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Bilingual word recognition in deaf and hearing signers: Effects of proficiency and language dominance on cross-language activation

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Abstract

Recent evidence demonstrates that American Sign Language signs are active during print word recognition in deaf bilinguals who are highly proficient in both ASL and English. In the present study, we investigate whether signs are active during print word recognition in two groups of unbalanced bilinguals: deaf ASL-dominant and hearing English-dominant bilinguals. Participants judged the semantic relatedness of word pairs in English. Critically, a subset of both the semantically related and unrelated English word pairs had phonologically related translations in ASL, but participants were never shown any ASL signs during the experiment. Deaf ASL-dominant bilinguals (Experiment 1) were faster when semantically related English word pairs had similar form translations in ASL, but slower when semantically unrelated words had similar form translations in ASL, indicating that ASL signs are engaged during English print word recognition in these ASL-dominant signers. Hearing English-dominant bilinguals (Experiment 2) were also slower to respond to semantically unrelated English word pairs with similar form translations in ASL, but no facilitation effects were observed in this population. The results provide evidence that the interactive nature of lexical processing in bilinguals is impervious to language modality.

Keywords

Bilingualism; Word Recognition; Sign Language; Deaf

With increasing globalization, multilingualism is on the rise. Research on bilinguals is well established, but only recently have investigators discovered that bilinguals activate words in both languages even when the task requires the use of one language only (Brown & Gullberg, 2011; Van Hell & Dijkstra, 2002; Thierry & Wu, 2007). These studies raise important questions about the structure of the lexicon and the way that the acquisition of

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alternative lexical forms and their meanings across the lifespan impacts the time course of word recognition, whether in the first (L1) or the second (L2) language. An enduring question is whether the earliest stages of word recognition can be limited to the target language only, *selective access,* or whether multilinguals generally activate representations from multiple languages even when there is no advantage to doing so, *nonselective access.* Critically, there are questions about the scope of language nonselectivity and the factors that might serve to limit processing to the intended language.

Both written and spoken word recognition studies provide evidence that L1 representations are active during L2 word recognition (Dijkstra, 2005; Marian & Spivey, 2003). These findings may not come as a surprise since the L1 is assumed to mediate and support L2 acquisition. Indeed, an early model of bilingual lexical representation, the Revised Hierarchical Model (RHM, Kroll & Stewart, 1994) predicts that a reliance on lexical associations between L2 and L1 is a central feature of language usage during second language learning. With increasing proficiency, the RHM assumes that bilinguals establish direct connections from L2 lexical forms to meaning, resulting in less reliance on L1 forms to access meaning during L2 tasks. There is no doubt that highly proficient bilinguals can access meaning directly in their L2. Nevertheless, accumulating evidence demonstrates that words from the L1 are active during L2 word recognition even for highly proficient bilinguals (Sunderman & Kroll, 2006) indicating that nonselective access is a general feature of the bilingual lexicon, not a characteristic specific to developing bilinguals.

Nonselective access is also not restricted to words acquired in the second language. Several studies show that the non-dominant language can influence word recognition in the dominant language. Van Hell and Dijkstra (2002), for example, found a cognate facilitation effect in Dutch-English-French trilinguals completing a lexical decision task in their native language. Participants responded more quickly to Dutch words with English and French cognates (e.g. Dutch *appel* with English cognate *apple)* than to Dutch noncognates. Other studies have shown that the influence of the L2 on the L1 can be observed even in a masked priming paradigm in which the participant is unaware that the L2 is present (e.g. Van Wijnendaele & Brysbaert, 2002). Word form similarities across languages appear to impact word recognition in all of the bilingual or trilingual's languages and for both highly proficient bilinguals and less skilled learners.

Perhaps the most robust evidence for cross-language activation comes from cognate facilitation effects (Lemhöfer, Dijkstra, & Michel, 2004; Van Hell & Dijkstra, 2002). Bilinguals are consistently faster to respond to cognates than noncognates in a variety of tasks. Lemhöfer, Dijkstra, Schriefers, Baayen, Grainger, and Zwitserlood (2008) concluded that cognate status is the only cross-language factor that produces comparable effects to within-language factors such as word frequency (see Strijkers, Costa, & Thierry, 2010, for recent ERP evidence in lexical production that suggests a similar basis for cognate and word frequency effects).

Interlingual homographs and homophones have also been reported to produce inhibition during bilingual processing tasks (e.g. De Groot, Delmaar, & Lupker, 2000; Dimitropoulou, Duñabeitia, & Carreiras, 2011; Jared & Szucs, 2002; Macizo, Bajo, & Martín, 2010; Von

Studnitz & Green, 2002), but these effects are more dependent on the conditions of presentation and task demands than cognate effects (e.g. Dijkstra, Van Jaarsveld, & Ten Brinke, 1998). For example, Bijeljac-Babic, Biardeau and Grainger (1997) found inhibition when highly proficient French-English bilinguals made lexical decisions about low frequency target words in English. When the targets were preceded by a masked orthographically-related high frequency English prime (within-language condition), participants experienced inhibition relative to the control condition when the masked prime was orthographically unrelated to the target. Crucially, the same pattern of response latencies was found when the primes were in French rather than English (cross-language condition). However, a replication with bilinguals who varied in proficiency revealed that the inhibition effects were only significant for the most proficient group. Wu and Thierry (2010) point out that most studies relying on interlingual homographs include a confound because homographs are often also homophones (e.g. French *plan* and English *plan* share not only orthographic similarities, but also phonological similarities). They performed an experiment that included separate orthographic and phonological manipulations in both spoken and written conditions, and concluded that in the absence of direct activation of orthography, cross-language effects are driven primarily by parallel activation of phonological representations. In sum, there is considerable evidence for nonselective access in both monolingual and bilingual tasks, with bidirectional effects, and across all proficiency levels, but the most robust effects rely on similar phonological forms across spoken languages.

Bilinguals who know a signed and a spoken language form a unique population, and allow us to bring new insights to questions that have been investigated only in the context of spoken language bilingualism.[1] Most previously identified effects of bilingualism are related in large part to the form similarities between the two languages in question. Because a signed language and a spoken language are much less likely to have form similarities than two spoken languages due to modality differences (Brentari, 2007), investigations of word recognition in deaf and hearing signers provide a novel contrast to prior studies. Furthermore, unlike spoken languages that may differ in the form of their written script (e.g. Chinese and English), signed languages are typically not written at all. Cross-language interactions that are observed between a signed and spoken language are therefore not a specific reflection of phonological and orthographic cross-language similarity, but a more general reflection of the way in which bilinguals activate the two languages in parallel.

Testing cross-language activation in bilinguals whose languages share neither phonological nor orthographic representations requires a paradigm that does not rely on cognates and interlingual homographs. Wu and Thierry (2010; Thierry & Wu, 2004, 2007) developed an implicit priming paradigm to study cross-language activation in Chinese-English bilinguals. Their participants decided whether two English print words, such as *experience* and *surprise,* were semantically related while ERPs were recorded. Although the task was performed in English only, some word pairs had phonologically-related translation equivalents in Chinese, while others had orthographically-related translation equivalents in Chinese. For example, the English words *experience* and *surprise* (*Jing Yan* and *Jing Ya*) have the same first

[1] Studies of deaf bilinguals who know two signed languages also have the potential to provide important insights to our understanding of bilingualism, but studies of this type are very rare (see Adam, 2011 and Boudreault, 2005).

syllable but unique characters in written form, while the English words *accountant* and *conference* (*Kuai Ji* and *Hui Yi*) share a character in their written form when translated into Chinese, but are phonologically unrelated. Thierry and Wu (2007) observed that the amplitude of the N400 response in the ERP record was reduced when the Chinese translations of the English words were phonologically related. The results provide evidence of cross-language activation without relying on either cognates or interlingual homographs.

In a recent study we adapted the semantic relatedness paradigm used by Thierry and Wu (2007) to ask whether deaf readers of English activate the translations of English words in ASL (Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011). Instead of using English words whose Chinese translations shared syllables, the English words in our experiment differed in the phonology or form of their ASL translations. ASL sublexical structure has been described with four formational parameters: handshape, location, movement and orientation (Battison, 1978; Stokoe, Croneberg, & Casterline, 1965). Signs that vary along only one of these dimensions form minimal pairs, such as the signs for *mother* and *father* in ASL, which use the same handshape, movement and orientation, but differ in location. We selected English word pairs that had translation equivalents that shared two of three parameters: handshape, location and/or movement. We did not include orientation as one of the parameters in this study because it is not contrastive in as many signs as the other three phonological parameters. We reasoned that if signers completed the English processing task without activating the ASL translation equivalents, there would be no effect of the phonological relationship of the ASL translations. Rejecting semantically unrelated English words should be the same whether or not the translations were phonologically related. Likewise, accepting related English words should also be the same regardless of the form of the translation equivalents. However, if ASL signs are activated when English print words are processed, then signers should find it difficult to reject two words that differ in meaning, such as *movie* and *paper,* but whose ASL translations are similar in form (see Figure 1). Likewise, signers should be faster to accept two words that are similar in meaning, such as *duck* and *bird,* when the ASL signs activated by these words are similar in form than when the ASL signs are not also phonologically similar. It is important to note, however, that because the stimuli are presented only in English, there was no a priori reason to expect ASL signs to be activated during the task, unless signers routinely activate signs while reading English words.

Despite the fact that ASL and English have very little form overlap in phonology and orthography, we found that deaf ASL-English bilinguals were slower to reject semantically unrelated English word pairs, and faster to accept semantically related English word pairs, when their translation equivalents were phonologically related than when they were unrelated. A control group of hearing L2 learners of English that were matched in English proficiency level to the deaf ASL-English bilinguals did not show the same effect. The results indicate that cross-language activation may be a general feature of the bilingual lexicon irrespective of the form similarity of the two languages in question. In the case of deaf bilinguals, printed words appear to activate signs in the bilingual lexicon.

In this article we report two experiments that expand upon this work, and provide insight into the effects of language proficiency and language dominance on cross-language activation in deaf and hearing bilinguals who know a signed language. Language proficiency, whether signed or spoken, is more variable in deaf than in hearing populations due largely to the variability in exposure to language in early childhood in this population (Mayberry, Lock, & Kazmi, 2002). Less than 5% of the deaf population is born to deaf parents who use a signed language in the home, and thus initial age of exposure to a signed language, and subsequent proficiency, is highly variable. Moreover, many deaf individuals are exposed to a signed language primarily at school through interactions with signers who are L2 learners themselves, and thus the quality and consistency of language exposure varies greatly across the deaf population. Similarly, exposure to English is also highly variable both in the age of first exposure and the quality and consistency of accessible language due to differences in hearing loss, corrected hearing, educational options, and other factors (Goldin-Meadow & Mayberry, 2001).

Morford et al. (2011) examined cross-language activation in a population of deaf ASL-English bilinguals who were highly proficient in both languages. In the present study, we ask whether proficiency modulates cross-language activation in the absence of overlapping lexical forms (phonological or orthographic). We replicate the design of the previous experiment with two groups of signing bilinguals who differ in language experience and language dominance.One group consists of deaf ASL-English bilinguals who are moderately proficient readers, but are ASL-dominant. The second group consists of hearing native English speakers who acquired ASL as a second language and are English-dominant. By testing hearing signers we can evaluate whether L2 processing impacts the L1 when there is little form overlap between the two languages.

How might differences in L2 proficiency and language dominance impact the nature of cross-language activation in bilinguals who know a signed and a spoken language? One study of the effect of proficiency on cross-language lexical activation found that less proficient bilinguals are more likely to experience form interference than more proficient bilinguals. Talamas et al. (1999) examined L2 Spanish learners performing a translation recognition task. Participants viewed a word in their L1, English, and had to decide whether a second word in their L2 Spanish was an acceptable translation of the L1 target word. Lower proficiency L2 learners were much slower to reject potential translations of the English target words when they were similar in form to the actual Spanish translation *(man – hambre* [hunger] vs. *hombre* [man]) than unrelated control words *(man – cansada* [tired]). They experienced much less interference from incorrect translations that were semantically similar to the correct translation *(man – mujer* [woman]). Higher proficiency L2 learners, by contrast, showed the opposite pattern. Ferré, Sánchez-Casas, and Guasch (2006) replicated the Talamas et al. (1999) study, but with a different bilingual population. Their bilinguals were Spanish-Catalán bilinguals who acquired the L2 through immersion rather than only through classroom instruction. These bilinguals are in some respects more similar to deaf bilinguals who are surrounded by English print from an early age. Ferré et al. suggest that bilinguals who acquire their second language through immersion would be less likely to rely on L2 to L1 lexical links since the L2 lexical forms are acquired in meaningful contexts. Nevertheless, they also found that less proficient bilinguals showed greater inhibition due to L1 form competitors than due to semantic distracters. The result suggests that the prevalence of form-based processing in less proficient bilinguals is not due solely to the context of L2 acquisition. Together, the results of these studies indicate that as proficiency increases, form processing is optimized such that semantics are more deeply engaged and form representations are rapidly de-activated following access. These results motivate our first hypothesis, namely, that ASL-dominant bilinguals will experience more form-based cross-language inhibition when trying to reject semantically unrelated English words, due to activation of phonologically related L1 translations, than facilitation of semantically similar L2 words due to cross-language activation of L1 translations that are similar in both form and meaning. These results would indicate that language proficiency in the L2 impacts the degree of form-based processing relative to semantic processing, requiring less proficient bilinguals to increase their level of controlled processing in the semantically unrelated condition to prevent the similar translation forms from interfering with the semantic decision to be made. For semantically related words with translation forms that are also related, the form-level processing does not interfere with the decision and has less impact on the bilingual's response, thus making a possible facilitation effect in this condition less robust than an inhibition effect in the semantically unrelated condition.

With respect to language dominance, the majority of cross-language activation studies have shown effects of L1 on L2. Studies investigating L2 effects on the L1 have primarily concerned language transfer and use (e.g. Cook, 2003; Pavlenko & Jarvis, 2002) rather than directly investigating word recognition (e.g. Van Hell & Dijkstra, 2002) or production (e.g. Jared & Kroll, 2001). In addition to Van Hell and Dijkstra's (2002) study of cognate facilitation in native language processing, Van Wijnendaele and Brysbaert (2002) found that recognition of L1 French words by French-Dutch bilinguals who were highly proficient in their second language could be facilitated by masked priming with phonologically similar Dutch nonwords. While these primes were not cognates, the L2 grapheme-phoneme correspondences would have allowed the generation of phonological forms nearly identical to the target, without activating competing semantic representations. The processing benefit that these bilinguals experienced as a result of generating a phonologically similar prime from L2 knowledge is an excellent demonstration of the nonselective nature of lexical activation. However, it is also clear that these results depend on the existence of form similarity between the two languages. In the absence of cognates or phonological form relatives, there is no basis to predict such L2 on L1 processing effects for signing bilinguals. Thus our second hypothesis is that cross-language activation effects will not be found for hearing English-dominant bilinguals in an English word-recognition task due to a lack of form similarity between English and ASL.

Experiment 1: ASL-dominant ASL-English Bilinguals

In Experiment 1 we investigated cross-language activation in deaf ASL-English bilinguals who are ASL-dominant. These participants used both ASL and English on a daily basis, but their English proficiency was not at the same very high level of the participants in Morford et al.'s (2011) study. We predicted that this group of ASL-English bilinguals would be slower and less accurate than balanced bilinguals, but would also be influenced by the form manipulation of the ASL translations of the English words.

Method

Participants.

Fifty-two deaf adults were recruited in Albuquerque, NM and Washington, DC through flyers and e-mail announcements (see Table 1). Participants' ASL proficiency was assessed with the ASL-SRT (M = 23, range [17, 31], American Sign Language – Sentence Reproduction Test; Hauser, Paludneviciene, Supalla, & Bavalier, 2008). The ASL-SRT is a novel assessment tool for directly assessing ASL proficiency, and standardization is still underway. Average score for native deaf signers included in the standardization study (*n*=23) is 23.4, *s.d.* = 4.4. Standards are not available for non-native signers. In the present study, only participants who obtained an ASL-SRT score within 1.5 *s.d.* of the average score for deaf native signers (17 or higher) were considered eligible (n=43). Participants' English proficiency was evaluated with the Passage Comprehension subtest of the Woodcock-Johnson III Tests of Achievement (*M* = 30, range [25, 34]). This assessment was selected because it taps comprehension of English vocabulary and syntax without relying on listening or lipreading ability. Participants with scores equivalent to grade 8.9 or higher were considered balanced bilinguals (see Morford et al., 2011, n=19). Those with scores equivalent to grade 7.7 or lower were considered ASL-dominant, and were included in the present study (n=24). Criteria for inclusion in the study included being between the ages of 18 and 65, having a self-reported prelingual hearing loss of 80 dB or greater in the better ear and a minimum ASL proficiency level of 17 or better on the ASL-SRT, and a maximum English proficiency score of 34 (reading equivalence Grade 7.7) on the Woodcock-Johnson III, Subtest 9. Two participants were excluded from the analysis because they did not complete the experimental task with an accuracy score of 85% or better, and one participant was excluded due to insufficient demographic information.

Materials.

The materials were identical to those used by Morford et al. (2011). English word pairs were selected such that half of the pairs were semantically related (e.g. *heart-brain),* and half were semantically unrelated (e.g. *baby-lion).* A subset of the English word pairs were experimental items: 32 semantically-related and 34 semantically-unrelated pairs. Half of the experimental items in each semantic condition had phonologically related translation equivalents in ASL (e.g. *movie-paper,* see Morford et al., 2011, Appendix 1 for a full list). Items in the phonologically related condition had translation equivalents that shared two of three ASL formational parameters: handshape, location and/or movement. Items in the phonologically unrelated condition had translation equivalents that shared one or fewer formational parameters. An additional 54 word pairs were included as fillers for a total of 120 item pairs.

The English word pairs were rated on a semantic similarity scale from 1 (no semantic relationship) to 7 (strong semantic relationship) by 27 hearing English monolinguals and 5 deaf ASL-English bilinguals. Semantically unrelated items that were assigned a mean similarity rating above 2.75 and semantically related items rated below 4.0 were eliminated from the experimental condition. The deaf ASL-English bilinguals also provided a categorical yes-no response to the question: Are these words semantically related? Any word pairs that were not assigned to the appropriate condition by 3 of the 5 informants were eliminated from the experimental items. Finally, the set of 120 words was presented to 13 hearing English monolinguals with no knowledge of ASL in the experimental task. Item analyses were then performed on the monolingual data to ensure that semantic effects on response time would not be confounded with an ASL phonology effect. There were also no effects of ASL phonology in a subject analysis of the monolingual data. We also controlled for word length, number of syllables and word frequency as reported in the English Lexicon Project database (http://elexicon.wustl.edu/). There were no differences in these characteristics across conditions (see Table 2).

Procedure.

The procedure was identical to that used by Morford et al. (2011). The consenting procedure followed guidelines identified by Singleton and colleagues for conducting research with deaf participants (Singleton, Jones, & Hanumantha, 2012), including the use of a DVD in ASL explaining risks and benefits. Participants were then asked to complete a background questionnaire. After administration of the language proficiency measures, the ASL-SRT (Hauser et al., 2008) and the Woodcock-Johnson III Subtest 9, participants performed the semantic similarity judgment task.

The experiment was conducted using E-Prime experimental software (Schneider, Eschman, & Zuccolotto, 2002). Each trial consisted of a 500 ms fixation cross, the first stimulus presented in lower case and centered on the screen for 500 ms, a 500 ms blank screen, and then the second stimulus which remained on the screen until the participant responded, up to 2500 ms. Participants responded with their dominant hand when the words were “related in meaning” and with the nondominant hand when the words were “not related in meaning”. RT was measured from the onset of the second word. Participants first completed 10 practice trials, during which they received feedback. The practice trials were repeated until participants achieved 80% accuracy or better. No feedback (accuracy or RT) was provided during the experiment.

After the experiment, participants translated the experimental stimuli into ASL. Translations were evaluated to determine which experimental items to include in the analysis. Participants did not supply the expected ASL translation for a variety of reasons, including regional variation, polysemy, and errors in reading the English word. If the response was consistent with the assigned condition (e.g. phonologically related or unrelated in ASL), then the trial was included in the analysis. If, however, the response did not fit the condition criteria, then the trial was removed for that participant only. A total of 2.2% of responses were excluded from the analysis because participants translated the English words into ASL differently than predicted on the post-experimental translation task. Outliers resulted in the elimination of an additional 2.0% of the responses. Inaccurate responses were replaced with condition means prior to the RT analysis.

Results

The results for the ASL-dominant group largely replicated the findings of Morford et al. (2011) for balanced ASL-English bilinguals. A 2 (semantics) x 2 (phonology) repeated measures ANOVA across subjects (F1) and items (F2) revealed effects of ASL similarity on semantic relatedness RTs. Participants were faster to accept semantically related English word pairs (737 ms) than to reject semantically unrelated English word pairs (830 ms), $F1(1, 20) = 16.90, p < .01, \eta^2_P = .458$, $F2(1, 62) = 33.08, p < .001, \eta^2_P = .348$. Crucially, there was an interaction of Semantics and Phonology, $F1(1, 20) = 15.63, p < .01, \eta^2_P = .439$, $F2(1, 62) = 6.32, p < .05, \eta^2_P = .092$. paired comparisons using adjustments for multiple comparisons indicated that participants were slower to reject semantically-unrelated English word pairs with phonologically related translation equivalents in ASL (853 ms) than word pairs with unrelated translations (807 ms, $p < .01, \eta^2_P = .427$). A slightly smaller but significant effect showed that participants were also faster to accept semantically related English word pairs with form related translation equivalents (719 ms) than those with unrelated translation equivalents (754 ms, $p < .05, \eta^2_P = .177$). Figure 2 shows the interaction of phonology and semantics with comparable data for balanced bilinguals from Morford et al. (2011) for comparison.

Correlation analyses were completed to determine whether the facilitation and inhibition effects were significantly associated with the degree of L2 English proficiency. None of the correlations were significant. This is perhaps not surprising since the participants with a high level of English proficiency were not included in this study. In order to increase the sample size as well as the variation in L2 English proficiency, the participants from Morford et al. (2011) were combined with the participants of the current study, for a total of 40 deaf ASL-English bilinguals, with uniformly high L1 proficiency in ASL, but varying in L2 proficiency in English. With this larger sample, we found a significant correlation between L2 English proficiency as measured by the Woodcock Johnson, and the size of the inhibition effect, $r(38) = .26, p = .05$. Because the inhibition effects were negative, and the English proficiency scores were positive, this positive correlation indicates that bilinguals with greater L2 proficiency experienced less inhibition than participants with lower L2 proficiency. Neither L1 nor L2 proficiency was significantly related to the size of the facilitation effect.

An analysis of accuracy scores revealed that participants were more accurate for semantically-unrelated than semantically-related word pairs, $F1(1, 20) = 8.91, p < .01, \eta^2_P = 298$, $F2(1, 62) = 4.09$, $p < .05, \eta^2_P = 062$. The effect of Phonology also approached significance in the subject analysis, $F1(1, 20) = 4.27, p = .051, \eta^2_P = .169$, but was not significant in the item analysis, $F2(1, 62) = 1.39$, n.s. There was no interaction of semantics and phonology on accuracy.

Discussion

Experiment 1 extends the results of Morford et al. (2011) to deaf ASL-English bilinguals who are ASL-dominant and have moderate proficiency in English as the L2. For both balanced and L1-dominant deaf bilinguals, the evidence indicates that English words activate their ASL translation equivalents. The less proficient bilinguals were slower to perform the English semantic relatedness task than the more proficient bilinguals, but more importantly, the cross-language activation effects indicated that lower proficiency in the L2 is associated with greater form-based inhibition. Previous studies that have examined the developmental course of sensitivity to the L1 translation equivalent with increasing proficiency in the L2 (e.g. Ferré et al., 2006; Sunderman & Kroll, 2006; Talamas et al., 1999) have investigated competition of similar forms across the two languages. The current study corroborates and extends these results by showing that concurrent changes in form-based competition and proficiency can be detected even when the similar forms are within a single language, but related to the target language through semantics. In other words, with increasing L2 proficiency, bilinguals engage form-based processing in their L1 to a lesser extent, whether or not the L1 and the L2 have similar lexical forms. We will return to this issue in the general discussion to consider whether these cross-language differences encourage greater reliance on translation into the L1.

Experiment 2: Hearing English-dominant English-ASL Bilinguals

In Experiment 2 we investigated cross-language activation in hearing English-dominant English-ASL bilinguals. These participants learned ASL as a second language for a variety of purposes, but the majority were certified ASL interpreters or training to become interpreters at the time of the experiment. Their L1 English proficiency was uniformly high. They differed in the duration of their L2 experience, from two to 36 years, and in their proficiency, but all scored within 2.5 s.d. of the average score for hearing native signers of ASL on an assessment measure that is currently being standardized. Further, all of the hearing bilinguals were living in bilingual settings and using their L2 actively on a daily basis. Nevertheless, even the most proficient signers in this group did not have comparable levels of ASL proficiency to the participants in Experiment 1, who considered ASL to be their L1. They did resemble the participants in Experiment 1 in that their L2 proficiency was lower than their L1 proficiency. Unlike the participants in Experiment 1, these participants were completing the within-language experimental task in English, their dominant language. Reports of L2 cross-language effects on L1 processing provide evidence that both languages are active even when there is no direct benefit to the participant who clearly can access L1 forms without relying on L2 knowledge; however, all studies to date documenting L2 effects on L1 lexical processing have exploited form similarities across two spoken languages. If these English-dominant participants show an effect of the ASL manipulation, this study would provide the first evidence of L2 cross-language effects on L1 processing in the absence of form overlap.

Method

Participants.

Forty-one hearing adult native speakers of English (33 female) who had acquired ASL as a second language were recruited in Albuquerque, NM and Washington, DC (see Table 3). Participants' English proficiency was evaluated with the Passage Comprehension subtest of the Woodcock-Johnson III Tests of Achievement ($M = 39$, range [35, 45]). The criteria for inclusion in the study included being between 18 and 65 years of age, having a minimum English proficiency level of 35 (reading equivalence Grade 8.9) on the Woodcock-Johnson III, Subtest 9, and a minimum ASL proficiency level of 4 on the ASL-SRT. In an ongoing standardization study of the ASL-SRT, the average score for native hearing signers (n=25) is 18.3, *s.d.* = 6.3. Standards are not available for hearing L2 signers. However, the ASL-SRT scores for the participants in the current study were within 2.5 *s.d.* of the average score for hearing native signers (4 or higher). Five participants were excluded from the analysis due to low proficiency in ASL, and one participant was excluded due to equipment malfunction. The remaining participants were divided into two groups based on their ASL-SRT scores. Sixteen participants scored 10 or above (M = 13.9, range [10, 21]) and nineteen participants scored 9 or below (M = 6.1, range [4, 9]).

Materials and procedure.

The materials and procedure were identical to those used in Experiment 1, except that the consenting procedure was completed in the dominant language, English, rather than ASL. A total of 3.0% of responses were excluded from the analysis because participants translated the English words into ASL differently than predicted on the post-experimental translation task. Outliers resulted in the elimination of an additional 3.9% of the responses. Inaccurate responses were removed from the RT analysis and replaced with condition means.

Results

A 2 (semantics) x 2 (phonology) x 2 (group) repeated measures ANOVA across subjects (F1) and items (F2) revealed a main effect of semantics on semantic relatedness RTs. Participants were faster to accept semantically related English word pairs (763 ms) than to reject semantically unrelated English word pairs (837 ms), $F1(1, 33) = 16.36$, $p < .001$, $\eta^2_P = .331$, $F2(1, 62) = 27.53$, $p < .001$, $\eta^2_P = .308$. As with the ASL-dominant bilinguals, there was an interaction of Semantics and Phonology, but it was only significant in the analysis by subjects, $F1(1, 33) = 6.32$, $p < .02$, $\eta^2_P = 161$, but not by items, $F2(1, 62) = 1.98$, *n.s.* Paired comparisons using adjustments for multiple comparisons indicated that participants were slower to reject semantically unrelated English word pairs with phonologically related translations in ASL (853 ms) than word pairs with unrelated translations (821 ms, $p < .01$). In contrast to ASL-English balanced bilinguals and ASL-dominant bilinguals, these English-dominant participants did not show evidence of facilitation when accepting semantically related English word pairs with form related translation equivalents (759 ms) compared to those with unrelated translation equivalents (767 ms, *n.s.,* see Figure 2). The three-way interaction between Semantics, Phonology and Group also approached significance in both the subject, $F1(1,33) = 2.27$, $p = .075$, $\eta^2_P = .093$, and the item analysis, $F2(1, 62) = 3.17$, $p = .08$, $\eta^2_P = .049$, because the interaction of semantics and phonology was driven almost entirely by the performance of the more proficient signers, who were slowed by 53 ms due to the ASL manipulation, while the less proficient signers were slowed by only 10 ms. A correlation analysis of L2 proficiency in ASL with the inhibition effect did not reveal a significant relationship, $r(33) = -.21$, *n.s.,* but the direction was as predicted, namely, that participants with higher L2 proficiency, had more negative, or larger, inhibition scores.

A similar analysis of the accuracy scores revealed a main effect of semantics significant in the subject analysis, $F1(1,33) = 10.09$, $p < .01$, $\eta^2_P = 234$, and approaching significance in the item analysis $F2(1,62) = 3.52$, $p = .07$, $\eta^2_P = .054$, indicating that the English-dominant bilinguals, like the ASL-dominant bilinguals, made significantly fewer errors on semantically unrelated word pairs (7.3%, see Figure 2) than on semantically related word pairs (11.4%).

There were no other significant effects in the accuracy analysis.

Discussion

Contrary to our hypothesis, the results suggest that hearing English-dominant bilinguals were sensitive to the ASL-manipulation even in a within-language L1 task. Prior evidence of L2 form activation during L1 processing has been limited to studies that present bilinguals with L1 forms that have considerable phonological or orthographic similarity to L2 forms. This study demonstrates for the first time that L2 forms can influence lexical processing even when they share little overlap with the L1.

For deaf ASL-English bilinguals, we have argued that print becomes associated with ASL phonological forms during the process of reading development. The same is not the case for hearing English-dominant bilinguals. The participants in the second experiment acquired spoken English prior to learning to read, and thus the most direct associations to orthographic words for this subject group are spoken English phonological forms. Are ASL phonological forms activated directly from English print, or are they activated only subsequent to the activation of English phonological forms? The current data are not sufficient to distinguish these possibilities, but we surmise that the latter case is more likely. A number of other findings in the literature suggest that hearing signers may associate spoken phonological forms with signed phonological forms. Emmorey, Petrich & Gollan (2012) investigate the frequent use of code-blends, simultaneously produced English words and ASL signs, by hearing bimodal bilinguals. Code-switching, a typical behavior of unimodal bilinguals, is fairly rare for bimodal bilinguals. They find that code-blends actually facilitate comprehension relative to either language alone. They propose that the frequent production of semantically-equivalent code-blends is an indication that lexical inhibition requires greater cognitive control than lexical selection, and that code-blends improve comprehension through semantic integration of the two signals. In our experiment, participants saw only English print. The absence of facilitation under these conditions suggest that code-blend processing benefits may be linked to spoken but not written words, or that they emerge only when the stimulus presentation unfolds over time, as is the case with speech and signs together, but not with print. English print forms alone most likely activated the associated English phonological forms most rapidly, leading to subsequent activation of associated ASL signs.

A comparison of the results from Experiment 1 and Experiment 2 demonstrate that language dominance plays an important role in cross-language activation. Effect sizes were much larger in Experiment 1, when participants were completing the task in their non-dominant language, and much smaller when participants were completing the task in their dominant language. This is consistent with prior studies that consistently show effects of the L1 on the L2, but much less frequently find effects of the L2 on the L1. Further, the results of Experiment 2 show only inhibitory effects of the L2 on the L1. One explanation for the lack of facilitation could be that word recognition in the native language is already fully optimized, and cannot benefit further from L2 knowledge. This interpretation is contradicted by Van Hell & Dijkstra's (2002) demonstration of faster lexical decision performance in trilinguals' L1. However, their stimuli were cognates. Thus, one possibility is that the L2 is activated during L1 processing regardless of form similarity, but it only facilitates lexical access in the case of cognates. Evidence that cognates may be special in this regard can be seen in recent studies of bilingual lexical access in sentence context (e.g., Titone, Libben, Mercier, Whitford, & Pivneva, 2011) that have compared cognate facilitation with homograph interference. The conflict between word form and meaning that is induced by interlingual homographs may be more similar to the conflict between the cross-language effects we have reported than cognate facilitation, where form and meaning always converge.

Variation in proficiency in the hearing bimodal bilinguals did not produce predictable results. While there was a trend for more proficient signers to show greater inhibition as a result of the ASL manipulation, participants at all ability levels showed some effects of the L2 on the L1. More sensitive measures of processing may be necessary to detect whether proficiency or other aspects of bilingual competence impact cross-language activation in this population.

General Discussion

This study investigated whether deaf and hearing bilinguals of American Sign Language and English activated ASL signs while performing a monolingual English word recognition task. The results provide the first replication of a recent study in which we found that deaf ASL signers who are highly proficient in English show evidence of activating ASL signs while reading English print words. The current study corroborates and extends these findings by investigating whether print words activate signs in deaf bilinguals with greater proficiency in ASL and in hearing bilinguals with greater proficiency in English. We found that deaf ASL-dominant bilinguals and hearing English-dominant bilinguals are both slower to decide that two English words are semantically unrelated when the ASL translations of those words are phonologically related relative to when the translations are not related, although the results are much more reliable for the deaf bilinguals. Further, the deaf bilinguals were faster to decide that two English words are semantically related when their ASL translations are also phonologically related. The results across the two studies indicate that nonselective access is a common characteristic of bilingual word recognition, irrespective of language dominance and language modality.

Novel findings in the current study also lead us to the following tentative conclusions about the role of language proficiency and language dominance on the nature of nonselective access. First, with respect to the question of language proficiency, we found that as L2 proficiency increased, participants were less likely to experience L1 form-based inhibition during an L2 processing task. Our results are consistent with prior studies that find changes in proficiency impact the degree of form-based mediation of parallel activation of the two languages. Talamas et al. (1999), Ferré et al. (2006), and Sunderman and Kroll (2006) all found that bilinguals with lower levels of L2 proficiency exhibited greater inhibition when presented with a phonologically similar form in a translation recognition paradigm (e.g. *man*

– *hambre* instead of *hombre)* than when presented with a semantically similar form (e.g. *man – mujer).* The ASL-dominant bilinguals in the current study showed form-related cross-language effects, but under very different circumstances. There was no ambiguity about the L2 words on the basis of form. Instead, the L1 translations of the L2 forms were phonologically similar, introducing ambiguity into the decision process that should only have concerned the L2 semantic relationship. The fact that similarity in L1 forms was disruptive to a semantic decision about L2 lexical items is an indication of the degree of activation of the L1 forms during the decision making process. An additional indication that L1 form-based mediation may have been particularly influential for the ASL-dominant bilinguals comes from the effect size of the cross-language manipulation in the semantically related vs. unrelated conditions. Variation in response time in the semantically unrelated condition, when L1 form activation was *inhibiting* responses, was more closely associated with phonologically related translations (η^2_P =.427) than in the semantically related condition (η^2_P =177), when L1 form activation was *facilitating* responses. Much more comparable effect sizes for cross-language activation in semantically unrelated and related conditions were found for the balanced bilinguals in Morford et al. (2011; η^2_P = 295 for semantically unrelated words; η^2_P =258 for semantically related words). While effect sizes are an estimate of association of the independent variable with the dependent variable, and cannot be assessed for statistical difference due to a lack of independence in the samples in studies using a repeated measures design, the larger inhibitory effect size is nevertheless consistent with past studies showing greater form-based interference in less proficient bilinguals. Alternative research designs will be necessary to provide more conclusive evidence that L1 form-level activation is more likely to slow L2 semantic processing in bilinguals with developing L2 proficiency. Midgley, Holcomb, and Grainger (2009) propose a similar explanation to account for greater ERP amplitude differences in anterior brain regions in the N400 for L1 than for L2 generated during a go/no-go semantic categorization task. They conclude that their results might reflect “a lower level of interconnectivity of L2 lexical and semantic representations in beginning bilinguals, that disappears with increasing competence in L2 and greater integration of L2 words in a common lexical-semantic network” (298).

Turning to the question of language dominance, we also investigated whether ASL as an L2 would impact L1 word recognition of English words in hearing English-dominant bilinguals. We found much weaker evidence that hearing English-dominant signers of ASL activate ASL signs while processing English print words than for deaf bilinguals. The result was significant by subjects but not items, and the effect size was considerably smaller for this population (η^2_P =.161). Further, we found only inhibitory effects. Thus, we suggest that a parsimonious interpretation of these results is that English orthography activates only English sublexical and lexical representations in this population, but that these phonological forms are associated with ASL signs. By contrast, English orthography may directly activate either ASL sublexical or lexical representations in bilinguals for whom ASL is the L1.

One tantalizing implication of this interpretation is that reading in the deaf signing population may be intricately linked to sign language processing, even though print is intended to represent an entirely different language. Some researchers have tried to instantiate such a model. Ormel (2008) has proposed that orthographic strings activate both semantic and lexical sign representations in sign-print bilinguals. More similar to the possibility we are proposing is the model outlined by Hermans, Knoors, Ormel, and Verhoeven (2008), which is an adaptation of Jiang's (2000) model of the development of lexical representations in adult L2 learners. Hermans et al. (2008) suggest that while deaf children may initially have both signs and spoken word forms associated with semantics, they may map printed words directly onto the signs of their dominant language. Only after this initial stage of word association would deaf readers develop direct links from orthographic forms in English to semantics, and in a final stage from orthographic forms to their spoken representations. Modeling work investigating this type of developmental path could be very fruitful. Ormel, Hermans, Knoors, and Verhoeven (2012) have in fact found evidence of cross-language activation between Dutch print and Sign Language of the Netherlands (SLN) in deaf children. They asked third and fifth grade children to decide whether a Dutch word described a picture. Responses were inhibited when the SLN translation of the Dutch word was phonologically similar to the SLN name of the picture, and facilitated when the SLN translation of the Dutch word was iconically related to the picture. Thus, bilingual deaf children also appear to experience cross-language activation.

Our results also leave many questions unanswered. Perhaps most importantly, the timecourse of the activation of signs and words in deaf and hearing bilinguals who know both a signed and a spoken language remains unclear. We reiterate a point from Morford et al. (2011) that it is doubtful that the L1 sign forms are mediating access to semantics for the deaf participants in our studies. Even the less proficient deaf bilinguals had sufficient knowledge of English to make the semantic judgments on the basis of L2 knowledge alone, and responded as quickly as the hearing English-dominant bilinguals. But a model of acquisition such as the one outlined by Hermans et al. (2008) predicts associations between lexical orthographic patterns in English and sign forms in ASL that continue to influence processing even after direct access is achieved. The possibility of sub-lexical relationships between English orthography and ASL sublexical structure seems somewhat more remote, but could be investigated by manipulating the features of ASL sublexical structure that have been shaped by contact with English. The most likely possibilities would be that the mouthing produced with some signs might be directly associated to orthographic patterns in English (Kubuş et al., in press). Alternatively, initialization might result in a direct association between signs and print. Initialization is a process by which the handshapes of ASL fingerspelling are integrated into the sublexical structure of a sign such that the handshape parameter of the sign represents the first letter of the English translation equivalent, e.g., the ASL signs for the colors *green* and *blue* are produced with the *g* and *b* handshapes, respectively.

In summary, our results confirm that nonselective access is not a product of the modality of spoken languages. Although much evidence in support of nonselective access relies on the presence of cognates and homographs/homophones across spoken languages (e.g. De Groot et al., 2000; Hoshino & Kroll, 2008), in the present study we find that when words in two languages share no phonology and have no orthographic overlap, activation of the non-selected language influences word recognition in both the L1 and the L2. Furthermore, a comparison with the results in Morford et al. (2011) suggests that L2 proficiency modulates the extent to which L1 forms affect L2 recognition among sign-print bilinguals as it does for spoken language bilinguals. The results of the present study extend the characterization of L2 development to deaf learners of English and hearing learners of ASL and further suggest that sign language bilingualism is not only interesting in its own right but provides a critical tool for investigating the mechanisms that underlie cross-language interactions.

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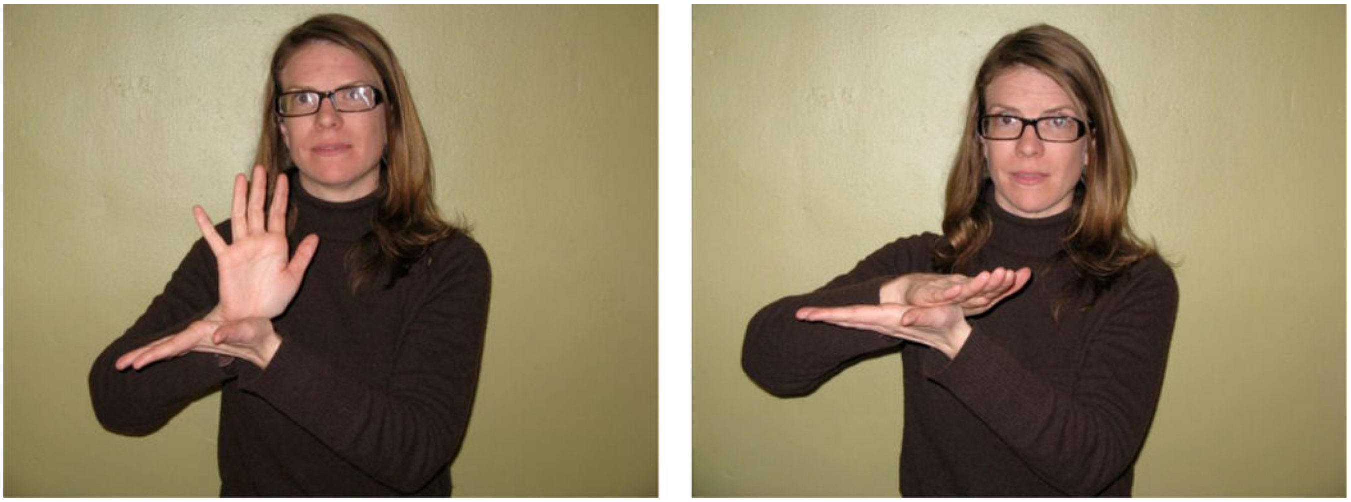

Figure 1.
ASL signs for *MOVIE* (left) and *PAPER* (right). This figure was originally published in Morford JP, Wilkinson E, Villwock A, Pinar P and Kroll JF (2011) When deaf signers read English: Do written words activate their sign translations? *Cognition* 118: 286–292.

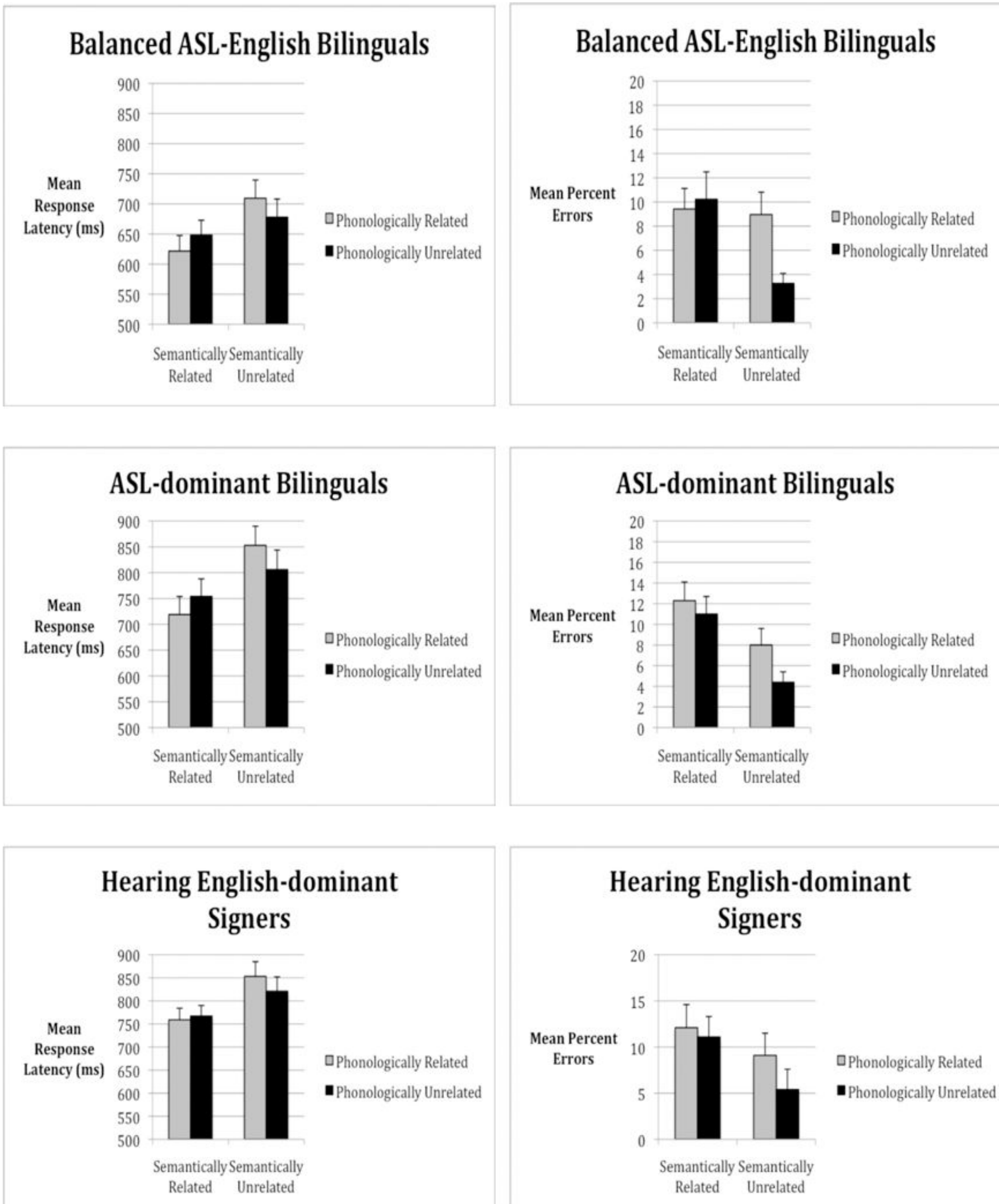

Figure 2.

Mean latencies (in milliseconds) and accuracy in the semantic judgment task as a function of the semantic relationship, the phonological form of the translation in ASL, and language background of the group.

Table 1

Mean and Range of Background Characteristics of Deaf Bilinguals

	n (# female)	Age of ASL exposure	ASL Proficiency (ASL-SRT)	English Proficiency (Woodcock-Johnson, Subtest 9)
Deaf ASL-dominant Bilinguals	21 (14 female)	.81 years [birth, 5]	23 [17, 31]	30 [25, 34]

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Table 2

Lexical characteristics of the English stimuli by condition

	Semantically Unrelated				**Semantically Related**		
	Phonologically				**Phonologically**		
	Unrelated	**Related**	**t-test**		**Unrelated**	**Related**	**t-test**
Semantic Similarity Rating (1 – 7)	1.61	1.61	n.s.		5.32	5.36	n.s.
Word length (# letters)	5.72	5.50	n.s.		5.47	6.11	n.s.
# Syllables	1.78	1.67	n.s.		1.75	1.82	n.s.
HAL Log Frequency	10.14	9.78	n.s.		9.69	9.49	n.s.

Table 3

Mean and Range of Background Characteristics of Hearing Bilinguals

	n (# female)	Years of ASL	ASL Proficiency (ASL-SRT)	English Proficiency (Woodcock -Johnson, Subtest 9)
Hearing English-dominant bilinguals with higher ASL proficiency	16 (11 female)	17 [3, 36]	14 [10, 21]	40 [35, 45]
Hearing English-dominant bilinguals with lower ASL proficiency	19 (17 female)	11 [2, 30]	6 [4, 9]	39 [35, 41]