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Simultaneous Communication Supports Learning in Noise by Cochlear Implant Users

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Abstract

Objectives—This study sought to evaluate the potential of using spoken language and signing together (simultaneous communication, SimCom, sign-supported speech) as a means of improving speech recognition, comprehension, and learning by cochlear implant users in noisy contexts.

Methods—Forty eight college students who were active cochlear implant users, watched videos of three short presentations, the text versions of which were standardized at the 8th grade reading level. One passage was presented in spoken language only, one was presented in spoken language with multi-talker babble background noise, and one was presented via simultaneous communication with the same background noise. Following each passage, participants responded to 10 (standardized) open-ended questions designed to assess comprehension. Indicators of participants' spoken language and sign language skills were obtained via self-reports and objective assessments.

Results—When spoken materials were accompanied by signs, scores were significantly higher than when materials were spoken in noise without signs. Participants' receptive spoken language skills significantly predicted scores in all three conditions; neither their receptive sign skills nor age of implantation predicted performance.

Discussion—Students who are cochlear implant users typically rely solely on spoken language in the classroom. The present results, however, suggest that there are potential benefits of simultaneous communication for such learners in noisy settings. For those cochlear implant users who know sign language, the redundancy of speech and signs potentially can offset the reduced fidelity of spoken language in noise.

Conclusion—Accompanying spoken language with signs can benefit learners who are cochlear implant users in noisy situations such as classroom settings. Factors associated with such benefits, such as receptive skills in signed and spoken modalities, classroom acoustics, and material difficulty need to be empirically examined.

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Keywords

cochlear implant; simultaneous communication; classroom acoustics; deaf learners

Individuals who are cochlear implant (CI) users report that while they find their devices very effective in one-on-one interactions, they often “shut down” in noisy situations (Battmer et al., 2010). Given the increasing prevalence of CI use in classrooms that often have excessive noise and poor acoustics (DeRaeve, 2015; Tsach & Most, 2016), it is important to consider alternative strategies for supporting learners who are CI users in such contexts. The present study considered one such strategy, using signs in accompaniment to spoken language in simultaneous communication (SimCom). Research has shown that sign and speech can be mutually supportive rather than mutually exclusive for deaf children (e.g., Giezen, Baker, & Escudero, 2014; Yoshinaga-Itano & Sedey, 2000), but its classroom utility for CI students has not yet been established.

Almost by definition, individuals vary in their linguistic abilities, their knowledge of the world, and their learning skills. Deaf learners vary even more than hearing learners as a function of all of the same sources of individual differences *plus* their hearing losses, possible concomitant neuropsychological issues, and challenges in early language development. From the early school years through postsecondary education, they experience various barriers to learning created by educational settings that all too often assume, erroneously, that they learn just like their hearing peers (Kral, Kronenberger, Pisoni, & O'Donoghue, 2016; Marschark & Knoors 2012). Not unrelated to these factors, deaf learners historically have demonstrated chronic underachievement from the school years through college (e.g., Cuculick & Kelly, 2003; Nagle, Shaver, Newman, & Marschark, 2016; Qi & Mitchell, 2012), despite parents', teachers', and researchers' efforts to close the gap between them and their hearing peers.

There is now abundant evidence that CI use contributes to deaf students' academic achievement, at least with regard to literacy (Archbold et al., 2008; Geers, 2003; Geers & Hayes, 2011; Spencer, Gantz, & Tomblin, 2004). However, there also is emerging, convergent evidence that, on average, the early academic benefits seen in primary school are reduced or absent in secondary and postsecondary settings (Geers, Tobey, Moog, & Brenner, 2008; Harris & Terlektsi, 2011; Marschark, Shaver, Nagle, & Newman, 2015; see also Fitzpatrick et al., 2012). This situation may result, at least in part, from the greater complexity of materials and differing goals in secondary school (Archbold, 2015), premature cessation of interventions for CI users who show age-appropriate language and reading skills in primary school (Nitttrouer & Caldwell-Tarr, 2016), lesser overlap between the language used at home and school in later grades (Chung, 2016), or because school-related skills increasingly are mediated by factors other than language level per se (H. Knoors, personal communication, May 19, 2016).

More globally, it is possible that we simply do not yet know how best to teach deaf learners with CIs so as to accommodate differences between them and their (deaf and hearing) peers and optimize their academic outcomes. Because learning is cumulative, early delays among CI users relative to hearing peers in vocabulary, language, and world knowledge grow during

the school years and into young adulthood (Convertino, Borgna, Marschark, & Durkin, 2014; Niparko et al., 2010; Stelmachowicz, Pittman, Hoover, & Lewis, 2004). This often will leave them lagging in the content knowledge needed to support learning in the classroom and from reading, lags that also increase with age.

Beyond the language and content knowledge that CI users bring to the classroom is the amount and quality of auditory information that is received through their devices. In particular, background (e.g., classroom) noise is far more disruptive for speech recognition among CI users than hearing individuals (e.g., Caldwell & Nitttrouer, 2013; Schafer & Thibodeau, 2006). Despite advanced speech processing strategies in modern CI processors that allow for improved speech recognition in noise (Eisenberg et al., 2016; Koch, Quick, Osberger, Saoji, & Litvak, 2014), listening in noise continues to be a challenge for CI users. De Raeve (2015) and Tsach and Most (2016) discussed the challenges created by poor classroom acoustics for learners who use CIs. De Raeve (2015, p. 556) noted, in particular, that “Poor acoustics can undermine the very purpose for which the classroom was intended” and offered a list of classroom adaptations that can improve speech reception in such settings.

A means of potentially improving CI users’ speech reception in noisy settings is to provide simultaneous access to both visual and auditory information. Previous studies have shown an advantage in speech reception by CI users with audiovisual presentation compared to auditory-only or visual-only (speechreading) information (Bergeson, Pisoni, & Davis, 2005; Geers, Brenner, & Davidson, 2003; Kaiser, Kirk, Lachs & Pisoni, 2003; Kirk, et al. 2007; Rouger et al., 2007; Rouger, Fraysse, Deguine, & Bagone, 2008). That work suggested that the audiovisual advantage derives from CI users having acquired both better speechreading ability and greater ability to integrate the visual information with the distorted speech signal. It thus seems reasonable to hypothesize that those deaf individuals who have sign language skills similarly would be able to integrate visual information from signs with the speech signal to improve speech reception.

The use of speech with signs, commonly referred to as “simultaneous communication” or “SimCom” in North America and “sign-supported speech” in Europe, could be valuable for deaf and hard-of-hearing (or even hearing) individuals in noisy environments. Despite the frequent reluctance of many to countenance signing among young CI users—and the requirement of some CI centers in the USA that parents sign contracts agreeing not to use sign language—there is now considerable evidence that early sign language can support the development and perception of spoken language by children with CIs (Connor, Hieber, Arts, & Zwolan, 2000; Geers, Brenner, & Tobey, 2011; Giezen et al. 2014; Seal, Nussbaum, Belzner, Scott, & Waddy-Smith, 2011; Spencer & Tomblin, 2006; Tomblin, Spencer, Flock, Tyler, & Gantz, 1999; Yoshinaga-Itano, 2006; Yoshinaga-Itano & Sedey, 2000). A number of observers also have argued against the use of SimCom on theoretical or philosophical grounds (e.g., the combination of English and American Sign Language, ASL is not a language; Johnson, Liddell, & Erting, 1989), there is abundant evidence that SimCom supports deaf students’ learning and memory as well or better than any other form of communication, at least when produced by skilled users¹ (Cokely, 1990; Hamilton & Holzman, 1989; Hyde & Power, 1992; Marschark, Sapere, Convertino, & Pelz, 2008;

Newell, 1978). This is especially important given the diversity of communication skills/modalities among deaf and hard-of-hearing learners in today's classrooms.

There are reasons why combining signing and spoken language might be useful in the classroom. Most obviously, at least for individuals who are bilingual in a signed language and a spoken language, there may be lexical units (words or signs) that are unfamiliar in one language but known in the other. Giezen et al. (2014), for example, showed that learning signs can support spoken word learning among young deaf children with CIs. Related, but perhaps more importantly for classroom situations, the redundancy provided by a teacher's (accurately) speaking and signing at the same time would allow a CI student who misses or mis-hears a spoken word or phrase to benefit from the manual redundancy (or, in principle, vice versa). This is an opportunity not provided in situations where either there is spoken language only or where a teacher is supported by sign language interpreter, the latter a case in which the two languages have different grammars and thus word-by-word redundancy is lost.

Studies of sign language use by CI users are not common. Geers et al. (2011), however, examined the extent to which SimCom might enhance language production by 8- to 9-year-old CI users through interviews in spoken language alone and using SimCom. In the SimCom interview, signed and spoken words were transcribed, counted, and analyzed in terms of the different words used per minute, mean length of utterance in words, sentence complexity, and use of noun phrases. The spoken language interview was similarly analyzed, but only intelligible spoken words were considered. Geers et al. found that all four measures indicated better language production outcomes in the SimCom condition than the speech-only condition.

Blom and Marschark (2015) examined potential benefits of SimCom for deaf college students' learning from short presentations. CI users watched two presentations, one delivered via spoken language alone and the other via SimCom; each was followed by a multiple-choice test. With the simpler of two passages (8th to 9th grade reading level), there was no significant difference in test scores between the two conditions. With a passage that was more difficult in terms of vocabulary and grammar (9th to 10th grade reading level), scores were significantly higher in the SimCom than the spoken language alone condition. The investigators concluded that "SimCom can have a place in the education of CIs users and deserves empirical and in situ evaluation" (p. 129). The present study was designed to do just that.

In this study, three passages were presented to deaf college students who were active CI users. One passage was presented via spoken language alone in a quiet classroom; one was presented in the same room but with multi-talker babble background noise; and a third was presented, also in noise, using speech and sign simultaneously. Based on anecdotal reports from CI users, it was expected that SimCom would support listening in noise, although the

¹In the studies cited here showing SimCom to be effective in the classroom, the materials were produced by highly skilled SimCom users, all of whom also were skilled users of ASL. The presenter in this study also was highly skilled in both modes of communication. The level of SimCom skill needed to effect such results in the classroom, undoubtedly related to the receptive skills of the learners, remains to be empirically determined (see Coryell & Holcomb, 1997).

extent of that benefit was unclear. In order to gain some insight into the relative contributions of participants' spoken language and sign language skills to comprehension in the three conditions, the study included both self-ratings and objective assessments of their receptive skills in the two language modalities.

Method

Participants

Active CI users were recruited from the student body at Rochester Institute of Technology (RIT) through advertising and volunteer mailing lists. RIT includes the National Technical Institute for the Deaf as one of its nine colleges, but participants were drawn from across the university. Forty eight CI users (27 females) participated in the study, 11 of whom had bilateral implants. All but two of the participants reported using their CI(s) all or most of all time. Age of implantation ranged from 1 to 13 years of age with a mean of 4.88 years ($SD = 2.99$). Although the ages/birthdates of the participants were not available, all appeared to be of typical college age (18–22 years). Two older students (who received cochlear implants at 17 and 22 years of age) were eliminated from the sample.

Material

Passages—Three brief, 8th-grade level passages were drawn from the *Basic Reading Inventory* (Johns, 2005). The presenter, a skilled sign language interpreter and former interpreter trainer, was recruited because she was widely recognized as outstanding in her use of SimCom in terms of both clarity and sign-speech correspondence. The presenter read *A Scientist's Search* (100 words) and *Mount Kilarna* (98 words) from a Teleprompter without signing. *Sunset Surprise* (98 words) similarly was read aloud while simultaneously signing with English word order but characteristics of American Sign Language (e.g., indexing, classifier use). Multi-talker babble tracks were added to the first and third videos to produce the speech-in-noise and SimCom-in-noise conditions, respectively. The passages and other materials described below were filmed and edited in a professional television studio. The audio for the noise conditions was calibrated using Audacity software such that the root-mean-square (RMS) amplitude of the speech was 10 dB above the level of noise, yielding a +10 dB signal-to-noise ratio at the source. Background noise levels were selected to represent a signal-to-noise ratio lying between recommended and actual classroom noise levels (ASHA, n.d.; Hodgson, Rempel, & Kennedy, 1999). Each story included ten open-ended questions (e.g., "What did the sun resemble as it was setting?") from the *Basic Reading Inventory* (Johns, 2005), and responses to the questions were scored according to the standard rubric, with one point given for each correct answer.

Language Measures—Receptive sign language and spoken language skills of the participants were assessed using questions taken from Hudgins, Hawkins, Karlin, and Stevens (1947), usually referred to as the Harvard Auditory Test. These questions originally were constructed based on common world knowledge so as to be easily answered by anyone who was able to accurately recognize the speech. Thirty-two questions were selected so as to have common vocabulary, various sentence structures, and require one-word answers (e.g., "What color is spinach?"). The items were quasi-randomly assigned to two sets of sixteen

questions each with the restriction that half of the items in each set would have one word that normally would be fingerspelled (i.e., did not have a commonly used sign). In one of the two sets, the same presenter who provided the passages read the questions from the Teleprompter using speech only. In the other set, she read the questions and signed them at the same time. After recording, however, the audio track was removed in order to provide a measure of sign reception (allowing for speechreading). Each correct word provided in response to the Harvard questions received one point.

Participants rated their conversational sign language skills using the scoring system from the Sign Language Proficiency Interview (SLPI). The SLPI normally involves a face-to-face signed conversation between an interviewer and interviewee (<https://www.rit.edu/ntid/slpi/>). In the present study, participants put themselves into one of the 6 SLPI scoring categories from 0 (e.g., “I either do not know any sign, or I know very few basic signs and have to fingerspell most of my responses to basic questions signed to me”) to 5 (e.g., “I am able to have a very comfortable, in-depth conversation about social and school topics. I have a very large sign language vocabulary”). Participants also indicated the mode of communication in which they best understand information (sign, speech, or SimCom), rated their receptive speech and receptive SimCom skills on 5-point Likert scales, indicated how often they use their implants (all of the time, most of the time, about half of the time, not often), and provided the age at which they received their first implant.

Procedure

A mock classroom was arranged with several student desks for presentation of the video materials. The three passages and the Harvard Auditory Test sentences were presented to participants using an Apple Mac Pro computer routed to a Sony Bravia 40-inch LCD television. Students were tested in groups varying from one to five students and sat at desks in a semi-circle 11 feet from the screen. The speech signal and noise were delivered from a single loudspeaker with volume set to a comfortable listening level approximating average classroom speech intensity. Participants were told only to watch each video carefully, as they would be asked questions afterwards and have to provide written answers. After seeing each passage, participants answered the appropriate 10 open-ended questions from the *Basic Reading Inventory*. The speech reception (Harvard) task and the sign perception (Harvard) task were presented between pairs of passages. In an effort to ensure that participants understood the primary task to involve listening in noise, materials initially were presented with the speech-in-noise passage first and the speech-in-quiet, baseline passage, last. Concerns about possible order effects led to the testing of additional participants with the order of conditions reversed. Ultimately, 31 of the participants received the materials in the order: speech-in-noise passage, sign reception task, SimCom-in-noise passage, speech reception task, speech-in-quiet passage; 17 participants received the materials in the opposite order.

Results

Means and standard deviations for scores in the three conditions and the language measures are provided in Table 1 and Table 2. A preliminary analysis examined possible differences in

scores as a function of participants' using unilateral or bilateral implants. No significant differences were obtained, and that variable will not be considered further.

The primary comparison of interest, scores on the 10-question tests following the SimCom-in-noise passage compared to the speech-in-noise passage was evaluated using a one-way analysis of variance in which condition was a within-subjects factor. That analysis yielded a significant main effect of condition ($F(2, 94) = 37.96, p < .01$, partial $\eta^2 = .45$). Sidak-adjusted post hoc tests indicated no significant difference between performance in the speech-in-quiet and SimCom-in-noise (see Table 1; $p = .997$), while performance in the speech-in-noise condition was significantly poorer than in both of the other conditions ($p < .001$). Controlling for participants' preferred mode of communication via an analysis of covariance yielded still yielded a main effect of condition ($F(2, 88) = 5.85, p < .005$, partial $\eta^2 = .12$), and a Sidak post hoc test indicated that scores in the SimCom-in-noise condition still were significantly higher than those in the speech-in-noise condition (mean difference $-1.78; p < .05$). These results indicate that listening to speech in noise greatly impaired test performance, while the addition of signs (SimCom) enhanced understanding of speech delivered in the presence of background noise, almost completely offsetting the noise-induced decrement in performance.

All but two of the 48 participants indicated that they used their CIs "all the time" or "most of the time." Four participants reported sign language as their preferred mode of communication, but 26 reported preferring SimCom over spoken language alone. Although the auditory and signed versions of the Harvard Auditory Test items may not be directly comparable, it is worthwhile noting that no difference was found in participants' performance on the two tasks ($t(47) = 0.13, p = .90$). Although null findings should be viewed with some caution, the fact that scores on the two tasks were not significantly related ($r(48) = -.16, p = .28$) suggests that they assessed different skills rather than some generalized language ability.

The impact of the various language measures (assessments, self-ratings, age of implantation, age of sign language acquisition) on participants' scores in the three conditions was evaluated using three stepwise, multiple regression analyses in which each of the three test scores alternately was used as the criterion variable. Therefore, frequency of CI use, number of CIs used, age of implantation, preferred communication mode, self-rated speech understanding, self-rated SimCom understanding, sign reception skill, speech reception skill, and SLPI rating were included as predictor variables to examine their relative contributions to the test-scores. In all three conditions, the only significant predictor of performance was Harvard speech reception scores: spoken-in-noise condition ($R^2 = .30, \beta = .55, p < .001$), SimCom-in-noise condition ($R^2 = .38, \beta = .62, p < .001$), and spoken-in-quiet condition ($R^2 = .46, \beta = .68, p < .001$).

Because of the limited number of CI users available to this study, conditions and passages were not counterbalanced. Rather, the three passages all were drawn from the standardized, 8th-grade level materials in the *Basic Reading Inventory* (Johns, 2005) and assumed to be comparable. Lacking empirical demonstration of their equivalence, indirect confirmation was obtained in two ways. First, a correlational analysis indicated that associations among

scores across the three conditions were significant and high (all $p < .01$, see Table 3). Second, reliability across the conditions was assessed using an intraclass correlation using the individual mean scores in each condition in a two-way mixed model. That analysis yielded an intraclass correlation coefficient of .88 for the average measures ($F(47, 94) = 8.28, p < .001$).² These results notwithstanding, future studies with larger samples would allow for full counterbalancing and would be preferable.

Discussion

The present study sought to determine whether the addition of signs to spoken language (in simultaneous communication) would facilitate the reception by CI users of information spoken in a noisy setting comparable to a school classroom. SimCom is used in a variety of settings involving deaf and hard-of-hearing learners, including in the classroom. At least in the United States, however, it generally is not used with cochlear implant users, who are urged to rely exclusively on spoken language. That emphasis notwithstanding, the present results indicate that in the case of deaf learners who use CIs and have at least minimal sign skills, speech reception in classroom learning can benefit from the use of SimCom in noisy situations. Performance on a 10-question test following a passage presented via SimCom and multi-talker babble was found to be significantly better than performance when a passage was presented via spoken language alone in the same noise. This result was independent of participants' reported preferred modes of communication, while performance in all three conditions was significantly predicted by their speech reception skill. Age of implantation and self-rated skills in the two language modalities did not significantly predict performance.

The fact that the participants in this study were college students who had varying levels of sign language as well as spoken language suggests caution in generalizing the results to individuals who may be lacking skills in both modalities. However, the fact that receptive sign skill, both assessed or self-reported, did not significantly predict performance in the SimCom condition suggests that a high level of sign skill is not necessary for individual CI users to benefit from the addition of signing to a spoken message. Given the lack of evidence indicating that signing interferes with the acquisition of spoken language by deaf children with or without CIs (Walker & Tomblin, 2014), the present findings suggest that SimCom should be considered as a potentially effective support for young CI users who have some knowledge of signing.

These results do not necessarily argue for the teaching of a natural sign language to CI users. SimCom is not a sign language, and the extent to which having a true sign language would support the understanding of speech through SimCom by young children remains to be determined. Similarly, this study does not argue that SimCom should replace a natural sign language in a classroom consisting of students whose primary or more dominant language is signed. In our sample of 48 CI users, only four indicated that sign language (ASL) was their preferred mode of communication, although no independent indicator of their ASL skills (as opposed to receptive sign skills) is available. Even if ASL users understand and sometimes

²The authors wish to thank an anonymous reviewer for suggesting this analysis.

use (good) SimCom (Newell, Stinson, Castle, Mallery-Ruganis, & Holcomb, 1990), there is no way to know whether it would be as effective as a true language over the longer term. In the case of deaf college students, however, Marschark, Sapere, Convertino, and Seewagen (2005) found that regardless of whether students were oriented toward ASL or English-based signing (as used in SimCom), they learned just as much from classroom instruction presented in the other mode. Marschark et al. (2008) found that deaf college students learned as much from SimCom as they did from ASL. The present results do argue for at least investigating the potential for SimCom to support classroom learning by those children who use CIs and who have or can gain some sign language skills. It may well be that despite continuing disagreements with regard to the benefits of educating deaf learners through sign language *or* spoken language only, a combination of the two might be most beneficial at least for some deaf learners.

The present study also emphasizes the need for recognition that the large individual differences among deaf learners with and without CIs means that when it comes to communication and language, everything works for somebody, but nothing works for everybody. Many “oral” deaf students, with and without CIs, eventually use signed communication to some extent, as adolescents and young adults if not as children (e.g., Cormier, Schembri, Vinson, & Orfanidou, 2012). The fact that some CI users might benefit from SimCom in the classroom the same way that some young CI users benefit from SimCom in language acquisition (e.g., Giezen et al., 2014) and language production (e.g., Geers et al., 2011) should not be either surprising or concerning. Deaf learners should be given any and all communication support that contributes to their language reception, comprehension, and learning.

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Table 1

Means and standard deviations (SD) for language measures

	Mean	SD
Age of implantation (yrs)	4.88	2.99
Frequency of CI use (1 = all the time, 5 = not often)	1.46	0.65
Speech reception (Harvard Auditory Test: Spoken)	13.44	3.51
Sign reception (Harvard Auditory Test: SimCom, no voice)	13.54	3.64
Speech understanding (self-rated)	2.12	0.70
SimCom understanding (self-rated)	1.69	0.62
Sign Language Proficiency Interview(self-rated)	3.65	1.33

Table 2
Results of Repeated Measures ANOVA for the test scores on the three conditions

Condition	Spoken in Noise		SimCom in Noise		Spoken in quiet		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>F</i>
	2.81	2.99	5.15	2.72	5.21	2.80	37.96**

Note:
** = $p < .01$

Table 3

Correlation coefficients among test scores in three conditions

	SimCom in Noise	Spoken in quiet
Spoken in Noise	.71 **	.75 **
SimCom in Noise		.66 **

Note:

**
= $p < .01$