Predicting Academic Success Among Deaf College Students

Carol M. Convertino
National Technical Institute for the Deaf—Rochester Institute of Technology

Marc Marschark
National Technical Institute for the Deaf—Rochester Institute of Technology and University of Edinburgh

Patricia Sapere
National Technical Institute for the Deaf—Rochester Institute of Technology

Thomastine Sarchet
National Technical Institute for the Deaf—Rochester Institute of Technology

Megan Zupan
New York School for the Deaf

For both practical and theoretical reasons, educators and educational researchers seek to determine predictors of academic success for students at different levels and from different populations. Studies involving hearing students at the postsecondary level have documented significant predictors of success relating to various demographic factors, school experience, and prior academic attainment. Studies involving deaf and hard-of-hearing students have focused primarily on younger students and variables such as degree of hearing loss, use of cochlear implants, educational placement, and communication factors—although these typically are considered only one or two at a time. The present investigation utilizes data from 10 previous experiments, all using the same paradigm, in an attempt to discern significant predictors of readiness for college (utilizing college entrance examination scores) and classroom learning at the college level (utilizing scores from tests in simulated classrooms). Academic preparation was a clear and consistent predictor in both domains, but the audiological and communication variables examined were not. Communication variables that were significant reflected benefits of language flexibility over skills in either spoken language or American Sign Language.

The present investigation is aimed at determining predictors of the performance of deaf and hard-of-hearing (DHH) students in mainstream college classrooms. Educators and educational researchers have long sought to determine the predictors of student success at the postsecondary level. For both practical reasons (institutional and economic) and theoretical interest, such studies define “success” variously in terms of grade point average (GPA, Rohde & Thompson, 2007), retention (first year and beyond, Tinto, 1987), or degree completion (Adelman, 1999, 2006). Other studies have sought predictors of success in particular content areas, such as reading (e.g., Cuculick & Kelly, 2003; Toscano, McKee, & Lepoutre, 2002) and science (e.g., Au & Sharma, 2007; Sadler & Tai, 2001).

The predictors of postsecondary success, however it is defined, typically encompass several categories of measures including aptitude, demographic variables, and prior academic achievement. Aptitude measures can include tasks of verbal and nonverbal intelligence, vocabulary or other language scores, and various cognitive tasks (e.g., memory, problem solving, visual-spatial processing). Demographic factors may include familial variables such as parental education, number and age of siblings, and whether both parents are living in the home and/or working, in addition to the more common variables of gender, ethnicity, geographic location, and socioeconomic status (SES). Measures of academic achievement can utilize GPAs, standardized tests, level of curriculum intensity and difficulty (e.g., number of advanced placement courses), and teacher evaluations. There also is a category of what are frequently termed “noncognitive” factors, which includes variables such as motivation, interest, and study habits (Richardson, McLeod-Gallinger, McKee, & Long, 1999; Stinson & Walter, 1997). Various studies, some of which will be mentioned below, have found different significant predictors of postsecondary achievement, retention, and degree completion from among these diverse variables,
separately and in combination, and some have accounted for quite large proportions of the variance.

DHH Students in Mainstream Classrooms

Attempts at predicting academic success of DHH students is inherently more difficult than similar studies involving hearing students for several reasons. First, because significant hearing loss among school- and college-age individuals is relatively infrequent (often referred to as a “low-incidence disability”), the number of participants available for such studies is limited. Large-scale surveys and the norming of instruments to be used with this population thus are extremely time consuming and expensive (e.g., Allen, 1986; Holt 1994; Traxler, 2000), even when they make use of existing data sets (Kluwin & Morris, 2006). Second, but not unrelated, is the considerable heterogeneity of DHH students. In addition to all the variability that would be found among hearing individuals of the same ages, DHH students vary in several additional domains which may affect their academic achievement including the etiology of their hearing losses, possible medical or psychological factors associated with those etiologies, early accessibility of language, educational background, and preferred modes of communication (see Marschark, 1993, chapters 2 & 6; Powers, 2003).

Issues associated with communication and language represent a third source of difficulty for investigators seeking to predict DHH students’ academic achievement at several levels. Most obviously, the reliability and validity of achievement tests and other standardized measures assume some level of fluency in the language of administration. DHH students’ challenges in print literacy are well documented (e.g., Allen, 1986; Traxler, 2000); however, several recent studies have indicated that their comprehension of “through the air” communication in the classroom—whether sign language or spoken language—may not be significantly greater (Marschark, Pelz, et al., 2005; Marschark et al., 2006). In seeking to understand the factors contributing to academic achievement in younger DHH students, investigators also need to be cognizant of the likelihood that children’s effective language exposure has been relatively inconsistent, at least compared to hearing peers. This situation is related to cognitive functioning at-large (both cause and effect) as well to as the academic success that is to be predicted. Bebko and McKinnon (1990), for example, found that the number of years experience that 5- to 15-year-old DHH children had in their preferred language modality (spoken or signed) was a better predictor of their use of memory rehearsal than was their chronological age.

Recent findings have indicated that even at the postsecondary level, DHH students may not understand as much communication in the classroom as they (and we) think they do (e.g., Marschark, Sapere, Convertino, Seewagen, & Maltzen, 2004). This situation creates significant challenges both for determining what might be the appropriate predictors of academic performance to examine and for interpreting results once obtained. In this context, issues of bilingual education, language orientation, and direct versus mediated instruction (i.e., via interpreting or real-time text), all are relevant and worthy of consideration, but most will be beyond the scope of this study.

Educational placement is another factor that has the potential to affect DHH students’ long-term achievement and learning (Kluwin, 1992; Stinson & Kluwin, 2003). Previous studies comparing achievement in mainstream versus separate academic settings have been plagued by a variety of confounds, as students enrolled in one kind of setting or another (often a function of utilizing one mode of communication or another) may not be the same in many respects as students enrolled in another setting (see Holt, 1994). Accordingly, several large-scale studies have indicated that prior differences among deaf students are far more important than placement per se in explaining their academic achievement during the school years (Allen & Osborn, 1984; Kluwin & Moores, 1985; Powers, 1999, 2003, 2006). Indeed, a review by Stinson and Kluwin (2003) concluded that student variables such as the presence of multiple handicaps and familial variables such as SES explain far more of the variability in achievement by DHH students than school placement, with placement accounting for as little as 1% of the variance.

Although we have been unable to find many studies that have considered prior educational placement as a predictor of current performance among DHH
college students, both Kluwin (1993) and Holt (1994) found higher levels of academic achievement among DHH students in mainstream classrooms than in schools for the deaf. Kluwin described what he referred to as a “cumulative effect” of mainstream placement, insofar as achievement was positively related to the number of classes taken in regular classrooms as well as their academic intensity (see Adelman, 2006). More recently, DHH children are moving between mainstream and separate settings as their academic success and social comfort waxes or wanes. Adding to the complexity of predicting school performance, such disruptions in educational programming may have long-term academic and personal consequences as well, but the issue appears to remain unexamined.

This study involved a large number of DHH students in an effort to determine predictors of their academic success in mainstream postsecondary classrooms. Insofar as all of the students had successfully entered college, this study may benefit from reduced variability in prior academic achievement and, indirectly perhaps, some of the other variables mentioned above. Nevertheless, it was the lack of any observed relationships among such variables and student learning in more than a dozen experiments involving DHH college students that led to the present investigation in the first place. Several recent studies have examined learning by deaf college students in mainstream classrooms that have utilized real-time text (captioning) and/or sign language interpreting (e.g., Marschark et al., 2006; Marschark et al., 2004; Stinson, Elliott, Kelly, & Liu, 2009). The studies by Marschark, Stinson, and colleagues all examined variables potentially related to classroom learning, but failed to find any consistent predictors, and very few significant predictors, in more than 20 independent conditions. Results relevant to the present investigation are summarized in Table 1, which lists 10 experiments and their results of analyses seeking to determine relations between classroom learning and various predictor variables.

Two salient findings among those listed in Table 1 are (1) the lack of a significant relation between DHH college students’ reading levels and learning from text and (2) the lack of significant relations between their reported sign language skills and learning via sign language. The studies all obtained robust effects with regard to other variables, and thus the consistent null finding with regard to predictors of classroom learning in these and several other experiments seemed unlikely to be due to any methodological weakness. The studies also included comparison groups and replications that eliminated the possibility that findings obtained were a consequence of less than adequate sign language (or text) input. This study therefore utilized
information drawn from those previous studies—including achievement, demographic, communication, audiological, and learning data—in order to examine potential predictors of classroom learning with a larger sample of DHH students. Similar analyses were used to predict college entrance scores.

Predicting Academic Success

DHH students are less likely than hearing students to attend college, and thus investigations of their academic success at the postsecondary level are less common. Let us therefore briefly review the four categories of factors to be considered in predicting college students’ learning and achievement in the present investigation.

Achievement Variables

In studies involving children, “it is generally true to say that the best predictor of educational attainment is some measure of prior attainment” (Tymms, Brien, Merrell, Collins, & Jones, 2003, p. 203). Investigations involving hearing college students’ academic information from high school (GPA or standardized test scores) and/or college entrance scores typically serve this purpose. In general, overall or composite scores tend to be better predictors of performance than individual subtests (Fitz-Gibbon, 1996). Adelman (1999), however, found that the best predictor of college completion was the highest level of mathematics course taken in high school, especially those beyond algebra II. More generally, Adelman (1999, 2006) found that the academic intensity of high school courses was a better predictor of college completion than scores on the Scholastic Aptitude Test or the American College Test (ACT).

Sadler and Tai (2001) emphasized the importance of course intensity in predicting success in college physics on the basis of high school preparation. They found that the lack of high school physics did not present insurmountable barriers to (hearing) college students’ passing courses in the area but that the students who succeeded without such backgrounds tend to be stronger academically. The situation of lacking the background knowledge necessary for (or at least helpful to) college courses is perhaps more significant with regard to DHH students, given their varied educational backgrounds. Yet, most studies of DHH students’ learning and reading comprehension have neglected to consider the possibility that they might come into the classroom less prepared than their hearing peers, a suggestion confirmed by several recent studies (e.g., Marschark et al., 2004; Marschark et al., 2006; Marschark, Sapere, Convertino, & Seewagen, 2005a). Just as we cannot fully assess the benefits of any particular educational programming to DHH children’s reading achievement without knowing what reading-related knowledge (Tymms et al., 2003) and cognitive skills (Hauser, Lukomski, & Hillman, 2008) they bring to the classroom, we need to know, at a minimum, what content knowledge DHH college students bring to the classroom if we are to assess their learning and achievement fairly and accurately.

Since 1996, the National Technical Institute for the Deaf (NTID), a college of Rochester Institute of Technology (RIT), has required the ACT for all students applying for admission, thus providing students and institution officials with “a standardized test measure of students’ academic readiness” (ACT, 2008) and researchers with more complete information with which to explore predictors of academic success. Cuculick and Kelly (2003), for example, examined the relationship between reading level and degree attainment among DHH students at RIT from 1990 to 1998. They found that 92% of students who received Bachelor of Science degrees and 65% of students who received Bachelor of Fine Arts degrees were at reading levels between grade 9 and grade 12. Of those students who received associate-level degrees, 82% of AAS and 47% of AOS graduates read at the grade nine level or above. These figures contrast with Traxler’s (2000) finding that 50% of DHH students in the United States were reading at or below the grade four level. Cuculick and Kelly pointed out that although BFA and AOS programs are characterized by less-intensive language requirements relative to BS and AAS degrees, the ability to independently read college-level textbooks is an essential part of deaf students’ success in college. The Cuculick and Kelly findings also indicate that the student population involved in this study had academic credentials somewhat above the U.S. national average for graduating DHH high school
seniors, and thus any results obtained here cannot be attributed to a lack of academic ability on their part.

Beyond reading ability, Adelman’s (1999) finding of the robustness of mathematics achievement as a predictor of college degree completion suggests that it, too, should be a variable of interest in examining college success of DHH students, especially at institutions like RIT which focus on science, technology, engineering, and mathematics (STEM). Dowaliby, Caccamise, Marschark, Albertini, and Lang (2000), however, found that almost 80% of DHH students entering RIT scored below the 50th percentile on the ACT Mathematics subtest, with 32% of them scoring at the chance level. We have not found previous studies of relations between mathematics achievement and DHH students’ college success, but it was considered in the study presented below.

Communication Variables

For those involved in deaf education, it is well recognized that because at least 95% of deaf children come from hearing families, the majority grows up without fluency in a natural sign language. Most DHH students who grow up using spoken language similarly lack fluency in that mode due to the lower fidelity of input, even if they have cochlear implants (see Geers, 2006).

There is relatively little direct information concerning DHH college students’ communication skills and their academic achievement, perhaps because of the tacit assumption that by the college level, they already have acquired sufficient language fluencies for academic success. Long, Stinson, and Brages (1991) found that deaf adolescents’ ratings of their ease of communication in the classroom were a significant predictor of both achievement test scores and grades. Students’ reports of engagement in the classroom predicted grades but not test scores. Long and Beil (2005) found that DHH students who use sign language at the postsecondary level report preferring instructors who sign for themselves, but they did not examine possible relations to learning or other indicators of success. Holt (1994), however, found no differences in the Stanford Achievement Test Mathematics Computation scores of deaf students who relied on spoken language or a sign language interpreter in the classroom; both groups scored higher than in classrooms in which sign was the language of instruction. Consistent with all three of these studies, recent investigations have indicated that instructors who sign for themselves do not necessarily facilitate learning to any greater extent than sign language interpreters (Marschark, Sapere, Convertino, & Pelz, 2008) or real-time text (Marschark et al., 2006).

Family Variables

Family income or SES has long been included in studies of academic achievement by school-aged hearing children. With regard to college students, SES is most obviously relevant as it pertains to whether or not students have to work, while in school, and Adelman (2006) found that SES, but not ethnicity or gender, was a significant predictor of college degree completion.

As in the general population, DHH children from higher SES families demonstrate greater achievements in both communication and educational domains (Kluwin, 1994; Powers, 2003). The possible effects of SES on academic achievement by deaf college students are less clear, but Pollard and Oakland (1985) found SES (as indicated by the amount of weekly allowance) to be the second-best predictor, after intelligence, of both reading achievement and mathematics achievement among deaf 15–18 year olds.

The contribution of family SES to the cumulative academic, cognitive, and language abilities of deaf college students also should not be discounted, although little information is available in that regard. Calderon (2000) examined the relation between parental involvement and academic progress of DHH students during the early school years. She found it a significant predictor of early reading, but not a strong predictor of academic achievement more broadly. Toscano et al. (2002) examined predictors of literacy achievement among 30 college students who showed excellent print literacy skills. The most important variable to emerge was parent involvement in early education and educational decisions (Luckner & Muir, 2001; Powers, 2006), although effective parent–child communication and early experience with reading and writing in supportive settings also were indicated. Other studies have shown that parents of deaf and hearing children
show little difference in how much time they participate in the education of their children, but there are qualitative differences. For example, parents of hearing children are more likely to participate in classroom activities, whereas parents of deaf children are more likely simply to observe their children in that setting (Powers & Saskiewicz, 1998).

It is frequently suggested that deaf children of deaf parents have higher academic achievement than deaf children of hearing parents, but there has been relatively little support for that claim since studies conducted during the 1970s and early 1980s (for reviews, see Marschark, 1993; Powers, 2003). Powers (2003) reanalyzed 1995 and 1996 data from a large sample of mainstream secondary school students taking examinations for entry into postsecondary programs in England. Multiple regression analyses revealed no significant relation between parental hearing status and total test scores in either year, although children in the 1996 sample who had deaf parents had higher English subscores. Stacey, Fortnum, Barton, and Summerfield (2006), in a study involving children in the United Kingdom with cochlear implants, found that parental hearing status was strongly related to communication skills but was much less strongly associated with academic achievement.

Most of the literature on academic effects of parental hearing status primarily pertains to early language development and literacy and thus is beyond the scope of the present discussion. Importantly, however, the majority of such studies have been correlational, demonstrating that high or low levels of performance in one of these domains are often accompanied by similar levels in the other. Most also have confounded having early access to sign language with the broader potential benefits of having deaf parents (more diverse social interactions, greater language fluency, more informal educational interactions, etc.). When the two were separated, DeLana, Gentry, and Andrews (2007) found that fluency in American Sign Language (ASL) was significantly correlated with later reading ability, but having a deaf parent was not.

Audiological Variables

Differences in the academic success of DHH and hearing students go beyond differences in how much they hear. Goldberg and Richburg (2004) reviewed the literature on children with “minimal hearing impairment,” those with hearing thresholds between 16 and 25 decibels, and Moeller, Tomblin, Yoshinaga-Itano, Connor, and Jerger (2007) reviewed the literature pertaining to children with mild to moderate hearing losses. Both studies emphasized that even relatively mild hearing losses create challenges with regard to reading, language, and attention. As a result, those children generally are at risk for academic difficulties and tend to be more likely to have to repeat a grade. Consistent with that argument, Calderon (2000) found that the degree of hearing loss had little effect on academic achievement, as measured by the Stanford Achievement Test. Powers (2003) included degree of hearing loss as a predictor variable in his study and obtained similar findings. Tymms et al. (2003) found that hearing thresholds were unrelated to composite reading and mathematics scores.

Consideration of audiological differences among DHH college students appears quite rare beyond the studies listed in Table 1, and we have not found any other studies that examined the degree of hearing loss unconfounded by preferred mode of communication or use of cochlear implants. The only studies that have shown students with implants performing academically at a level fully commensurate with their hearing peers are those that included middle school and high school students who use sign language as well as spoken language (Spencer, Barker, & Tomblin, 2003; Spencer, Gantz, & Knutson, 2004). This study examined learning and academic achievement scores of deaf college students with and without cochlear implants, including students who use sign language as well as those who rely solely or primarily on spoken language.

Identifying Predictors of Learning and Academic Achievement

The above review indicates that communication, familial, and audiological factors, as well as prior academic preparation, have the potential to influence
academic success for DHH students at the college level. Yet, over a series of studies by Marschark and his colleagues examining DHH students’ learning in college classrooms, analyses consistently failed to produce any consistent predictors and only rarely yielded any significant predictors at all. Given the considerable heterogeneity of DHH students for the reasons described above, it may be that individual experiments involving only 20–40 students simply lack the power to reveal true relationships. Hauser et al. (2008) and Marschark, Convertino, and LaRock (2006), however, have argued that there are cognitive differences between DHH and hearing students that can result in very different academic strengths and needs. The present investigation therefore utilized existing data, drawn from 10 previous experiments, in order to explore possible predictors of academic success at the college level. Importantly, essentially all the predictors examined here have been utilized in previous studies. Most earlier investigations, however, considered these variables individually or in pairs. Utilization of a large sample of DHH college students in this study allowed for the statistical control of possible interactions and confounds in evaluating over two dozen potential predictors.

For the present purposes, several indicators of “academic success” were utilized, recognizing that they still represent a relatively narrow range of measures. Following up our previous failures to find significant predictors of learning from lectures in college classrooms, three measures were of particular interest: scores on tests of prior content knowledge specific to each lecture, post-lecture assessments of learning (multiple-choice tests developed in collaboration with the instructors), and gain scores (posttest minus pretest scores). Students undoubtedly learn more from a classroom lecture than is reflected by a multiple-choice test. The methodology employed in the original studies had been selected as a convenient method of assessment frequently experienced by DHH and hearing students in a variety of college courses.

We initially started using content-specific pretests as a means of determining whether hearing students’ consistent outscoring of deaf students on post-lecture assessments might be the result of the two groups coming into the classroom with different levels of prior knowledge. Analyses of covariance allowed for the statistical controlling for prior knowledge, and the calculation of gain scores (when posttest questions included a subset of pretest questions) provided measures of how much students learned from a lecture relative to their prior knowledge. Importantly, the predictors of pretest, posttest, and gain scores might be different, insofar as the first is assumed to reflect primarily prior knowledge; the second provides an indicator of how much is learned from a lecture given (or in addition to) prior knowledge, abilities, and skills; and the third offers a measure of “value added” independent of students’ individual starting points (Tymms et al., 2003).

This investigation also offered the opportunity to examine predictors of DHH students’ scores on college entrance and placement tests. The instruments listed in the top section of Table 2 all were available to the investigators and had been used in the previous studies in attempts to predict pretest, posttest, and gain scores. Analyses described below utilized communication, family, and audiological variables in an effort to discover predictors of those gateway measures as well.

Method
Participants
A total of 568 different DHH students serving in 10 experiments (21 conditions, 794 cases) are included in the present analyses. Where students participated in more than one condition (i.e., within-subjects designs), they were treated as separate cases in the analyses described below. Participants in all of the experiments were enrolled at RIT. RIT includes the NTID as one of its eight colleges, but deaf participants came from all RIT colleges. Other characteristics of the participants are dealt within the context of independent variables.

Design and Procedure
Table 2 divides the individual difference variables examined in the present investigation into four categories: achievement information, audiological information, communication information, and family
information. Information available from institutional databases included college entrance scores, two standardized reading tests, and NTID placement tests for reading, writing, and mathematics, although there were occasional missing data for some students.\(^1\) The reading tests were the California Reading Comprehension Test and the Michigan Test of English Language Proficiency, which is 20% reading comprehension, 40% grammar related, and 40% vocabulary. The three placement tests have been developed by departments at NTID over several years and have been found to be more accurate at predicting DHH students' course success than the standardized tests, which have been normed only for hearing students.

Whereas the achievement, audiological, and family variables listed in Table 2 had been obtained (with student consent) from institutional files, the communication variables were collected at the time of testing utilizing a version of the self-reported Language and Communication Background Questionnaire (LCBQ). NTID utilizes the LCBQ in lieu of face-to-face communication interviews because it is more efficient and has been found to correlate highly (around .80) with interview assessments (Hatfield, Caccamise, & Siple, 1978; McKee, Stinson, & Blake, 1984). The LCBQ is not intended as a definitive, precise assessment of student language skills but provides estimates sufficient for the present purposes. Looking ahead, support for this methodological assumption is obtained from correlations between LCBQ ratings and the age at which students began to learn sign language. Consistent with previous studies of spoken language (Birdsong & Molis, 2001) and sign language (Mayberry & Lock, 2003), age of sign language acquisition was significantly correlated (inversely) with self-reports of production and receptive skills in both ASL and English-based signing. The version of the LCBQ used in the original studies is provided in Appendix 1.

Demographic and learning data for this study were drawn from 10 experiments (see Table 1) involving nine different university instructors who provided a total of 11 different lectures (most experiments included two different instructors for the purposes of counterbalancing). The instructors all taught hearing students on a regular basis, although they occasionally had DHH students in their courses. The content of individual lectures varied across STEM disciplines, including biology, engineering, physics, chemistry, computer science, and electronics. All the lectures were relatively short, ranging from 12 to 20 min (one experiment included three 20-min segments of a longer lecture). Most of the studies involved life-sized, digitally videotaped presentations, after Marschark, Pelz, et al. (2005) demonstrated no significant differences in learning by either hearing or DHH students with live versus video presentations.

Most of the lectures were interpreted by three different sign language interpreters, reported by departmental managers to be among the best of more than 120 educational interpreters on the RIT campus.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Achievement, audiological, communication, family, and learning variables examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achievement information</td>
<td>ACT English, Mathematics, Natural Science, and Composite Scores</td>
</tr>
<tr>
<td></td>
<td>Michigan Test of English Language Proficiency</td>
</tr>
<tr>
<td></td>
<td>California Reading Comprehension Test</td>
</tr>
<tr>
<td></td>
<td>College reading, writing, and mathematics placement tests</td>
</tr>
<tr>
<td></td>
<td>Program degree level (Associate vs. Bachelor)</td>
</tr>
<tr>
<td>Audiological information</td>
<td>Pure Tone Threshold in each ear</td>
</tr>
<tr>
<td></td>
<td>Age of hearing loss onset</td>
</tr>
<tr>
<td></td>
<td>Use of cochlear implants and hearing aids</td>
</tr>
<tr>
<td>Communication information (self-report)</td>
<td>Languages other than English and sign language used in the home</td>
</tr>
<tr>
<td></td>
<td>Age at which began learning to sign</td>
</tr>
<tr>
<td></td>
<td>Primary mode of communication (sign language or spoken language)</td>
</tr>
<tr>
<td></td>
<td>Skilled signer versus “oral” student</td>
</tr>
<tr>
<td></td>
<td>Sign communication preference (ASL, English-based sign)</td>
</tr>
<tr>
<td></td>
<td>ASL production skills</td>
</tr>
<tr>
<td></td>
<td>ASL receptive skills</td>
</tr>
<tr>
<td></td>
<td>English-based sign production skills</td>
</tr>
<tr>
<td></td>
<td>English-based sign receptive skills</td>
</tr>
<tr>
<td></td>
<td>Simultaneous communication (SimCom) receptive skills</td>
</tr>
<tr>
<td>Family information</td>
<td>Number of deaf parents</td>
</tr>
<tr>
<td></td>
<td>Mother’s and father’s education</td>
</tr>
<tr>
<td></td>
<td>Mother’s and father’s occupation</td>
</tr>
<tr>
<td></td>
<td>Gender</td>
</tr>
<tr>
<td>Experiment learning scores</td>
<td>Content-specific test of prior knowledge (pretest score)</td>
</tr>
<tr>
<td></td>
<td>Content-specific learning assessment (posttest score)</td>
</tr>
<tr>
<td></td>
<td>Gain score (posttest–pretest)</td>
</tr>
</tbody>
</table>
Two additional studies involved groups of 8 and 23 different interpreters. The interpreters either stood next to the instructor or were video projected, lifesized in an area adjacent to the projection of the instructor. The use of classroom lectures that prevented student–instructor interactions is unlikely to be the best means of teaching university students. Nevertheless, it allowed for careful control of the learning context and provided uniform conditions for DHH and hearing students across all of the studies.

Because performance naturally varied across the original experiments, the pretest, posttest, and gain scores were standardized separately for each experiment. The use of $z$-scores (mean $= 0$, standard deviation $= 1$) allows examination of predictors of performance using data all 10 experiments, retaining within-experiment variability across individuals, even though raw scores varied significantly between experiments.

Analyses

In the first set of analyses described below, ACT Composite scores served as the dependent variable, providing a general measure of academic readiness at the college level (ACT, 2008). All the other individual difference variables in Table 2 served as independent (predictor) variables. The second set of analyses examined classroom learning using, as the dependent variables, the pretest, posttest, and gain scores (all as $z$ scores) from the 10 experimental conditions listed in Table 1. All the other variables in Table 2 served as independent (predictor) variables. Each set of analyses involved a series of iterative linear regression analyses, both simple and stepwise. Linear regression entails using one or more independent variables in order to predict the value of a dependent variable (e.g., predicting reading comprehension based on vocabulary size). In the simple regression analyses utilized here (first level of analysis), separate regressions were performed for each dependent variable, using one predictor at a time.

Stepwise multiple regression entails using multiple independent variables at one time, alternately holding all but one of the variables constant in order to determine which accounts for the greatest proportion of variance in the dependent variable. Once the effects of that most powerful predictor are removed, the process is repeated in order to determine the second most powerful predictor, and so on, until a criterion (usually $p < .05$) is reached. At the second level of analysis utilized here, separate stepwise multiple regressions were performed for each dependent variable using all the predictor variables within a category of predictors (achievement, audiological, communication, family) that were significant at the first level of analysis. At a third level of analysis, predictors that had accounted for significant amounts of variance in the second-level analyses were combined into a final stepwise multiple regression. This grouping together of similar variables and only analyzing those significant at lower levels has the advantage of eliminating potential predictors that normally would reduce the power of a test without providing useful statistical or practical information.

Results

In all analyses, an alpha level of .05 was adopted. Unless otherwise noted, all predictors described were positive (i.e., higher scores on one variable predict higher scores on another) and significant at that level. They are reported in decreasing order of the amount of variance explained. The results of regression analyses predicting ACT Composite scores are presented in Table 3; results of analyses predicting learning data (pretest, posttest, gain scores) are presented in Table 4. Because the first and second level of analyses were only preliminary, a means to an end (the third and final level of analysis), the results of those two sets of analyses are provided in Appendix 2. The first-order analyses are interesting, however, because they correspond to the correlational analyses that are normally reported in studies of DHH students’ academic performance (Luckner, Sebald, Cooney, Young, & Muir, 2005/2006).

Predicting Academic Readiness of DHH College Students

The third-order stepwise multiple regression included all the significant predictors that emerged from the first-order and second-order levels of analyses. That is, the independent variables were all those variables
Table 3  Significant predictors of ACT Composite scores of DHH college students

<table>
<thead>
<tr>
<th></th>
<th>$R^2$</th>
<th>F</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First-order analyses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achievement variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT English</td>
<td>.846</td>
<td>(1,548) = 3005.30</td>
<td>.788</td>
</tr>
<tr>
<td>ACT Mathematics</td>
<td>.706</td>
<td>(1,548) = 1317.15</td>
<td>.839</td>
</tr>
<tr>
<td>ACT Natural Science</td>
<td>.785</td>
<td>(1,548) = 2000.60</td>
<td>.883</td>
</tr>
<tr>
<td>Michigan test</td>
<td>.222</td>
<td>(1,320) = 91.26</td>
<td>.173</td>
</tr>
<tr>
<td>California test</td>
<td>.216</td>
<td>(1,386) = 106.41</td>
<td>1.49</td>
</tr>
<tr>
<td>Reading placement test</td>
<td>.053</td>
<td>(1,321) = 17.92</td>
<td>.026</td>
</tr>
<tr>
<td>Writing placement test</td>
<td>.103</td>
<td>(1,332) = 38.29</td>
<td>.098</td>
</tr>
<tr>
<td>Mathematics placement test</td>
<td>.228</td>
<td>(1,258) = 76.31</td>
<td>.242</td>
</tr>
<tr>
<td>Program degree level</td>
<td>.284</td>
<td>(1,534) = 211.78</td>
<td>-5.09</td>
</tr>
<tr>
<td><strong>Audiological variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PTA right ear</td>
<td>.012</td>
<td>(1,498) = 6.107</td>
<td>-0.33</td>
</tr>
<tr>
<td>Use of hearing aids</td>
<td>.048</td>
<td>(1,548) = 27.50</td>
<td>-2.10</td>
</tr>
<tr>
<td><strong>Communication variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Languages used in the home</td>
<td>.034</td>
<td>(1,533) = 18.72</td>
<td>2.58</td>
</tr>
<tr>
<td>Communication preference</td>
<td>.044</td>
<td>(1,542) = 25.20</td>
<td>-0.78</td>
</tr>
<tr>
<td>Sign preference (ASL ~ English)</td>
<td>.042</td>
<td>(1,532) = 23.42</td>
<td>-0.69</td>
</tr>
<tr>
<td>ASL production skills</td>
<td>.069</td>
<td>(1,548) = 40.92</td>
<td>-1.08</td>
</tr>
<tr>
<td>ASL receptive skills</td>
<td>.025</td>
<td>(1,548) = 14.00</td>
<td>-0.69</td>
</tr>
<tr>
<td>English sign receptive skills</td>
<td>.012</td>
<td>(1,548) = 6.77</td>
<td>0.46</td>
</tr>
<tr>
<td>SimCom receptive skills</td>
<td>.025</td>
<td>(1,548) = 13.97</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>Family variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of deaf parents</td>
<td>.037</td>
<td>(1,469) = 18.22</td>
<td>0.83</td>
</tr>
<tr>
<td>Mother’s education</td>
<td>.060</td>
<td>(1,456) = 29.19</td>
<td>0.95</td>
</tr>
<tr>
<td>Father’s education</td>
<td>.039</td>
<td>(1,345) = 14.18</td>
<td>0.49</td>
</tr>
<tr>
<td>Father’s occupation</td>
<td>.001</td>
<td>(1,252) = 4.92</td>
<td>0.004</td>
</tr>
<tr>
<td><strong>Second-order analyses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achievement variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT English</td>
<td>.846</td>
<td>(1,258) = 1414.90</td>
<td>.788</td>
</tr>
<tr>
<td>ACT Natural Science</td>
<td>.095</td>
<td>(1,257) = 416.53</td>
<td>0.455</td>
</tr>
<tr>
<td>ACT Mathematics</td>
<td>.022</td>
<td>(1,256) = 152.94</td>
<td>0.232</td>
</tr>
<tr>
<td>Michigan test</td>
<td>.005</td>
<td>(1,255) = 43.37</td>
<td>0.031</td>
</tr>
<tr>
<td>Mathematics placement test</td>
<td>.001</td>
<td>(1,254) = 6.52</td>
<td>0.022</td>
</tr>
<tr>
<td>California Test</td>
<td>.001</td>
<td>(1,253) = 11.58</td>
<td>-0.245</td>
</tr>
<tr>
<td>Reading placement test</td>
<td>.001</td>
<td>(1,252) = 4.92</td>
<td>0.004</td>
</tr>
<tr>
<td><strong>Audiological variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of hearing aids</td>
<td>.048</td>
<td>(1,498) = 24.99</td>
<td>-2.102</td>
</tr>
<tr>
<td><strong>Communication variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ASL production skills</td>
<td>.069</td>
<td>(1,532) = 39.73</td>
<td>-1.08</td>
</tr>
<tr>
<td>Languages used in the home</td>
<td>.033</td>
<td>(1,531) = 19.38</td>
<td>0.54</td>
</tr>
<tr>
<td>SimCom receptive skills</td>
<td>.023</td>
<td>(1,530) = 14.13</td>
<td>0.81</td>
</tr>
<tr>
<td><strong>Family variables</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father’s education</td>
<td>.60</td>
<td>(1,345) = 22.09</td>
<td>0.95</td>
</tr>
<tr>
<td><strong>Third-order analysis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT English</td>
<td>.846</td>
<td>(1,258) = 1414.03</td>
<td>.788</td>
</tr>
<tr>
<td>ACT Natural Science</td>
<td>.095</td>
<td>(1,257) = 416.53</td>
<td>0.455</td>
</tr>
<tr>
<td>ACT Mathematics</td>
<td>.022</td>
<td>(1,256) = 152.94</td>
<td>0.232</td>
</tr>
<tr>
<td>Michigan test</td>
<td>.005</td>
<td>(1,255) = 43.37</td>
<td>0.031</td>
</tr>
<tr>
<td>Mathematics placement test</td>
<td>.001</td>
<td>(1,254) = 6.52</td>
<td>0.022</td>
</tr>
<tr>
<td>California test</td>
<td>.001</td>
<td>(1,253) = 11.58</td>
<td>-0.245</td>
</tr>
<tr>
<td>Use of hearing aids</td>
<td>.001</td>
<td>(1,252) = 6.00</td>
<td>-0.260</td>
</tr>
<tr>
<td>Reading placement test</td>
<td>.001</td>
<td>(1,251) = 4.61</td>
<td>0.003</td>
</tr>
<tr>
<td>SimCom receptive skills</td>
<td>.000</td>
<td>(1,250) = 4.11</td>
<td>-0.119</td>
</tr>
</tbody>
</table>
Table 4  Significant predictors of classroom learning scores by DHH college students (see Table 1)

<table>
<thead>
<tr>
<th></th>
<th>Pretest</th>
<th>Posttest</th>
<th>Gain score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R^2$ Change</td>
<td>$F$ Change</td>
<td>$\beta$</td>
</tr>
<tr>
<td>First-order analyses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achievement variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT English</td>
<td>.125</td>
<td>(1,532) = 75.78</td>
<td>.063</td>
</tr>
<tr>
<td>ACT Mathematics</td>
<td>.086</td>
<td>(1,532) = 50.18</td>
<td>.061</td>
</tr>
<tr>
<td>ACT Natural Science</td>
<td>.122</td>
<td>(1,532) = 74.20</td>
<td>.073</td>
</tr>
<tr>
<td>ACT Composite scores</td>
<td>.147</td>
<td>(1,532) = 91.46</td>
<td>.086</td>
</tr>
<tr>
<td>Michigan test</td>
<td>.063</td>
<td>(1,392) = 26.35</td>
<td>.019</td>
</tr>
<tr>
<td>California test</td>
<td>.040</td>
<td>(1,481) = 19.87</td>
<td>.133</td>
</tr>
<tr>
<td>Reading placement test</td>
<td>.013</td>
<td>(1,394) = 5.29</td>
<td>.003</td>
</tr>
<tr>
<td>Mathematics placement test</td>
<td>.20</td>
<td>(1,330) = 6.75</td>
<td>.015</td>
</tr>
<tr>
<td>Program degree level</td>
<td>.048</td>
<td>(1,745) = 57.78</td>
<td>-.437</td>
</tr>
<tr>
<td>Audiological variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of hearing aids</td>
<td>.006</td>
<td>(1,772) = 4.95</td>
<td>-.160</td>
</tr>
<tr>
<td>Communication variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Languages used in the home</td>
<td>.022</td>
<td>(1,750) = 16.71</td>
<td>.432</td>
</tr>
<tr>
<td>Communication preference (sign ‘speech)</td>
<td>.007</td>
<td>(1,764) = 5.45</td>
<td>-.065</td>
</tr>
<tr>
<td>ASL production skills</td>
<td>.011</td>
<td>(1,772) = 8.40</td>
<td>-.088</td>
</tr>
<tr>
<td>English sign production skills</td>
<td>.009</td>
<td>(1,772) = 6.83</td>
<td>.083</td>
</tr>
<tr>
<td>English sign receptive skills</td>
<td>.011</td>
<td>(1,772) = 5.77</td>
<td>.091</td>
</tr>
<tr>
<td>SimCom receptive skills</td>
<td>.038</td>
<td>(1,770) = 30.50</td>
<td>.215</td>
</tr>
<tr>
<td>Speech reading skill</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mother's education</td>
<td>.013</td>
<td>(1,435) = 5.910</td>
<td>.060</td>
</tr>
<tr>
<td>Father's occupation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second-order analyses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achievement variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ACT Composite scores</td>
<td>.147</td>
<td>(1,258) = 44.36</td>
<td>.80</td>
</tr>
<tr>
<td>Michigan test</td>
<td>.016</td>
<td>(1,257) = 5.22</td>
<td>-.011</td>
</tr>
<tr>
<td>Audiological variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of hearing aids</td>
<td>.006</td>
<td>(1,772) = 4.95</td>
<td>-.160</td>
</tr>
<tr>
<td>Communication variables</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SimCom receptive skills</td>
<td>.038</td>
<td>(1,764) = 30.27</td>
<td>.215</td>
</tr>
<tr>
<td>ASL production skills</td>
<td>.012</td>
<td>(1,763) = 9.37</td>
<td>-.092</td>
</tr>
</tbody>
</table>
that were significant predictors of ACT Composite scores when the other variables were controlled. The English, Natural Science, and Mathematics subscores emerged as the first three predictors, with the English subscore accounting for more than 80% of the variance. Those three were followed by the Michigan test and the NTID mathematics placement test as positive predictors and then the California test and hearing aid use as negative predictors. Finally, the NTID reading placement test was a positive predictor and SimCom receptive skill was a negative predictor. Each of the last six predictors, however, accounted for less than .5% of the variance (see Table 3).

Taken together, the above analyses make two general points. The finding that DHH college students’ ACT Composite scores—as an indicator of academic readiness at the college level—were predicted by their skills in English, natural science, and mathematics is not surprising, especially given that all the lectures involved STEM content. Perhaps more interesting are findings indicating the relatively weak relation between communication skills and academic readiness. In the first- and second-order analyses, variables associated with ASL and the use of sign language over spoken language were negative predictors of academic readiness, whereas those associated with spoken language were positive, but weak and confounded predictors (see Appendix 1). When all the other variables were controlled (i.e., in the third-order regression analysis), communication preferences and skills were largely irrelevant for predicting academic readiness for university-level education.

These findings suggest that the claims made by proponents of the educational superiority of spoken language (e.g., Khan, Edwards, & Langdon, 2007) or sign language (e.g., Johnson, Liddell, & Erting, 1989) for DHH students may be somewhat overstated. At least by the time they get to college, neither sign language nor spoken language skills are definitive predictors of academic performance for DHH students, performance that is, on average, consistently below the level of their hearing peers (Marschark, Sapere, et al., 2005b). Whether this “glass ceiling effect” is a consequence of differing cognitive skills that are not fully accommodated during the school years (Hauser et al., 2008), a relative lack of automatic
language comprehension subskills (Marschark & Wauters, 2008) or some other factor is unclear. In any case, it appears not to be a function of a student’s preferred mode of communication or fluency within that mode.

It should be re-emphasized that although the ACT is considered a test of college readiness (ACT, 2008), college entrance scores provide only a limited window onto DHH students’ academic potential, particularly because of the restricted range of abilities inherent in a study involving only a college population. The greater heterogeneity of DHH students relative to hearing peers is associated with considerable variability in academic performance, regardless of its origins, and students in the lower range of academic ability for DHH students as a whole (those who do not attain college) are not represented in this investigation. Because scores on college entrance examinations are limited in what they can tell us about how those students will perform in a postsecondary setting, academic performance in simulated classrooms was examined, providing a more ecologically valid assessment of potential predictors of DHH students’ academic success.

Predicting Learning in Mainstream College Classrooms

Results of the first- and second-order regression analyses predicting classroom learning are reported in Appendix 2. When all the other variables were controlled in a third-level analysis, students’ ACT Composite scores significantly predicted their standardized pretest, posttest, and gain scores. That result is consistent with the finding that composite scores generally are better predictors of performance than subscores among hearing students (Fitz-Gibbon, 1996). Sim-Com receptive skills positively predicted both pretest and posttest performances, whereas Michigan reading scores negatively predicted posttest and gain scores.

In the absence of strong contributions from the various communication variables, it should be remembered that lectures from the original experiments all were presented to relatively small classes of students by highly skilled sign language interpreters working with mainstream college faculty. Students therefore had greater access to sign language and spoken language than would be likely in most mainstream classrooms. The raw scores from the original experiments, however, indicated that deaf students’ consistently scored significantly below their hearing peers, regardless of whether (1) they were highly skilled in ASL or relied fully on spoken language (or anywhere in between), (2) they had their learning evaluated through written or signed tests, and (3) they were familiar with their interpreters or not. The new results thus suggest that the mode of communication used in the college classroom, and even students’ communication histories, are of lesser importance than their academic preparation. As indicated by analyses in the previous section, communication history also is not a good predictor of the academic achievement on which entrance to college is based, so the fact that access to classroom communication was optimized in the studies underlying the present investigation is insufficient to explain the results. Success for DHH students at the college level clearly depends on their how well prepared they are when they walk in the door, and the other variables examined here pale in comparison.

Discussion

This study examined the predictors of DHH students’ college readiness (ACT college entrance scores) and their academic performance as evaluated in experimental, mock classrooms. The latter included three measures: prior content knowledge, learning from a spoken and interpreted lecture, and gain scores (learning assessment score minus prior content knowledge score). The predictor (independent) variables of interest included achievement measures, audiological information, communication skills/preferences, and family demographics. Data concerning classroom learning were drawn from 10 previous experiments in which DHH students had been seen lectures provided by mainstream university instructors supported by highly skilled sign language interpreters. When all other variables were controlled, ACT Composite scores were the best predictors of pretest (prior knowledge), posttest, and gain scores. Students’ skills in simultaneous communication were positively related to pretest and posttest performance, whereas
Michigan reading scores negatively predicted posttest and gain scores.

It is noteworthy that the variables which predicted DHH students’ readiness for the college classroom (ACT Composite scores) were somewhat different than those that predicted learning scores. Among the achievement variables, English ability was clearly the most important predictor of doing well on the ACT and gaining entrance to college. After controlling for all of the other variables through regression analyses, students’ ACT Composite scores were best predicted by their English skills (ACT English subscore), which accounted for more than 80% of the variance. The other ACT subscores, as well as reading and mathematics placement tests, also were significant positive predictors. In general, neither audiological variables nor communication variables predicted college readiness. In contrast, an academic setting that provides good support services in the form of sign language interpreting appears to provide students with the flexibility to use whatever modes of communication they find more comfortable, and English scores are not predictive of classroom learning.

Three other variables are of particular interest. First, as noted earlier, the consistent lack of a relation between academic success and having deaf parents, as well as the generally poor predictive power of ASL, suggests that relations between early sign language use and literacy (e.g., Calderon & Greenberg, 1997; Padden & Ramsey, 1998, 2000; Singleton, Supalla, Litchfield, & Schley, 1998) are of somewhat lesser importance to academic performance for older students. However, whether or not students had deaf parents was the least frequently available datum. Only 88 students reported that information, 13 of whom had at least one deaf parent. As far as we can tell, the only studies that have linked literacy or academic performance to having deaf parents and early sign language use have involved young children, whereas such a relation has never been indicated for students beyond the elementary school years.

The consistent lack of predictive power of either spoken language or cochlear implant use also suggests that DHH students’ communication skills once they reach college is far less dependent on spoken language than frequently is claimed. Overall, a majority of the DHH college students reported preferring to use spoken language in the classroom, yielding a mean of 3.62 on a five-point Likert scale from sign to speech. At the same time, the mean rating of their ASL production skills was 3.58, that for ASL receptive skill was 3.98, and the median on all four sign language scales was 4.0. In short, these students were very comfortable with their sign language skills.

Contrary to expectations, our literature review failed to turn up evidence in support of spoken language per se as a predictor of academic achievement for DHH students at any level, when other variables were controlled. Similarly, the evidence described by Marschark, Rhoten, and Fabich (2007) with regard to cochlear implants and academic achievement suggested that although implants clearly support early literacy and academic achievement for deaf children, the case for high school and college students has not been made. There is some evidence that by high school age, early advantages with regard to reading appear to fade (Geers, Tobey, Moog, & Brenner, 2008), whereas the importance of sign language in addition to spoken language appears to grow (Spencer et al., 2004). Whether these patterns are a function of social-motivational factors, increasing cognitive abilities as children mature, or simply an indicator of the early stage of research in this area remains unclear.

The predictive power of SimCom receptive skills is another consistent aspect of the present findings that deserves mention, if only because the simultaneous use of sign language and spoken language is frequently described as problematic (e.g., Cokely, 1990; Johnson et al., 1989). Studies with less skilled users of SimCom directed at young children have shown that some proportion of signs are omitted during SimCom, as...
speech takes priority for hearing individuals (Marmor & Petitto, 1979). To the extent that it fails to fully represent either ASL or English grammar, SimCom thus may not be appropriate as a primary means of communication with young DHH children. Long-term studies involving skilled SimCom users do not appear to be available. Studies with older students, however, have demonstrated that in the hands of a skilled user, SimCom can be as effective as other forms of communication for classroom learning from middle school onward (Leigh & Power, 1998; Marschark et al., 2008; Power & Hyde, 1997). Importantly, in the experiments from which the present data were drawn, simultaneous communication was never used. The predictive value of that variable thus might lie in students’ more general ability to integrate sign language and spoken language or simply indicate that students who have effectively comprehended the SimCom in previous educational settings have benefited from a powerful learning tool. In view of the contrast between the present findings and the rhetoric against SimCom in deaf education, the issue clearly merits further investigation.

The consistent failure to obtain significant predictors of gain scores is another interesting aspect of the findings. Whereas pretest scores and, to a great extent, posttest scores are indicators of the content knowledge that students bring to the classroom, gain scores presumably reflect more about learning strategies and general cognitive flexibility than prior knowledge. Yet, they also reflect instructor and setting factors, including the quality of support services. In the 10 experiments underlying the present investigation, participating instructors varied in teaching experience as well as discipline. It thus may be that gain scores are more reflective of factors extrinsic to students who already have sufficient skills to gain entrance to university. Gain scores have been shown to be a good indicator of academic success in DHH children (Tymms et al., 2003), but they have not been extensively studied with older students.

Finally, it should be acknowledged that the present investigation and the experiments that led to it did not consider “noncognitive” factors described earlier, such as motivation or study habits. Richardson et al. (1999) found that DHH and hearing students in mainstream college classrooms did not differ greatly in their approaches to studying, even if the DHH students had somewhat more difficulty in integrating information from lectures and textbooks (see Marschark, Convertino, & LaRock, 2006). Stinson and Walter (1997), however, argued that motivation among DHH students should be a particularly important predictor of academic achievement at the college level, insofar as it reflects a commitment to college, institutional and social integration, and program and social satisfaction. Such a relationship might be linked to the demonstrated influence of parental expectations and support of DHH students’ academic achievement (Luckner & Muir, 2001; Toscano et al., 2002) or to self-esteem among students who see themselves as succeeding because of their own competencies (Luckner & Muir, 2001). In any case, the present results indicate that academic preparation is as good a predictor of academic success for DHH students as it is for hearing students. Audiological, communication, and family factors undoubtedly have a variety of effects on development and education during the school years. For DHH students who attend college, those variables likely have already had their influence, and when all else is held constant, there appears no better predictor of academic performance than coming into the classroom prepared in terms of content knowledge, learning skills, and communication flexibility.

Funding
National Science Foundation (REC-0207394, REC-0307602, and REC-0633928).

Appendix 1
Language and Communication Questionnaire

1. If I had to choose ONE, I would want to get this lecture material from:
   a. an interpreter
   b. a teacher signing
   c. reading about it
d. captions

e. C-Print

2. How do you prefer to communicate most of the time? (circle one):
   a. Sign alone
   b. Speech alone
   c. Sign and speech together (simultaneous communication)
   d. Sign with English mouth movements

3. Please rate your skills in understanding simultaneous communication (speech and sign together).
   I understand (circle one number):
   Everything 5 4 3 2 1 Nothing

4. a. Please rate your skill in producing ASL:
      Excellent 5 4 3 2 1 No skill
    b. Please rate your skill in understanding ASL:
      Excellent 5 4 3 2 1 No skill
    c. Please rate your skill in producing signed English:
      Excellent 5 4 3 2 1 No skill
    d. Please rate your skill in understanding signed English (no voice):
      Excellent 5 4 3 2 1 No skill

5. Age you began to learn sign language:
   a. Since birth  b. _____ years old (or grade _____)

6. Do you use a hearing aid? Yes ____ No ____

7. Do you have a cochlear implant? Yes ____ No ____

8. If Yes, do you use your implant? Yes ____ No ____

9. Do you use another kind of Assistive Listening Device? Yes ____ No ____

10. Do you use a spoken language other than English with your family?
    Yes ____ No ____
    If yes, what language? ______________

11. Please tell me the number of years you had interpreters in school before you came to RIT.

Please circle one number to answer each of the following two questions:

12. Overall, I prefer to use
    Sign language 5 4 3 2 1 Spoken language

13. Overall, I prefer to use
    ASL 5 4 3 2 1 English-based signing

Appendix 2

First- and Second-Order Regression Analyses for Predicting Academic Readiness (Composite ACT Scores) and Classroom Learning

Predicting academic readiness of DHH college students.

First-order analyses. In individual analyses, ACT Composite scores were significantly predicted by all of the other achievement variables: the English, Mathematics, Natural Science ACT subtests; NTID reading, writing, and mathematics placement tests; and Michigan and California scores (Table 3). Enrollment in a baccalaureate program also was a positive predictor. Consistent with the methodological assumption that pretest scores reflect students’ academic preparation, those scores also were a positive predictor of ACT Composite scores ($R^2 = .147$).

Significant audiological predictors consisted of hearing thresholds in the right ear (i.e., more hearing associated with higher scores) and hearing aid use (greater use associated with lower scores), but there was no effect of cochlear implant use.

Among the communication variables, having a greater number of languages used in the home was a significant predictor of the ACT Composite scores. Preference for sign language over spoken language was a negative predictor, as was a preference for ASL over English-based signing. Self-rated ASL production and receptive skills also were negative predictors, whereas receptive skills in English-based signing and receptive skill in simultaneous communication (SimCom) were positive predictors. These results are consistent with the findings that neither having deaf parents nor the
age at which students learned to sign were significant predictors.

First-order analyses involving the family variables indicated that both parents’ levels of education predicted ACT Composite scores, as did fathers’ occupational level. In studies involving hearing children, mothers’ educational level is the aspect of SES most frequently found related to developmental growth (Hoff-Ginsberg & Tardiff, 1995).

**Second-order analyses.** When all of the achievement variables were included in a second-order analysis predicting the ACT Composite score, the first three predictors were the ACT English subscore, the Natural Science subscore, and the Mathematics subscore. They were followed by the Michigan test, the mathematics placement test, the California test, and the reading placement test.

The second-order analysis including hearing thresholds in the right ear and hearing aid use yielded only the latter variable as a significant negative predictor.

The analysis including the seven communication variables significant in the first-order analyses, yielded ASL production skill as a significant negative predictor, followed by multiple languages in the home and SimCom receptive skill as positive predictors.

Fathers’ education level remained significant for the ACT Composite score at this level, whereas mothers’ educational levels and fathers’ occupational levels did not.

Predicting learning in mainstream college classrooms.

**First-order analyses.** Achievement variables. Table 4 lists the results of first-order regression analyses examining students’ performance on pre-experimental tests of content-specific knowledge (pretests) and post-lecture assessments (posttests), as well as their gain scores. These reveal that the several ACT scores and reading and mathematics placement scores are all significant predictors of pretest and posttest scores but not gain scores. Students’ Michigan and California scores also were positive predictors of pretest and posttest performance, but Michigan scores were a negative predictor of gain scores (as were the nonsignificant California scores). Being enrolled in a baccalaureate as opposed to an associate degree program is a variable largely a consequence of prior academic achievement and, accordingly, it predicted pretest and posttest performance but not gain scores. The writing placement test was the only test score that was not a significant predictor of classroom learning (cf. Kobrin et al., 2008).

Audiological variables. The audiological variables accounted for little variance in pretest, posttest, and gain scores. The use of hearing aids was a negative predictor of pretest performance, and the use of cochlear implants again was unrelated to performance.

Communication variables. The various communication variables generally were not strong predictors of prior content knowledge or classroom learning. A preference for signing over spoken language and self-ratings of ASL production skills again were negatively related to pretest performance. English-based sign receptive skills positively predicted both pretest and posttest performance, whereas English-based sign production skills positively predicted pretest performance. Receptive SimCom skill positively predicted both pretest and posttest performance. In contrast to what one might expect with younger children still acquiring language, having more languages spoken in the home of these college students was a positive predictor of pretest and posttest performance. Superficially, this suggests that foreign and immigrant DHH students with sufficient cognitive, academic, and family resources to gain entry to university bring greater knowledge with them into the classroom, reflecting earlier academic achievement. None of the communication variables predicted learning in the classroom when the effects of prior learning were removed (gain scores).

Family variables. Learning in a mainstream classroom was not significantly predicted by whether or not these DHH students had deaf parents. Performance on the pretest and posttest, however, was significantly predicted by fathers’ occupational level, whereas mothers’ level of education predicted posttest and gain scores.
**Second-order analyses.** Second-order regression analyses involving achievement variables included all of the achievement measures except for the writing placement test (see Table 2). As can be seen in Table 4, the ACT Composite score predicted pretest and posttest scores; the Michigan negatively predicted posttest and gain scores.

Hearing aid use remained a significant negative predictor of pretest performance.

Among the several communication variables examined, ASL production skill (negatively) predicted pretest performance. Only SimCom receptive skill was a significant (positive) predictor of pretest and posttest performance.

Fathers’ level of occupation remained a significant positive predictor of pretest and posttest performance, although it only accounted for a little more than 1% of the variance in each case. Powers (2003) similarly found only a small effect of SES on academic achievement of DHH secondary school students (5%) relative to effects that have been obtained with hearing students taking the same tests (53%).

**Notes**

1. Placement tests are not administered to students with higher ACT scores, thus creating more missing data reflected in the degrees of freedom in Tables 3 and 4.

2. It could be argued either that having fewer interpreters reduces variability and hence increases the power of relevant analyses or that having more interpreters increases the generalizability of the results. In any case, regardless of the number of interpreters involved, all of the original 10 experiments yielded the same results (significantly better performance by hearing students and no consistent predictors of DHH students’ learning).

3. One of the 10 experiments did not include pretests, and thus gain scores could not be computed. That experiment was retained, because it involved the same experimental paradigm as all of the others.

**References**


Goldberg, L. R., & Richburg, C. M. (2004). Minimal hearing impairment: Major myths with more than minimal...
Hatfield, N., Caccamise, F., & Siple, P. (1978). Deaf students’
language competency: A bilingual perspective. American
of deaf and hard-of-hearing students’ executive function. In
M. Marschark & P. C. Hauser (Eds.), Deaf cognition: Founda-
tions and outcomes (pp. 286–308). New York: Oxford Uni-
versity Press.
and parenting. In M. Bornstein (Ed.), Handbook of parent-
Holt, J. (1994). Classroom attributes and achievement test scores
for deaf and hard of hearing students. American Annals of
the Deaf, 139, 430–437.
curriculum: Principles for achieving access in deaf education
(Working Paper 89–3). Washington, DC: Gallaudet Univer-
city, Gallaudet Research Institute.
and behavior of children with cochlear implants, children
with hearing aids, and their hearing peers: A comparison.
Audiology & Neuro-Otology, 10, 117–126.
from the classroom perspective. In T. N. Kluwin, D. F.
Moores, & M. G. Gaustad (Eds.), Toward effective public
school programs for deaf students: Context, process, and out-
achievement of deaf adolescents. Exceptional Children, 60,
73–81.
class effects in the education of deaf students. American
Annals of the Deaf, 139, 463–471.
of hearing impaired adolescents in different placements.
Exceptional Children, 55, 327–335.
Kluwin, T. N., & Morris, C. S. (2006). Lost in a giant data-
base: The potentials and pitfalls of secondary analysis for
deaf education. American Annals of the Deaf, 151,
121–128.
Kobrin, J. L., Patterson, B. F., Shaw, E. J., Mattern, K. D., &
first-year college grade point average. Research Report No.
students: Does simultaneous communication inhibit the devel-
lopment of oral skills? Paper presented at the Sixth Asia-Pa-
cific Congress on Deafness. Beijing, China, August.
communication during continuing education workshops for
deaf and hard-of-hearing professionals. Journal of Postsec-
ondary Education and Disability, 18, 5–11.
ceptions of communication ease and engagement: How they
relate to academic success. American Annals of the Deaf, 136,
414–421.
Luckner, J. L., & Muir, S. (2001). Successful students who are
deaf in general education settings. American Annals of the
Luckner, J. L., Sebald, A. M., Cooney, J., Young, J. III, & Muir,
research in deaf education. American Annals of the Deaf,
150, 443–456.
Marmor, G., & Petitto, L. (1979). Simultaneous communication
in the classroom: How well is English grammar repre-
New York: Oxford University Press.
cognition, communication, and learning by deaf students.
In C. Hage, B. Charlier, & J. Leybaert (Eds.), L’évaluation
de la personne sourde (pp. 26–53). Brussels: Mardaga.
Marschark, M., Leigh, G., Sapere, P., Burnham, D., Conver-
interpreting and text alternatives to classroom learning by
deaf students. Journal of Deaf Studies and Deaf Education,
11, 421–437.
Marschark, M., Pelz, J., Convertino, C., Sapere, P., Arndt, M.
E., & Seewagen, R. (2005). Classrooms interpreting and
visual information processing in mainstream education for
deaf students: Live or Memorex® American Educational
Marschark, M., Pelz, J., Convertino, C., Sapere, P., & Marshall,
M. (in preparation). Do deaf students have a visuospatial
advantage? Effects of speed and visual angle.
cochlear implants on children’s reading and academic
achievement. Journal of Deaf Studies and Deaf Education,
12, 269–282.
Marschark, M., Sapere, P., Convertino, C., & Seewagen, R.
(2005a). Access to postsecondary education through sign
language interpreting. Journal of Deaf Studies and Deaf
Education, 10, 38–50.
Marschark, M., Sapere, P., Convertino, C., & Seewagen, R.
In M. Marschark, R. Peterson, & E. A. Winston (Eds.),
Interpreting and interpreter education: Directions for research
and practice (pp. 57–83). New York: Oxford University
Press.
Marschark, M., Sapere, P., Convertino, C., Seewagen, R., &
interpreting: Deciphering a complex task situation. Sign
Language Studies, 4, 345–368.
Learning via direct and mediated instruction by deaf stu-
dents. Journal of Deaf Studies and Deaf Education, 13,
546–561.
and learning by deaf students. In M. Marschark & P. C.
Hauser (Eds.), Deaf cognition: Foundations and outcomes (pp.


Received September 7, 2008; revisions received February 17, 2009; accepted February 25, 2009.