Journal of Deaf Studies and Deaf Education, 2015, 215–228

doi:10.1093/deafed/env007
Advance Access publication April 1, 2015
Empirical Manuscript

EMPIRICAL MANUSCRIPT

Sensitivity to Verb Bias in American Sign Language–English Bilinguals

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Abstract

Native speakers of English are sensitive to the likelihood that a verb will appear in a specific subcategorization frame, known as *verb bias*. Readers rely on verb bias to help them resolve temporary ambiguity in sentence comprehension. We investigate whether deaf sign–print bilinguals who have acquired English syntactic knowledge primarily through print exposure show sensitivity to English verb biases in both production and comprehension. We first elicited sentence continuations for 100 English verbs as an offline production measure of sensitivity to verb bias. We then collected eye movement records to examine whether deaf bilinguals' online parsing decisions are influenced by English verb bias. The results indicate that exposure to a second language primarily via print is sufficient to influence use of implicit frequency-based characteristics of a language in production and also to inform parsing decisions in comprehension for some, but not all, verbs.

The unique population of sign–print bilinguals—deaf bilinguals who use a signed language for face-to-face communication and access a spoken language through reading and writing—has the potential to reveal aspects of bilingual language processing at a new level of universality and add to the sum of our understanding of online sentence processing. Online studies examining the reading patterns of these bilinguals, however, have heretofore been rather scarce. Further, studies of this population have frequently been completed without reference to their bilingual status. Thus, studying sentence processing in sign–print bilinguals in a framework that directly acknowledges the distinction between first language (L1) and second language (L2) status can bring new insights to the patterns and processes documented for this population. This is a mutually beneficial arrangement; studies on bilingualism enrich our understanding of deaf bilinguals, and studies of deaf bilinguals enrich our understanding of bilingualism. In light of these goals, this study investigates sensitivity to an experience-dependent syntactic cue during second language sentence processing in sign–print bilinguals who use American Sign Language (ASL) and written English.

Sign–print bilinguals differ from other hearing bilingual populations in two ways: they learn their second language primarily through print, and as a group, they have more variable first language experiences. Sign languages, like many minority languages, do not have a widely used written form. Deaf ASL–English bilinguals first encounter print through their second language, English. Although many hearing bilinguals develop literacy skills in their second language, Kuntze (2004) has argued that deaf ASL–English bilinguals are unique in their use of print as a primary linguistic source. Hearing bilinguals can access both the spoken and written form of their second language. Deaf ASL–English bilinguals acquire their proficiency in English through a different balance of exposure to spoken and written English, skewed toward written representations.

Variability in first language proficiency in Deaf ASL–English bilinguals stems from limited access to language from an early age. The majority of deaf individuals have hearing parents who typically do not have any familiarity with a signed language prior to the birth of their deaf child (Mitchell & Karchmer, 2005).

Received: July 10, 2014; **Revisions Received:** January 25, 2015; **Accepted:** February 10, 2015

Numerous demographic variables influence the age of first exposure to ASL and the quality of early first language interactions. Due to these factors, it can be difficult to determine which language is truly the first and which is the second language for sign–print bilinguals. Exposure to English may precede exposure to ASL, but full proficiency in ASL may nevertheless be attained prior to proficiency in English. Importantly, like other bilinguals, deaf sign–print bilinguals maintain and use two languages across their life span, with proficiency in each language shaped by the contexts in which those languages are used (Grosjean, 2010). For the purposes of this article, we will refer to ASL as the L1 and English as the L2. Just as with any population of bilinguals, sign–print bilinguals are heterogeneous when it comes to age of first exposure and fluency levels in both dominant and nondominant languages. Moreover, language dominance in any given individual often fluctuates as patterns of use and exposure vary over time. Our use of the term *sign–print bilingual* is not intended to exclude the possibility of effects of residual auditory experience; in fact, sign–print bilinguals may recruit their knowledge of articulatory spoken language patterns in language processing. We use this term to bring into focus characteristics of the population under study we deem important, not as a bid to make theoretical assertions that these characteristics are the only factors that influence representation and use for deaf bilingual signers with knowledge of a spoken language.

L2 Sentence Processing

Sensitivity to syntactic cues has traditionally been one cognitively valuable measure of sentence processing in the study of bilingual populations (e.g., Clahsen & Felser, 2006; Frenck-Mestre & Pynte, 1997; Hopp, 2013; Williams, Möbius, & Kim, 2001). Results for deaf bilinguals in this area are mixed. Earlier studies suggested that deaf readers were not sensitive to written language syntactic cues (e.g., Robbins & Hatcher, 1981), but these studies rarely took L1 proficiency into account. Other studies of deaf readers have reported evidence of sensitivity to English syntactic cues but fail to find a relationship between L2 proficiency levels and sensitivity to L2 syntactic cues (Lillo-Martin, Hanson, & Smith, 1992, Kelly, 2003). These studies also do not take L1 proficiency into account.

More recent studies continue to argue that incomplete acquisition of L2 syntax is a barrier to sentence processing but rely on comprehension accuracy rather than online measures of parsing. For example, Miller (2005, 2010) found that many deaf readers parse semantically plausible sentences correctly but are much more likely to misparse semantically implausible sentences than hearing individuals with matched education levels. This suggests that deaf readers rely more heavily on semantic cues than syntactic cues to guide parsing decisions. There is extensive debate in the literature concerning whether lexically coded information may be processed simultaneously with syntactic information (Garnsey, Pearlmutter, Myers, & Lotocky, 1997), or whether lexical and syntactic material may undergo processing sequentially where each level is operated on independently (Ferreira & Henderson, 1990). As will become evident below, our findings are more consistent with the former view than the latter; however, our study is not intended to provide evidence that adjudicates between these two proposals and our results should not be seen to be in conflict with evidence arguing that deficits in bottom-up processing are largely responsible for lower average reading levels in deaf populations.

Two recent online studies of L2 sentence processing in sign–print bilinguals evaluated the L1 proficiency of participants, and both found that L1 rather than L2 proficiency accounted for variability in L2 parsing strategies (Piñar, Dussias, Carlson, & Morford, 2015; Traxler, Corina, Morford, Hafer, & Hoversten, 2014). Both studies investigated parsing of relative clauses in English, probing the well-documented object relative penalty, which arguably signals sensitivity to structural difficulty (Traxler, Morris, & Seely, 2002), and the use of semantic cues to overcome the difficulty posed by object relative clauses (Traxler, Williams, Blozis, & Morris, 2005). Deaf bilinguals showed evidence of both effects while reading L2 English subject and object relative clauses that were matched for lexical content; however, ASL and not English proficiency was most closely associated with similarities in processing time and accuracy to hearing monolinguals. Bilinguals who acquired ASL later in life (Traxler et al., 2014) or who had weaker self-rated ASL skills (Piñar et al., 2015) exhibited lower levels of comprehension, slower processing, and less sensitivity to syntactic cues in their L2, English. These studies establish an important precedent for studying written sentence processing by deaf ASL–English bilinguals in a bilingual framework and lead us to consider that controlling or factoring in L1 proficiency in a population with such varied L1 language histories is just as important as controlling for L2 proficiency in our understanding of written sentence processing in deaf sign–print bilinguals. Although most studies of adult bilinguals assume proficiency in the L1, no such assumption can be made for all deaf sign–print bilinguals, as explained above. A strong foundation in the L1 might enhance attention to syntactic cues in the L2 even if proficiency gaps are present in the L2, and it could be an important predictive factor for differences in syntactic processing during reading tasks in the L2.

We build on these prior studies by investigating whether deaf sign–print bilinguals also show sensitivity to aspects of syntactic structures that are not explicitly taught but that have been shown to influence sentence parsing decisions in monolingual speakers. A fundamental discovery about sentence processing in monolinguals that has emerged from online processing studies is that readers (and listeners) do not wait until the end of a sentence to decide how the words in a sentence are related to one another (Bever, 1970; Kimball, 1973). Instead, as readers encounter each incoming word, they integrate the new information into the prior sentence context immediately (e.g., Frazier & Rayner, 1982; Garnsey, Lotocky, et al., 1997) and they do this despite the fact that a “wait and see” strategy could be possible because written words remain accessible on paper. On occasion, however, readers make incorrect decisions about the syntactic role of a word relative to prior words. These interpretation errors require a reanalysis of the sentence and also provide important clues about the parsing decisions that readers make during reading.

It has been suggested that readers may make decisions about the syntactic roles of upcoming words in a sentence based on a number of strategies. One view is that readers prioritize the simplest syntactic structure consistent with each word they encounter in a sentence, even if this will, on occasion, require reanalysis (Frazier & Fodor, 1978). Another view (MacDonald, Pearlmutter, & Seidenberg, 1994a, 1994b; MacDonald & Seidenberg, 2006) is that readers can simultaneously consider multiple possible sentence structures and that multiple cues inform the likelihood of any one interpretation being selected, including implicit knowledge of frequency patterns in a language. One prime example of experiential-based implicit syntactic information is the association of subcategorization frames with specific verbs. Subcategorization frames are the regular patterns in a given language for the type and ordering of syntactic constituents such as noun phrases (NP), prepositional phrases (PP), adverbial phrases (AdvP), complementizer phrases (CP), and so on, relative to verbs. The frequency of these patterns is known as *verb bias* and has been observed to affect processing difficulty and reading speed in sentence comprehension. For example, the English verb *believed* can occur in the subcategorization frame [NP_NP] as in (1) or in the frame [NP_CP] as in (2) as well as various other frames ([NP_PP], [NP_AdvP]). *Believed*, due to a much higher probability of occurring in an [NP_CP] frame, can be said to have a clausal or sentential complement (SC) bias (Gahl, Jurafsky, & Roland, 2004; Garnsey, Pearlmutter, et al., 1997). (1) is an example of an NP direct object (DO) frame, whereas (2) is an example of a SC frame:

(1) The child believed the fable because his brother convinced him.
(2) The child believed (that) the fable might not really be true.

Note that sentences (1) and (2) are identical until after the postverbal noun phrase. Thus, a reader who has viewed only the first five words of the sentence cannot yet know whether the sentence will continue with a DO frame or a SC frame. In other words, the sentence is ambiguous up to this point. Studies documenting sentence processing in monolinguals indicate that English speakers anticipate the subcategorization frame of a verb based on its bias (Gahl, 2002; Garnsey, Pearlmutter, et al., 1997; Hare, McRae, & Elman, 2003; MacDonald, 1994; MacDonald et al., 1994a, 1994b; Trueswell, Tanenhaus, & Kello, 1993, Wilson & Garnsey, 2009). Garnsey et al., for example, asked English monolinguals to read DO-bias and SC-bias verbs that were followed by SC and DO sentence frames. Sentences were lexically matched up to and including the postverbal noun phrase. In both a self-paced reading task and an eye-tracking task, readers were slower to process the sentence region following the postverbal noun phrase, called the *disambiguating region*, if the verb's bias did not match the sentence frame, as in sentence (1) above. These data provided initial evidence for the claim that readers will make online parsing decisions consistent with a more complex syntactic structure, a SC, rather than selecting a simpler syntactic structure, a DO complement, if the verb occurs more frequently in a SC frame.

Few studies have investigated whether nonnative speakers are able to learn distributional information specific to their second language and whether they can use this information during online syntactic processing. Recently, Dussias and Cramer Scaltz (2008) replicated the study of verb bias effects with Spanish–English bilinguals by Garnsey, Pearlmutter, et al. (1997). They demonstrated for the first time that bilinguals, specifically, can develop sensitivity to verb bias in their second language (see also Lee, Lu, & Garnsey, 2013 for Korean–English speakers). Spanish–English bilinguals' L2 sentence processing was slowed when verbs were embedded in atypical sentence frames relative to lexically matched predictable sentence frames. In a subsequent study, they found that Spanish–English bilinguals' production patterns also matched English monolinguals' patterns (Dussias, Marful, Gerfen, & Bajo Molina, 2010). When given a sentence fragment consisting only of a proper noun followed by either a SC-bias or DO-bias verb, bilinguals more often generated SC completions with SC-bias verbs and DO completions with DO-bias verbs, despite a general preference for DO constructions. When given the translation equivalents of these sentence fragments in Spanish, the elicited Spanish completions matched distributional patterns of Spanish but not English because only half of the verbs have a similar bias in the two languages. Therefore, Dussias et al. concluded that participants displayed evidence of having learned L2 (English) biases of varying complexity and were not using the simplest structure available in their second language.

In this paper, we investigate whether sign–print bilinguals who have acquired English syntactic knowledge primarily through print exposure show sensitivity to English verb biases in both production and comprehension, taking into account L1 and L2 proficiency. We first elicited sentence continuations for 100 English verbs that have been previously normed by hearing English monolinguals and hearing Spanish–English bilinguals as an offline measure. In a subsequent study, we performed an eye-tracking task to determine whether sensitivity to English verb bias influences parsing decisions online.

Study 1: Elicitation

Study 1 explores the extent to which English verb biases influence deaf ASL–English bilinguals in an offline elicitation task. We compare the number and type of sentence completions entered after two-word sentence prompts. The use of sentence elicitation to tap sensitivity to verb bias in the past has generated norms that are consistent with corpus studies (Gahl et al., 2004), self-paced reading data (Dussias & Cramer Scaltz, 2008), and eye-tracking data (Wilson & Garnsey, 2009). The prompts used matched those of studies that have examined verb bias for monolinguals and Spanish–English bilinguals (Dussias et al., 2010). If exposure to a language primarily through print is sufficient to develop sensitivity to the distribution of verbs in specific syntactic frames, then we predicted that deaf ASL–English bilinguals would generate sentence continuations for English verbs that matched their verb bias.

Method

Participants

One hundred ASL–English bilinguals (75 females) were recruited over 6 months. All participants considered themselves deaf or hard of hearing, were students at Gallaudet University, and reported using ASL and English print on a daily basis. Average age was 23 years old (standard deviation [*SD*] = 5.9).

Traditionally, psycholinguistic studies have relied on parental hearing status to establish proficiency in ASL. We break with this tradition here and report age of first exposure to ASL and self-reported ASL proficiency. Participants rated their ASL production and comprehension skills on a scale of 1–10. Self-ratings were summed across production and comprehension for a maximum score of 20. The same procedure was used in Study 2. For both studies, any participants with a summed self-rating below 10 or a rating below 5 on either the production or comprehension scales were eliminated. None were found below threshold for this study. Average age of ASL acquisition was 2 years old (*SD* = 3.2), and average self-rating of ASL proficiency was 18.4 (*SD* = 1.9). Participants exposed to ASL from birth ($M = 18.9$, $n = 70$) reported higher levels of proficiency in ASL than those exposed later in life ($M = 17.6$. $n = 30$) [$t(98) = 3.19$, $p < .005$, $d = .70$], but the sample as a whole was essentially at ceiling, so it was not possible to calculate an L1 proficiency effect.

L2 (English) proficiency for each participant was measured with self-ratings of English writing and reading ability on a scale of 1–10 as well as with a ratio of grammatical to nongrammatical sentence completions. Grammaticality coding is explained in *Procedure*. We elected to use grammaticality measures over self-ratings because they are more likely to be an objective measure. No participants were excluded from the study based on English proficiency. Table 1 reports self-ratings of ASL and

Table 1. Participant background Study 1 (N = 100, 75% female)

	Mean (*SD*)
Age	23 (5.9)
Self-rated ASL comprehension[a]	9.4 (0.8)
Self-rated ASL production	9.0 (1.2)
Self-rated English writing	8.5 (1.3)
Self-rated English reading	7.8 (1.5)

Note. ASL = American Sign Language.
[a]All self-ratings were made on a scale of 0 (*not at all*) to 10 (*excellent*).

English proficiency. We analyzed the relationship between participant background and the likelihood that participants generated grammatically correct responses with a correlation analysis. There was a significant, negative correlation between the proportion of grammatically correct responses on the task and self-reported age of first language acquisition (r = −.30, p < .001), indicating that as age of exposure increased, English proficiency decreased. This observation of our participant pool is in line with observations that early exposure to language, regardless of modality, yields long-term benefits including benefits to L2 proficiency (Mayberry & Lock, 2003). The average age participants began reading was three and a half (SD = 2.1).

Materials

One hundred verbs, matching those from the Garnsey, Lotocky, Pearlmutter, and Myers (1997) norming study, were selected. All 100 verbs can be used by monolingual speakers in both DO and SC syntactic frames. Target verbs were embedded in a two-word sentence fragment headed by a proper name subject, such as *John decided* _____.

Procedure

Verbs were presented to participants in alphabetical order. Participants were instructed to complete each phrase so that the result was a complete sentence, responding with the first thing that came to mind after reading the prompt. A minimum of eight words (no maximum) per completion was specified, given that past studies have shown that participants' completions average about eight words for sentences with SC-bias verbs (Dussias et al., 2010).

Before coding for sentence completions, all sentences were evaluated for their grammaticality. Native English speakers read all responses and made grammaticality judgments; any errors detected by a native speaker resulted in a response being labeled ungrammatical. Ten percent of the total data (100 items) was checked by a second coder. Cohen's kappa, a measure of intercoder reliability, was 0.90 (95% CI confidence interval [95% CI]: 0.79–0.99), indicating strong agreement.

Coding of the grammatical responses followed Garnsey, Pearlmutter, et al. (1997). Sentence completion responses were coded as DO, SC, and other. Other included 10 subcategories including postverbal constituents that were prepositional phrases, infinitive clauses, reflexive pronouns, verbal particles, gerunds, and nouns immediately followed by a gerund or infinitive. Coding for DO and SC was undertaken as follows: if the postverbal sentence completion was a noun with no verb in the clause, it was marked as DO regardless of intervening adverbials. If postverbal material was immediately followed by "that," then it was marked as SC, even if preceded by an adverbial. If postverbal material was a noun with a verb in the same clause, then it was marked as SC unless infinitive or gerund.

Coding for non-DO or SC continuations was also specified. If postverbal material was a prepositional phrase, then it was marked as PP. If postverbal material was a noun with infinitive in the same clause or a noun followed by an infinitive, then it was marked as INF. If postverbal material was a reflexive pronoun, then it was marked as REF. If postverbal material was a relative pronoun, then it was marked as REL. If postverbal material was a verbal particle (but not PP), then it was marked as PRT. If postverbal material was a gerund or a noun followed by a gerund, then it was marked as GER. If there was no postverbal NP (such as in the case of an intransitive or elided DO), then it was marked as NNP. All other cases were marked with a question mark. A summary of the coding rubric is available in Appendix. Cohen's kappa between coders following this rubric was 0.89 (95% CI: 0.79–0.99).

Results

Coding

Participants produced a total of 9,120 responses out of 10,000 possible. Of these responses, 8,759 (96%) were completed according to instructions; 362 (4%) of these sentences were removed because the task was completed incorrectly, such as when additional material was added between the prompted subject and verb (e.g., *John really might have decided (…)*).

Ungrammatical completions were also eliminated because a syntactic structure could not be unambiguously assigned to these responses. Of correctly completed responses, 6,730 were coded as grammatical (77%, Figure 1). This grammaticality rate is consistent with populations of second language learners (Francis, Romo, & Gelman, 2002). One thousand eight hundred thirty-seven (27%) grammatically correct responses included sentence completions other than DO or SC, leaving 4,893 (72%) with DO or SC continuations. All 6,730 grammatical responses were included in calculations to determine verb bias classification, following Garnsey, Pearlmutter, et al. (1997). Thus, the tendency to respond with a DO or SC continuation was evaluated relative to all possible sentence continuations, and not only to DO and SC responses (Figure 2). This method is crucial, as eliminating all continuations other than DO or SC continuations could artificially inflate the apparent frequency of use of DO or SC responses.

Participants were also separated into high and low English proficiency groups based on their percentage of grammatical

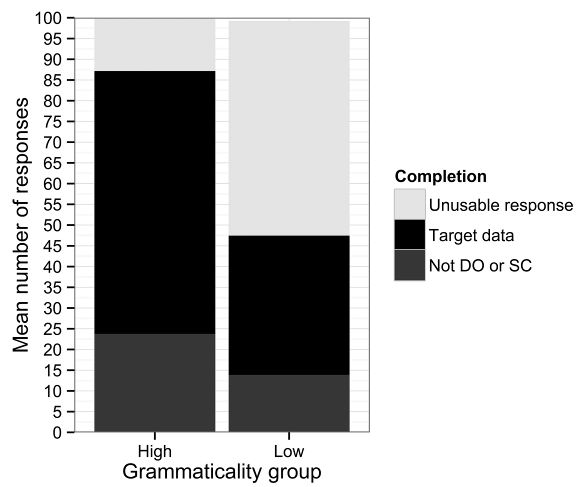

Figure 1. Distribution of item responses by grammaticality group.

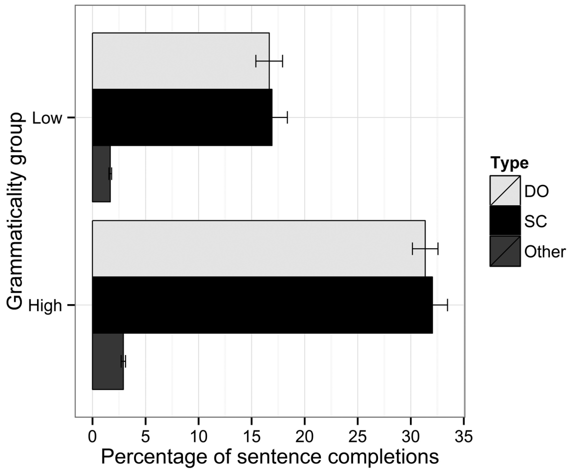

Figure 2. Distribution of sentence completion types by grammaticality group.

completions divided by their total number of responses. Participants with grammatical completions at 75% or higher were included in the high English proficiency group (n = 50), and participants with fewer than 75% grammatical completions were included in the low English proficiency group (n = 50).

Verb bias

Using the coded DO and SC sentence completion responses, the bias for each verb was calculated using relative frequency (following Garnsey, Pearlmutter, et al., 1997; Trueswell et al., 1993; Wilson & Garnsey, 2009). In order to be classified as demonstrating a construction-specific bias (DO or SC), the ratio of sentence continuations for a specific verb had to be 2:1 or greater. For example, for the verb *worried*, participants responded with 13% DO completions and 33% SC completions. Because the ratio of average responses for SC completions in this case was 2:1 or greater (actual ratio was equal to 2.5:1), this verb was determined to have an SC-bias. An absolute frequency calculation (such as in Lapata, Keller, & Im Walde, 2001; Merlo, 1994) would yield a no bias result for *worried* because SC completions account for less than half of the total responses.

For verbs that differed by less than a 2:1 ratio, we distinguished between "equivalent bias" (EQ) verbs that had less than a 15% difference in DO and SC completions and "no bias" verbs for those that differed by more than 15% but still under the 2:1 ratio threshold. For example, *responded* received 4% DO completions, 7% SC completions (ratio = 1.75:1, difference = 3%), and was classified as having an EQ bias. By contrast, *remembered* was assigned a "no bias" classification because it received 51% DO completions and 27% SC completions (ratio = 1.88:1, difference = 24%). This approach allows us to distinguish verbs that are used equally often in both constructions (EQ), from verbs for which the evidence is not sufficient to indicate a bias even though their use in the two constructions is not comparable (no bias). As mentioned above, we elected to use relative frequency calculations rather than absolute frequency to better align our analysis with existing English norms and also due to evidence that only relative frequency for verb bias classification can account for the results of many previous psycholinguistic studies (Gahl et al., 2004, Experiment 4).

From the total 100 verbs normed, 30% were DO biased, 40% were SC biased, 19% were EQ biased, and 11% had no bias. Supplementary Appendix shows all 100 verbs with their percentages of DO and SC responses as well as the total number of responses for each verb. The average frequency of a response with a DO-continuation was 36% (SD = 11.39), of SC was 37% (SD = 12.64), and of other responses was 27% (SD = 8.93).

Proficiency group comparisons

Splitting participants by ASL proficiency into a high proficiency group (self-rating ≥ 19, n = 43, M = 19.8, SD = 0.37) and a low proficiency group (self-rating < 19, n = 57, M = 17, SD = 1.52) yielded no significant differences in sentence continuation patterns, $t(98) = 0.28$, ns. Although we would expect participants with a higher ASL proficiency self-rating to show better mastery of English verb biases than those with a lower ASL proficiency, our population as a whole was highly skilled in ASL. To detect effects of ASL proficiency on English responses, it may be necessary to recruit a more diverse sample of deaf ASL–English bilinguals. All subsequent tests were completed on the entire sample though English proficiency was also included as a factor in some analyses.

We tested for an effect of English proficiency, comparing participants with high grammaticality scores to English monolinguals versus participants with low grammaticality scores to English monolinguals. See Coding section for a discussion of how these groups were determined. No difference in percentage of completion types was revealed by grouping participants by grammaticality rating. The high grammaticality group had 30% DO biased, 43% SC biased, 8% EQ biased, and 19% had no bias. The low grammaticality group had 31% DO biased, 46% SC biased, 6% EQ biased, and 17% had no bias. No significant differences were found between groups for this measure. For both high and low grammaticality groups, strong significant positive correlations were present for the likelihood of providing a DO-continuation (high group: $r = .80$, $p < .001$; low group: $r = .76$, $p < .001$) or a SC-continuation (high group: $r = .87$, $p < .001$; low group: $r = .77$, $p < .001$). Responses for both groups were also highly correlated with each other for DO ($r = .91$, $p < .001$) and SC ($r = .88$, $p < .001$). Given the similarity in completion patterns between the high and low grammaticality groups, we treated them as one population for the remainder of our analyses.

Language group comparisons

We compared the norms we collected from deaf ASL–English bilinguals to the norms for hearing English monolinguals reported by Garnsey, Pearlmutter, et al. (1997). Significant positive correlations were present for the likelihood of providing a DO-continuation ($r = .83$, $p < .001$) and a SC-continuation ($r = .87$, $p < .001$) in response to each verb for the two groups of participants (Figure 3).

We then tested the degree to which the average type of sentence completion for our 100 verbs was different for ASL–English bilinguals when compared to the Garnsey, Pearlmutter, et al. (1997) English monolinguals. A 2 (population: ASL–English bilinguals vs. English monolinguals) × 2 (bias: SC-bias vs. DO-bias) analysis of variance (ANOVA) on average responses revealed a main effect of population [$F(1,99) = 7.97$, $p < .005$, $\eta_p^2 = .07$], no main effect of bias [$F(1,99) = 2.15$, n.s.], and an interaction of population and bias [$F(1,99) = 39.94$, $p < .005$, $\eta_p^2 = .29$]. ASL–English bilinguals were less likely to produce DO responses compared to English monolinguals [$t(99) = -5.86$, $p < .001$, $d = .58$], and SC responses were more frequently produced by the bilinguals than by the monolinguals [$t(99) = 4.74$, $p < .001$, $d = .47$].

We subsequently compared the verb norms for the ASL–English bilinguals to those published by Dussias et al. (2010) for Spanish–English bilinguals. We found that ASL–English

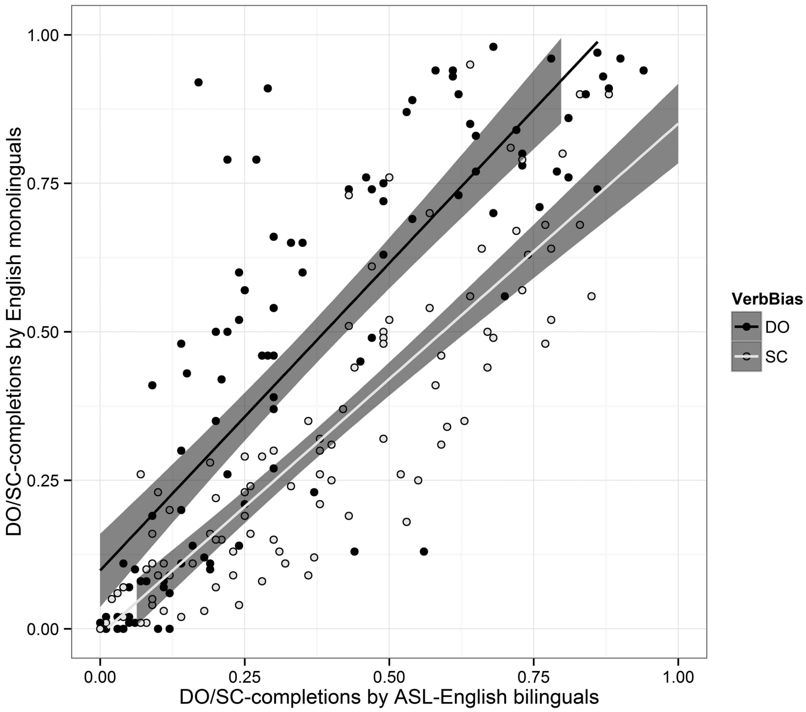

Figure 3. Correlation of ASL–English bilinguals and monolinguals verb biases.

bilinguals' average DO and SC responses were more highly correlated with English monolinguals (r = .83, p < .001 for DO; r = .87, p < .001 for SC) than they were with Spanish–English bilinguals (r = .63, p < .001 for DO; r = .68, p < .001 for SC). Further, the Spanish–English bilinguals' responses were not as highly correlated with English monolinguals' responses (r = .61, p < .001 for DO; r = .67, p < .001 for SC) as the ASL–English bilinguals' responses were. Thus, despite substantive differences in language experience between ASL–English bilinguals and English monolinguals, the ASL–English bilinguals are nevertheless quite similar to English monolinguals in their production patterns for these verbs.

How can the degree of L2 verb bias adaptation be quantified? Do these results reflect L2 learning or do the ASL translation equivalents of these verbs have the same bias as these verbs have in English? Ideally this question can only be answered completely by replicating English corpus and sentence completion tasks in ASL. Failing this, we attempted to address the issue by identifying which of the 100 verbs selected might have more than one possible translation in ASL. If a substantial number of verbs fell into this category and we subsequently found that they did not match English monolingual verb biases, we could conclude that participants were using ASL biases rather than English biases to complete the task. For example, the English verb *accepted* has two possible ASL translations; one meaning "to take possession" and another meaning "to comprehend." Because these two meanings, respectively, match the DO and SC interpretations of the English verb, it could be that one interpretation of *accepted* (and hence a specific English subcategorization frame) was more likely to be activated when participants encountered it. A native user of ASL identified 24 verbs from the stimuli for which disambiguating ASL lexical translations could potentially match with a DO or an SC interpretation of the verb. Of these, a small proportion was identified for which the best translation expressed a different bias than the English monolingual bias. A Cohen's kappa test reveals that there was no significant difference in the bias of the 24 verbs identified as potentially divergent in their distribution across the two languages relative to monolinguals (0.04, 95% CI: 0.00–0.46). This analysis provides additional support for our interpretation that ASL–English bilinguals have developed sensitivity to the syntactic environments of verbs in their second language.

Discussion

The results of Study 1 provide evidence that deaf ASL–English bilinguals who are highly proficient in ASL are sensitive to English DO/SC verb bias in an offline task. The specific proportions of DO and SC responses to each of 100 verbs were significantly correlated with native speakers' responses. When ASL–English bilinguals encounter English verbs in semantically empty contexts, they produce syntactic structures consistent with the most common syntactic environments in which the verbs occur. This study is the first to demonstrate that acquisition of a language primarily through print is sufficient to develop sensitivity to distributional properties of a language in the absence of explicit instruction.

Dussias et al. (2010) published the first study documenting sensitivity to L2 verb bias in a sentence elicitation task. Interestingly, although access to English is restricted primarily to print for ASL–English bilinguals, our participants' responses were more similar to monolinguals' responses on this task than the responses of Dussias et al.'s Spanish–English bilingual participants. One explanation for this outcome could be that fewer translation equivalents have conflicting verb biases in ASL and English than in Spanish and English. Although both bilingual groups give similar responses in English to monolinguals, there is less variability in ASL–English bilinguals' responses. Alternatively, ASL–English bilinguals may experience more exposure to English despite the modality restrictions, and from an earlier age, given that they are growing up in an English-dominant society.

It is worth noting, however, that although our participants showed very high correlation with English monolingual biases, there was a higher percentage of SC completions overall, whereas monolinguals show a slight preference for DO completions overall. By contrast, Dussias et al. (2010) found a higher percentage of DO completions for Spanish–English bilinguals than monolinguals. Why, then, might deaf ASL–English bilinguals show a different pattern? The basic information structure of ASL may give us insight to this question. Some linguists have noted an interaction between English verb biases and discourse focus where a verb's syntactic frame selects thematic roles for prominence (Bezuidenhout 2010, p. 93). Wilbur (1997, p. 89) argues that in ASL, focus/new information is sentence final—a position of syntactic prominence. Because verb bias can combine syntactic and discourse prominence, ASL signers may exhibit a general preference for syntactic structures that place focused information after the verb, rather than before it. When considering the English DO/SC alternation, we can predict that SC continuations better follow ASL syntactic preferences because focused information is placed in the clause following the verb. DO-continuations, on the other hand, place focused information at the left-most sentence edge. For illustration, the focused information in (3) and (4) is underlined. In (3), the subject *The talented photographer* is prominent, whereas in (4), it is backgrounded.

(3) <u>The talented photographer</u> accepted the money after being asked twice.
(4) The talented photographer accepted (that) <u>the money</u> might not be legally obtained.

SC completions better fit the ASL information packaging patterns by placing the focused information later in the sentence—in this case, in the next clause. We propose that although English DO-bias verbs are globally more likely to be completed with DO-continuations, ASL signers may tend to use SC continuations overall more frequently than DO-continuations because they place focused information later in the sentence. If this is indeed the case, then a preference for this sentence structure should also be apparent in comprehension performance, a question investigated in our second study.

Study 2: Eye-tracking

Knowledge of distributional patterns in a language does not necessarily indicate that second language learners use this knowledge during moment-to-moment online processing to anticipate the structure of a sentence. The purpose of Study 2 was to investigate whether the verb bias sensitivity uncovered in Study 1 influences online parsing of English sentences by deaf ASL–English bilinguals. We examined eye fixation patterns of ASL–English bilinguals as they read English sentences in which the verb bias either matched or conflicted with the sentence continuation, alternating between SC-bias and DO-bias. These sentences are lexically matched and thus ambiguous with respect to the syntactic alternations until after the postverbal noun phrase. If ASL–English bilinguals select the syntactic frame on the basis of the verb, they should make parsing decisions affecting the role assignment of the postverbal noun phrase. When those decisions affect the role assignment in such a way that they are in conflict with the subsequent region of the sentence, referred to as the *disambiguating region*, eye fixation patterns should result in longer fixations and/or higher rates of regression due to the need to reanalyze the sentences. We hypothesized that ASL–English bilinguals will read sentences in which the verb bias is consistent with the sentence continuation more rapidly and with fewer regressions than sentences in which the verb bias conflicts with the sentence continuation.

Method

Participants

Twenty-seven participants (15 females) were recruited from Gallaudet University to participate in the study. These were not the same participants recruited for Study 1. One participant was eliminated due to failure to meet eligibility requirements, and one participant was eliminated due to sparse data. The remaining 25 participants ranged in age from 18 to 33 (M = 22) and reported hearing losses of 80 dB or greater in the better ear. Participants were bilingual in ASL and English although, as in Study 1, age of first exposure and proficiency in the two languages varied. Fourteen participants reported being exposed to ASL from birth, whereas the remaining participants ranged in age of first exposure to ASL [2, 17]. Participants rated their ASL production and comprehension skills as well as English writing and reading skills on a scale of 1–10 (Table 2). Self-ratings were summed across production and comprehension. Anyone reporting a proficiency level below 5 on either scale or a summed score below 10 was excluded. Although ASL proficiency ratings were generally high, they differed significantly between participants exposed to ASL from birth (M = 19.2, n = 14) and signers who acquired ASL later in life (M = 17.2, n = 11), $t(23)$ = 2.10, p < .05, but the sample as a whole was essentially at ceiling, so it was not possible to evaluate effects of L1 proficiency. Participants' English reading proficiency was assessed with the passage comprehension subtest of the Woodcock–Johnson III and proficiency ranged from third grade level to postcollegiate level [25, 44] with an average reading level of ninth grade for native (M = 34.7, SD = 4.9, [25, 44]) and seventh grade for nonnative (M = 33.4, SD = 3.4, [28, 40]) signers. To investigate effects of English proficiency on the experimental task, participants were divided into two groups: those reading at or below eighth grade equivalency (n = 14, [25, 34]) and those reading above eighth grade equivalency (n = 11, [35, 44]).

Materials

Sentences were the same as those employed in Wilson and Garnsey (2009). They were constructed by using 40 verbs, 20 SC-bias verbs (see examples 5–7), and 20 DO-bias verbs (see examples 8–10). Each verb appeared embedded in three sentence types: an ambiguous SC-continuation (illustrated in examples 5

Table 2. Participant background Study 2 (N = 25, 56% female)

	Mean (*SD*)
Age	22 (3.8)
Self-rated ASL comprehension[a]	9.4 (1.1)
Self-rated ASL production	8.8 (1.4)
Self-rated English writing	7.3 (1.3)
Self-rated English reading	7.9 (1.5)
Woodcock–Johnson III, Subtest 9	34.1 (4.3)

Note. ASL = American Sign Language.
[a]All self-ratings were made on a scale of 0 (*not at all*) to 10 (*excellent*).

and 8), an unambiguous SC-continuation (see 6 and 9, in which the complementizer *that* unambiguously signals to the reader that the postverbal noun is a sentential subject), and an ambiguous DO-continuation (see 7 and 10). Each presentation of a particular verb contained a different subject and postverbal noun. All postverbal nouns were highly plausible as DOs of the verbs they followed.[1] Each participant read 13 sentences in each of the conditions exemplified in (5)–(10), for a total of 78 experimental sentences. Sentence onsets and the first NP following the verb were held constant across all ambiguous SC-complement and DO-complement continuations such that the syntactic ambiguity could only be resolved when readers saw the text following the postverbal NP (e.g., *might not* or *because she* in examples 5–10). This region is underlined in (5)–(10) and will be referred to as the disambiguating region.

(5) SC bias verb + SC-continuation (ambiguous):
The ticket agent admitted the mistake might not have been caught.
(6) SC bias verb + SC-continuation (unambiguous):
The ticket agent admitted that the mistake might not have been caught.
(7) SC bias verb + DO-continuation (ambiguous):
The ticket agent admitted the mistake because she had been caught.
(8) DO-bias verb + SC-continuation (ambiguous):
The talented photographer accepted the money might not be legally obtained.
(9) DO-bias verb + unambiguous SC-continuation (unambiguous):
The talented photographer accepted that the money might not be legally obtained.
(10) DO-bias verb + DO-continuation (ambiguous):
The talented photographer accepted the money because he was asked twice.

In addition to the 78 experimental sentences, participants also read 10 practice sentences and 44 filler sentences, for a total of 132 sentences. Filler sentences consisted of 22 subject relative clauses and 22 object relative clauses (see Piñar et al., 2015).

Three lists were created with 78 experimental sentences representing each of the conditions in (5)–(10), 44 fillers, and 10 practice sentences. The lists were created such that each verb appeared twice during a list, except for two verbs that only appeared once to allow for the even distribution of the experimental items (78 in total). Each list contained exactly one version of each experimental sentence and equal numbers of items in each condition.

Study 2 included fewer verbs than were used in Study 1. Focusing only on the subset of 40 verbs used in Study 2, we compared the verb bias classifications with those reported in the norming study by Garnsey, Lotocky, et al. (1997). Results indicate that 11/40 (28%) English verbs differed in their verb bias assignment between ASL–English bilinguals and English monolinguals, but only one verb (*emphasized*) changed category. No verbs showed a stronger bias (changing from either equal or no bias in the monolingual English data to either DO or SC for the bilinguals) and 10 showed a weaker bias (changing from either a DO or SC bias for monolinguals to equivalent or no bias categories).

Procedure

Participants' eye movements were recorded using an Eyelink 1000 eyetracker (SR Research, Toronto, Ontario, Canada) while they read the 78 experimental and 44 filler sentences, presented on a computer monitor one by one. Sampling rate of the equipment was 1,000 Hz. A chin rest was used to prevent head movement. Participants were asked to read sentences that appeared on a single line on a computer screen. A calibration procedure was performed after participants received instructions to read the sentences at a normal pace for comprehension. The experiment was divided into two halves, with a programmed break when the participant reached the midpoint of the experiment. Participants were recalibrated at the onset of the second half of the task. Recalibration was also performed at mid points during each of the two halves and if track loss occurred at any point during the experiment. A yes/no comprehension question followed each sentence. For example: Stimulus sentence: *The talented photographer accepted the money because he was asked twice*. Comprehension question: *Was the photographer offered money?* Participants answered by clicking either a YES or a NO button. Response accuracy was automatically recorded. Following a long-standing convention in the sentence processing literature, no feedback was provided on the participants' response because feedback can potentially influence the strategies participants engage in during reading.

Results

Eye-tracking fixations were analyzed for three regions of the target sentences: the verb (admitted/accepted), the postverbal noun phrase (the mistake/the money), and the subsequent disambiguating region (underlined in the examples above). Dependent measures included (a) gaze duration, defined as the sum of all fixations beginning with the first fixation in a region until the reader's gaze leaves the region, left or right, (b) regression path time, defined as the sum of all fixations in a region plus subsequent fixations to the left of that region until the reader's gaze leaves the region to the right, (c) total time, defined as the sum of all fixations in a region at any time, including any regressions back to that region, and (d) number of regressions. As is standard practice, sentences that received an incorrect response were excluded from the analysis, as were fixations that were 2 *SD*s from each participant's mean for each dependent measure. Participant and item means were replaced with the condition means for any cell with fewer than three measurements. Average accuracy was 81%.

The experimental design incorporated three factors: verb bias (SC- vs. DO-bias verbs), ambiguity (ambiguous vs. unambiguous constructions), and sentence continuation (SC vs. DO continuation). Due to the incomplete crossing of the experimental design (i.e., it is not possible to construct sentences with unambiguous DO-continuations), two ANOVAs were completed for each dependent measure and for each region of interest (verb, postverbal NP, disambiguating region). The first set of ANOVAs investigated the effect of verb bias on the parsing of ambiguous or unambiguous SC constructions. This ANOVA was conducted on sentences (5) and (6) versus (8) and (9). The second set of ANOVAs investigated the effect of verb bias on the parsing of SC and DO constructions. This analysis was conducted on sentences (5) and (7) versus (8) and (10). When the between-participant factor of English proficiency was included in the ANOVAs, the main effect of language proficiency on all four dependent measures (gaze duration, regression path time, total time, and number of regressions) in all regions of interest (the verb, noun phrase, and disambiguating region) was <1, ns. No significant interactions of language proficiency in English with verb bias, ambiguity, or continuation were found, possibly due to insufficient power.

Verb bias × ambiguity effects

In this first set of ANOVAs, we investigated whether deaf ASL–English bilinguals would take advantage of verb bias information to anticipate the sentence continuation in a single syntactic environment (SC). Half of the sentences were unambiguous due to the presence of the complementizer, whereas half of the sentences were ambiguous because no complementizer was included. If readers are sensitive to verb bias information, they should anticipate a SC structure following SC-bias verbs and display no delays at the disambiguating region for either ambiguous or unambiguous sentences. By contrast, when reading sentences with DO-bias verbs, readers should have longer fixations on the ambiguous SC continuations, but not on the unambiguous continuations in which the complementizer *that* signals the SC continuation. In other words, participants who rely on verb bias cues during online parsing should exhibit an interaction of verb bias and ambiguity in the disambiguating region, with ambiguous SC continuations following DO-bias verbs presenting the greatest difficulty.

We tested these predictions with a 2 (DO-bias verb, SC-bias verb) × 2 (ambiguous SC continuation, unambiguous continuation) repeated measures ANOVA computed over participants (F1) and items (F2). Table 3 reports the gaze duration and Table 4 reports total time for the three regions of interest.

Contrary to our predictions, we did not find an interaction of verb bias and ambiguity on gaze duration in the disambiguating region. However, we found a main effect of verb bias on gaze duration in the disambiguating region, $F1(1,24) = 12.17$, $p < .01$, $\eta_p^2 = .34$, $F2(1,76) = 4.18$, $p < .05$, $\eta_p^2 = .05$. The disambiguating region was read more slowly in the presence of SC-bias verbs relative to DO-bias verbs. There were no other significant effects of bias or ambiguity on gaze duration that were significant in both the participant and the item analyses.

We also found a main effect of verb bias on total time in the verb region, $F1(1,24) = 6.51$, $p < .05$, $\eta_\pi^2 = .21$, $F2(1,76) = 3.91$, $p = .052$, $\eta_p^2 = .05$. Total fixations were longer on DO-bias verbs (431 ms) than SC-bias verbs (397 ms). There was not a significant effect of verb bias on gaze duration, that is, the initial fixation, in the verb region. These results may thus be an indication that the participants refixated the verb more often when the continuation did not match the bias of the verb, which was always the case for DO-bias verbs and never for SC-bias verbs. Barring this explanation, the finding is somewhat counterintuitive given that the DO-bias verbs are more frequent on average in both spoken (60 times per million words) and written (70) corpora[2] than the SC-bias verbs (29 spoken and 38 written). On the basis of frequency alone, the DO-bias verbs should have required less time for processing than the SC-bias verbs. Possible explanations for this effect are addressed in the discussion. No other effects of verb bias or ambiguity on total time, regression path time, or number of regressions were significant in both participant and item analyses.

Verb bias × continuation effect

The second set of ANOVAs compared reading times for sentences with SC-bias and DO-bias verbs in ambiguous SC- and DO-continuations. If readers are sensitive to verb bias information, they should assume that the postverbal noun phrase is the subject of a complement following SC-bias verbs and encounter difficulty when a DO-continuation follows the verb instead. Likewise, following DO-bias verbs, participants should assume that the postverbal NP is a DO and exhibit difficulty parsing a SC continuation. In sum, for the second analysis, we predicted an interaction of verb bias and continuation. We tested these predictions with a 2 (DO-bias verb, SC-bias verb) × 2 (DO-continuation, SC-continuation) repeated measures ANOVA computed over participants (F1) and items (F2).

Contrary to prediction, no significant effects of verb bias or continuation on gaze duration were found in the disambiguating region. Further, no effects were found in the verb region. However, we found an interaction of bias and continuation on gaze duration in the postverbal noun phrase region, $F1(1,24) = 6.28$, $p < .05$, $\eta_p^2 = .21$, $F2(1,76) = 4.81$, $p < .05$, $\eta_p^2 = .06$. Pairwise comparisons revealed that participants had significantly longer fixations on the NP region in DO-continuations than in SC-continuations following SC-bias verbs, $p < .01$ (Figure 4). No such difference was found for the two continuations following DO-bias verbs. In summary, an interaction of bias and continuation was found, but paired comparisons indicate that participants may only have benefited from verb bias for SC-bias verbs and that benefits were found in the postverbal NP region rather than the predicted disambiguating region.

Table 3. Gaze duration in milliseconds (*SD*) by condition and region

Condition	Verb	Postverbal NP	Disambig. region
SC-bias + “that” + sentential complement	320 (71)	355 (75)	364 (101)
SC-bias + sentential complement	332 (81)	328 (67)	332 (74)
SC-bias + direct object	355 (102)	380 (95)	344 (93)
DO-bias + “that” + sentential complement	357 (95)	356 (71)	311 (87)
DO-bias + sentential complement	323 (76)	369 (106)	313 (67)
DO-bias + direct object	330 (94)	373 (96)	348 (110)

Note. SC = sentential complement; DO = direct object; NP = noun phrases.

Table 4 Total time in milliseconds (*SD*) by condition and region

Condition	Verb	Postverbal NP	Disambig. region
SC-bias + “that” + sentential complement	383 (93)	426 (120)	418 (125)
SC-bias + sentential complement	411 (123)	393 (116)	403 (123)
SC-bias + direct object	462 (147)	468 (149)	424 (117)
DO-bias + “that” + sentential complement	424 (136)	420 (118)	367 (139)
DO-bias + sentential complement	437 (165)	443 (178)	393 (144)
DO-bias + direct object	433 (134)	427 (132)	408 (158)

Note. SC = sentential complement; DO = direct object; NP = noun phrases.

There was also a main effect of continuation on regression path time for the NP region, F1(1, 24) = 4.92, $p < .05$, $\eta_p^2 = .17$, F2(1,76) = 5.99, $p < .02$, $\eta_p^2 = .07$. Readers fixated on the NP and preceding regions prior to continuing to the disambiguating region longer in DO-continuations (446 ms) than in SC-continuations (395 ms). No other significant effects of bias or continuation were found on regression path time or number of regressions in any region. Table 5 reports regression path time for the three regions of interest.

In the follow-up analysis of total time, there was also an interaction of continuation and bias, F1(1,24) = 8.79, $p < .01$, $\eta_p^2 = .27$, F2(1,76) = 12.17, $p < .001$, $\eta_p^2 = .14$. Pairwise comparisons indicated longer total fixations on the NP region in DO-continuations (468 ms) than in SC-continuations (393 ms) following SC-bias verbs, $p < .001$, and in SC-continuations following DO-bias (443 ms) than SC-bias (393 ms) verbs, $p < .02$. This finding parallels the results for gaze duration, indicating an advantage for processing SC-continuations following SC-bias verbs in their predicted syntactic context over all other sentence types.

Discussion

The results of Study 2 are more equivocal than Study 1, raising a number of new questions as to the nature of the primary cues used to guide L2 sentence parsing in ASL–English bilinguals. They do, however, indicate that verb bias is a cue to sentence structure for some, but not all, verbs. Fixation patterns across the three regions of interest differed following SC-bias and DO-bias verbs. Contrary to our predictions, those differences occurred when participants fixated the postverbal noun phrase, one fixation earlier than has been found in studies of hearing readers, and particularly for SC-bias verbs. A novel and unanticipated finding of the results is that ASL–English bilinguals appear to find DO constructions more cognitively taxing than SC constructions. Total time fixating the verb was longer for DO-bias than for SC-bias verbs, and regression path time was longer for the postverbal NP in DO-continuations than in SC-continuations.

These results differ in two fundamental ways from prior studies evaluating the effects of verb bias. A convincing account of the use of a verb bias cue by deaf ASL–English bilinguals must explain why these effects occur earlier within the sentence and why the effects are found only for SC-bias verbs. An explanation of the timing of verb bias effects is informed by recent findings from other eye-tracking studies with deaf readers that indicate a unique profile for eye fixation patterns in deaf individuals related to both visual attention and language proficiency. These studies find that highly skilled deaf readers have shorter fixations and a wider perceptual span than hearing readers of comparable reading levels (Bélanger, Slattery, Mayberry, & Rayner, 2012) and that deaf readers skip more words and often do not fixate words in sequence (Piñar et al., 2015). This growing body of literature could explain why apparent, early effects of verb bias are observed when deaf readers fixate the postverbal NP rather than the disambiguating region. If deaf skilled readers have a wider perceptual span than hearing readers, they may actually begin processing words in the disambiguating region during fixations on the postverbal NP. This explanation, however, is not without complications. Namely, a wider perceptual span has only been documented in deaf ASL–English bilinguals with

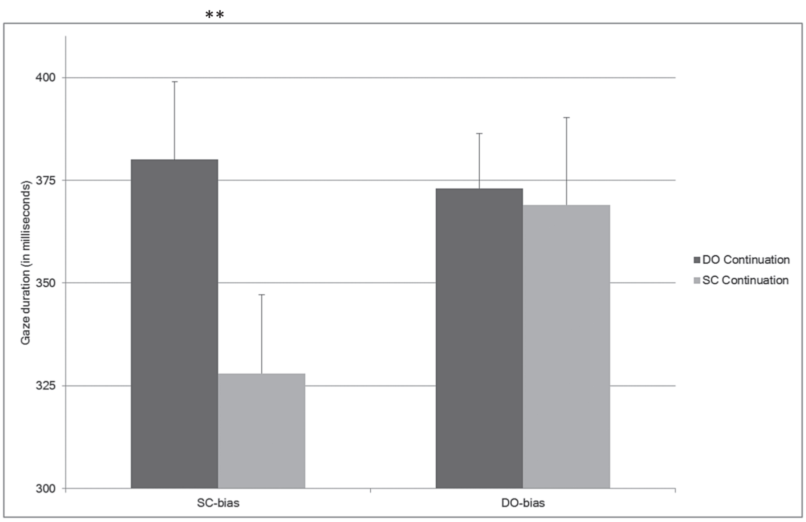

Figure 4. Gaze duration by bias and continuation on the postverbal noun phrase. **$p < .01$.

Table 5. Regression path time in milliseconds (*SD*) by condition and region

Condition	Verb	Postverbal NP	Disambig. region
SC-bias + “that” + sentential complement	418 (152)	436 (154)	412 (128)
SC-bias + sentential complement	420 (135)	388 (115)	384 (121)
SC-bias + direct object	452 (180)	429 (127)	430 (157)
DO-bias + “that” + sentential complement	451 (155)	412 (146)	360 (145)
DO-bias + sentential complement	438 (174)	402 (150)	380 (136)
DO-bias + direct object	438 (123)	463 (197)	384 (121)

Note. SC = sentential complement; DO = direct object; NP = noun phrases.

high levels of proficiency in their second language. Participants in our study ranged in reading level from third grade to postcollegiate, and attempts to distinguish fixation patterns by English proficiency level did not indicate differences across the more and less proficient bilinguals. It is unclear why there was no effect of English proficiency level on the pattern of fixations as would be predicted if only the most proficient readers were able to extract more detailed information from words to the right of fixation. ASL proficiency ratings also failed to predict differences in fixation patterns.

Participants were also slower to read the disambiguating region of SC-continuations following SC-bias verbs than DO-bias verbs, contrary to expectation. Consistent with the explanation we propose for the pattern of fixations in the NP region, this result may signal the participants' sensitivity to the region *following* the disambiguating region while fixating on the disambiguating region. The word following the disambiguating region (DR + 1) was not controlled in our materials (cf. Wilson & Garnsey, 2009). Although the word length of this word is not systematically longer in the SC-continuations following SC-bias verbs than following DO-bias verbs, words in this position are highly variable in length (1–11 letters), and there is a wider range of word length in this position in the SC-continuations following SC-bias verbs [1, 11] than following DO-bias verbs [1, 8]. If the wider perceptual span of the deaf readers is influencing their fixation patterns, effects in the DR region may reflect sensitivity to subsequent words in the stimulus sentences.

Even if we accept that the interaction of verb bias and continuation on the noun phrase instead of the disambiguating region is the result of a wider perceptual span and associated changes in fixation patterns in deaf readers, the finding of the predicted effect following SC-bias verbs and not DO-bias verbs must still be explained. One possibility is that the bilingual status of the participants is influencing their processing of SC-bias verbs and DO-bias verbs differently. Bilinguals, in general, have different levels of exposure to language than monolinguals because their experience is distributed across two (or more) languages. In the case of deaf ASL–English bilinguals, this different distribution is further shaped by the fact that most face-to-face communication relies on ASL or concurrent exposure to ASL and forms of spoken English that are likely to be only partially accessible. Written communication, by contrast, is entirely in English. If differences in exposure to English influenced our study results, we could provide corroborating evidence in one of two ways. First, if English verbs have different distributional characteristics in spoken versus written corpora, we could modify our study to reflect verb biases based only on written corpora. This route seems unlikely to provide a satisfactory account of the results found here. A prior investigation of the stability of verb bias estimates across corpora and elicitation methods (Gahl et al., 2004) indicates that very few verbs change bias across spoken and written corpora and that these biases are largely consistent with those used by Garnsey, Pearlmutter, et al. (1997) and Wilson and Garnsey (2009).

Alternatively, it is possible that deaf ASL–English bilinguals associate different syntactic structures with English verbs than hearing monolinguals, perhaps due to the subcategorization frames associated with the ASL translation equivalents of the English verbs. However, this possibility is not supported by the results of Study 1, which showed high correlations between elicited responses of ASL–English bilinguals and hearing English monolinguals to SC- and DO-bias verbs, nor by the fact that only one verb switched bias category as previously discussed.

In sum, Study 2 suggests that deaf ASL–English bilinguals rely on verb bias as a cue to sentence structure in the second language, but not for all verb types. Variability in fixations may be an indication of differences in processing DO and SC structures in English. Surprisingly, sentences displaying the more complex of these two structures, SC structures, were read more efficiently than sentences displaying the simpler syntactic structure, DO complements.

Conclusion

In two studies, we investigated whether deaf ASL–English sign–print bilinguals show sensitivity to an implicit syntactic cue in their second language, English. The study brings two important innovations to the study of sentence processing by deaf signers. First, the study uses sensitive online measures of syntactic processing (cf. Piñar et al., 2015; Kelly, 2003; Traxler et al., 2014) that have rarely been used with deaf participants. Second, the study addresses sentence processing in a bilingual framework, considering how syntactic cues are deployed in a second language while controlling for first language proficiency. Although our measures of ASL proficiency did not predict differences in fixation patterns in our participant pool, the results indicate that exposure to a second language primarily via print is sufficient to influence use of implicit frequency-based characteristics of a language in production and also to inform parsing decisions in comprehension for some, but not all, verbs.

Study 1 indicated that deaf ASL–English bilinguals correlate with hearing English monolinguals in the production of sentence structures that match verb bias more closely than do hearing Spanish–English bilinguals. Both groups of bilinguals generate sentence continuations that are well matched to a verb's typical syntactic environment. When Spanish–English bilinguals diverge from this pattern, they demonstrate a preference for a simpler grammatical structure, a DO-continuation. Deaf ASL–English bilinguals, interestingly, tend to produce more SC structures than either hearing monolinguals or hearing Spanish–English bilinguals.

In Study 2, ASL–English bilinguals read English sentences with verbs that are more typical or less typical of the subsequent sentence continuation. Gaze duration and total time were measured while participants viewed three sentence regions: the verb, the postverbal noun phrase, and the subsequent disambiguating region. The verb and postverbal noun phrases were matched across sentence conditions, such that sentences did not differ until the disambiguating region. Prior eye-tracking studies of hearing English monolinguals and hearing Spanish–English bilinguals using the same stimuli indicate a slowing of processing in the disambiguating region where participants discover that the verbs are used in a less typical manner. This pattern from prior studies has been used to argue that English monolinguals and Spanish–English bilinguals anticipate the upcoming sentence structure on the basis of the frequency with which verbs occur in their typical syntactic environments. ASL–English bilinguals displayed a different pattern of eye fixations across these sentences. Participants exhibited shorter gaze duration on the postverbal NP when SC-bias verbs were paired with SC-continuations relative to the other conditions. Further, two measures suggested a general slowing of processing associated with DO structures. Participants fixated DO-bias verbs longer than SC-bias verbs in ambiguous and unambiguous SC continuations, and participants fixated the postverbal NP longer in DO-continuations than in SC-continuations after having viewed the disambiguating region (i.e., total time measure).

Together, the studies suggest that exposure to print is sufficient to detect distributional patterns impacting subcategorization frames in a second language. Despite detection of these characteristics, deaf ASL–English bilinguals may not always utilize this knowledge strategically to anticipate sentence structure. Further, the results of the two studies combined reveal the unanticipated finding that deaf ASL–English bilinguals prefer a complex syntactic structure, SCs, to a simpler syntactic structure, DO complements, in their second language. Our conclusions are necessarily tentative because this is the first study to investigate sensitivity to verb bias in deaf bilinguals and because this population is different in important respects from others who have been studied previously using the experimental paradigms we selected.

One reason for the tentative nature of our conclusions concerns the fact that there is good reason to question the interpretation of eye-tracking data for deaf participants relative to the use of these measures to evaluate sentence processing in hearing readers. A reliance on visual sensory information to the exclusion of auditory experience causes changes in visual perception and accompanying social and cognitive adaptations (Corina & Singleton, 2009). These include, but are not limited to, changes in the allocation of attentional processing from central space to peripheral space when these two are in competition (Dye, Hauser, & Bavelier, 2008). It is often assumed that a lack of auditory experience should lead to enhanced visual ability, but Bavelier, Dye, and Hauser (2006) demonstrate that visual enhancements are selective rather than general and typically affect domains where hearing individuals rely on cross-modal integration of audition and vision. Both deaf and hearing children, for example, develop foveal detection earlier than peripheral (parafoveal) detection. Deaf adults, however, allocate more visual attention to the periphery compared to hearing adults, presumably because hearing individuals rely more on auditory cues to monitor the periphery. Hearing native signers do not show this adaptation, indicating that it is related to the primacy of visual interaction with the world, rather than sign language experience. For our studies, this difference in the organization of visual attention is relevant because it may impact the way that deaf bilinguals select portions of text in the service of L2 sentence processing (Bélanger et al., 2012). Though the lion's share of the act of reading comes from words fixated in foveal vision, preprocessing takes place in peripheral vision and the particular information extracted during parafoveal processing differs for deaf and hearing readers (Bélanger, Mayberry, & Rayner, 2013). This preprocessing informs readers about where to fixate next and can speed up processing of target words once they are fixated directly.

Differences in fixation patterns for deaf and hearing readers may account in part for the unexpected pattern of results in Study 2. Specifically, the results indicate a different time course for extracting lexical content from sentences in deaf as opposed to hearing readers. Although differences in the visual attentional profile of our participants may account for the novel pattern of fixations during sentence parsing we found in deaf ASL–English bilinguals compared to other groups, visual attention is unlikely to explain the preference our participants demonstrated for SCs over DO complements. This result is surprising given that SCs are syntactically more complex than DO complements. However, deaf participants were more likely to produce SCs than DO complements in the elicitation task, and they anticipated SCs in the eye-tracking task on the basis of the verb. Our study is not the first to document faster processing of syntactically more complex structures in L2 parsing by deaf ASL–English bilinguals. Traxler et al. (2014) found that deaf ASL–English bilinguals read passive-voice sentences faster than active-voice sentences in a self-paced reading task.

MacDonald and Christiansen (2002) propose that differences in language proficiency are intrinsically related to the role of experience. Specifically, they observe that the frequency of exposure to a given linguistic structure interacts with its regularity—how similar it is to other language patterns. This creates apparently qualitative differences in performance. The regularity by frequency interaction means regular constructions depend less on language experience and extensive exposure than do irregular ones. This theory helps explain why L2 learners exhibit the capacity to develop sensitivity to complex L2 distributional cues because overall exposure can circumvent the challenge of learning "more difficult" patterns. This argument inherently supposes that language users compare stimuli to the sum of previous experience. It is therefore perfectly reasonable to conjecture that L2 input would be compared not only to previously experienced L2 structures but also to entrenched L1 language patterns. L1 experience would have the capacity to shape L2 processing in various ways, such as our explanation of the role of syntactic prominence elaborated in the Discussion section of Study 1.

More globally, ASL signers may not rely on the primarily linear, collocational frequency cues in comprehension that are intrinsic to the sequential nature of the aural/oral mode of communication in such phenomena as verb bias, the predictability of lexical items in idioms (Fillmore, Kay, & O'Conner, 1988), prefabricated language (Bybee, 2006), pragmatic coherence relations (Rohde, Levy, & Kehler, 2011), and so on. Rather, they may rely on comprehension strategies better suited to the visual/manual mode, managing conceptual–spatial interactions between content units like those that exist in classifier constructions (Emmorey, 2002), locational buoys (Liddell, 2003), or iconic lexical items (Thompson, Vinson, & Vigliocco, 2009). Importantly, the results of both Studies 1 and 2 point to the conclusion that deaf ASL–English bilinguals' sensitivity to and processing of L2 syntax may be related as much to L1 experience as to syntactic complexity.

Further research is needed to explore the parsing strategies common for ASL, rather than focusing exclusively on deaf ASL–English bilinguals' behavior in English parsing tasks. Additionally, studies that explore the interaction of ASL typology with L1 and L2 sentence processing are sparse, and this knowledge is needed to adequately elucidate the language comprehension strategies and patterns of this unique population.

Supplementary Data

Supplementary material is available at http://jdsde.oxfordjournals.org/.

Notes

1. See Wilson and Garnsey (2009) for details on the criterion followed to norm the plausibility of the postverbal nouns.
2. Frequencies are based on the spoken and written portions of the Corpus of Contemporary American English (http://corpus.byu.edu/coca/). Because the corpus is constantly being updated, the values reported in this article may change in future searches of the corpus.

Conflicts of Interest

No conflicts of interest were reported.

Funding

National Science Foundation Science of Learning Center Program (SBE-0541953, SBE-1041725). Any opinions, findings, and conclusions or recommendations expressed are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Acknowledgments

We thank the participants of our research as well as Yunjae Hwang, Richard Bailey, Brian Burns, Jeannine Kammann-Cessac, and Corrine Occhino-Kehoe for help in data coding and collection. Portions of this study were presented at the Fifth Inter-Science of Learning Center Conference, Theoretical Issues in Sign Language Research 11, London, England, and at the Society for Research in Child Development Conference, Seattle, WA.

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Appendix: Coding Rubric Study 1

Material	Code
V…NP	DO
V…that	SC
V…NP VP	SC
V…adv NP	DO
V…adv that	SC
V…PP	PP
V…to+V	INF
V…reflexive	REF
V…relative pronoun	REL
V…+particle	PRT
V…V+ing	GER
V…*else*	NNP
V…NP to+V	INF
V…NP V+ing	GER
Unknown	?