EMPIRICAL STUDY

Lexical-Semantic Organization in Bilingually Developing Deaf Children with ASL-Dominant Language Exposure: Evidence From a Repeated Meaning Association Task

Wolfgang Mann,[a, b] Li Sheng,[c] and Gary Morgan[b]

[a]University of Roehampton, [b]City University London, and [c]University of Texas at Austin

This study compared the lexical-semantic organization skills of bilingually developing deaf children in American Sign Language (ASL) and English with those of a monolingual hearing group. A repeated meaning-association paradigm was used to assess retrieval of semantic relations in deaf 6-10 year-olds exposed to ASL from birth by their deaf parents, with responses coded as syntagmatic or paradigmatic. Deaf children's responses in ASL and English were compared at the within-group level, and their ASL was compared to the English responses of age-matched monolingual hearing children. Finally, the two groups were compared on their semantic performance in English. Results showed similar patterns for deaf children's responses in ASL and English to those of hearing monolinguals, but subtle language differences were also revealed. These findings suggest that sign bilinguals' language development in ASL and English is driven by similar underlying learning mechanisms rooted in the development of semantic frameworks.

Keywords sign bilingual; vocabulary knowledge; semantic development; lexical-semantic organization; word association; deaf

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Correspondence concerning this article should be addressed to Wolfgang Mann, University of Roehampton, School of Education, Roehampton Lane, London, SW15 5PJ, United Kingdom. Email: wolfgang.mann@roehampton.ac.uk

Introduction

The acquisition of word meanings is a fundamental aspect of language development, and once children have begun to acquire lexical items, how they organize their steadily growing vocabulary into an efficient system is of great interest (e.g., Bloom, 2002). Until recently, theories of lexical development were based on only typically hearing children acquiring spoken languages (see Clark, 1993, for a review of lexical acquisition). It is of interest if these findings relate also to deaf children acquiring a signed language (e.g., British Sign Language, Woll, 2013).

Previous research has investigated how children acquire basic organizational principles (e.g., thematic and taxonomic relations between words), focusing on developmental changes in the use of these semantic links (Markman, 1991; Waxman & Gelman, 1986). This work established that children form semantic networks through the combination of strong links between words that are closely related and weaker links between words that share fewer semantic relations (see Clark, 2009, for a review). This development of networks also has an effect on semantic memory as it enables individuals to structure information in such a way that it can be later searched more efficiently. These changes in vocabulary storage are therefore linked to children's developing memory efficiency, growth in speed of retrieving lexical items from the memory store, and faster assimilation of world knowledge (Gathercole, 2003).

Many studies have indicated that hearing children's general experience of overhearing language and conversation are linked to vocabulary acquisition (Akhtar, Jipson, & Callanan, 2001) including in non-Western cultures where children are often not directly addressed by their parents (Lieven, 1994). Studies using single-word association tasks to measure children's semantic knowledge have also shown that children are apt to produce word associations of both syntagmatic and paradigmatic nature (Nelson, 1977). Syntagmatic responses are words that follow the stimulus in a syntactic sequence (e.g., *cold-outside*) or words that share a thematic relationship with the stimulus (e.g., *cold-sweater*, *cold-winter*); whereas paradigmatic responses are words from the same word class (or paradigm) as the stimulus (e.g., *cold-hot*) (Sheng, McGregor, & Marian, 2006). Both response types bear clear semantic relations to the stimulus, but syntagmatic responses may be derived from tangible perceptual and conceptual experiences, whereas paradigmatic responses represent more abstract linguistic relationships. Hence, paradigmatic responses have sometimes been regarded as developmentally more mature (Lippman, 1971; Nelson, 1977).

Lexical-Semantic Organization in Monolingual Children

Children are exposed to massive amounts of information as they are acquiring much of their vocabulary in the school years. A typical school-age child acquires 3,000-5,000 new words each year or about 10 to 13 words per day (Miller & Gildea, 1987). It has been suggested that children utilize both linguistic and perceptual types of information when acquiring the meaning of a lexical item (Nelson, 1991). This is based on the idea that knowledge of word meaning is understood as the interconnected range of a learner's different associations with that word, including linguistic and perceptual associations.

One way of modeling lexical-semantic organization is by means of a network of nodes, links, and spreading activation (Collins & Loftus, 1975). Different words, or nodes, are linked to other nodes that share semantic relationships. The strength of these links varies, depending on the degree of meaning overlap between words and/or the frequency of co-occurrence of words. For instance, upon hearing the word *dog*, the conceptual node representing that word is activated. Then the activation spreads such that nodes bearing strong links to the activated node (e.g., *cat* or *animal*) are immediately activated and are produced early on in free or continuous word association, whereas weakly linked nodes (e.g., *leash*) receive a smaller and/or delayed activation and are produced later in free or continuous word association (Sheng & McGregor, 2010). A mature network will consist of many links with the strength of the activation diminishing the further it moves away from its core. This effect of spreading activation has been observed and reported in many studies and under different experimental conditions for first (L1) and second (L2) language (for a review, see McNamara & Holbrook, 2003).

In another approach, the single (or discrete) word association task, which is widely used in L1 and L2 research, has been extended to elicit more than one response (Elbers & van Loon-Vervoorn, 1998). This technique requires participants to generate three or sometimes four different associations to a single word prompt. The repeated nature of this task allows measurement of both storage (i.e., overall number of paradigmatic and syntagmatic responses) and accessibility (i.e., relative frequency of responses at each elicitation point) of different types of semantic relations. In studies that have utilized the repeated word association task, individuals are usually found to generate fewer and fewer semantic responses in each additional elicitation trial, indicating that access of semantic relations, particularly paradigmatic relations, becomes progressively more difficult as semantic activation travels along the network (Elbers & van Loon-Vervoorn; Sheng & McGregor, 2010).

Lexical-Semantic Organization in Bilingual Children

Lexical-semantic organization in typically developing hearing bilingual children has been studied using the repeated word association task (Sheng et al., 2006; Sheng, Bedore, Peña, & Fiestas, 2013). In Sheng et al. (2006), Mandarin-English bilingual children produced similar numbers of paradigmatic responses in their L1 (Mandarin) and L2 (English). When cross-group comparisons were made, the bilingual children were found to generate a comparable number of paradigmatic associations as monolingual English-speaking children. Production of syntagmatic responses was not compared in this study, but descriptive statistics showed a higher number of syntagmatic than paradigmatic responses in all groups and all languages. In addition, whereas paradigmatic responses decreased across elicitation trials, syntagmatic responses remained stable or increased.

In another study, Sheng et al. (2013) examined the effect of age and language experience on Spanish-English bilingual children's association performance. Four groups of children who differed in their chronological age and amount of English/Spanish use participated. Age affected the production of paradigmatic responses but not syntagmatic responses. Older children produced more paradigmatic responses than younger children, but the two groups did not differ significantly on syntagmatic responses. On the other hand, amount of language use had an effect on both paradigmatic and syntagmatic performance. The groups with high English experience generated more paradigmatic and syntagmatic responses in the English task than those with high Spanish (low English) experience. The opposite was true in the Spanish task: The high English experience groups produced fewer paradigmatic and syntagmatic responses than the high Spanish experience groups.

Studying Semantic Networks in Signing Deaf Children

As described, most studies targeting the development of semantic networks have focused on hearing children learning spoken languages. In comparison, very little is known about this in deaf child users of signed languages (Marshall, Rowley, & Atkinson, 2014). Most deaf signers, particularly those in Western or urban societies, are bilingual to some degree as they may be exposed to signs while, at the same time, acquiring the language of the linguistic majority. Lexical acquisition in sign bilingual deaf populations is interesting because it provides both a means of studying language acquisition in itself and a way of comparing language acquisition across different contexts of age of first exposure. Only a small percentage of deaf children (5-10%) have deaf parents and receive signed language input from birth (Mitchell & Karchmer, 2004). These children reach developmental milestones in their signed language at a pace that is comparable to that of hearing children learning spoken languages (Corina & Singleton, 2009; Morgan & Woll, 2002; Newport & Meier, 1985; Schick, 2003), and their vocabulary growth patterns during the first years have been reported to be similar (Anderson & Reilly, 2002; Woolfe, Herman, Roy, & Woll, 2010).

The study of sign bilingual deaf children's lexical-semantic knowledge allows researchers to raise and explore issues that would not and could not be raised if human languages were confined only to the spoken modality (Meir, 2012). Deaf children learning a signed language experience a different type of acquisition. For example, American Sign Language (ASL) and other sign languages lack a standardized written form (Meir, 2012), leaving deaf children without this resource for augmenting their face-to-face learning experiences (Goldin-Meadow & Mayberry, 2001). In addition to an overall smaller lexicon in signed languages (e.g., ASL) compared to the lexicon of spoken languages (e.g., English), both the number of users of a given signed language as well as the contexts by which signed language can be observed are very reduced compared to those for spoken language. As a result, little is known about whether deaf children who use a signed language have similar experiences to their hearing peers in learning new lexical items through formal or informal ways (Marschark & Wauters, 2008). Despite these different experiences in learning language by deaf children, many studies of ASL and other sign languages have suggested similar developmental trends to those reported for spoken languages. This research includes studies of ASL (Novogrodsky, Caldwell-Harris, Fish, & Harris, 2014; Novogrodsky, Fish, & Hoffmeister, 2014), British Sign Language (BSL, Mann & Marshall, 2012; Marshall, Rowley, Mason, Herman, & Morgan, 2013; Mason et al., 2010), and Italian Sign Language (Tomasuolo, Fellini, Di Renzo, & Volterra, 2010). For instance, recent research on lexical semantic acquisition in ASL by Novogrodsky and colleagues explored depth of lexical knowledge in deaf children aged 4-18 years, specifically the acquisition of synonyms (Novogrodsky, Fish, et al., 2014) and antonyms (Novogrodsky, Caldwell-Harris, et al., 2014). Children's performance on a set of receptive multiple choice tasks revealed similar developmental trajectories as those reported for hearing children acquiring a spoken language, including growing reliance on semantic knowledge and less on phonological knowledge (Novogrodsky, Fish, et al., 2014). Similarly, a study on semantic knowledge in BSL by Marshall and colleagues (2013) showed an increase in deaf children's productivity and semantic clustering of responses in their signs in BSL on a semantic fluency task.

The Current Study

While the extant literature on bilingual deaf children's semantic knowledge in sign language has reported similar organization of the lexicon in signed languages to that of spoken languages, studies that have directly compared lexical-semantic organization in deaf children's L1 (signed language) and their L2 (spoken language) are rare. Although deaf children with deaf parents are native and fluent users of their L1, that language is not the language that they are learning to read and use with the wider, hearing community. Therefore, we examined the accessibility of semantic information in bilingually developing deaf children with ASL-dominant language exposure and in monolingual hearing children, using a repeated word association paradigm. Our main goals were: (a) to investigate the status of lexical-semantic organization, specifically the number and accessibility of paradigmatic and syntagmatic relations in L1 (i.e., ASL) of deaf children with deaf parents (referred to as native signers) in relation to their L2 (i.e., English), and (b) to compare deaf children's lexical-semantic organization in both ASL and English to hearing children's lexical-semantic organization in English.

With regard to the first goal, we hypothesized that deaf children would generate an overall larger number of paradigmatic and syntagmatic relations in ASL compared to English due to their earlier access to sign but show similar accessibility of these types of semantic relations in both languages/modalities over multiple elicitation trials.[1] With regard to the second goal, we expected that deaf native signers' proportion of generated semantic responses in ASL, but not in English, would be similar to those of the hearing controls, with activation patterns in both modalities showing a similar spread and also comparable frequency of response to hearing peers. Between-group differences in semantic performance for English were expected due to deaf children's having limited access to the auditory base that normally hearing children have access to (Goldin-Meadow & Mayberry, 2001).

To compare deaf ASL-English bilinguals with hearing English monolinguals, we first explored deaf bilinguals' semantic performance in ASL and English across multiple elicitation trials, using a repeated word association paradigm adapted from Sheng, Peña, Bedore, and Fiestas (2012). For this analysis, we calculated the mean percentage of different types of responses (i.e., paradigmatic and syntagmatic). Second, we examined changes in the relative frequency of responses in ASL and English for deaf bilinguals and in English for hearing monolinguals at each elicitation point. In addition, we investigated possible effects of vocabulary size (an index of general language/verbal ability) on children's ability to form semantic links. Given the posited close relationship between abstract paradigmatic responses and decontextualized verbal explanation, we expected to find the ability to form paradigmatic associations to be strongly correlated with vocabulary. Lastly, we examined the effects of age in our analysis of children's performances, given the relatively wide age range of the deaf sample (6-10 years).

Method

Participants

The group of deaf participants (D) consisted of 12 children (5 boys) between the ages of 6 and 10 years (M = 8.7, SD = 1.0). They were recruited from a residential school for deaf children that provides ASL/English bilingual education. None of the children had any identified educational need (e.g., autism, attention deficit hyperactivity disorder, intellectual disability) other than deafness. All participants were exposed to ASL from birth by their deaf parent(s) and were thus considered to be native signers.

To determine participants' ASL proficiency, we used a questionnaire adapted from Quinto-Pozos, Forber-Pratt, and Singleton (2011) and Peña, Reséndiz, and Gillam (2007). Teachers (8 deaf, 2 hearing) rated participants' signed language proficiency at school based on vocabulary, sentence production, and comprehension. Ratings were combined to produce a mean score for children's ASL proficiency. Data from this questionnaire are included in Appendix S1 in the Supporting Information online. In addition, teachers self-assessed their own ASL skills on a set of two 5-point scales, one for receptive skills, the other for productive skills, adapted from Haug (2011). This was carried out to confirm the validity of ASL proficiency of the participants based on the information provided in the teacher questionnaires. The mean rating was 4.9 (SD = .31, *range* = 4-5) for receptive skills and 4.9 (SD = .31, *range* = 4-5) for productive skills, with 5 indicating near-native signing competency.

The hearing comparison group (HG) comprised 49 (22 boys) age-matched children between the ages of 6 and 11 years (M = 8.5, SD = 1.3) recruited from a local primary school. All children were monolingual native speakers of English. Deaf and hearing groups were equivalent in age, $t(59) = 1.33$, $p = .19$, $d = .35$. None of the participants had any cognitive delays reported by their teachers. Ethical approval and parental consent for all participants was obtained prior to the beginning of the study.

For both groups, we collected information on productive vocabulary by means of a picture naming task by Mann and Marshall (2012), which we adapted for ASL and for English. There were no significant differences between deaf participants' performance on the naming task in ASL ($M = 81.72$, $SD = 7.42$) and the hearing group's performance on the same task in English ($M = 75.62$, $SD = 10.16$), $t(59) = -1.95$, $p = .06$, $d = .51$. In comparison, deaf participants produced a smaller proportion of responses on the naming task in English ($M = 58.33$, $SD = 22.48$) than the hearing control participants ($M = 75.59$, $SD = 1.83$), $t(59) = 2.56$, $p = .02$, $d = .67$ One possible explanation for the marginally higher score by deaf participants in ASL could be that some items were more familiar to them than to the hearing test takers (e.g., SIGN, WEBCAM, or TEXT).

Stimuli

Stimuli for the repeated meaning association task and the picture naming task consisted of 80 items selected from the BSL Vocabulary Test (Mann & Marshall, 2012). Items included nouns, verbs, and adjectives. The signs (listed in Appendix S2 in the Supporting Information online) were adapted for ASL and English by the first author and a US-based panel of deaf and hearing experts (Mann, Roy, & Morgan, 2015). The original selection of items was informed by a number of sources, including a BSL norming study (Vinson, Cormier, Denmark, Schembri, & Vigliocco, 2008), a receptive vocabulary test for German Sign Language (PERLESKO, Bizer & Karl, 2002), a number of standardized English vocabulary tests, and feedback from a group of experts, including deaf and hearing researchers and teachers of the deaf in the UK. This resulted in the final item list. During the adaptation process, two deaf panel members (both native signers) reviewed the list of items from the BSL Vocabulary Test to discuss whether they were appropriate for use in ASL. One signer had a background in linguistics, the other in educational psychology. Both had taught at the school where the study was carried out and were well acquainted with the sign vocabulary used by children in the target group. Following these discussions, 66 of the 80 items were accepted for adaptation without further changes and could be translated directly to ASL. Of the remaining 14 items, 10 items required a change to the target item (and development of new distractor items). These included the sign for PARIS, which was replaced by NEW YORK, in part because the sign in ASL is fingerspelled, but also to make the item more culturally appropriate. Three items required a change to the label, due to differences between British and American English. These items were *tap* (*faucet* in American English), *rugby* (*football* in American English), and *rubbish* (*trash* in American English). Upon completion of the item revisions, the final list was presented to the deaf experts, who agreed that it was a representative sample of ASL vocabulary items for the targeted age group. These items were then adapted for English.

Procedure

Deaf Children

All deaf children were tested in ASL and in English during separate sessions. The stimuli (i.e., signs, words) were presented, one at a time, on a laptop computer. Children were invited to play a game and asked to think of three signs that come to mind when seeing a prompt. We chose to elicit three responses given our previous experiences using this task with children. Constraining the number of responses to three allowed us to obtain information about semantic depth for a large number of stimuli in a short amount of time. In addition, it reduced the possibility of chaining, that is, when participants begin to associate to their own associations instead of to the stimuli. To help them understand the task, participants watched a prerecorded video with signed instructions in ASL in which a deaf native signer prompted them with the sign APPLE and provided examples of both paradigmatic (e.g., ORANGE) and syntagmatic associations (e.g., EAT) to this prompt as well as examples of incorrect responses (e.g., CAR, RUN). Following the instruction, children were able to practice with two items, CARROT and DOG. During practice, the examiner, a different deaf native signer, provided non-contingent feedback and encouraged only single sign or word responses. During the ASL task, some children copied the target sign or generated a regional variation of the target sign. These children were reminded by the examiner to generate different signs with a related meaning. The procedure for eliciting English responses was similar but adapted to the modality. Target words were presented in digital print on a computer screen. While this approach made the test conditions less comparable to the hearing control, who received the items live, it was considered the most appropriate condition for presenting English words to deaf children. Accepted response formats for the English task included voicing, fingerspelling in ASL, or writing in English.

All testing took place in a quiet room at the participants' school. Children were seated by a table next to the examiner, with both facing the computer screen. The 80 items were administered to the participants in two sessions, each taking roughly 20-30 minutes. During each session, participants completed one of two sets (A and B) with 40 items, which were counterbalanced across participants. This format was chosen as part of a related intervention study. After each item, the examiner prompted the child to provide three responses. For both ASL and English, the examiner entered each response into a separate text box on the computer screen. Sign languages, including ASL, do not have a traditional written form, so we used

English glosses as a formal method for describing sign language in the written modality. In this method, signs are presented in their natural order by upper case words taken from their nearest word equivalents, though not as true definitions or translations (Zhao et al., 2000). Responses were automatically saved upon clicking the "next item" button. Items were presented in randomized order across children. The rationale for not videotaping children's responses in ASL was to make task administration more time efficient for practitioners. We accounted for possible inaccuracies by using a deaf native signer to administer the task. To ensure fidelity of the administration, approximately 20% (5 out of 24) of initial sessions were observed live by the first author. No administration errors or inconsistencies were noted. Inter-rater reliability (as reported below) was sufficiently high, although the live assessment of the appropriateness of responses for the meaning association task remains challenging.

Due to time restrictions, it was not possible to collect performance data for English on both item sets for all deaf children. Therefore, only one set (A) was used for comparative analysis of deaf bilinguals' semantic performance in ASL and English and for analysis of deaf bilinguals' and hearing monolinguals' performance in English.

Hearing Children

The procedure for the hearing control group was the same as that for the deaf children except that the practice and test items were presented in live voice instead of by video recordings. Examiners included three undergraduate students, all of whom were native English speakers, and the first author. Hearing children provided responses verbally, and the examiner typed them into the computer. Approximately 20% (10 out of 49) of initial sessions were observed live by one of the students or the first author. Responses were coded by the first author, who is fluent in ASL and has near-native English proficiency.

Coding

Paradigmatic and syntagmatic sign and word associations were coded following Sheng et al. (2006). Paradigmatic associations included synonyms (e.g., *happy-excited*), antonyms (e.g., *old-new*), coordinates (e.g., *cherry-strawberry*), superordinates (e.g., *cat-animal*), subordinates (*shop-Safeway*), or direct negations of the stimulus sign (e.g., *proud-not proud*). Syntagmatic associations indicated thematic relationships with the prompts (e.g., *hospital-doctor*, *bike-ride*, *drip-water*). Errors encompassed no responses, which included "don't know" responses or repetitions of the stimulus or earlier responses, phonological responses (e.g., *cat-cap*), and unrelated responses (e.g., *bike-hungry*). Any responses that could be either paradigmatic or syntagmatic were coded as paradigmatic. We did not code for phonological similarity.

Reliability

Reliability of coding was verified by having two graduate students independently code the responses of 11 children (18%), including five deaf children, and six hearing children. The student who coded the ASL responses had a background in ASL linguistics, and the student who coded the English responses was an English native speaker. Cohen's κ was run to determine the level of agreement between the raters' judgments. The agreements between raters' judgments for scoring the responses in ASL ($\kappa = .85$) and in English ($\kappa = .88$) were very good. Most disagreements were related to scoring items as paradigmatic and syntagmatic with a smaller fraction (24%) related to scoring items as errors.

Results

Semantic Organization in Deaf Bilinguals' L1 and L2

Mean percentages for deaf participants' paradigmatic and syntagmatic responses in ASL and English are shown in Table 1. A majority of the children's responses (ranging from 67.3% for

English at Trial 3 to 92.3% for ASL at Trial 1) belonged to these two categories. The rest of the responses were (a) phonological errors (e.g., producing the ASL sign AWAKE as a response for SURPRISED or THROW for ASK),[2] (b) unclassifiable responses (e.g., AWARD for the prompt SATURDAY in ASL or *energy* as response to *mirror* and *thunder* as response to *boots* in English), or (c) "don't know" responses.

TABLE 1

Two parallel two factor (ASL, English) by three factor (Trial 1, Trial 2, Trial 3) repeated-measures ANOVAs were conducted, one with the percentage of paradigmatic responses (averaged over participants), the other with the percentage of syntagmatic responses as the dependent variable. Deaf children's paradigmatic responses did not differ significantly in ASL and in English, $F(1, 11) = .36$, $p = .56$, $\eta_p^2 = .03$. There was a statistically significant main effect of trial, $F(2, 22) = 19.49$, $p < .001$, $\eta_p^2 = .64$. Posthoc comparisons showed a significant decrease in paradigmatic responses between Trial 1 ($M = .33$) and Trial 2 ($M = .23$), $p < .05$, and between Trial 1 and Trial 3 ($M = .20$), $p < .05$. There was no language × trial interaction, $F(2, 122) = 2.03$, $p = .16$, $\eta_p^2 = .16$, indicating that patterns of paradigmatic responding were not significantly different across languages.

In comparison, we found a statistically significant main effect of language for deaf children's syntagmatic performance, $F(1, 11) = 7.14$, $p = .022$, $\eta_p^2 = .39$, with children generating more responses in ASL ($M = .58$) than in English ($M = .44$), $p < .05$. There was no significant main effect of trial, $F(2, 22) = 3.69$, $p = .06$, $\eta_p^2 = .25$. The language effect was qualified by a statistically significant language × trial interaction, $F(2, 22) = 4.43$, $p = .04$, $\eta_p^2 = .29$. Pairwise comparisons showed that deaf children produced significantly more syntagmatic responses in ASL than in English during the first two elicitations (Trial 1, $p = .01$; Trial 2, $p = .01$), whereas the difference between languages was not significant for the third elicitation.

To summarize, there was no effect of language for deaf children's paradigmatic performance. In both languages, finding responses became progressively more difficult although the decrease in responses was only significant between the first two elicitations. Syntagmatic performance by deaf children in L1 and L2 was different in that they generated more responses in ASL compared to English. These differences were significant for the first two elicitations but not for the third elicitation.

Comparing Semantic Organization in Deaf and Hearing Children

Mean percentages of paradigmatic and syntagmatic responses as a function of group and trial are shown in Table 2. To address our second goal, we compared deaf bilinguals' semantic performance in ASL (L1) and in English (L2) to hearing monolinguals' semantic performance in English (L1). These analyses were carried out with mixed-model ANOVAs, using a two-level between-subjects factor (deaf bilingual, hearing monolingual) and a three-level within-subjects factor (Trial 1, Trial 2, Trial 3). Paradigmatic and syntagmatic scores were the dependent variables.

TABLE 2

Deaf Bilinguals' and Hearing Monolinguals' L1: ASL Versus English

Comparisons between paradigmatic performance in ASL (deaf bilinguals) and English (hearing monolinguals) revealed no significant differences, $F(1, 59) = .44$, $p = .51$, $\eta_p^2 = .01$. There was a statistically significant main effect of trial, $F(2, 118) = 78.37$, $p < .001$, $\eta_p^2 = .57$, with responses decreasing between Trial 1($M = .32$) and Trial 2 ($M = .21$) and between Trial 2 and Trial 3 ($M = .17$), $p < .001$. There was no significant group × trial interaction, $F(2, 118) = .05$, p

= .93, η_p^2 = .01, indicating that patterns of paradigmatic responding were similar within groups. Similarly, there were no statistically significant differences between syntagmatic performance in ASL (deaf bilinguals) and English (hearing monolinguals), $F(1, 59) = 1.38$, $p = .25$, η_p^2 = .02. As for paradigmatic performance, there was a significant main effect of trial, $F(2, 118) = 6.30$, $p = .003$, η_p^2 = .10, as syntagmatic responses increased from Trial 1 (*M* = .60) to Trial 2 (*M* = .65), $p < .05$, followed by a significant decrease between Trial 2 and Trial 3 (*M* = .59), $p < .001$. There was no group × trial interaction, $F(2, 118) = .98$, $p = .35$, η_p^2 = .02.

To summarize, there were no differences between ASL (deaf bilinguals) and English (hearing monolinguals) for either paradigmatic or syntagmatic performance. Both groups produced significantly fewer paradigmatic responses at each consecutive elicitation trial. In comparison, the groups showed a significant increase in syntagmatic responses from the first to second elicitation trial and a significant decrease from the second to third elicitation trial.

Deaf Bilinguals' L2 and Hearing Monolinguals' L1: English

Paradigmatic performance in English did not differ significantly between groups, $F(1, 59) = .57$, $p = .45$, η_p^2 = .01. There was a statistically significant main effect of trial, $F(2, 118) = 35.64$, $p < .001$, η_p^2 = .38, with responses decreasing between Trial 1 (*M* = .30) and Trial 2 (*M* = .21) and between Trial 1 and Trial 3 (*M* = .18), *p*s < .001. There was no significant group × trial interaction, $F(2, 118) = .40$, $p = .67$, η_p^2 = .01, indicating that patterns of paradigmatic responding were similar across groups. Syntagmatic performance in English revealed a significant group difference, $F(1, 59) = 28.51$, $p < .001$, η_p^2 = .33, indicating that hearing children (*M* = .65) generated more syntagmatic responses than deaf children (*M* = .44). The main effect of trial was also significant, $F(2, 118) = 6.01$, $p = .011$, η_p^2 = .09, as syntagmatic responses increased from Trial 1 (M = .51) to Trial 2 (M = .58), $p < .001$, followed by a minimal decrease between Trial 2 and Trial 3 (M = .55). There was no significant group × trial interaction, $F(2, 118) = 2.92$, $p = .08$, $\eta_p^2 = .05$.

Lexical-Semantic Organization and Vocabulary Size

Next, we conducted correlational analyses to examine possible links between participants' performance on the repeated word association task and productive vocabulary, measured through our picture naming task. Because vocabulary and age grow in tandem, we first checked if we needed to control for age. For bilingually developing deaf children, age (in months) was significantly correlated with performance on the picture naming task for ASL (r = .59, $p < .05$) but not for English (r = .18, p = .58). With regard to semantic performance, we found a significant association between age and syntagmatic performance (r = .57, p = .05) but not between age and paradigmatic performance (r = .24, p = .46) in ASL. For English, there was no significant correlation between age and either paradigmatic (r = –.10, p = .76) or syntagmatic performance (r = .40, p = .20). For monolingual hearing children, there was a strong correlation between age and performance on the picture naming task (r = .63, $p < .001$). In addition, we found strong correlations between age and paradigmatic performance (r = .32, $p < .05$) and between age and syntagmatic performance in English (complete set r = .29, $p < .05$). Therefore, we controlled for age in our follow-up analyses.

Partial correlational analysis between deaf participants' semantic responses (paradigmatic and syntagmatic) and their performance on the picture naming task in ASL revealed a strong correlation for paradigmatic (r = .56, p = .07) but not for syntagmatic responses (r = –.01, p = .99). For English, we found significant correlations between deaf children's picture naming performance and both paradigmatic responses (r = .86, p = .001) and syntagmatic responses (r =

.84, $p = .001$). For the hearing group, performance on the English picture naming task was not significantly correlated with either their paradigmatic responses ($r = .02$, $p = .91$) nor with their syntagmatic responses ($r = .22$, $p = .13$). The correlations were run a second time, using bootstrapped confidence intervals to account for the small sample size, and no differences emerged. Figures 1 and 2 are scattergrams illustrating the partial correlations between individual scores for picture naming performance and paradigmatic and syntagmatic responses in English, controlling for age in both deaf and hearing samples. The scattergrams and regression lines show the strong associations between vocabulary and semantic performance for the small sample of deaf children. Both scattergrams illustrate the lower performance and wider range of vocabulary scores in the deaf sample compared to the hearing sample, with low and high scores in the deaf group corresponding to low and high performance on the semantic measures; the scattergrams also show the massive range in scores for the deaf group, whereas the range for the hearing group is much more limited.

FIGURE 1

FIGURE 2

Age Effects on Lexical-Semantic Organization

Following on from the significant associations noted previously, the relationship between age and performance was investigated. Two parallel mixed ANOVAs were conducted with a two-level between-subjects factor (older, younger) and a three-level within-subjects factor (Trial 1, Trial 2, Trial 3). One ANOVA used the percentage of paradigmatic responses as the dependent variable, the other used the percentage of syntagmatic responses as the dependent variable. This was done for the hearing group only due to the small size of the deaf group ($n = 12$). Participants were divided into two groups according to their age: 6-8 years ($n = 32$, $M = 7.8$, $SD = .7$) and 9-

11 years (n = 17, M = 9.9, SD = .6), based on findings from previous studies which showed that children's responses at around 5 years are indicative of a less developed semantic system compared to children's responses at the age of 9 years (Nelson, 1977). Paradigmatic performance differed significantly between age groups, $F(1, 47) = 11.02$, $p = .002$, $\eta_p^2 = .19$, with older children generating more paradigmatic responses (M = .28) than younger children (M = .18). Posthoc analysis of the significant main effect of trial, $F(2, 94) = 50.78$, $p < .001$, $\eta_p^2 = .52$, showed a significant decrease in participants' responses between Trial 1 (M = .31) and Trial 2 (M = .21) and between Trial 1 and Trial 3 (M = .17), ps < .001, and between Trial 2 and Trial 3, $p < .05$. There was no significant trial × age interaction, $F(2, 94) = .12$, $p = .85$, $\eta_p^2 = .00$.

Syntagmatic performance showed no difference between age groups, $F(1, 47) = .54$, $p = .467$, $\eta_p^2 = .01$. There was a significant main effect of trial, $F(2, 94) = 4.01$, $p = .041$, $\eta_p^2 = .08$, as responses increased between Trial 1 (M = .63) and Trial 2 (M = .69), $p = .003$, followed by a decrease between Trial 2 and Trial 3 (M = .64), $p = .04$. In addition, there was a marginally significant trial × age interaction, $F(2, 94) = 3.69$, $p = .05$, $\eta_p^2 = .07$. Posthoc tests indicated a significant decrease in syntagmatic responses between Trial 2 (M = .68) and Trial 3 (M = .60), $p < .001$, for younger children and a significant increase in responses between Trial 1 (M = .63) and Trial 2 (M = .69), $p < .05$, for older children. None of the group differences across elicitation trials were significant.

Discussion

The acquisition of word meanings is a fundamental aspect of language development, and one area of great interest is how children organize their growing vocabulary into an efficient system. This study investigated lexical-semantic organization in a group of bilingually developing deaf native signers between the ages of 6 and 10 years. Our goals were to compare semantic performance between deaf signers' L1 (ASL) and L2 (English), between deaf signers' L1 (ASL) and monolingual hearing children's L1 (English), and between the two groups' English performance. We start by discussing deaf children's performance in ASL and English. Next, we examine the similarities and differences between the bilingual deaf and the monolingual hearing group for L1 semantic performance, followed by a comparison of these groups for English semantic performance. Finally, we discuss the theoretical and practical implications of the reported work and provide suggestions for future studies.

Lexical-Semantic Organization in Deaf Sign Bilinguals' L1 and L2

Similarities

With reference to our first goal, we found comparable performances by bilingually developing deaf children in ASL and English on a repeated word association task, including (a) a larger proportion of syntagmatic links than paradigmatic links in each language, (b) a comparable number of network links of paradigmatic responses, and (c) a steady decrease in the production of paradigmatic responses across all trials versus a significant increase in production of syntagmatic responses from Trial 1 to Trial 2.

The comparable performance in deaf children's L1 and L2 is consistent with previous research by Sheng and colleagues (2006) carried out with hearing Mandarin-English speakers of a similar age range using the same task format. The similarity in performance for both languages suggests that deaf children use similar organizational principles to structure their mental lexicon in each language and that, together, syntagmatic and paradigmatic responses construct a pool of sign/word associations. We argue that this supports the idea that lexical-semantic development in both languages is driven by similar underlying language learning mechanisms rooted in the development of semantic networks and that the order of production of words in a semantic association task provides a window into the underlying organization of the mental lexicon. From a spreading activation perspective (Collins & Loftus, 1975), these findings indicate that deaf children's semantic networks in ASL consist of more semantic links compared to those in their L2 English but show a similar activation spread across languages.

The comparison of paradigmatic/syntagmatic performance across multiple elicitation trials provides us with more nuanced information about how deaf bilinguals go about retrieving lexical items from their semantic networks. If bilingual deaf children have exposure to both ASL and English but are influenced by the same language learning mechanisms as monolingual hearing children, we should see a similar semantic performance in both languages. This was exactly what we observed in the effect of trial, namely the same relative frequency in paradigmatic and syntagmatic responses across multiple elicitation trials as semantic activation becomes attenuated along its path of travel from the node of origin (Collins & Loftus, 1975; McClelland, 1995; Nevid, 2009).

A closer look at Table 1 shows that the observed decrements in deaf children's paradigmatic associations in ASL and English co-occurred with an increase in errors. At the same time, syntagmatic associations stayed relatively stable over trials. As expected, deaf bilinguals produced significantly more error responses ("I don't know") for English compared to ASL. The observed high amount of error responses in English across elicitation trials may be attributed to language experience, in particular deaf children's limited language access as a result of their hearing loss. This is consistent with a recent claim by Hoff and colleagues (2012) that the difference between monolingual and bilingual children's skills in any language depends on the level of exposure to that language.

These findings suggest that paradigmatic and syntagmatic associations represent two kinds of valid semantic responses which require different sets of skills: While paradigmatic associations may be more related to categorization skills and general cognitive level, the ability to generate syntagmatic associations may be more dependent on exposure to collocations (e.g., *fast train*, *quick meal*) in a certain language. One possible reason that deaf children produced significantly more syntagmatic than paradigmatic associations could be that there are potentially more such responses available as syntagmatic associations may entail a broad range of semantic relations (temporal, spatial, causal, collocational) compared to paradigmatic associations which are taxonomic.

Differences

We found that deaf children generated considerably more syntagmatic responses in ASL than in English during the first and second elicitation. At the same time deaf bilinguals produced more error responses in English during the first and second elicitation of meaning associations. Paradigmatic performance remained the same across elicitation trials for both languages. These findings were in line with our expectations of deaf children's smaller vocabulary in English and was further confirmed by their lower picture naming performance in English compared to ASL. These findings were also consistent with results from Spanish-English bilinguals, who showed more errors in their L2 English than L1 Spanish (Sheng et al., 2012).

Lexical-Semantic Organization in Deaf Sign Bilinguals and Hearing Monolinguals

Similarities in L1 ASL and L1 English

With reference to our second goal, we compared bilingually developing deaf children's semantic performance in their L1 (ASL) to monolingual hearing children's English performance. Findings revealed striking similarities across the two groups, suggesting that L1 semantic development is remarkably similar despite modality and linguistic differences (e.g., verb agreement). This is in line with previous findings by Novogrodsky on deaf children's acquisition of synonyms (Novogrodsky, Fish, et al., 2014) and antonyms (Novogrodsky, Caldwell-Harris, et al., 2014) in ASL as well as with research on other sign languages (Mann & Marshall, 2012; Tomasuolo et al., 2010). The similarity in semantic performance suggests that deaf and hearing children are using similar age-appropriate organizational principles to structure their mental "filing" systems. Apart from a few isolated cases where a response in ASL shared the same sign (e.g., COAT/JACKET, PERFUME/SPRAY), our data do not show any evidence of a lack of lexicalized semantic associates of the target words in ASL despite its smaller lexicon compared to English.

Another point of convergence was the effect of trial. Both the deaf bilinguals and the hearing monolinguals demonstrated the same patterns in their paradigmatic and syntagmatic responding across all elicitation trials. The decrease in paradigmatic responses across multiple elicitation trials suggests that children's knowledge of hierarchical relational terms was similarly shallow. In other words, children may not have stored many words that belong to the same category or words that are similar in meaning to the targets, so that generating paradigmatic associations became more demanding with each new elicitation. With regard to syntagmatic responses, both groups showed an increasing pattern between the first and the second elicitation trial. In addition, both groups generated more syntagmatic responses than paradigmatic responses across all elicitation trials. These findings demonstrate that the semantic system is organized according to both paradigmatic and syntagmatic relations. In addition, they support a point made earlier regarding the availability of syntagmatic responses due to the broad range of semantic relations they entail compared to paradigmatic associations.

Similarities in L1 and L2 English

In comparing deaf bilinguals' L2 with hearing monolinguals' L1, we found similar response patterns across elicitation trials, including a steady decrease in the production of paradigmatic relations and an increase in syntagmatic responses between first and second trial, followed by a decrease between the second and third trial. These response patterns were the same for deaf children's L1.

Differences Between L1 and L2 English

We found a group difference in syntagmatic performance with hearing monolinguals generating more associations than deaf bilinguals across all trials. One possible explanation for this lag in acquiring syntagmatic associations is deaf children's lack of exposure to English. As a result, their vocabulary is too small to support formation of semantic links in L2. This is evident in part in the considerable amount of errors deaf children made, most of which were "I don't know" responses, and also in their lower performance compared to hearing monolinguals' performance on our measure for vocabulary size (i.e., picture naming task). This result is similar to studies with hearing L2 English bilinguals, which have found robust group differences in English vocabulary size between monolinguals and bilinguals (e.g., Bialystok, Luk, Peets, & Yang, 2010; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Roberts, Garcia, Desrochers, & Hernandez, 2002).

Our findings are in line with an argument from the literature on spoken language that language development in bilingually developing children is a function of the relative amount of exposure (Hoff, 2006; Hoff et al., 2012). This argument is of particular relevance in the context of deaf bilinguals, most of whom may not receive balanced input in either L1 or L2, partly because their hearing parents do not sign but also due to limited access to spoken language as a result of their hearing loss. While all deaf children in our study were exposed to ASL from birth by their deaf parents, their access to (spoken) English had been possibly affected by their hearing loss. Although we did not directly measure amount of language exposure, the reported strong correlations between sign bilinguals' performance on the picture naming task and their paradigmatic/syntagmatic responses in English suggest that children's ability to form these association is at least partially driven by vocabulary size. In comparison, these correlations were much weaker in deaf children's L1 (ASL) and in hearing children's L1 (English), both languages that children have access to from birth. This suggests that the link between vocabulary size and the organization of the lexicon may be more complex than previously assumed. At some point in development for children acquiring English, for example, literacy begins to become both a major source of new vocabulary and also a strong organization constraint on how words can be linked together. As there is no systematic way of writing ASL or a large "literacy" tradition, this influence may be much less pronounced for native signers in ASL.

Effect of Age

An additional finding was that hearing children were equally adept at producing syntagmatic responses regardless of age. Age-related differences were only manifested in paradigmatic responses with older children. These patterns are in agreement with the literature on lexical development which shows that school-age children gain semantic depth by acquiring semantic connections that are categorical, synonymous, or antonymous in nature (Nelson, 1977). While we did not conduct such analysis for our deaf sample due to small sample size, we would expect to see the same patterns in a larger group of age-matched deaf native signers, given the similar developmental trajectories in signed and spoken language acquisition (e.g., Corinna & Singleton, 2009, Newport & Meier, 1985).

What our data suggest is that, by age 6, sign bilingual deaf children have developed a comparable amount of links in their semantic network in ASL (their L1) to hearing children, with similar proportions of paradigmatic and syntagmatic connections. This is in line with results from spoken language (Doherty & Perner, 1998) as well as recent findings from research on ASL (Novogrodsky, Fish, et al., 2014), which indicate that children's knowledge of synonyms emerges at the age of 4 years in both modalities. In comparison, both deaf children's vocabulary and their total number of semantic responses in English are smaller than those in same-aged monolingual hearing children (although both groups show similar response patterns across multiple elicitation trials). This finding is consistent with results from studies with hearing bilinguals (Bialystok & Feng, 2011; Marchman, Fernald, & Hurtado, 2010). From a theoretical perspective, our findings are important as they reveal outcomes of language development that transcend modality and linguistic differences. These results emphasize the importance of early and sustained language exposure for deaf children. While children with cochlear implants are increasingly developing better spoken language skills, access to a signed language can occur from the first few months of life (e.g., Mellon et al., 2015). From a practical point of view, the repeated association task, which is part of a set of vocabulary tasks, can be used by teachers of deaf students to guide their educational planning by pinpointing areas of weakness as well as strengths in students' vocabulary knowledge.

Conclusions

The current study provides valuable preliminary data on bilingually developing deaf children's semantic knowledge in their L1 (ASL) and L2 (English), which needs to be replicated with a larger sample from different sites to allow or substantiate any conclusive statements. In our approach, we controlled for exposure to sign language by focusing on children with at least one deaf parent. This is critical in exploring deaf children's ASL and English skills on their own and also in allowing us to compare them to typically developing hearing peers with access to language from birth. However, since the majority of deaf children are born to hearing parents, it would be useful for future research to further explore the importance of early (dual) language input in nonnative signers. Similarly, we encourage research that examines the effect of deafness on development of semantic knowledge. One way of doing this could be by comparing deaf signers and hearing signing controls to see how they differ on ASL and English association responses. A third area for future studies could explore similarities and differences between deaf and hearing L2 English learners by adding a control group of spoken bilinguals performing the current study task in L2 English.

Language development in bilingually developing children largely depends on the relative amount of exposure in each language. In this context, particular focus needs to be given to deaf sign bilinguals due to the unique language experiences of this group. Taking these variables into account, we introduced a novel approach to investigating sign bilingual deaf children's semantic knowledge in L1 (ASL) and L2 (English) by specifically measuring the number and accessibility of paradigmatic and syntagmatic relations in ASL in relation to English. Additionally, we compared sign bilinguals' semantic performance in both languages to English semantic performance by monolingual hearing peers. The data show that L1 semantic development is remarkably similar across groups despite modality and linguistic differences. This finding is important because it reveals aspects of language development that are robust and less susceptible to environmental influences.

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Notes

1 The term elicitation trial refers here to the first, second, and third responses of the child.

2 AWAKE and SURPRISED are two-handed signs that share the same location (face) and handshape (fingerspelling for G) but differ in movement. In the sign for SURPRISED, the touching of the thumb and index is more accentuated, whereas the emphasis in the sign AWAKE is on the opening movement. THROW and ASK share the same location and movement but differ in the handshape. THROW opens to a 5-handshape whereas ASK ends in an X-handshape.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1. Deaf Participant Information.

Appendix S2. Sign Items Used as Target Materials.

Table 1 Deaf participants' mean paradigmatic, syntagmatic, and error response scores (percentage) across test trials (T1, T2, T3)

	ASL (40 items)		English (40 items)	
Response	*M*	*SD*	*M*	*SD*
Paradigmatic				
T1	35.63	13.23	30.63	18.22
T2	24.38	11.39	21.67	11.45
T3	18.96	9.68	20.21	11.89
Syntagmatic				
T1	56.67	11.79	37.71	11.75
T2	63.13	10.23	46.88	16.31
T3	54.17	15.79	47.08	17.28
Error				
T1	7.71	5.69	31.67	25.50
T2	12.50	8.66	31.46	25.24
T3	26.88	21.30	32.71	26.32

Table 2 Deaf and hearing participants' mean paradigmatic, syntagmatic, and error response scores (percentage) across test trials (T1, T2, T3)

	ASL-English (80 items)				English-English (40 items)			
	Deaf (*n* = 12)		Hearing (*n* = 49)		Deaf (*n* = 12)		Hearing (*n* = 49)	
Response	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Paradigmatic								
T1	32.81	11.97	31.35	12.60	30.63	18.22	29.13	13.58
T2	22.40	10.23	20.33	8.77	21.67	11.45	19.44	10.55
T3	18.13	9.68	15.92	7.38	20.21	11.89	16.17	9.19
Syntagmatic								
T1	58.75	10.81	60.79	10.31	37.71	11.75	63.62	12.70
T2	63.65	11.06	65.82	10.36	46.88	16.31	68.32	12.08
T3	55.52	16.78	61.99	12.18	47.08	17.28	63.21	16.89
Error								
T1	8.44	5.69	7.86	6.79	31.67	25.50	7.24	8.14
T2	13.96	10.95	13.85	11.38	31.46	25.24	12.24	12.87
T3	26.35	21.15	22.09	15.72	32.71	26.32	20.61	20.84

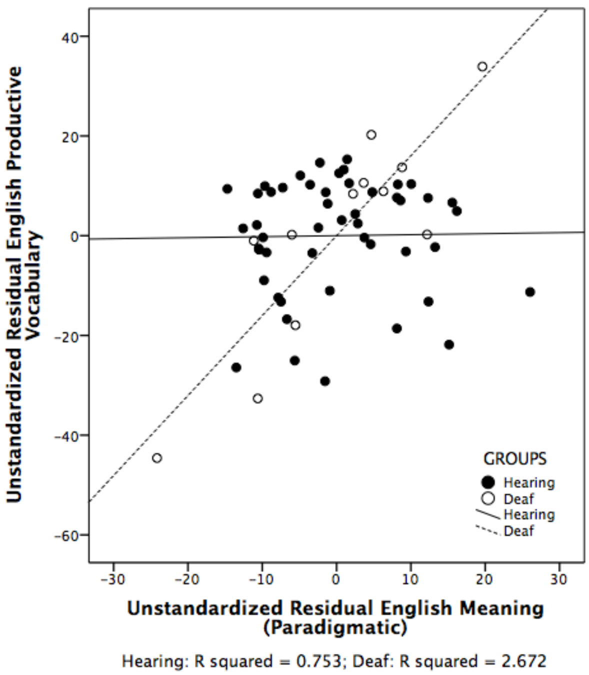

Figure 1 Scatterplot showing the unstandardized residuals of picture naming performance against mean percentage of paradigmatic responses.

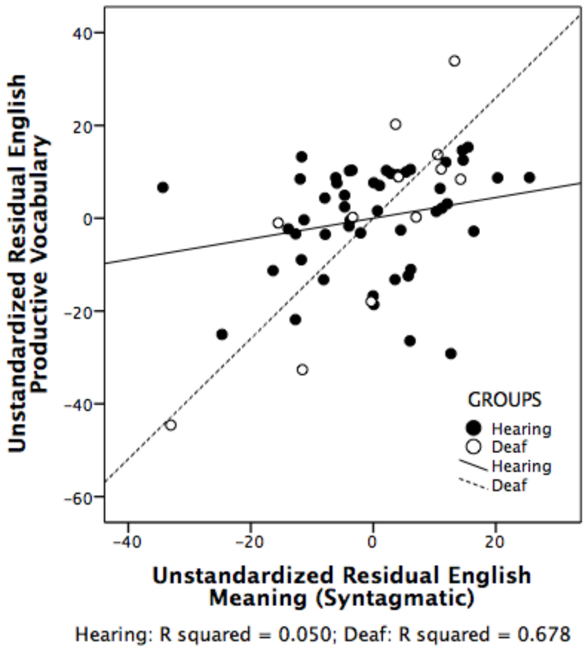

Figure 2 Scatterplot showing the unstandardized residuals of picture naming performance against mean percentage of syntagmatic responses.