et al., 2008). Gestures are a complementary modality that speakers can use to enhance their communication, which could be particularly beneficial to bilinguals given such challenges. Indeed, some studies have reported that bilingual adults and school-aged children use more gestures than monolinguals (Nicoladis, 2007; Nicoladis et al., 2009). Little is currently known about whether bilingualism impacts gesture use earlier in life. The current study investigated the relationship between bilingualism and infants' gesture repertoire at 14 months, an age of emergent word production and gesture development.

Even before they express themselves in words, infants begin communicating using gestures (Capone & McGregor, 2004). Infants' first gestures include showing and pointing, which emerge around age 9 to 10 months (Ramos-Cabo et al., 2019). A few months later, around 16 months, infants begin to communicate using speech in combination with gestures (Butcher & Goldin-Meadow, 2000; Capone & McGregor, 2004; Ramos-Cabo et al., 2019), and by 22 months their communicative repertoire expands, including more complex word utterances and gesture production (Ramos-Cabo et al., 2019). Although infants tend to gesture more as they age (Özçalışkan & Goldin-Meadow, 2010), they rely most on gestures before they reach the two-word combination milestone, which is around 18 months (Iverson et al., 2008). Around 26 months, when infants' vocabulary significantly grows, their rate of gesture use decreases and preference is given to oral productions (Limia et al., 2019; Özçalışkan & Goldin-Meadow,

2009). As spoken language develops during childhood, gestures continue to play a supportive role in communication (Capone & McGregor, 2004; Goldin-Meadow, 2009).

Despite this consistent overall developmental pattern, there are individual and demographic differences in the number of gestures that infants produce at different ages. Gender, for example, is a factor that has been consistently reported to influence gesture use (Eriksson et al., 2012; Özçalışkan & Goldin-Meadow, 2010), with girls pointing earlier than boys (Butterworth & Morissette, 1996), producing gestures combined with words at a younger age (Özçalışkan & Goldin-Meadow, 2010), and using a greater number of gestures earlier in development (Simonsen et al., 2014; Tamis-LeMonda et al., 2012; although see Nicoladis et al., 2009 for other results with school-age children). For example, two large-scale studies involving more than 15,000 infants across diverse language communities (Norwegian, French, Swedish, Spanish, Slovene, etc.) compared the number of different parent-reported gestures and actions used by girls and boys, using the MacArthur-Bates Communicative Development Inventory: Words and Gestures (CDI) (Eriksson et al., 2012; Simonsen et al., 2014). Both studies reported that girls produced more gesture types and actions than boys, starting at 10 months of age and onwards. It has been hypothesized that these gender differences might be partly explained by different rates of brain development and fine motor skills between females and males at early ages (Butterworth & Morissette, 1996; Özçalışkan & Goldin-Meadow, 2010).

One demographic factor that has received little attention in infant gesture development is bilingualism. Bilingual infants grow up with regular exposure to two languages, and this yields some similarities and some differences with monolingual language development (Werker & Byers-Heinlein, 2008). Bilingual infants reach developmental milestones such as their first word and their first two-word combinations at the same age as monolinguals (Werker & Byers-

Heinlein, 2008). However, there are differences between bilingual and monolingual infants on the perception of some speech sounds and the discrimination of different languages (for a review, see Byers-Heinlein & Fennell, 2014). Bilingualism also has some important effects on early lexical development. While monolingual and bilingual children have similar vocabulary sizes when both languages are considered together, bilinguals have smaller vocabularies when counting words in a single language (Bialystok et al., 2010). Moreover, bilingual infants must learn and use two words for each object they encounter—one in each language—which leads to differences in word learning (Byers-Heinlein & Werker, 2009, 2013) and lexical organization (DeAnda et al., 2016; Jardak & Byers-Heinlein, 2019).

Oral vocabulary requires bilinguals to produce specific linguistic forms depending on the language they are using, for example, producing the word “apple” in English contexts versus the word “pomme” in French contexts to name the same red fruit. Some gestures also have meanings that differ by linguistic or cultural group; for example, a gesture in which the thumb and index finger create a circle while the three other fingers extended spread, signals approval in some countries (“ok”), but indicates the number zero in others (Archer, 1997; Kita, 2009). On the other hand, the meanings of infants’ early communicative gestures appear to be largely invariant across languages and cultures: a pointing gesture has the same meaning for an English-speaking interlocutor as a French-speaking one, for example. Indeed, infants from a range of linguistic and cultural backgrounds produce the same set of early communicative gestures, although there is mixed evidence concerning whether the developmental timing of gestures varies by culture (Cameron-Faulkner et al., 2020; Kwon et al., 2018; Salomo & Liszkowski, 2013). Gestures that are specific to particular ethnolinguistic groups appear to emerge later in development. For example, Turkish-English bilingual children aged 2 and 5 used similar gestures in both of their

languages when retelling a story, with language-specific differences in gesture use emerging around age 9 (Özyürek et al., 2008).

Most studies on gesture use in bilinguals have included preschoolers, school-age children and adults; yet there are no large studies including bilingual infants that investigate whether differences in gesture use can be observed earlier in development. Examining whether there are differences between bilingual and monolingual infants in gesture use is relevant, as delays in this skill can be an early sign of language difficulties (Capone & McGregor, 2004; Goldin-Meadow, 2009). For example, infants with developmental conditions such as Autism Spectrum Disorders gesture less relative to their neurotypical peers (Watson et al., 2013). However, the development of gesture use in young bilinguals is poorly understood, which makes it unclear how to appropriately assess gesture use in bilingual infants in a clinical setting. In sum, differences in monolingual and bilingual language development in other language domains raise the possibility that there could be early differences in gesture development as well. However, to date, only some small-scale descriptive studies have been conducted of bilinguals' early gesture use (e.g., Mayberry & Nicoladis, 2000; Nicoladis, 2002; Nicoladis et al., 1999), but these studies did not make direct comparisons between monolinguals and bilinguals.

Extant research with school-age children and adults has indicated that bilingual children may gesture more often than monolinguals (Nicoladis et al., 2009; Pika et al., 2006). For example, Nicoladis and colleagues (2009) found that 4- to 6-year-old bilingual children gestured more often than their monolingual peers while retelling a story. Most explanations of the observed difference have posited that bilinguals use gestures in order to support weaker language skills. Specifically, bilinguals have more difficulties than monolinguals in oral fluency, and so bilinguals might increase gesture use to bolster fluency (Frick-Horbury & Guttentag, 1998;

Rauscher et al., 1996), perhaps by decreasing cognitive load (Goldin-Meadow et al., 2001). Gestures could also help bilinguals to compensate for reduced vocabulary or weaker lexical access (Nicoladis et al., 2009), especially in their non-dominant language. Importantly, such hypotheses would also apply early in development, as research with monolinguals has found that infants use gesture to compensate for limitations in their oral language abilities during the early stages of word learning (Özçalışkan & Goldin-Meadow, 2009).

There are additional reasons to predict that bilingual infants might have larger gesture repertoires than monolingual infants. Some studies with preschool-aged children have found that bilinguals are better at following subtle nonverbal cues from the speaker (such as eye-gaze and pointing) than their monolingual peers (Yow & Markman, 2011). The authors attributed this enhanced performance to bilingual children's need to closely monitor communicative exchanges given the challenges they face, such as interacting in two languages depending on the specific context or being exposed to language switches. This heightened awareness of nonverbal referential cues during communicative interactions could enable bilinguals to use certain gestures at a younger age than monolinguals.

1.2. The Current Study

In the current study, we asked whether monolingual–bilingual differences in gesture use might be observable in infancy. As a first step to exploring this question, we examined parent-reported gesture use in a large archival dataset of 14-month-olds growing up in Montréal and learning French and/or English (the majority languages in this community), thus controlling for major cultural differences. This age was optimal for our research question, as 14-month-old infants are developing their oral vocabulary but still largely use gestures to communicate (Butcher & Goldin-Meadow, 2000; Capone & McGregor, 2004). We compared three groups of

infants: monolingual, bilingual, and exposed. Following other studies with this age group (Coté et al., 2021; Mattock et al., 2009; Sundara et al., 2008), monolingual infants were defined as those with 90% or greater exposure to one language (i.e., English or French), and bilingual infants were defined as those with 25-75% exposure to each of two languages (i.e., English and French; see Byers-Heinlein, 2015, for a longer discussion of different cutoffs using to define bilingualism in infant research). We also had incidental data from exposed infants, who had some exposure to a second language (between 11% to 24% to English or French) but did not meet our definition of bilingual. We chose to analyze exposed infants as a separate group, given that some studies have found that children exposed to but not fluent in a second language might have a unique path of development (e.g., Akhtar et al., 2012), and there has been growing interest in children with this language profile (DeAnda et al., 2016).

Our data allowed us to investigate whether infants' gesture repertoire (i.e., the number of different gesture types they produce) varied by infants' language background. Following prior studies that have reported differences in infants' gesture use at early ages (e.g., Eriksson et al., 2012; Tamis-LeMonda et al., 2012), we used parent questionnaires to examine our hypothesis. We predicted that bilingual infants would have a larger gesture repertoire (i.e., produce a greater variety of communicative gestures, as reported by their parents) relative to their monolingual peers. This would indicate that bilinguals start using more gestures at an earlier age than monolinguals. In addition, if gesture use at this age is indeed related to exposure to a second language, we predicted that the number of gestures of infants who have some exposure to a second language (between 11% to 24%), but who are not considered bilinguals (following our laboratory's strict criteria), would be greater than that reported for monolingual infants, but lesser than that reported for bilinguals.

We measured infants' gesture repertoire using the MacArthur-Bates Communicative Development Inventories (CDI). This is a parental-report checklist, where caregivers indicate which of different actions and gestures their infant produces. Infants receive scores that represent their gesture repertoire (i.e., the number of different gesture types they are able to produce). Research with more mature populations of bilinguals (school-age children and adults) has focused on gesture frequency (i.e., how often gestures are produced), which might be a more sensitive measure than gesture repertoire for older populations as they have likely already acquired the repertoire of canonical gestures in their language/culture. For developing language learners, this repertoire is still under development, with more advanced infants producing more different gesture types. Moreover, previous research has shown that gesture repertoire as measured by the CDI can reliably detect group differences (e.g., Eriksson et al., 2012; Tamis-LeMonda et al., 2012). An advantage of measuring parent-reported gesture repertoire is that we were able to achieve a large sample size ($N = 150$). By contrast, gesture frequency must be hand coded from video data, which is highly laborious, leading to small sample sizes (e.g., $N = 5$ longitudinal, Mayberry & Nicoladis, 2000; $N = 30$ cross-sectional, Nicoladis et al., 2009).

We expected to find group differences on Section A of the CDI, which measures communicative gestures such as pointing and nodding/shaking the head, predicting that bilingual infants, and to a lesser degree exposed infants, would have larger gesture repertoires than monolingual infants. Given all infants are expected to develop these gestures eventually, this would imply that bilingual and exposed infants have a larger variety of gestures available at a younger age, which could enhance their ability to communicate gesturally. As a control, we also compared the groups on Sections C, D, and E which assess non-communicative actions such as trying to eat/drink/wash, pretending to be a parent, or imitating adult actions such as

sweeping/typing/reading. We did not expect group differences on these sections. Section B: Games and Routines, was not included in the analyses because some items on the French and English versions are not directly comparable to one another (i.e., they ask about language/cultural-specific games such as “so big” and patty cake), and thus the forms are not equivalent for French- and English-learners. Analyses included gender as an additional predictor given that this has been shown to explain important variance in infants’ gesture production (Fenson et al., 2007). As an exploratory analysis of individual differences, we also investigated correlations between gesture and action repertoire and several vocabulary size metrics.

Finally, an important consideration was how to best score bilinguals’ gesture repertoires. Caregivers of bilingual infants (and in some cases exposed infants) completed a CDI in both of their child’s languages, while caregivers of monolingual infants completed a single CDI in their child’s native language. For vocabulary sections of the CDI, it is common to create combined vocabulary scores for bilinguals that take into account the words and concepts lexicalized across both languages (Pearson et al., 1993). For questions related to gesture, it would be possible to combine caregivers’ answers across the different languages in an analogous way, creating a “cumulative score” where an endorsement on either form is counted. However, this type of multi-rater scoring tends to lead to higher counts than single-rater scoring (De Houwer et al., 2005). Given that we only had data from one reporter from monolinguals, this approach would be confounded with bilingualism, biasing our data towards our hypothesis. Moreover, we argue that this type of cumulative scoring is unnecessary for early communicative gestures, as these are language independent. The questions asked on the French and English versions of the CDI are direct translations of each other, and do not refer to language context (e.g., parents simply indicate whether the child waves bye-bye, not whether they do so in a particular language

context). Thus, we opted to score each child using only one form, regardless of their language background. In a reliability analysis, we demonstrate that responses on one form in one language are highly consistent with responses on the form in the other language, validating our approach.

2. Material and Methods

This research was conducted according to the guidelines laid down in the Declaration of Helsinki, with written informed consent obtained from a parent for each infant before data collection. All procedures involving human subjects in this study were approved by the Human Research Ethics Board of Concordia University (certification numbers UH2011-04 and 10000439). Study hypotheses, methods, and analysis plans were pre-registered on the Open Science Framework (OSF) at <https://osf.io/gh5q8>

2.1. Participants

We analyzed archival data from 150 14-month-olds ($M = 14.5$ months, $SD = 0.45$ months, range: 13.5 to 15.5 months) who participated in unrelated experimental studies on language development at the Concordia Infant Research Laboratory between May 2012 and October 2018 (see Table 1 for demographic information). Data from a further 35 infants were excluded for the following reasons: prematurity (i.e., born before 37 weeks, $n = 10$), missing gestation data ($n = 1$), low birth weight (i.e., < 2500 g, $n = 5$), missing birth weight data ($n = 4$), major health issues ($n = 1$), and missing data on the relevant sections of the CDI ($n = 3$). Additionally, we excluded bilingual and exposed infants who did not hear both languages (i.e., English and French) since birth ($n = 11$). Participants were recruited in Montréal, Québec, Canada through government birth lists, community events, and social media. All infants were from the same cultural context and had a similar socioeconomic status as measured via maternal education, thereby controlling

for several relevant variables that could influence gesture development (Iverson et al., 2008; Rowe & Goldin-Meadow, 2009; Tamis-LeMonda et al., 2012).

Table 1. *Participants' Demographic Characteristics*

	Bilinguals	Exposed	Monolinguals
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
	<i>n = 54</i>	<i>n = 22</i>	<i>n = 74</i>
Age in months	14.5 (0.46)	14.4 (0.53)	14.5 (0.42)
Maternal education in years	15.9 (2.89)	16.5 (2.76)	15.8 (2.48)
Dominant/unique language	52% English	59% English	50% English
% Language exposure to unique or dominant language	63 (7.34)	79 (2.87)	99 (2.73)
Gender	56% females	41% females	43% females

Note. Maternal education was used as a proxy for socioeconomic status (SES).

We compared three groups of infants with different levels of bilingual exposure: bilinguals (exposed to each language at least 25%, $n = 54$), exposed (exposed to a second language between 11% and 24%; $n = 22$), and monolingual infants (exposed to one language 90% or more $n = 74$). Bilingual and exposed infants were acquiring their dominant and non-dominant language since birth. Infants' productive and receptive vocabulary scores by group are provided in Table 2. Compared to monolingual children's single-language vocabulary, bilingual and exposed children had statistically significantly smaller receptive and expressive non-dominant language vocabularies, significantly larger receptive total vocabularies, and statistically equivalent vocabularies on other measures (expressive and receptive dominant language, expressive total vocabulary). We also note that most infants (98%) produced fewer than 100 total expressive words (i.e., English words + French words in the case of bilinguals and exposed infants), a maximum vocabulary cut-off used as an inclusion criterion in prior studies examining gesture in early development (e.g., Bates et al., 1989).

Table 2. *Participants' Vocabulary Size by Language Group*

Vocabulary Measure		Bilingua l	Expose d	Monolingua l	<i>p</i>
		M (SD)	M (SD)	M (SD)	
		$n = 54$	$n = 22$	$n = 74$	
Receptive	Dominant/ unique language	129 (69.1)	134 (76.6)	142 (80.2)	.592

	Non-dominant language	88 (72.0)	51 (36.7)	-	<.001 ^a b
	Total (English + French)	211 (117.3)	160 (94.8)	142 (80.2)	.002 ^a
	Range (English + French)	25 - 578	22 - 431	8 - 396	
Expressive	Dominant/ unique	13 (14.1)	24 (33.2)	18 (21.7)	.158
	language				
	Non-dominant language	8 (16.2)	7 (4.6)	-	<.001 ^a b
	Total (English + French)	20 (22.2)	27 (35.7)	18 (21.7)	.334
	Range (English + French)	0 - 112	2 - 160	0 - 110	

Note. n reported in top row represents total number of participants in each group. Values in some cells represent somewhat smaller n's, where there was missing data.

Monolingual infants do not have a non-dominant language; ANOVAs' results for dominant and non-dominant language were calculated using monolinguals' number of words in their unique language.

^aStatistically significant difference between monolinguals and bilinguals.

^bStatistically significant difference between monolinguals and exposed.

^cStatistically significant difference between exposed and bilinguals.

2.2. Measures

2.2.1. Language Exposure Questionnaire and MAPLE. Language exposure estimates were measured via parent report using the Language Exposure Questionnaire (Bosch & Sebastián-Gallés, 2001), using the Multilingual Approach for Parent Language Estimates (MAPLE; Byers-Heinlein et al., 2019). The LEQ is a structured interview used to obtain a global

estimate for the degree to which a child has been exposed to various languages over their lifetime, while MAPLE is a set of best practices for collecting this type of information. The LEQ gives a percentage estimate of a child's global exposure to different languages. Scores were calculated by breaking down a child's waking hours into blocks in which they were exposed to different languages, and then these blocks were multiplied by the days in the week, followed by the months for which that exposure applied. These proportions were then converted into percentage points denoting cumulative exposure to either English or French. Bilingual and exposed infants' dominant language was deemed the language with the higher exposure, or the mother's dominant language when exposure to both languages was equal ($n = 1$). Infants' dominant language and amount of exposure to their dominant language are presented in Table 1.

2.2.2. MacArthur-Bates Communicative Development Inventories: Words and Gestures (CDI). The CDI Words and Gestures form (Fenson et al., 2007) is designed for infants 8 months to 18 months of age (up to 16 months in the Québec French adaptation; Trudeau et al., 1999). It contains a vocabulary checklist (Part I) and a section concerning actions and gestures (Part II). Our analyses focused on Part II of the CDI, which contains five sections (A through E) on types of gestures and actions performed in infancy, from basic pointing and reaching behaviors, to imitation and object manipulation (see Eriksson et al., 2012; Tamis-LeMonda et al., 2012, for previous studies that have used this instrument to measure infants' productions of gestures and actions). Section A (Early Communicative Gestures; 12 items) was the main dependent variable of interest. Sections C (Actions with Objects; 17 items), D (Pretending to be a Parent; 13 items), and E (Imitating other Adult Actions; 15 items) served as controls, as they measure actions that are not communicative gestures. Parents of monolingual infants were administered only one CDI form—either the American English (Fenson et al., 2007) or the

Québec French adaptation (Trudeau et al., 1997). Parents of bilingual infants were asked to fill out both adaptations, following best practice recommendations for measuring vocabulary development in Part I of the CDI (Byers-Heinlein et al., 2019; Pearson et al., 1993). Thirty-three bilingual infants (61%) had complete questionnaires in both languages. Parents of exposed infants completed either one or both questionnaires, depending on the study for which they were originally recruited (9 exposed infants had data in both languages, 41%). Data from bilingual and exposed infants who had questionnaires available in both languages ($n = 42$) were used for a reliability analysis.

2.3. Procedure

During their visit to the lab, parents completed 3 questionnaires. First, a demographics form used to collect information on the child's age, birth weight, gestation time, maternal education, and any health or sensory issues. Then, a structured interview to gather information on the child's language exposure background was administered by a research assistant to the infant's primary caregiver(s). Finally, parents filled out the MacArthur Bates Communicative Development Inventory: Words and Gestures (CDI; Fenson et al., 2007). We asked the parent more familiar with the child's knowledge in each language to fill out this questionnaire. Thus, in the case of bilingual and exposed children, questionnaires for each language were sometimes both completed by one parent (typically the main caregiver) and sometimes by different parents separately. Our main analyses focused on data from Part II of the CDI. Sections A, C, D, and E are direct translations of each other in the Québec French and American English versions. As previously described, we excluded section B because the English and Québec French forms are not directly comparable as they ask about language-specific songs and games.

One additional difference between the English and French versions is that for section A, the English version provides 3 possible answers (“not yet”, “sometimes”, or “often”), while the French version provides 2 (“oui” [yes], “non” [no]). For other sections, the answer keys are direct translations (“yes” and “no” in English; “oui” and “non” in French). Thus, for section A, the answers “sometimes”, “often”, “oui”, and “yes” (all responses indicating some presence of the behavior) were coded as 1, and “not yet”, “no”, and “non” were coded as 0.

We calculated a score for each section (number of items produced in that section), as well as a total endorsement score which was the percentage of all items endorsed across sections A, C, D, and E. We also planned to collapse scores on sections C, D, and E into a single index score for imitation and motor skills if no statistically significant differences were found among the aforementioned sections.

An a-priori power analysis for a between-subjects ANOVA with 3 groups using G*Power (Faul et al., 2007), with an alpha level of .05 and a power level of 80%, allowed us to estimate that our sample size was sufficient to detect an effect size of Cohen’s $d = .25$. Statistical analyses were performed in R (R Core Team, 2020), and figures in JASP (JASP Team, 2019) and jamovi (The jamovi project, 2020).

3. Results

3.1 Data preparation. For our main analysis, we used data from the CDI form completed in the infant’s unique/dominant language ($n = 137$), or else the form completed for the infant’s non-dominant language if only this form was available ($n = 13$). We reasoned that responses to forms in each language should be similar, as the items in the Gesture Section of the CDI are not language-specific and simply ask the parent whether the child performs that gesture (regardless of the oral language context in which the child is communicating). We provide more

direct evidence for the interchangeability of the two forms in a reliability analysis. Moreover, when we restricted our main analyses to only infants who had data in their dominant language, the effects of language background were identical.

3.2. Analytic approach. Our main hypothesis—that language background would be linked to infants’ production of communicative gestures—was tested in a 3 (Language Group: bilingual, exposed, monolingual) $\times$ 2 (Gender: male, female) ANOVA with infants’ scores on section A as the dependent variable. Additionally, we conducted four control analyses using dependent variables that we did not expect to be related to language group: infants’ scores on section C, section D, section E, as well as combined scores on CDE (later gestures section). Note that the combined CDE score is a commonly-computed summary on the CDI. Finally, we also conducted an ANOVA with total endorsement on ACDE, which was converted to a percentage for analysis, following other studies where total number of actions and gestures are also analyzed (e.g., Simonsen et al., 2014). When significant differences were detected, we followed up with planned independent-sample *t*-tests. Assumptions for factorial ANOVAs, including additivity, linearity, homogeneity of variance, and normality were checked and met. The only exception was a departure from normality due to floor effect for section D, where we thus also ran non-parametric tests. All analyses were confirmatory, following the pre-registered analysis plan, except where described as exploratory. A summary of results is presented in Figure 1; results on each section by gender are presented in Figure 2; and group means from each language group are presented in Table 3. Raw data, codebooks, and analysis outputs are available in supplemental materials on the OSF (<https://osf.io/gh5q8>).

3.2. Communicative gestures. Testing our main hypothesis, the ANOVA for section A: Early Communicative Gestures showed no statistically significant main effect of language group,

($F(2, 144) = .38, p = .687, \eta^2 = .005$), and no interaction between language group and gender ($F(2, 144) = .01, p = .993, \eta^2 = < .001$). Thus, our hypothesis was not supported. We did observe a statistically significant main effect of gender ($F(1, 144) = 10.19, p = .002, \eta^2 = .066$). A planned *t*-test showed that girls ($M = 9.10, SD = 1.59$) produced approximately one more gesture on average than boys ($M = 8.11, SD = 1.67, 95\% CI [0.46, 1.51]$), ($t(148) = 3.70, p < .001, d = .603$).

3.3. Other actions. These analyses tested our control variables, which we did not expect to be related to infants' language background. The ANOVA for section C: Actions with Objects, showed no statistically significant differences among the three language groups, ($F(2, 144) = .50, p = .610, \eta^2 = .007$) and there was no statistically significant interaction of language group and gender ($F(2, 144) = .81, p = .446, \eta^2 = .011$). Again, there was a statistically significant main effect of gender, ($F(1, 144) = 6.06, p = .015, \eta^2 = .040$). Girls ($M = 11.03, SD = 2.39$) performed approximately one and a half more actions on average than boys ($M = 9.56, SD = 2.95, 95\% CI [0.60, 2.33]$), ($t(148) = 3.37, p = .001, d = .545$).

For Section D: Pretending to be a Parent, data were not normally distributed, so following our pre-registered plan we ran both non-parametric and parametric analyses. A Kruskal-Wallis H-Test was conducted, with one independent variable entered at a time. There was no statistically significant effect of language group ($\chi^2(2) = .96, p = .619, \varepsilon^2 = .007$). There was a statistically significant effect of gender ($\chi^2(1) = 12.9, p < .001, \varepsilon^2 = .081$), where gender explained approximately 9% of the variance in section D. A planned pairwise comparison using a Wilcoxon rank sum test found that girls produced significantly more actions than boys ($p < .001$). Results from the parametric ANOVA mirrored those from the non-parametric test: no statistically significant differences were found among the three language groups ($F(2, 144) = .82,$

$p = .441$, $\eta^2 = .011$), and there was no statistically significant interaction between language group and gender ($F(2, 144) = .62$, $p = .537$, $\eta^2 = .009$). However, there was a statistically significant main effect of gender ($F(1, 144) = 9.42$, $p = .003$, $\eta^2 = .061$) where girls ($M = 3.70$, $SD = 3.15$) produced approximately one and a half more actions than boys ($M = 2.05$, $SD = 2.25$, 95% CI [0.78, 2.53]), $t(148) = 3.73$, $p < .001$, $d = .61$).

For section E: Imitating other Adult Actions, there was no statistically significant main effect of language group ($F(2, 144) = .01$, $p = .992$, $\eta^2 < .001$) or gender ($F(1, 144) = .51$, $p = .479$, $\eta^2 = .003$; girls $M = 6.76$, $SD = 2.51$; boys $M = 7.01$, $SD = 2.88$), and no interaction between language group and gender ($F(2, 144) = 0.10$, $p = .901$, $\eta^2 = .001$). However, we note that infants' mean scores on this section were quite low, indicating a floor effect that would make it difficult to observe group-level differences.

Results from the compilation of these sections (i.e., sections C, D and E) showed no statistically significant main effect of language group ($F(2, 144) = 0.30$, $p = .740$, $\eta^2 = .004$), and no interaction of language group and gender ($F(2, 144) = 0.60$, $p = .552$, $\eta^2 = .008$). The main effect of gender was exactly at the threshold for statistical significance ($F(1, 144) = 3.90$, $p = .05$, $\eta^2 = .026$). Results showed that girls ($M = 21.49$, $SD = 6.53$) performed approximately three more actions on average than boys ($M = 18.62$, $SD = 6.61$, 95% CI [0.75, 5.00]), $t(148) = 2.67$, $p = .008$, $d = .437$).

3.4. Total endorsement of items. A final ANOVA was conducted to examine the total amount of endorsement across all four sections we analyzed, combining both communicative gestures and other items. In this case, scores were converted into percentage points because different scales had different numbers of items. Here, there was no statistically significant main effect of language group ($F(2, 144) = .19$, $p = .827$, $\eta^2 = .003$), and no interaction between

language group and gender ($F(2, 144) = .43, p = .654, \eta^2 = .006$). There was a statistically significant main effect of gender ($F(1, 144) = 5.76, p = .018, \eta^2 = .038$), with girls ($M = 53.60, SD = 13.11$) scoring approximately 7 percentage points higher than boys ($M = 46.90, SD = 13.20, 95\% CI [2.44, 10.95]$), $t(148) = 3.11, p = .002, d = .509$).

Figure 1. Line graphs illustrating group means on different CDI section scores on the y-axis plotted by language group on the x-axis, with two separate lines for gender. A main effect of gender can be observed for sections A, C, D, CDE, and for Total Endorsement. Error bars represent the 95% confidence interval.

Table 3. *Group Means on the Gesture Section of the CDI by Language Group*

CDI Gestures and Actions Section	Bilingual <i>n</i> = 54 <i>M</i> (<i>SD</i>)	Exposed <i>n</i> = 22 <i>M</i> (<i>SD</i>)	Monolingual <i>n</i> = 74 <i>M</i> (<i>SD</i>)
Section A: First Communicative Gestures	8.7 (1.70)	8.7 (1.96)	8.4 (1.63)
Section C: Actions with Objects	10.1 (2.50)	10.6 (2.91)	10.3 (2.98)
Section D: Pretending to be a Parent	2.7 (2.90)	2.5 (2.39)	3.0 (2.91)
Section E: Imitating other Adult Actions	6.9 (2.48)	7.0 (3.34)	6.9 (2.69)
Sections CDE	19.7 (6.32)	20.0 (7.10)	20.2 (6.94)
Total endorsement ACDE	49.7 (13.00)	50.4 (14.68)	50.2 (13.75)

Figure 2. Pairwise comparisons of CDI scores on the y-axis plotted by gender group on the x-axis, with individual cases. Girls were reported to produce more gesture and action types than boys on sections A, C, D, CDE and Total Endorsement. Error bars denote the 95% confidence interval.

Table 4. *Group Means on the Gesture Section of the CDI by Gender*

CDI Gestures and Actions Section	Girls	Boys
	<i>n</i> = 71	<i>n</i> = 79
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)
Section A: First Communicative Gestures	9.1** (1.59)	8.1** (1.67)
Section C: Actions with Objects	11.0** (2.39)	9.6** (2.95)
Section D: Pretending to be a Parent	3.7** (3.15)	2.1** (2.25)
Section E: Imitating other Adult Actions	6.8 (2.51)	7.0 (2.88)
Sections CDE	21.5** (6.53)	18.6** (6.61)
Total endorsement ACDE	53.6** (13.11)	46.9** (13.20)

* $p < .05$, ** $p < .01$

3.5. Links with vocabulary size. To examine individual differences, we conducted exploratory *t*-tests comparing French-dominant and English-dominant infants' scores on Sections A, C, D, CDE, and total endorsement to examine potential cross-linguistic differences. The only difference that approached significance was for Section A ($t(148) = 1.92$, $p = .057$, $d = .31$). However, the magnitude of the effect was small: English-dominant infants ($M = 8.83$, $SD = 1.72$) produced $\frac{1}{2}$ gesture more on average than French-dominant babies ($M = 8.31$, $SD = 1.64$). Because this comparison did not reach statistical significance and the effect size was small, we did not further interpret this result.

Next, we explored whether infants' scores on Section A (First Communicative Gestures) were related to their receptive and expressive vocabulary sizes, both in total and separately for

dominant and non-dominant language vocabulary. Generally, we observed positive correlations between Section A and receptive and expressive vocabulary measures, which were statistically significant for monolinguals and on some measures for bilinguals (see Table 5 for all correlations). For exposed children, correlations with receptive vocabulary were positive and correlations with expressive vocabulary were negative, although none were statistically different from zero, which may be due to the smaller sample in this group.

Table 5. *Correlations between Vocabulary Measures and scores on Section A (Early Communicative Gestures) from the CDI by Language Group*

Vocabulary measure		Bilingual (<i>n</i> = 54)	Exposed (<i>n</i> = 22)	Monolingua l (<i>n</i> = 74)
Receptive	Unique/dominant language	.17	.35	.24*
	Non-dominant language	.34*	.24	–
	Total (English + French)	.23	.28	–
Expressive	Unique/dominant language	.41**	-.22	.39**
	Non-dominant language	.28*	-.03	–
	Total (English + French)	.41**	-.22	–

Note. *n* reported in top row represents total number of participants in each group. Values in some cells represent somewhat smaller *n*'s, where there was missing data.

p* < .05 *p* < .01

3.6. Reliability analysis. Finally, following our pre-registered analysis plan, we examined agreement between the gesture and action sections of the English and French CDIs for 42 bilingual and exposed infants who had data on questionnaires completed in each language by calculating Cohen's Kappa. Note that questionnaires in each language asked identical questions that were translations of each other (except Section B). Agreement refers to test-retest reliability when the same parent completed both versions, and inter-rater reliability when different parents completed each form. Results from Cohen's Kappa analyses across the different sections of Part II ranged between .73 to .84, indicating high agreement between questionnaires for bilingual and exposed children (see Table 6). This validated our approach of scoring all groups based on a single CDI, rather than combining across reporters for bilingual and exposed infants.

Table 6. *Agreement on CDI Part II Sections and Totals across French and English Forms for Bilingual and Exposed Infants*

CDI Gestures and Actions Section	Cohen's Kappa <i>n</i> = 42
Section A: First Communicative Gestures	.79
Section C: Actions with Objects	.84
Section D: Pretending to be a Parent	.73
Section E: Imitating other Adult Actions	.75
Sections CDE	.80

4. Discussion

The current study examined the influence of bilingualism on gesture production in 14-month-old infants who were monolingual, bilingual, or minimally exposed to a second language. Following prior work on bilingual language development and gesture (Nicoladis et al., 2009), we predicted that second language exposure would relate to 14-month-olds' use of communicative gestures, with infants who have greater exposure to a second language having a larger gesture repertoire. We expected that this would be the case when infants are beginning to say their first words, around 14 months, since gesture use facilitates word retrieval and decreases cognitive load (Goldin-Meadow et al., 2001; Nicoladis et al., 2009) and thus might be used as a strategy to compensate for bilingual and exposed children's smaller vocabulary size in each language relative to monolinguals. The only effect we observed was a gender difference whereby girls generally produced both more gesture and action types than boys. This finding is consistent with previous gender differences reported in studies of monolingual infants (Eriksson et al., 2012), although it does not speak to our main research question.

Why did we not observe differences in gesture use at 14 months amongst monolingual, exposed, and bilingual children? Our hypothesis was based on findings that bilingual children and adults gesture to compensate for challenges in lexical access and retrieval (Frick-Horbury & Guttentag, 1998; Nicoladis et al., 2009; Rauscher et al., 1996), which we reasoned bilingual and to some degree exposed infants might also experience. In our sample, bilingual and exposed infants did have significantly smaller receptive and expressive vocabularies in their non-dominant language compared to monolinguals' vocabulary in their unique language, but this did

not appear to lead to an enhanced gesture repertoire. At the same time, their vocabulary size across both languages was comparable to that of monolinguals and they produced few, if any, translation equivalents. Prior research has shown that the number of translation equivalents known by bilingual and exposed infants influences their word learning mechanisms and lexical organization (Byers-Heinlein & Werker, 2013; DeAnda et al., 2016). It is possible that only when these infants acquire richer productive vocabularies, with more translation equivalents, they do experience higher cognitive load or/and language competition relative to monolinguals, which in turn leads to differences in gesture use. A related possibility is that, at this young age, infants do not use gestures to compensate for lexical retrieval difficulties. As found in previous studies of monolingual children (Blake et al., 2003; Morin-Lessard et al., 2020; Özçalışkan et al., 2017), we generally observed positive correlations between communicative gestures and vocabulary size. Thus, at this age, gesture repertoire appears to develop alongside stronger verbal language skills, rather than compensating for weaker skills.

Another possibility is that monolingual and bilingual infants at this age might differ in metrics of gesture development beyond what we measured. Our study focused on infants' repertoire of gestures (i.e., how many different gesture types they produced). We expected this to be a sensitive and appropriate metric for infants, given that prior work using the CDI has found differences across infants from different backgrounds on this metric (e.g., Eriksson et al., 2012; Tamis-LeMonda et al., 2012). However, we cannot rule out the possibility that monolingual and bilingual infants might nonetheless differ on their *rate* of gesture use, and most studies with bilingual adults and school-aged children have focused on the rate of gesture production (e.g., Nicoladis et al., 2009). While the English version of the CDI does provide a crude metric of gesture rate ("often", "sometimes", and "never"), the Québec French version does not. Thus,

while in the current study we were not able to compare the groups' rate of gesture production, this would be an important direction for future research.

Our results demonstrate that bilingualism neither boosts nor reduces the repertoire of communicative gestures that infants produce at 14 months. This has important implications for clinical assessment of children from multilingual backgrounds. Although bilingual children are expected to have a smaller vocabulary relative to monolinguals when only one of their languages is assessed (Bialystok et al., 2010; Authors, under review), our results suggest that 14-month-olds' gesture repertoire does not differ systematically across different levels of second language exposure. This is important, as gesture development has been shown to differ between typically developing infants and infants with developmental conditions such as Autism Spectrum Disorders (Watson et al., 2013). Thus, our results suggest that gesture repertoire is an equivalent index of typical development for infants acquiring French and/or English from a variety of language backgrounds. Moreover, we found a high level of agreement between questionnaires completed in each of the child's languages, supporting the position that early communicative gestures are independent of specific language contexts (e.g., infants do not necessarily produce separate "French" gestures and "English" gestures). This means that data from one questionnaire could provide relevant insight into a bilingual infant's gesture development, even if there is not available data from a second questionnaire (e.g., only data available in one language), which would not typically be the case for vocabulary development.

Future work should address some limitations of the current study. As our data were collected via parent report, it is possible that parents may over-report or under-report gesture use by their infants. Still, parent report methods are faster, cost-effective, more feasible to administer, and are not subject to artificial differences in behavior that in-lab observation may

induce (Byers-Heinlein et al., 2019). Nonetheless, data on gesture use that combines direct observation and parent report might provide greater insights into infants' gesture development, by also providing information on the rate of infants' gesture use in everyday interactions. Furthermore, our study focused on French–English bilinguals at 14 months from a highly bilingual context. It is possible that different results would be found with infants from other language backgrounds and cultures, or at other ages.

5. Conclusions

Overall, results from the current study suggest that bilingual infants' use of different gesture types at 14 months is similar to that observed in exposed and monolingual children, which is consistent with prior work showing that comparable mechanisms support language acquisition across these groups (Byers-Heinlein et al., 2013). These results provide a relevant contribution to the field of language development, as well as important information for parents of bilingual children and practitioners working in a bilingual context. Future work is needed to examine differences in gesture as a function of second language exposure at older ages, where gesture and vocabulary are perhaps more tightly intertwined. Taken together, these and future results will allow us to better understand the emergence of early differences between monolingual and bilingual children's gesture abilities, and how this contributes to the development of oral language skills.

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