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Subjective Frequency Ratings for 432 ASL Signs

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Abstract

Given the importance of lexical frequency for psycholinguistic research, and the lack of comprehensive frequency data for sign languages, we collected subjective estimates of lexical frequency for 432 signs in American Sign Language. Participants were 59 deaf signers who first began to acquire ASL at ages ranging from birth to 14 years with a minimum of 10 years experience. Subjective frequency estimates were made on a scale ranging from 1 = *rarely see the sign* to 7 = *always see the sign*. Mean subjective frequency ratings for individual signs did not vary in relation to age of sign language exposure (AoLE), chronological age, or length of ASL experience. Nor did AoLE show significant effects on response time for making the ratings. However, RT was highly correlated with mean frequency rating. These results suggest that the distributions of subjective lexical frequencies are consistent across signers with varying AoLE. The implications for research practice are that subjective frequency ratings from random samples of highly experienced deaf signers can provide a reasonable measures of lexical control in sign language experiments. The appendix gives the mean and median subjective frequency rating, and the median and mean log(RT) for the ASL signs for the entire sample; the supplemental material gives these measures for three AoLE groups, Native, Early, and Late.

Lexical frequency is known to influence linguistic processing and, when uncontrolled, can confound the results of psycholinguistic experimentation. Lexical frequency is also used to model how the mental lexicon is acquired, organized, and processed (Bock & Griffin, 2000; Dahan, Magnuson, & Tanenhaus, 2001; Dell, 1990; Gardner, Rothkopf, Lapan, & Lafferty, 1987). Although researchers of many spoken languages have multiple resources available to them to control lexical frequency, sign language researchers have few such resources. Here, we help fill this gap with a study of subjective frequency for signs from American Sign Language (ASL). Sign language research is further complicated by the fact that any random sample of adult signers, in contrast to any random sample of adult speakers, will be characterized by marked heterogeneity in age of sign language exposure (AoLE).[1] Hence, we also investigate the effects of sign language AoLE on subjective frequency ratings for signs. Subjective frequency is but one of a number of metrics researchers use to estimate the distribution of words in the linguistic environment of language users. To contextualize it, we

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[1]Sign languages are perhaps unique in that native users constitute a small minority of the linguistic community; most estimates place the figure at less than 10% (Schein, 1989). Except for native learners, the distribution of AoLE within the ASL community is currently unknown.

discuss subjective frequency ratings in comparison to other measures, objective frequency, and familiarity ratings in particular. We then consider the few studies that have examined lexical frequency in sign languages before describing the present study.

Objective measures of lexical frequency typically come from large-scale corpora and are often text-based. For example, the Brown corpus is based on a million words of text (Kucera & Francis, 1967). The CELEX corpus represents over 17 million items, 92% of which come from text (Baayen, Piepenbrock, & van H. Rijn, 1993). Note that these large-scale corpora require a widely used orthography. Even speech-based corpora require a codified system for representing spoken words (e.g. SWITCHBOARD, Holliman & McDaniel, 1992; Pastizzo & Carbone, 2007). For sign languages, neither of these tools is readily available.

Measures of objective frequency are based on counts of a lexeme's occurrence, often measured in units of one per million words, and are thought to reflect an individual's exposure to a given word. Of course, words do not occur with equal frequency across all contexts. This leads to biases in objective frequency counts known as contextual dispersion (Baayen, 2001). For example, chefs use the word *cleaver* more often than do bankers. For this reason, some researchers have proposed that familiarity ratings -- an individual's intuition about how well he or she knows a given word -- provide a more accurate measure of lexical exposure (Gernsbacher, 1984). The definition of lexical familiarity is not as straightforward as that of frequency, however. While some researchers equate familiarity with an individual's exposure to a given word (Gilhooly & Logie, 1980; Kreuz, 1987; Morrison, Chappell, & Ellis, 1997), other researchers think that familiarity primarily applies to knowledge of a word's meaning (Gardner, Rothkopf, Lapan, & Lafferty, 1987; Gaygen & Luce, 1998; Nusbaum, Pisoni, & Davis, 1984). Familiarity ratings can be affected by several factors that are unrelated to objective lexical frequency. For example, the degree to which the form of a given word is a common phonological or orthographic pattern can inflate familiarity ratings (Peereman, Content, & Bonin, 1998), as can the number of meanings associated with a word (Toglia & Batting, 1978). Lexical familiarity can also vary with age because older adults have larger vocabularies than do younger ones (Spieler & Balota, 2000).

A factor related to lexical familiarity is *lexical* AoA, that is, the age when a given word is first learned (for example the age when the word *chair* is learned in contrast to the word *ottoman*) which must be distinguished from AoLE -- the age when an individual is first immersed in a given language. Norms for lexical AoA are often based on subjective ratings: individuals estimate when they first learned a particular word at ages ranging, for example, from 3 to 12 years. Subjective lexical AoA ratings have been found to correlate with objective measures of lexical AoA (Morrison, Chappell, & Lewis, 1997). These latter measures are derived from large-scale studies of vocabulary development in which lexical AoA is defined as the age when 75% of children know a given word. Some researchers have argued that lexical AoA effects are cumulative lexical frequency effects in disguise (Zevin & Seidenberg, 2002), following the logic that the younger the age when a given word is learned, the more often it will have been encountered at any point later in life. However, the available evidence suggests that lexical AoA effects arise from a different factor than those associated with lexical frequency. AoA effects on lexical processing tend to increase as a

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linear function of age rather than decrease. By contrast, lexical frequency effects tend to show a logarithmic function. When directly compared across various lexical processing tasks, lexical AoA effects have been found to be significantly greater than frequency effects (Ghyselink, Lewis, & Brysbaert, 2004).

An alternative to objective lexical frequency is subjective frequency ratings where individuals estimate how often they have encountered a given word. Subjective frequency ratings have been found to predict lexical processing better than objective frequency ratings. For example, Balota, Pilotti and Cortese (2001) gathered subjective frequency ratings for 2,938 English words from 2,254 participants of various ages and backgrounds. Participants rated the subjective frequency of the stimulus words on a scale where each number was anchored to a time interval ranging from 1 = *the word is never encountered* to 7 = *the word is encountered several times a day*. Subjective frequency ratings correlated more highly with objective log frequency (r = .83) than with familiarity ratings (r = .53) and accounted for 21% of the variance in lexical decision and naming latencies after the variance associated with objective frequency was removed. Subjective frequency ratings have also been found to correlate with objective frequency for both spoken and written words in French (Ferrand, Bonin, Meot, Augustinova, New, Pallier, & Brysbaert, 2008; Thompson & Desrochers, 2009). In lieu of using lexical frequency to control stimuli, some researchers recommend the use of lexical response time (Balota, Yap, Cortese, Hutchinson, Kessler, Loftis, Neely, Nelson, Simpson, & Treiman, 2007). To our knowledge, no studies have yet systematically examined subjective frequency ratings in relation to AoLE, years of language experience, chronological age, and response time, which we do in the present study.

A handful of studies have tackled the issue of lexical frequency in various sign languages. Using a large number of commercially available videotapes, Morford and MacFarlane (2003) computed the frequency of 4,111 ASL signs produced by 27 signers, using a base unit of one occurrence per thousand signs. The most frequent signs were closed class, specifically pronouns, but some of the most frequent signs were content lexical items as well. McKee and Kennedy (2006) analyzed 50 hours of videotaped New Zealand Sign Language (NZSL) produced by 80 signers in a database of 100,000 signs. Consistent with the ASL findings, the most frequent NZSL signs were closed class -- again pronouns -- but the most frequent signs also included some content lexical items. Johnston (2012) observed a similar pattern of lexical frequency for Australian Sign Language (Auslan) in an analysis of video clips of 63,436 signs produced by 109 signers. In contrast to the previous studies where the sign language corpora were derived from a cross-section of signers and sociolinguistic contexts, the Auslan corpus was heavily weighted with examples of signers telling the same stories and answering the same questions. This sampling bias had the effect of inflating the frequency rankings of many lexical items (e.g., *wolf* and *frog*) relative to their rankings in the corpora of other sign languages. The compilation and annotation of other sign language corpora, such as the one for the Sign Language of the Netherlands, NGT (Ormel, Crasborn, van der Kooij, van Dijken, Nauta, Forster, & Stein, 2010), should yield valuable data for cross-linguistic comparisons of lexical frequency in sign languages.

In the absence of lexical frequency data for sign languages, some researchers have used *ad hoc* subjective frequency ratings as a means to control experimental stimuli. For example, Emmorey (1991) asked two native signers to rate ASL stimulus signs on a ten point scale representing most to least frequently occurring. Using a seven point scale, Carreiras, Gutiérrez-Sigut, Baquero, & Corina (2008) asked 19 “deaf people with very good knowledge” of Spanish Sign Language to rate “how familiar they thought each sign was and if they used the sign very often or just on rare occasions” (p. 105). Although the scale may have conflated the factors of lexical familiarity and subjective lexical production, a significant difference between the ratings of native and nonnative signers was not found.[2]

To collect frequency data for experimental purposes, Vinson, Cormier, Denmark, Schembri, and Vigliocco (2008) asked 33 deaf signers (whose age of BSL acquisition ranged from “before 3” to the age of 15) to give subjective frequency and iconicity ratings for 300 signs from British Sign Language (BSL) on a scale from 1 to 7.[2],[3] The participants also gave estimates of lexical AoA on a scale that ranged from birth to 17 years. As is the case for spoken languages, subjective frequency ratings correlated with lexical AoA estimates for the BSL signs. In contrast to the sign language corpus studies, however, only one of the three most frequently ranked signs was closed class, again a pronoun. This no doubt reflected the fact that th e stimulus signs were selected for experimental purposes and not intended to represent the BSL lexicon.

In addition to scant information on lexical frequency, another challenge facing sign language researchers is the question of how to deal with possible AoLE effects. In spoken language populations, the majority of speakers are native learners who acquired the language from birth and thus share the same AoLE. In sign language research, focusing only on native learners represents a tradeoff between removing potential AoLE effects from the lexical frequency data or more accurately reflecting the AoLE variation endemic to deaf signers by sampling broadly across the population. The available sign language corpus studies did not control for AoLE and instead sampled widely across the respective sign language populations, ASL, NZSL, and Auslan (Johnston, 2012; McKee & Kennedy, 2006; Morford & MacFarland, 2003). In their experimental study, Vinson et al, 2008 did not test for AoLE effects on subjective frequency ratings for BSL signs. Because AoLE has been found to have robust effects on the psycho- and neurolinguistic processing of sign language (Boudreault & Mayberry, 2006; Cormier, Schembri, Vinson, & Orfanidou, 2012; Mayberry, Chen, Witcher, & Klein, 2011; Mayberry & Lock, 2003; Mayberry, Lock & Kazmi, 2002; Newport, 1990), it is essential to understand how AoLE affects subjective frequency ratings.

In the present study, we collected subjective frequency ratings from deaf signers who had a controlled range of AoLE to examine the relation of AoLE to subjective frequency ratings for a set of ASL signs. We analyzed the extent to which subjective frequency ratings were stable across signers with varying AoLE, and further tested whether frequency ratings were affected by years of ASL experience or chronological age. In addition, we explored the relationship between response latency and frequency ratings, and tested whether it interacted with AoLE.

[2]The number of native vs nonnative signers was not reported.

[3]Although Vinson et al (2008) used the term *familiarity* rating, the participants were instructed to rate how often they encountered each sign, which is more akin to a subjective frequency rating as we use the term here.

Methods

Participants

Sixty-seven adults who were born deaf (≥ 80 dB pure-tone-average in the better ear confirmed by audiometric testing) volunteered for the study. All participants had used ASL as their preferred language for 10 years or more. Participants were recruited by members of various Deaf communities and compensated for their time. The majority of participants resided in Montreal and in various cities in Ontario; a few participants resided in Alberta, Canada. All but three participants, whose data were not used, scored within the normal range on a nonverbal IQ screening task. An additional four participants performed the task, but did not use the rating scale in accordance with the instructions, and their data were excluded from analysis.[4] A technical issue resulted in the loss of all data from one other participant. The remaining 59 participants were grouped as a function of the age when they first began to learn ASL, operationalized as the age when they first began to learn ASL in an immersion setting where they used it regularly with other deaf signers. The *Native* learner group consisted of 22 participants, 20 whose deaf parents signed to them from birth and two with hearing parents who began to acquire ASL before 3 years of age. Seventeen participants were *Early* learners who first learned ASL in school between the ages of 4 and 8 years. Twenty participants were *Late* learners who first learned ASL in school between the ages of 9 and 14 years. The groups consisted of approximately equal numbers of men and women (see Table 1). Participants were recruited into the three AoLE groups and not matched on age or length of experience. The Native group was younger than the Early but not the Late group (One-way ANOVA, $F[2,56] = 7.39$, $p<.002$; Tukey HST, $p<.05$). Although the length of ASL experience (years beyond AoLE) of the Native group (29.09 years) did not differ from that of either the Early or Late groups (37.64 and 23.40 years respectively), the Early group had more ASL experience than did the Late group (One-way ANOVA, $F[2,56] = 7.64$, $p<.002$; Tukey HST, $p<.05$)

Stimuli

The stimuli were 432 ASL signs not intended to be representative of the ASL lexicon. The stimulus set consisted of 255 nouns, 93 verbs, 78 adjectives, 8 adverbs, and 6 closed class items (first-person pronoun, conjunctions, and prepositions) that were selected for ASL lexical processing experiments (Mayberry, in preparation). The stimulus list did not include fingerspelled items or classifiers (sometimes called mimetic depictions; Emmorey, 2003). To create the stimuli, a deaf native signer produced each ASL stimulus sign several times with neutral facial expression and no mouthing while being videotaped. Those renditions judged by three native signers (two deaf) to represent the clearest sign production were then selected as stimuli and edited into a series of individual video clips. The *completion* point of each stimulus sign was identified, by which we mean the video frame within which all of the sign's parameters could first be detected to be in place, handshape, orientation, movement, and location. The completion point was then made the midpoint of the video clip. This was accomplished by editing each video clip such that an equal number of video frames

[4]These four participants responded almost exclusively with the highest rank of 7 to indicate that they knew the meaning of a sign, rather than estimating how often they saw it in ASL conversations.

preceded and followed the completion point video frame, beginning with the sign's parameters transitioning into place and ending when sign's parameters moved out of place.

Procedure and Materials

Stimuli were presented on an Apple PowerBook G3 computer using PowerLaboratory software (Chute & Westall, 1996), which recorded the frequency ratings and response times. The experiment was self-paced, and each trial consisted of several steps, shown in Figure 1. First, a fixation cross appeared on the screen for 300 ms. Second, the video clip of the stimulus sign appeared with a mean duration of 666.67 ms with a range from 333.36 to 1167.0 ms. Third, when the screen went blank after the stimulus sign was completed, participants estimated its frequency with a mouse click using their dominant hand. Last, the participant clicked the green GO box (Figure 1) to view the next stimulus sign. The GO box was centered below the rating scale to ensure that each estimate of sign frequency began from the same location on the screen.

Participants were told that they would see a sequence of ASL signs and were instructed to use a mouse click to select which number along a scale of 1 to 7 best represented how often they encountered the sign in conversations with deaf people, 1 = *rarely see the sign* and 7 = *always see the sign*. We limited the linguistic environment to conversations with deaf people rather than anchoring the scale to specific time intervals, e.g., per day or week (Balota et al., 2001) because the opportunity to converse with deaf signers varies widely from person to person and does not necessarily occur on a daily basis. Participants practiced estimating frequency with a set of 20 signs not included in the stimulus list. The 432 stimulus signs were randomly assigned to four blocks of 108 signs each. Presentation order of the four blocks was counter-balanced across participants with a Latin squares design. Participants were offered a break after each block but few participants took one. Testing lasted about 20 minutes.

Results

First, we asked whether signers who had native, early, and late AoLE differed in the average rating they gave the signs. Because we did not provide the participants with explicit time-interval anchors on which to base their ratings (Balota et al., 2001), it is possible that "5" was a relatively high rating for some participants, but only a moderate or low rating for others. In addition, individual variation may not have been distributed randomly across the AoLE groups. We therefore used a one-way ANOVA to test for mean rating differences across groups, with subjects as a random factor. Although the early learners had a higher mean rating overall (4.65 vs. 4.42 from native learners vs. 4.37 from late learners), the ANOVA did not approach significance, $F(2,56) = .93$, $p = .39$.

Although Likert scales have most commonly been analyzed as interval scales in the comparable literature (Balota et al., 2001; Carreiras et al., 2008; Emmorey, 1991; Ferrand et al., 2008; Thompson & Desrochers, 2009; Vinson et al., 2008), they are underlyingly ordinal scales; therefore, we considered both parametric and non-parametric approaches to the present data. The Kruskal-Wallis test is a non-parametric alternative to one-way ANOVA; it also revealed no differences among the groups (X^2 (2) = 1.31, $p = .52$).

The above analyses examined whether we have evidence to reject the null hypothesis that the groups do not differ, and the answer is that we do not have such evidence. Traditional statistics do not allow us to accept the null hypothesis as true, but Rouder and colleagues (Rouder, Morey, Speckman, & Province, 2012; Rouder, Speckman, Sun, & Morey, 2009) offer a Bayesian approach that allows the null hypothesis to be either rejected or accepted. Following Rouder et al. (2009), we conducted three pairwise comparisons (Native vs. Early, Native vs. Late, and Early vs. Late) and used the resulting values of t and N to compute Bayes factor, which is an odds ratio measuring the relative likelihood of the null versus alternative hypothesis given the data. The results indicate that for each pair, the null hypothesis is at least twice as likely as the alternative hypothesis: Native vs. Early, Bayes factor = 2.65:1, Native vs. Late: Bayes factor = 4.26:1, Early vs. Late: Bayes factor = 2.01:1. Typically a BF < 3 is considered inconclusive evidence that slightly favors the null hypothesis. Thus, it is unlikely that AoLE influenced the mean rating that the participants gave for the signs.

Next, we asked whether Native, Early, and Late learner groups agreed on the frequency for each of the 432 stimulus signs. To accomplish this, we computed the mean rating given to each item by all the participants within each group, and then plotted that value against the mean rating given to the same item by the participants in each other group. As the scatterplots clearly show (Figure 2), there was strong agreement among the groups on the frequency of the ASL signs. Once again, a non-parametric version of this analysis yielded the same pattern, using each population's median rating for each item, and computing Spearman's rho (ρ), as listed in Table 2.[5] The strength of these three correlations did not differ, either for Pearson r (Fischer's Z transformation: X^2 (2) = 2.81, p = .25) or for Spearman ρ (Fischer's Z transformation: X^2 (2) = 2.88, p = .24).

The above analyses treat AoLE as a categorical variable when it is in fact a continuous one ranging from birth to 14 years in the present study. We therefore used linear regression to determine whether AoLE influences subjective frequency ratings. If so, we would expect a significant correlation between AoLE and subjective frequency rating, but no such correlation emerged, either for mean ratings (r^2 = .03, p = .57) or median ratings (ρ = −.25, p = .38).

Next, we asked whether years of ASL experience or chronological age influenced the subjective frequency ratings. Native learners had a range of 17 to 59 years of ASL experience, while early learners had a range of 16 to 54 years, and late learners had a range of 10 to 43 years experience. If subjective frequency ratings are influenced by the cumulative number of encounters a signer has had with a given sign, and not its relative frequency in the linguistic environment, then signers with more years of ASL experience should give higher subjective frequency ratings resulting in a significant positive correlation. We therefore repeated the regression analyses with years of ASL experience as the predictor

[5]We also collected ratings from a group of 10 hearing participants who had acquired ASL as a second language in adulthood and had used it for more than 10 years. Their ratings were also correlated with those of Native (r = .77), Early (r = .75), and Late learner groups (r = .80). Given the unequal numbers of participants, we caution against overgeneralization of these results. Ratings could also be gathered from hearing children of deaf adults; although often bilingual in ASL and spoken English, Codas are also typically dominant in spoken English so that their ratings would also have to be interpreted with caution.

variable, but did not find a significant correlation for mean ratings (r^2 = .06, *p* = .17) or for median ratings (ρ = .22, *p* = .22). The chronological age of the participants ranged from 19 to 59 years (Table 1) and so we also asked whether age affected the subjective frequency ratings. There was no significant relation between age and subjective frequency ratings for means (r^2 = .0001, *p* = .95) or medians (ρ = .01, *p* = .95).

Although the participants were not instructed to perform the task as quickly as possible, we measured response latency for each trial. There was no upper limit on how long participants could spend deliberating their rating, which resulted in some clear outliers. We excluded 27 trials with response times over 15000 ms (14 from native learners, 4 from early learners, and 9 from late learners), as well as 11 trials with response times under 1000 ms (6 from native learners, 4 from early learners, and 1 from a late learner). This eliminated 0.14% of trials from the set of 25,488 trials. The resulting distributions were log-distributed, as expected for response times (RT). We therefore based the subsequent analyses on log(RT). Outliers were defined as any trials where log(RT) fell outside 2.5 standard deviations of a given participant's own mean. This resulted in the exclusion of 578 additional trials (2.2%). To test the effects of group and rating on response times, we conducted a 2 × 2 mixed ANOVA with group as a nominal between-subjects factor and rating as a nominal[6] within-subjects factor.[7]

Mean response times to make the frequency ratings increased slightly across the AoLE groups (2922, 3056, and 3168 ms respectively for the native, early, and late learner groups); however, the ANOVA on log(RT) did not reach significance, F(2,52) = .92, *p* = .41. As before, we computed Bayes factors for each pairwise comparison (following Rouder et al., 2009), and found that for each pair, the null hypothesis was at least twice as likely as the alternative: Native vs. Early, 2.58:1, Native vs. Late, 2.16:1, Early vs. Late, 3.99:1. Thus, it is reasonable to conclude that RT in this task was not affected by AoLE.

In contrast, RT was affected by the mean subjective frequency of the stimulus signs. The omnibus ANOVA revealed a main effect of rating: F(6,52) = 24.93, *p* < .001. A post-hoc test for linear trend revealed that subjective frequency rating is a significant linear predictor of response times: higher frequency ratings were associated with faster RTs [*F*(1,312) = 126.84, p < .001]. There was no group x rating interaction: F(12,52) = 1.33, *p* = .20.

Given that deaf signers with varying AoLE of ASL strongly agree in their frequency ratings of signs, independent of years of ASL experience or chronological age, we computed the mean and median rating for each item (raw ratings and standard deviations) across all participants. These are given in the Appendix along with median and mean log(RT) with English glosses for the stimulus ASL signs (as given in Costello, 1994). For completeness, the same information is given for each group separately in the Supplemental Material.

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[6]JMP 8 does not support random effects with ordinal predictors.

[7]Four subjects (1 native, 2 early, 1 late) never gave a rating of "1"; to prevent the model from returning a singularity, these subjects were excluded from this analysis.

Discussion

We presented here the first subjective frequency ratings for a set of ASL signs. A novel contribution of the results is the direct comparison of ratings by deaf signers who were all highly experienced but who first began to acquire ASL at ages varying from birth to 14 years. This comparison provides valuable insights into the relation of AoLE and subjective frequency ratings. Because they began to acquire ASL from birth, the Native learners were comparable to the typical participants in studies of subjective lexical frequency in spoken and written language and thus provide a comparable control for ASL signs. Although deaf native learners constitute less than 10% of the ASL population, we observed high agreement in the subjective frequency ratings across the participants, independent of AoLE, years of ASL experience (beyond a minimum of 10), and chronological age. Thus, future psycholinguistic studies of sign language processing can be more confident in assuming that frequency distributions are relatively stable across participants with varying AoLE among highly experienced signers.

Although null effects must be interpreted with caution, the present results suggest that obtaining frequency information about signs from subjective ratings across diverse groups of deaf signers constitutes good experimental practice that can provide some control over lexical frequency in sign language experiments in the absence of objective frequency data. The subjective frequency ratings among the AoLE groups were highly correlated, for both mean and median ratings, and for items ranked as highly frequent and those ranked as relatively rare. Even the subjective frequency ratings of an additional small group of hearing L2 ASL learners correlated with those of the deaf AoLE groups, although less strongly, but we caution against using this type of ASL learner to provide baseline measures for sign frequency because their linguistic exposure to ASL probably differs from that of deaf signers.

The present results also suggest that lexical frequency is an important factor in the organization of the ASL mental lexicon, just as it is in the English mental lexicon. This was indicated by the high correlation between a sign's mean frequency rating and the median and mean log(RT) to estimate its frequency: the more often a stimulus sign was estimated to be seen in conversations with deaf signers, the more quickly the participants assigned a frequency rank to it; conversely, the less often the participants estimated they saw a stimulus sign in conversations, the more slowly they assigned a frequency rank to it. The fact that the AoLE groups did not differ in the strength of the correlations between frequency rank and RT to make frequency judgments further suggests that AoLE does not affect signers' sensitivity to lexical frequency in the linguistic environment. If AoLE has an effect on sensitivity to lexical frequency, it is too small to detect with a sample size of 59 participants.

As noted in the introduction, AoLE for language is not the same factor as lexical AoA (the age of learning a given word) and we did not gather such ratings here. It remains for future research to determine whether subjective lexical frequency ratings and lexical AoA estimates interact. If AoLE does not affect sensitivity to lexical frequency, then this may explain the similarities in ASL vocabulary acquisition among first-language learners of ASL of diverse ages. In other research, we have found that deaf adolescents acquiring ASL for the first time show lexical acquisition patterns remarkably similar to those of young deaf children (Ferjan Ramirez, Lieberman, & Mayberry, 2013). The apparent similarities in lexical acquisition patterns independent of the age when the learning begins may arise from lexical frequency in the sign language environment. This possibility suggests that lexical frequency may influence the development of the sign lexicon.

On the basis of the present results and our interpretation of them thus far, it might be tempting to conclude that AoLE does not affect lexical processing of signs. However, such a conclusion would be premature. Although the subjective frequency ratings from different AoLE groups in the present study are broadly consistent, previous studies using a variety of psycholinguistic paradigms have found AoLE to affect the processing of sign lexical structure of (Best, Mathur, Miranda, Lillo-Martin, 2010; Carreiras et al, 2008; Dye & Shih, 2006; Emmorey & Corina, 1990; Hall, Ferreira & Mayberry, 2012; Mayberry & Fischer, 1989; Morford & Carlson, 2011; Morford, Grieve-Smith, MacFarland & Waters, 2008; Orfanidou, Adam, McQueen & Morgan, 2009). There were hints in the present results that the native learners made frequency estimates the fastest, followed by early learners, with late learners taking the longest to make their decisions. This non-significant trend was due neither to chronological age or length of ASL experience. However, because we did not instruct the participants to make ratings as quickly as possible, this trend must be interpreted with caution. It is also important to note that the present data do not provide evidence of equal-sized frequency effects in relation to AoLE. For example, Native learners and Late learners might show differential responses to high vs. low frequency signs in a lexical decision paradigm. Instead, the present results demonstrate that when lexical items are frequent in the linguistic environment of Native learners, they are also highly frequent in the linguistic environment of non-native learners; the same is true for infrequent lexical items. This is logical because all signers contribute to the linguistic environment regardless of AoLE. The present results suggest that Early and Late learners of ASL are just as sensitive to lexical frequency in the linguistic environment as are Native learners, so as long they are highly experienced.

The ASL signs in the present study were selected for experimental purposes and not intended to be representative of the distribution of the ASL lexicon. Nonetheless, there was some overlap in the present results and those of the ASL corpus study by Morford and McFarlane (2003). The first-person pronoun was the most frequent closed class item in the ASL corpus, and it was the most highly ranked closed class item in the present results. The first-person pronoun was also among the most frequently occurring signs in both the New Zealand Sign Language (McKee & Kennedy, 2006) and the Auslan (Johnston, 2011) corpora. One of the most frequently occurring content items in the ASL corpus study was BOY, and this sign received a high mean frequency rating from the ASL signers in the present study. BOY was also among the most frequently occurring signs in the Auslan corpus (Johnston, 2011); it also received a high mean frequency rating from British Sign Language signers (Vinson et al, 2008). Although few in number, the similarities between objective lexical frequency and subjective frequency rankings for signs across studies is encouraging. This also suggests that correlations between objective lexical frequency and subjective frequency ratings will be found for sign languages as have been found for spoken languages (Balota et al., 2001; Ferrand et al., 2008; Thompson & Desrocher, 2009).

Much remains to be learned about the acquisition, processing, and organization of the ASL mental lexicon in relation to lexical frequency and AoLE. The present results demonstrate that collecting subjective frequency ratings for signs provides a viable means of controlling lexical frequency so that these important questions can be investigated.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

Baayen, RH. Word Frequency Distributions. Dordrecht, The Netherlands: Kluwer; 2001.

Baayen, RH.; Piepenbrock, R.; Rijn, van H. The CELEX lexical data base (CD-ROM). Philadelphia: University of Pennsylvania, Linguistic Data Consortium; 1993.

Balota DA, Pilotti M, Cortese MJ. Subjective frequency estimates for 2,938 monosyllabic words. Memory & Cognition. 2001; 29:639–647. [PubMed: 11504012]

Balota DA, Yap MJ, Cortese MJ, Hutchinson KA, Kessler B, Loftis B, Neely JH, Nelson DL, Simpson GB, Treiman R. The English lexicon project. Behavior Research Methods. 2007; 39:445–459. [PubMed: 17958156]

Best CT, Mathur G, Miranda KA, Lillo-Martin D. Effects of sign language experience on categorical perception of dynamic ASL pseudosigns. Attention, Perception, and Psychophysics. 2010; 72:747–762.

Bock, K.; Griffin, Z. Producing words: How mind meets mouth. In: Wheeldon, LR., editor. Language Production. London: Psychology Press; 2000. p. 7-48.

Boudreault P, Mayberry RI. Grammatical processing in American Sign Language: Age of first-language acquisition effects in relation to syntactic structure. Language and Cognitive Processes. 2006; 21:608–635.

Carreiras M, Gutiérrez-Sigut E, Baquero S, Corina D. Lexical processing in Spanish Sign Language (LSE). Journal of Memory and Language. 2008; 58:100–122.

Chute, D.; Westall, RF. PowerLaboratory. Devon, PA: MacLaboratory, Inc; 1996.

Costello, E. Random House American Sign Language Dictionary. New York, NY: Random House; 1994.

Dahan D, Magnuson JS, Tanenhaus MK. Time course of frequency effects in spoken-word recognition: Evidence from eye movements. Cognitive Psychology. 2001; 42:317–367. [PubMed: 11368527]

Dye, MW.; Shih, SI. Phonological priming in British Sign Language. In: Goldstein, Louis M.; Whalen, Douglas H.; Best, Catherine T., editors. Laboratory Phonology. Vol. 8. Berlin: Mouton de Gruyter; 2006. p. 241-264.

Dell GS. Effects of frequency and vocabulary type on phonological speech errors. Language and Cognitive Processes. 1990; 5:313–349.

Emmorey K. Repetition priming with aspect and agreement morphology in American Sign Language. Journal of Psycholinguistic Research. 1991; 20:365–388. [PubMed: 1886075]

Emmorey, K., editor. Perspective on classifier constructions in sign language. Mahwah, N.J.: Lawrence Erlbaum Associates; 2003.

Emmorey K, Corina D. Lexical recognition in American Sign Language: Effects of phonetic structure and morphology. Perceptual and Motor Skills. 1990; 71:1227–1252. [PubMed: 2087376]

Ferjan Ramirez N, Lieberman AM, Mayberry RI. The initial stages of first-language acquisition begun in adolescence: When late looks early. Journal of Child Language. 2013; 4,0:391–414.

Ferrand L, Bonin P, Meot A, Augustinova M, New B, Pallier C, Brysbaert M. Age-of-acquisition and subjective frequency estimates for all generally known monosyllabic French words and their relation with other psycholinguistic variables. Behavior Research Methods. 2008; 40:1049–1054. [PubMed: 19001395]

Gardner MK, Rothkopf EZ, Lapan R, Lafferty T. The word frequency effect in lexical decision: Finding a frequency-based component. Memory & Cognition. 1987; 15:24–28. [PubMed: 3821488]

Gaygen DE, Luce PA. Effects of modality on subjective frequency estimates and processing of spoken and printed words. Perception & Psychophysics. 1998; 60:465–483. [PubMed: 9599996]

Gernsbacher MA. Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. Journal of Experimental Psychology: General. 1984; 113:256–281. [PubMed: 6242753]

Ghyselinck M, Lewis MB, Brysbaert M. Age of acquisition and the cumulative-frequency hypothesis: A review of the literature and a new multi-task investigation. Acta Psychologica. 2004; 115:43–67. [PubMed: 14734241]

Gilhooly KJ, Logie RH. Age-of-acquisition, imagery, concreteness, familiarity, and ambiguity measures for 1,944 words. Behavior Research Methods & Instrumentation. 1980; 12:395–427.

Hall ML, Ferreira VS, Mayberry RI. Phonological similarity judgments in ASL: Evidence for maturational constraints on phonetic perception in sign. Sign Language and Linguistics. 2012; 15:104–127.

Holliman EC, McDaniel J. SWITCHBOARD: telephone speech corpus for research and development. IEEE International Conference on Acoustics, Speech, and Signal Processing. 1992:517–520.

Johnston T. Lexical frequency in sign languages. Journal of Deaf Studies and Deaf Education. 2011; 17:163–192. [PubMed: 21841168]

Kreuz RJ. The subjective familiarity of English homophones. Memory & Cognition. 1987; 15:154–168. [PubMed: 3683180]

Kucera, H.; Francis, WN. Computational analysis of present-day American English. Providence: Brown University Press; 1967.

McKee D, Kennedy G. The distribution of signs in New Zealand Sign Language. Sign Language Studies. 2006; 6:372–390.

Mayberry RI, Chen JK, Witcher P, Klein D. Age of acquisition effects on the functional organization of language in the adult brain. Brain and Language. 2011; 119:16–29. [PubMed: 21705060]

Mayberry RI, Fischer S. Looking through phonologival shape to lexical mleaning: The bottleneck of non-native sign language processing. Memory & Cognition. 1989; 17:740–754. [PubMed: 2811671]

Mayberry RI, Lock E. Age constraints on first versus second language acquisition: Evidence for linguistic plasticity and epigenesis. Brain and Language. 2003; 87:369–383. [PubMed: 14642540]

Mayberry RI, Lock E, Kazmi H. Linguistic ability and early language exposure. Nature. 2002; 417:38. [PubMed: 11986658]

Mayberry RI. Lexical processing in ASL. in preparation

Morford JP, Carlson ML. Sign perception and recognition in non-native signers of ASL. Language Learning and Development. 2011; 7:149–168. [PubMed: 21686080]

Morford JP, Grieve-Smith AB, MacFarlane J, Staley J, Waters G. Effects of sign language experience on the perception of American Sign Language. Cognition. 2008; 109:41–53. [PubMed: 18834975]

Morford JP, MacFarlane J. Frequency characteristics of American Sign Language. Sign Language Studies. 2003; 3:213–225.

Morrison CM, Chappell TD, Ellis AW. Age of acquisition norms for a large set of object names and their relation to adult estimates and other variables. Quarterly Journal of Experimental Psychology. 1997; 50:528–559.

Newport E. Maturational constraints on language learning. Cognitive Science. 1990; 14:11–28.

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NIH-PA Author Manuscript

Nusbaum, HC.; Pisoni, D.; Davis, CK. Sizing up the hoosier mental lexicon: Measuring the familiarity of 20,000 words. Bloomington: University of Indiana Speech Research Laboratory; 1984. No. 10 Research on Speech Perception Progress Report

Orfanidou E, Robert A, McQueen JM, Morgan G. Making sense of nonsense in British Sign Language (BSL): The contribution of different phonological parameters to sign recognition. Memory & Cognition. 2009; 37:302–315. [PubMed: 19246345]

Ormel, E.; Crasborn, O.; van der Kooij, E.; van Dijken, L.; Nauta, E.; Van Zuilen, M.; Forster, J.; Stein, D.; De Meijer, A. Glossing a multi-purpose sign language corpus; Malta. Proceedings of the 4th Workshop on the Representation and Processing of Sign Languages: Corpora and Sign Language Technologies, LREC 2010; 22–23 May 2010; 2010. p. 186-191.

Pastizzo MJ, Carbone RF. Spoken word frequency counts based on 1.6 million words in American English. Behavioral Research Methods. 2007; 39:1025–1028.

Peereman R, Content A, Bonin P. Is perception a two-way street? The case of feedback consistency in visual word recognition. Journal of Memory & Language. 1998; 39:151–174.

Rouder JN, Morey RD, Speckman PL, Province JM. Default Bayes factors for ANOVA designs. Journal of Mathematical Psychology. 2012; 56:356–374.

Rouder JN, Speckman PL, Sun D, Morey RD. Bayesian *t* tests for accepting and rejecting the null hypothesis. Psychonomic Bulletin & Review. 2009; 16:225–237. [PubMed: 19293088]

Schein, JD. At home among strangers: Exploring the deaf community in the United States. Washington, DC: Gallaudet University Press; 1989.

Spieler DH, Balota DA. Bringing computational models of word naming down to the item level. Psychological Science. 2000; 8:411–416.

Toglia, MP.; Battig, WF. Handbook of semantic word norms. Hillsdale, NJ; New York; Toronto: Lawrence Erlbaum Associates; 1978.

Thompson GL, Desrochers A. Corroborating biased indicators: Global and local agreement among objective and subjective estimates of printed word frequency. Behavior Research Methods. 2009; 41:452–471. [PubMed: 19363186]

Vinson DP, Cormier K, Denmark T, Schembri A, Vigliocco G. The British Sign Language (BSL) norms for age of acquisition, familiarity, and iconicity. Behavior Research Methods. 2008; 40:1079–1087. [PubMed: 19001399]

Zevin JD, Seidenberg MS. Age of acquisition effects in word reading and other tasks. Journal of Memory and Language. 2002; 47:1–29.

Appendix

Subjective Frequency Ratings for 432 ASL Signs[8,9]

Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
$5	4.54	5	2843	7.99
70	4.27	4	3025	8.14
89	4.22	4	3507	8.21
9 o'clock	6.03	7	3092	8.08
About	4.17	4	2836	7.99
Accident	4.80	5	2686	7.97
Accomplish	4.14	4	2648	7.93
Act	4.81	5	2897	8.03
Afraid	4.88	5	2561	7.90
After	4.24	4	2921	8.01
Age	4.95	5	2572	7.93
Agree	4.68	5	3041	8.04

Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
America	4.81	5	2933	8.04
And	4.54	5	3222	8.13
Angry	5.27	5	2551	7.95
Animal	4.46	4	2862	8.08
Announce	5.41	5	2637	7.93
Appear	4.27	4	2964	8.00
Anyway	5.32	6	2581	7.92
Apple	4.53	5	2483	7.90
Appointment	4.47	4	2962	8.04
Army	3.64	4	2704	7.94
Ask	4.51	5	2716	7.98
Awkward	4.24	4	2940	8.06
Baby	5.15	5	2748	7.95
Bad	5.42	6	2657	7.93
Baggage	4.44	5	2658	7.92
Bake	3.25	3	2684	8.00
Balance	3.97	4	2681	8.01
Ball	4.10	4	2854	8.04
Banana	4.36	4	3024	8.10
Baseball	4.17	4	2640	7.97
Basement	4.37	4	2727	7.91
Basketball	3.78	4	2587	7.92
Bath	5.08	5	2470	7.91
Beard	3.47	3	2810	8.05
Because	4.63	5	2656	8.00
Beer	4.44	4	2881	8.04
Behind	4.64	5	2941	8.02
Bird	4.46	4	2732	7.95
Birth	4.58	5	2861	8.00
Black	4.24	4	2767	8.04
Blind	3.64	4	2722	8.04
Blood	4.12	4	3052	8.06
Blue	4.47	4	2843	7.97
Body	4.53	5	2833	8.01
Book	5.63	6	2682	7.99
Bored	5.03	5	2948	8.02
Borrow	5.12	5	2582	7.89
Boss	3.58	3	2695	8.00
Bowl	4.36	4	2786	7.95
Box	4.27	4	2852	8.07
Boy	5.68	6	2430	7.90
Brave	4.80	5	2748	8.02

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Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
Bread	5.46	6	2673	7.98
Break	5.42	6	2611	7.94
Breakdown	4.95	5	2474	7.85
Bridge	3.68	4	2691	7.93
Brother	5.15	5	2592	7.94
Butter	4.47	5	2716	8.01
Butterfly	3.69	4	2730	7.92
Cabbage	4.98	5	2719	7.97
Cabinet	4.05	4	2910	8.02
Call	5.10	5	2554	7.91
Camera	5.02	5	2493	7.86
Canada	5.49	6	2601	7.91
Cancel	5.41	5	2647	7.98
Candy	3.68	4	2765	8.00
Captain	2.76	3	2805	8.05
Caption	4.41	4	2885	8.07
Car	6.10	7	2578	7.96
Careful	4.76	5	2620	8.00
Catholic	3.88	4	2765	7.94
Center	4.64	4	2647	7.98
Cereal	4.39	4	2803	8.05
Certificate	4.05	4	2481	7.92
Chair	4.95	5	2504	7.92
Challenge	4.63	5	2942	8.05
Character	4.27	4	2810	7.99
Chat	6.03	7	2425	7.85
Check	5.22	5	2801	7.97
Cheese	4.27	4	2846	7.99
Children	4.92	5	2592	7.90
Chocolate	4.83	5	2553	7.97
Church	3.83	4	2791	7.99
Cigarette	3.17	3	2842	7.97
City	5.10	5	2677	7.93
Class	4.19	4	2709	7.97
Clergy	3.64	4	2805	8.05
Clown	3.03	3	2803	7.99
Cold	4.71	5	2669	7.96
College	5.10	5	2692	7.94
Colour	4.54	4	2697	7.97
Comb	3.42	3	2969	8.04
Communication	5.63	6	2659	7.94
Congrat.	4.41	4	2715	7.96

Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
Cookie	4.29	4	2478	7.91
Cost	5.08	5	2705	7.93
Cough	3.97	4	2993	8.06
Counsellor	4.42	4	2810	7.98
Country	4.59	5	2826	7.98
Court	4.56	5	2618	7.97
Cousin	4.02	4	2733	7.97
Cow	3.90	4	2700	8.00
Cracker	2.97	3	2834	8.00
Cruel	4.14	4	2612	7.93
Cry	4.46	4	2515	7.92
Cup	4.32	4	2965	8.06
Cute	3.19	3	2890	7.99
Day	5.20	6	2789	8.00
Debt	4.46	5	2771	8.01
Decide	5.37	5	2722	7.98
Deep	4.31	4	2869	8.03
Delicious	3.37	3	2593	7.94
Disagree	4.78	5	3061	8.04
Divorce	4.19	4	2794	7.97
Don’t mind	5.00	5	2849	7.98
Doubt	4.02	4	2747	7.99
Drama	4.46	5	2759	7.97
Drawer	3.32	3	3374	8.13
Dream	4.64	5	2719	7.95
Drink	6.22	7	2543	7.87
Drop	4.47	5	2909	7.97
Drunk	4.61	5	2790	7.98
Earn	4.22	4	2497	7.96
Earring	3.29	3	2964	8.05
Egypt	2.46	2	2617	7.97
Embarrass	4.17	4	2732	7.96
Emotion	4.58	5	2774	7.98
Engagement	3.64	4	2815	8.02
England	4.02	4	3116	8.11
Equal	5.29	5	2608	7.92
Establish	4.92	5	2439	7.92
Europe	4.08	4	2806	7.97
Exercise	4.56	4	2961	8.07
Expensive	4.66	5	2835	8.01
Experience	5.51	6	2715	8.00
Explain	5.41	6	2568	7.96

Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
Eye	3.29	3	3037	8.10
Fall (autumn)	4.66	4	2603	7.93
Fall (down)	3.61	3	2687	8.01
Family	5.61	6	2503	7.88
Farm	3.86	4	2751	7.97
Fast	5.22	5	2726	8.00
Fat	2.73	2	2884	8.10
Father	5.47	6	2589	7.89
Fault	4.20	5	2860	8.07
Favorite	4.86	5	2627	7.95
Feel	5.32	5	2564	7.94
Few	2.90	3	2738	8.02
Fight	4.56	5	2532	7.93
Finish	6.07	7	2868	7.95
Fire	4.44	4	2576	7.94
Fish	2.97	3	2583	7.91
Flower	4.25	4	2540	7.93
Food/Eat	6.14	7	2533	7.91
Football	3.78	4	2723	7.97
For	5.14	6	2476	7.89
Four	5.00	5	2765	8.02
Freckles	2.93	3	2823	7.99
Freeway	4.25	4	2869	8.02
France	4.69	5	2779	7.98
French-fries	4.32	4	3179	8.09
Friday	5.98	6	2702	8.01
Friendly	4.71	5	2379	7.93
Front	3.39	3	2569	7.98
Fruit	4.20	4	2686	8.01
Furniture	3.44	3	3355	8.09
Gallaudet	4.46	4	3072	8.06
Game	5.10	5	2627	7.92
Get	5.64	6	2470	7.89
Girl	5.12	5	2720	7.99
Glasses	5.14	5	2784	7.98
Good	5.95	6	2550	7.88
Government	4.15	4	2716	7.96
Graduate	5.22	5	2583	7.94
Grandfather	4.37	4	2764	7.98
Grandmother	4.41	4	2899	8.03
Grass	3.49	4	2795	7.97
Greece	2.42	2	2959	8.04

Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
Green	4.44	4	2672	7.92
Grow	4.36	4	2712	7.98
Hair	4.92	5	2899	8.00
Hairdryer	2.92	3	2883	8.08
Hamburger	4.81	5	2720	7.96
Hammer	3.32	3	2891	8.11
Happy	6.17	6	2546	7.91
Hard	5.03	5	2745	7.92
Hat	4.00	4	2849	8.03
Have	4.71	5	3055	8.02
Headache	4.78	5	2552	7.95
Health	5.15	5	2629	7.94
Hearing (person)	5.14	6	2759	8.02
Hearing-aid	3.53	3	2716	7.99
Heart	4.95	5	2655	7.98
High	5.32	5	2390	7.88
High School	4.39	4	2691	7.93
History	4.03	4	2802	8.01
Hockey	5.27	5	2466	7.92
Home	6.37	7	2451	7.92
Honest	4.47	5	2634	7.95
Honor	4.47	5	2433	7.86
Horse	3.81	3	2422	7.86
Hospital	4.44	4	2897	8.03
Hotdog	4.71	5	2704	7.97
Hour	5.20	6	3125	8.07
Hungry	5.83	6	2440	7.89
Hunt	3.15	3	3563	8.18
Ice Cream	4.10	4	2925	8.00
Imagine	4.95	5	2676	8.01
Impossible	4.68	5	3040	8.05
Indian	3.29	3	3101	8.09
Insect	3.64	4	2752	7.98
Internet	6.24	7	2628	7.89
Invite	4.78	5	2792	7.99
Island	3.66	4	2664	7.96
Israel	3.08	3	2961	8.02
Jacket	5.10	5	2815	8.02
Jewish	3.59	3	2734	7.96
Key	5.34	6	2717	7.99
Kid	4.53	5	2704	8.00
King	3.80	3	2674	7.96

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Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
Kneel	3.32	3	2805	8.03
Knife	4.51	5	3014	8.08
Knob	2.80	3	3120	8.03
Know	5.31	6	2585	7.91
Language	4.71	5	2664	7.99
Last	5.49	5	2677	7.97
Late	4.71	5	2669	7.96
Laugh	5.00	5	2671	8.00
Learn	5.42	6	2617	7.92
Leave	4.90	5	2718	7.98
Lecture	4.81	5	2507	7.91
Letter	4.83	5	2704	8.01
Lie	3.56	4	2603	7.96
Life	5.08	5	2479	7.90
Light-Weight	3.92	4	2957	8.02
Lipstick	3.63	4	2815	8.02
Lonely	2.88	3	2850	8.04
Look-for	5.34	5	2579	7.96
Lose-game	2.47	2	3090	8.10
Machine	4.53	5	2561	7.97
Magazine	5.14	5	2700	7.94
Make	5.24	6	2541	7.94
Man	5.20	5	2834	7.98
Math	4.22	4	2633	7.95
Me	5.81	7	2757	8.00
Measure	4.20	4	2677	7.93
Medicine	5.10	5	2727	7.97
Milk	5.81	6	2443	7.89
Mind	4.78	5	2660	7.95
Mirror	3.71	3	2905	8.04
Miss/Gone	4.54	5	2330	7.90
Misunderstand	4.68	5	2760	8.01
Mock	4.00	4	2754	8.00
Monday	5.27	6	3022	8.03
Money	5.71	6	2523	7.90
Monkey	3.36	3	2703	8.03
Moon	3.93	4	3030	8.01
More	5.29	5	2606	7.94
Morning	6.00	6	2603	7.91
Moron	4.63	5	2661	8.00
Mother	5.85	6	2242	7.78
Mouth	3.20	3	3074	8.03

Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
Movies	5.00	5	2760	7.97
Much	4.98	5	2595	7.95
Multiply	4.54	5	2820	7.99
Mumps	2.22	2	2775	7.98
Mustache	3.07	3	2752	7.97
My	4.90	5	2989	8.05
Nephew	3.31	3	2894	8.03
New	5.53	6	2676	7.97
New York	3.64	4	2660	8.00
Night	6.34	7	2359	7.87
No	5.85	6	2596	7.99
Nothing	4.05	4	2863	8.03
Numbers	5.53	6	2540	7.89
Nurse	3.39	3	2900	8.02
Onion	4.49	4	2738	7.94
Oral	3.90	4	2754	8.00
Orange	3.85	4	2882	7.99
Other	5.22	5	2564	7.99
Pain	4.68	5	2752	8.05
Paper	5.66	6	2584	7.99
Parade	3.17	3	2675	7.96
Parents	6.00	7	2424	7.86
Past	5.00	5	2906	8.04
Patient (adj)	4.63	5	2663	7.97
Peace	4.12	4	2953	8.05
Person	4.49	5	3117	8.04
Phone	5.85	6	2526	7.92
Pie	3.98	4	2831	8.02
Pig	3.24	3	2586	7.89
Pile	3.54	4	2924	8.05
Pill	3.88	4	2831	8.03
Pipe	3.03	3	3128	8.06
Pity	4.73	5	2532	7.89
Play	5.49	5	2430	7.93
Please	6.00	7	2579	7.91
Poison/Bone	2.22	2	2610	8.00
Polite	3.27	3	3018	8.05
Poor	4.44	4	2905	7.99
Potato	4.58	4	2654	8.06
Power	4.47	5	3239	8.21
Pray	3.66	3	2804	8.01
Pretty	5.25	5	2458	7.97

Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
Price	4.59	4	3634	8.31
Print	5.27	5	2806	8.00
Protect	4.02	4	2815	8.01
Punish	4.20	4	2346	7.89
Purple	3.69	4	2616	7.89
Puzzled	3.49	3	2861	8.00
Quiet	3.98	4	2917	7.99
Rabbit	3.34	3	2525	7.96
Radio	2.34	2	2768	8.04
Rain	4.51	5	2842	8.00
Real	4.08	4	2783	8.05
Reason	4.63	5	2576	7.96
Red	4.34	5	2703	7.99
Relationship	4.93	5	2535	7.90
Religion	4.00	4	2653	7.97
Require	4.58	5	2593	7.99
Research	3.69	4	2886	8.01
Responsible	5.15	5	2451	7.90
Ring	2.51	2	2919	8.06
Room	4.75	5	2630	7.90
Rude	4.51	5	3011	7.99
Run	4.66	5	2557	7.97
Russia	3.58	3	2568	7.97
Sad	4.93	5	2520	7.91
Salad	5.14	5	2731	7.94
Salt	3.81	4	2965	8.05
Same	5.59	6	2605	7.95
School	5.05	5	2692	7.96
Scissors	4.12	4	2572	7.91
Secret	4.27	4	3071	8.07
Secretary	4.02	4	3016	8.07
Sentence	4.24	4	2985	8.03
Serious	4.36	4	2820	8.00
Sew	3.71	4	2631	7.92
Sheep	3.24	3	2724	7.95
Shirt	4.42	5	2827	8.03
Shopping	5.81	6	2598	7.89
Shorts	2.54	2	2903	8.08
Show	5.49	6	2469	7.99
Shower	4.47	5	3134	8.07
Shy	4.22	4	2712	7.95
Sick	5.25	5	2579	7.90

Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
Silly	3.63	4	2724	7.96
Skate	3.92	4	2871	8.05
Sleep	5.58	6	2718	8.01
Slow	4.14	4	2934	8.03
Smoke (to)	3.78	4	2842	8.08
Snob	2.98	2	2743	7.95
Socks	3.39	3	3461	8.22
Some	4.37	4	2804	8.00
Son	4.92	5	2668	8.01
Sorry	5.98	6	2664	7.93
Spaghetti	3.97	4	2879	8.07
Speak/Talk	1.97	1	2644	7.97
Stamp	3.25	3	2724	8.01
Star	4.02	4	3015	8.02
Stomach	3.37	3	2812	8.02
Strange	4.68	5	2704	7.97
Stress	4.93	5	2617	7.95
Strict	4.14	4	2833	8.01
Stubborn	4.66	5	2505	7.90
Subtract	3.78	4	2651	7.95
Summer	4.93	5	2765	8.00
Sunny	4.44	5	2957	8.07
Sunset	3.58	3	2675	7.96
Surprise	4.88	5	2472	7.93
Suspect	4.44	4	2835	8.04
Swallow	3.73	4	2983	8.07
Talk/Dialogue	2.69	2	2973	8.05
Tall	3.75	4	2550	7.88
Tea	4.64	5	2585	7.97
Tear	3.27	3	2880	8.08
Television	6.12	7	2636	7.93
Tempt	4.39	4	2548	7.89
That	4.47	5	2828	8.03
Thief	3.20	3	2497	7.92
Thin	4.49	5	2695	7.96
Thing	5.08	5	2613	7.98
Thirst	5.08	5	2554	7.94
Three	4.47	5	2882	8.02
Throw	3.10	3	2965	8.07
Thursday	4.95	5	2906	8.04
Time	6.42	7	2335	7.82
Tired	5.31	6	2471	7.86

Sign	Mean Rating	Median Rating	Median RT	Mean log(RT)
Toilet	6.14	7	2453	7.87
Tournament	4.22	4	2806	7.94
Traffic	3.68	4	2801	8.02
Train	4.14	4	2713	8.01
Travel	5.24	5	2593	7.96
Trouble	5.08	5	2777	7.98
Turtle	3.08	3	2819	7.99
Two	4.53	4	3126	8.07
Type/Kind	4.59	5	2635	7.94
Ugly	4.10	4	2752	7.96
Umbrella	3.46	3	2765	7.97
Understand	6.19	7	2565	7.88
University	5.08	5	2687	7.99
Vacation	4.61	5	2844	7.94
Vegetables	5.08	5	2664	7.98
Victim	4.68	5	2626	7.94
Voice	3.83	4	2830	8.04
Vote	4.19	4	2887	7.98
Wait	5.46	6	2409	7.87
Warm	4.54	5	2885	8.03
Warn	5.37	6	2513	7.91
Wash machine	5.15	5	2481	7.91
Waste	4.05	4	2721	8.02
Weak	4.76	5	2661	8.00
Wear	2.10	1	2686	7.99
Weather	2.93	2	2975	8.05
Wednesday	5.08	5	2938	8.01
Week	6.02	6	2685	7.92
Wet	3.73	4	2819	8.02
What-for	5.66	6	2542	7.91
Where	5.59	6	2575	7.95
Which	5.41	6	2543	7.90
Who	5.14	5	2743	7.98
Win	4.49	4	3001	8.12
Wish	5.64	6	2574	7.93
Wonder	4.66	5	2772	7.98
Work	6.20	7	2578	7.87
World	4.97	5	2743	8.00
Worry	5.41	6	2757	7.93
Wrist-watch	3.22	3	3128	8.03
Year	5.42	6	2683	7.97
Yourself	3.78	4	2981	8.05

[8]The English glosses for the ASL signs correspond to those used in Costello (1994).

[9]Ratings and RT are computed for the entire sample; see the supplemental material for results for each AoLE group.

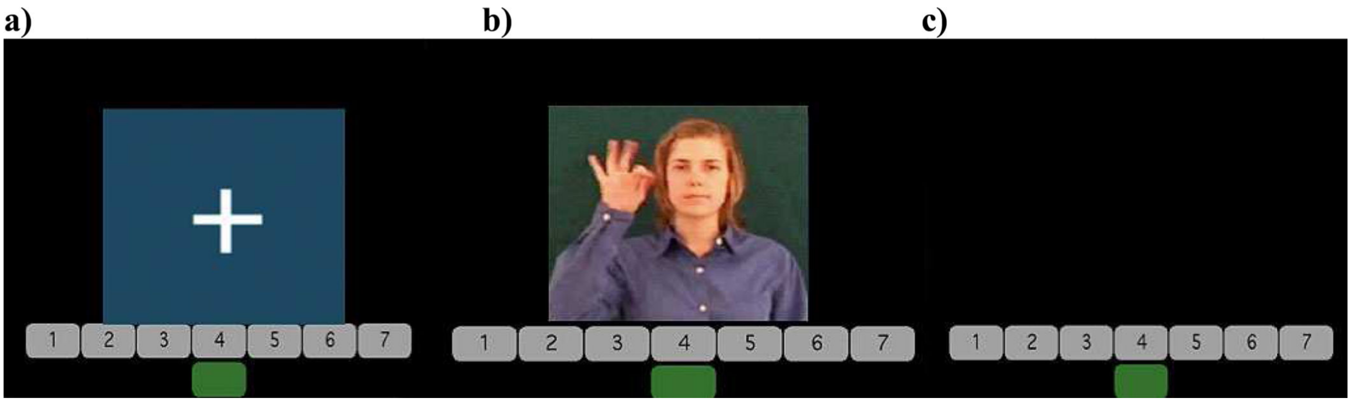

Figure 1.
Screen images showing the format and sequence of the subjective frequency rating task. Each trial consisted of several steps: a) a focus signal appeared for 300 ms, b) followed by the stimulus sign which appeared dynamically in real time; c) when the sign disappeared, the participant made a frequency rating with a mouse click (1 = *rarely see*; 7 = *usually see*). Last, the participant clicked the green GO box under the scale to initiate the next trial.

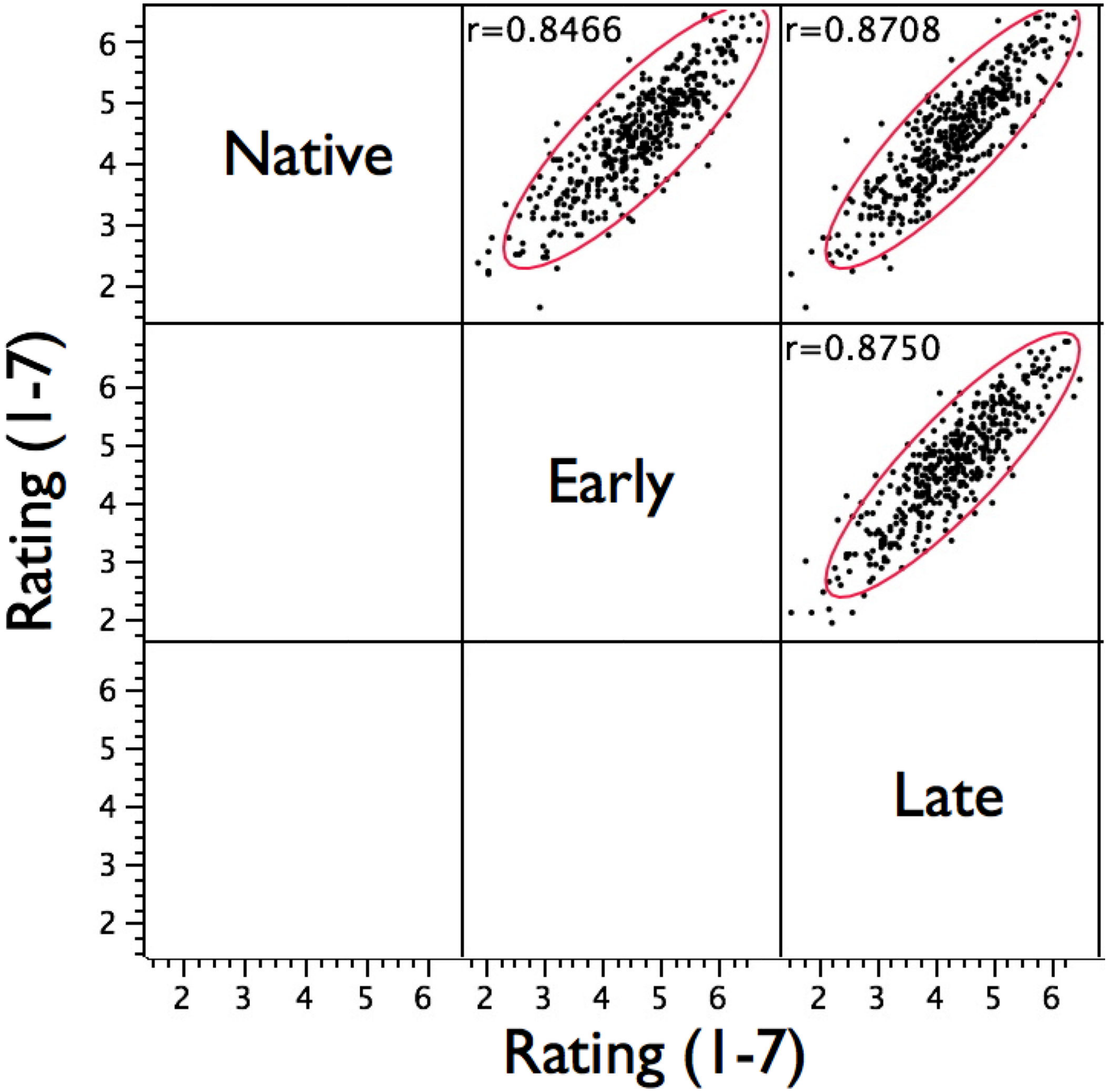

Figure 2.
Inter-group scatterplots and Pearson *r* for each item (raw ratings).

Table 1

Background of the participant groups

Group	Female/n	Age of ASL Exposure Mean (Range)	Chronological Age Mean (SD)	Length of ASL Experience Mean (SD)
Native	12/22	0.45 (0–3)	29.6 (11.55)	29.9 (11.52)
Early	8/17	5.76 (4–8)	43.35 (10.35)	37.64 (9.98)
Late	10/20	11.86 (9–14)	35.2 (10.45)	23.4 (10.64)

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Table 2

Parametric (and non-parametric) correlation coefficients for subjective frequency ratings by learner group: Pearson *r* (Spearman ρ).

AoLE Group	Native	Early	Late
Native	-	.847* (.731*)	.871* (.789*)
Early	-	-	.875* (.768*)
Late	-	-	-

*$p < .001$