DOES PERCEPTION PRECEDE PRODUCTION? EVIDENCE FROM KOREAN-ENGLISH BILINGUALS

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INTRODUCTION. Knowing whether and how speech perception and production are related has important implications for research involving, among many other things, first language acquisition (e.g., Vihman 1991), language impairment (e.g., Tallal & Stark 1976), artificial speech recognition (e.g., Rose et al. 1996), as well as linguistic and psychological theories (e.g, Labov et al. 1991). Such a link is not necessarily apparent, considering that the two skills—one involving motor control and the other auditory processing—may or may not be controlled by different mechanisms (e.g., Allport et al. 1987). However, support for the interdependence of perception and production is more positive than negative (e.g., Fox 1982), although the nature of such interdependence is still unknown and heavily debated (Lindblom 1996, Fowler 1996).

One area of research where the relationship between perception and production is less transparent is adult second-language acquisition, which, in comparison to relatively uniform language development in children, is variable along many dimensions (e.g., Mack 1989, Flege et al. 1999). Among the most salient are such individual differences as amount of second-language experience and age at the time of second-language learning. However, by carefully controlling these individual differences, it is possible to gain insights into speech processing in general, and second-language speech perception and production in particular. Understanding such a relationship is important for both theoretical and pedagogical reasons. Theoretically, knowing whether perception does in fact influence production abilities may illuminate how second languages are acquired (Rochet 1995). For pedagogical reasons, such an understanding may help determine what types of second-language training will be most effective, and how foreign accents can be minimized (Bradlow et al. 1999).

In general, three hypotheses about the relationship between speech perception and production have been advanced. In both first- and second-language studies, the most widely supported hypothesis is that accurate perception is at least one necessary component of accurate production (Flege 1995), which translates into perception abilities usually surpassing, and therefore preceding, production abilities, especially for beginning second-language learners. Even advanced language learners, whose perception and production abilities are nearly asymptotic, perceive some vowels more accurately than they produce them (Flege et al. 1999).

The results of second-language acquisition studies, however, are not conclusive. Other researchers working within the same framework have proposed that production and perception are interdependent and develop simultaneously (Best 1995,

Fowler 1996). Assuming that perception entails the ability to detect distal articulatory properties of speech (i.e., tongue movement, vocal tract size, etc.), this hypothesis maintains that perception and production are always aligned, so that perception never surpasses, and therefore never precedes, production and vice versa. The McGurk effect (McGurk & MacDonald 1978), the phenomenon that listeners use both visual and auditory information to recover speech, and the results of imitation studies (Ryalls & Pisoni 1997), which illustrate that children rely on imitation when learning to speak, support the hypothesis that perception and production abilities are interdependent. Speech processing models based on this hypothesis predict that speech perception and production abilities in second-language learners develop in synchrony and depend on how difficult it is to recover slight articulatory differences between first- and second-language sounds (Best 1995). In support of this hypothesis, for example, Flege et al. (1997) demonstrated that, at least for some bilinguals, perception and production abilities are aligned.

In contrast, yet another hypothesis states that accurate production actually precedes accurate perception, so that some speech contrasts are maintained in production before they are actually perceived. Many first-language studies of dialect change, for example, have proposed that changes first occur in production before they are sustained in perception (Labov et al. 1991; see, however, Bowie 2001). Second-language studies often demonstrate that at least some learners are able to produce differences between non-native sounds that they cannot perceive (Flege et al. 1997), such as Japanese-English bilinguals who can produce a contrast between /r/ and /l/ without being able to perceive it (Sheldon & Strange 1982). These findings suggest that there is at best only a weak relationship between perception and production, and that the two develop independently.

Conflicting results such as these suggest that the perception/production relationship may change over time. If perception and production abilities are completely aligned initially, the first hypothesis proposes that, as the learner gains experience, perception precedes production. Conversely, the second hypothesis would predict that both perception and production would be aligned regardless of language experience. Finally, the third hypothesis would predict that production may in fact outstrip perception as a second language is learned. Therefore, observing the *development* of perception and production abilities may be essential in differentiating among these three hypotheses. Thus, the primary objectives of this study were (1) to determine which of the three hypotheses most accurately describes the development of perception and production abilities in second-language learners, and (2) to explore what other factors may influence or explain the perception-production link.

1. RELATIONSHIP BETWEEN PERCEPTION AND PRODUCTION. To explore the development of second-language speech perception and production abilities, in this study Korean-English bilinguals performed perception and production tasks of English vowels. To specifically understand how the relationship between the two skills develops, the results from these experiments were correlated and examined on an indi-

	AOA	LOE	Chron. Age	Use of Korean
Late+3	23.96 (3.69)	3.04 (0.40)	27.28 (3.52)	63.00 (20.03)
Late+10	21.35 (2.82)	9.82 (2.26)	32.08 (2.67)	44.00 (22.21)
Early+10	8.98 (1.18)	11.05 (1.88)	20.33 (1.63)	19.00 (20.25)
K. Mono	29.02 (2.68)	0.23 (0.10)	29.25 (2.69)	74.00 (22.21)
E. Mono			25.60 (4.53)	

Table 1.*Means of age of arrival (AOA), length of experience (LOE), chronological age (Chron. Age), and percentage of use of Korean (Use of Korean). Standard deviations appear in parentheses.*

/i/	/ɪ/	/u/	/ʊ/	/æ/	/ɛ/
beat	bit	boot	book	bat	bet
bead	bid	booed	good	bad	bed
heed	hid	who'd	hood	had	head

Table 2. *Vowel stimuli used in the study.*

vidual basis. In Part 1, the influence of age at the time of learning (age) and amount of exposure (experience), as indicators of linguistic experience, on the perception/production relationship was evaluated to understand the developmental component of speech processing. In Part 2, the data were re-analyzed along factors other than age and amount of exposure to gain better insights into the role of individual differences in the perception/production relationship.

1.1 SUBJECTS. Thirty adult Korean-English bilinguals participated in the study. Bilinguals differed in age of first exposure to English, defined as age at the time of arrival in the United States (early vs. late), and the amount of linguistic experience, defined as length of stay in the United States (3 vs. 10 years). In addition, 10 English monolinguals and 10 Korean monolinguals participated as comparison groups for a total of 50 participants altogether. Korean monolinguals had resided in the United States for an average of 3 months and were beginning learners of English. Based on age of arrival and length of residence, the bilinguals were assigned to three groups, with 10 subjects in each group. Table 1 presents demographic variables for the groups used in the study.

1.2. STIMULI. Most previous studies which explore the relationship between second-language perception and production examine difficult consonant contrasts (Sheldon & Strange 1982, Bradlow *et al* 1999). In order to extend the results of these previous studies to vowel contrasts, we chose three English vowel pairs which are confusable and particularly difficult for Korean-English bilinguals to both perceive and produce (Flege et al. 1997): /i/-/ɪ/, /u/-/ʊ/, and /æ/-/ɛ/ placed in the phonetic environments bVt/k, b/gVd, and hVd (see Table 2).

The stimuli used in experiment 1, the speech perception experiment, were produced by three native English speakers and recorded using a Shure unidimensional head-mounted microphone and Sony tcd-d8 dat recorder. All speakers were English monolinguals from Illinois and had had no or minimal exposure to a foreign language. Recordings were digitized at 22,050 Hz, normalized for peak intensity, and ramped off during the first and last 15 msec. to prevent audible clicks. Recorded stimuli were not edited in any other way and were representative of the variability in fundamental frequency, vowel duration, stop-consonant closure duration, and voice-onset time which are found in natural speech. Prior to the experiment, 10 monolingual speakers of English identified the stimuli with a 98% accuracy in a fixed-choice identification task.

1.3. PROCEDURE. In order to obtain a measure of the bilinguals' perceptual abilities, experiment 1 used a fixed-choice identification task. In this task, subjects heard an English word presented over the headphones and matched it, on the computer screen, with one of six response alternatives labeled orthographically as English words. The stimuli on each trial were played individually, with each new trial presented 1 sec. following the subject's response to a previous trial. No feedback and no practice session were given. However, subjects could listen to each token as many times as they wished. Six test stimuli in hVd context recorded by three speakers were presented in three randomized lists for a total of 54 one-stimulus trials per subject. The perception score (or percent correct in identification) obtained in this experiment was used as a measure of bilinguals' perception abilities.

To explore the relationship between the bilinguals' ability to perceive and produce the same sounds, in experiment 2 the same bilinguals performed a word production task. In this task, bilinguals used the word stimuli from experiment 1 to name black-and-white line drawings. For example, the word *bat* was used to name the drawing depicting a baseball bat, whereas the word *booed* was used to name the drawing depicting sports fans at a stadium. While some drawings did not unambiguously depict the objects to be named, the subjects were familiarized with the intended words during the study phase. During the study phase, bilinguals twice viewed each drawing and repeated the intended word recorded by a female native English speaker. The intended word was presented first in a sentence, which provided the necessary context, and then in citation form. In the test phase, which contained two blocks of 18 randomized trials, subjects attempted to spontaneously name the drawings. When no response was given, the expected name was played over a loudspeaker and the subject repeated it. Overall, each subject produced 18 words for a total of 720 words altogether. Only spontaneous productions from the test phase were used in subsequent analyses.

Tape recordings of the production data were further used to obtain word production ratings. Digitized at 22,050 Hz, normalized for peak intensity, and ramped off during the first and last 15 msec. to prevent audible clicks, the 720 word tokens were randomized and recorded onto a high-quality audio tape, with each stimulus presented with a 4-second interval. To obtain word production ratings, this audio tape was played

	E.Mono. (1)		Early+10 (2)		Late+10 (3)	
	mean	s.d.	mean	s.d.	mean	s.d.
Perc.	94.26	4.57	95.19	5.60	59.81	10.69
Prod.	96.39	1.98	91.89	7.20	64.00	10.65

	Late+3 (4)		K.Mono. (5)		ANOVA	
	mean	s.d.	mean	s.d.	F (4.45)	Tukey HSD
Perc.	62.96	18.52	50.37	13.46	31.30**	1,2 > 3,4,5
Prod.	57.67	14.46	50.39	9.53	46.03**	1,2 > 3 > 5

Table 3. *Percentage of vowels perceived and produced correctly by the subjects in the five groups. 'HSD' indicates the results of a Tukey HSD test (alpha = 0.05; ** p < 0.001) comparing the performance of the five groups on perception and production tasks when the group factor reached significance.*

to a group of 10 English monolingual listeners for identification. In this task, the English monolingual listeners were instructed to choose, on an answer sheet, one of four response alternatives. For example, for the word token 'bit', the response alternatives were: 'bit', 'beat', 'bet', or 'bid'. The production ratings (or percent correct in production) obtained in this task were used as a measure of bilinguals' production abilities.

1.4. RESULTS AND DISCUSSION. Calculated across vowels and phonetic environments, perception and production data were submitted to two separate one-way analyses of variance (ANOVAs), using age at the time of learning (AOA) and length of experience (LOE) as the grouping variable. Because the group factor (AOA and LOE) reached significance for percent correct in perception [$F(4,45)=31.30$, $p=0.00$] and production [$F(4,45)=46.03$, $p=0.00$], Tukey HSD *post hoc* tests were used to pursue between-group differences (see Table 3). Interestingly, AOA, not LOE, predicted the bilinguals' perception and production performance, therefore suggesting that only early bilinguals are able to both produce and perceive vowels similarly to English monolinguals. Similarly, both groups of late bilinguals performed identically to Korean monolinguals in perception and production.

To test the claim that perception and production abilities may differ for bilinguals assigned to the same age and experience group (within-group differences), separate *t-tests* were performed within each group on perception and production data. Surprisingly, however, perception and production abilities were identical within each group ($p>0.05$), thus indicating that all groups both perceived and produced sounds with the same accuracy. These results may be taken to indicate that perception does not precede production, and that these two perceptuomotor skills develop simultaneously.

To further explore the relationship among the variables, bilinguals' production and perception scores were correlated with demographic variables. Shown in Table 4 (overleaf), the results attest to a strong relationship among the variables. Perception and production data do strongly correlate positively at the 0.71 level. Furthermore, although both correlations are strong and significant, age at the time of learning

	Production	Perception
Perception	0.71 **	
Age or Arrival	-0.82 **	-0.69 **
Use of Korean	-0.60 **	-0.53 **
Length of Experience	0.57 **	0.41

Table 4. *Correlations between perception, production scores and subject variables (alpha=0.05; ** $p < 0.001$).*

correlates more strongly with production than with perception accuracy. This suggests that perception is perhaps less susceptible to the influence of age and experience than is production. Assuming that perception and production abilities, at least in some measure, develop as a function of age, this result may also indirectly indicate that perception does, in fact, precede production. Speculative and perhaps premature, such a conclusion, however, merely confirms that perception and production are related; it does not indicate whether one ability precedes the other.

Indeed, the obtained group data and correlations do not provide accurate insights into how perception and production abilities are related, nor how such a relationship develops as a language is learned. Presumably, our failure to detect oft-cited within-group differences between perception and production in bilinguals (Sheldon & Strange 1982, Flege et al. 1999) was an artifact of the grouping variables used in the analyses—age and amount of experience. Therefore, to specifically address this issue, we performed an individual analysis of the data, paying close attention to intra-subject differences in perception and production accuracy.

In close agreement with perceptually based accounts of the development of bilingual perception and production abilities (e.g., Flege 1995, Rochet 1995), we hypothesized that good production would be associated with good perception, and poor production with poor perception. For intermediate learners, such a hypothesis would entail a possible misalignment of both skills (a characteristic of an intermediate learning stage) if accurate perception is indeed an important factor in the development of accurate production.

Based on the bilinguals' production abilities, instead of age or experience, data re-analysis yielded 3 groups of bilinguals: those with good (85-100%), intermediate (70-85%), and poor (less than 70%) production accuracy. In addition, perception and production scores obtained for Korean and English monolinguals were used for comparison purposes. Perception and production accuracy, calculated across vowels and phonetic environments, was examined in two one-way ANOVAs to determine whether the resulting groups indeed differed in these two skills. Presented in Table 5, results included a significant main effect of group for both perception [$F(4,45)=23.34$, $p= 0.00$] and production [$F(4,45)=97.90$, $p=0.00$], indicating that both skills did indeed differ across the three new groups. However, no differences emerged within each group when individual perception and production performance was compared ($p>0.05$), suggesting that perception and production appeared again to be aligned.

	E.mono. (1) (N=10)	Good (2) (N=8)	Interm.+ (3) (N=3)	Interm.- (3) (N=5)	Poor (4) (N=14)
Perc.	94.26 (4.57)	95.83 (5.84)	93.83 (4.28)	55.19 (16.58)	61.11 (11.28)
Prod.	96.39 (1.98)	94.86 (3.25)	78.34 (5.30)	75.78 (5.86)	54.48 (9.13)

	K.mono. (5) (N=10)	ANOVA F (4.45)	Tukey HSD
Perc.	50.37 (13.46)	23.34 **	1,2>3,4,5
Prod.	50.39 (9.53)	97.90 **	1,2>3>4,5

Table 5. *Percentage of vowels perceived and produced correctly by Korean-English bilinguals (individual reanalysis). 'Intermediate +' and 'Intermediate –' indicate the bilinguals with intermediate production skills and respectively high and low perception skills. 'HSD' indicates the results of a Tukey HSD test (alpha = 0.05; ** p < 0.001) comparing the performance of the five groups when the group factor reached significance.*

Surprisingly however, the bilinguals whose production accuracy was intermediate (75-80%) displayed a rather large amount of variability in their perception scores given similar production performance. As Figure 1 (overleaf) depicts, in half of these bilinguals, perception accuracy was in fact identical to the monolingual perception norm and surpassed production accuracy. Assuming a perceptual basis for accurate speech production, for these bilinguals production ability may, in fact, eventually align with their perception ability and the monolingual production norm. However, the other half of the bilinguals in this group attained better accuracy in production than perception (e.g., Sheldon & Strange 1982). It may be the case that either production precedes perception for these bilinguals, thus lending support to the third hypothesis entertained earlier, or perhaps factors other than perception underlie production accuracy in these individuals.

One such factor might be the ability to perceive contrasts of a speaker's own productions. There is empirical evidence in first-language acquisition that in order to learn to speak, infants, through babbling and cooing, may attempt to match the acoustics of their own productions with the acoustics of others' speech, thus defining categories for native-language sounds (Vihman 1991, Kuhl & Meltzoff 1996). In fact, auditory self-perception, or the ability to hear one's own speech, is deemed critical for establishing accurate perceptual and articulatory representations in early language development. Similar evidence is marshaled in research on language-impaired children, in whom inaccurate language production is frequently associated with an inability to understand one's own speech, given an overall superior ability to understand others (Panagos & King 1975). Findings such as this strongly implicate self-perception as a necessary and perhaps fundamental element in the native-language production ability.

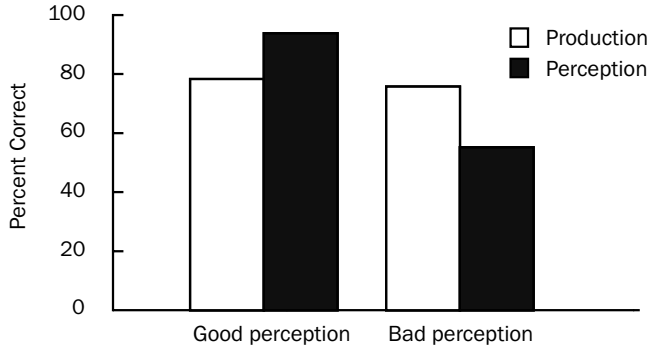

Figure 1. *Percentage of vowels perceived and produced correctly by Korean-English bilinguals with intermediate production accuracy.*

Extended to second-language acquisition, a similar claim may offer a feasible explanation for the somewhat surprising finding of the present study. It may be that auditory self-perception provides the perceptual basis for superior production abilities for those speakers whose production abilities exceed their perception abilities, allowing for the needed mapping of auditory targets onto accurate articulatory targets. More importantly however, from a theoretical perspective, such an explanation would accentuate perceptual bases of accurate production, much in line with most research in the field (e.g., Flege 1995, Rochet 1995).

Beyond doubt, however, auditory self-perception in the absence of the ability to accurately perceive others may not in itself translate into accurate production. Perhaps what self-perception, as part of an auditory-articulatory feedback mechanism, underlies is the ability to *compare* one's own attempts at speech with others' productions. Essential to both first- and second-language learning, self-perception cast in such terms would entail the ability to perceive differences between one's own speech and the auditory targets in others' speech, thus allowing speakers to modify their speech to match these targets.

Because both production and self-perception are contingent upon hearing auditory targets in others' speech, we hypothesize that, for all bilinguals, perception will be better than, or equal to, production and self-perception. By the same token, bilinguals with good production will be equally good at perception and self-perception, because they are able to match their own productions with the auditory targets in others' speech. On the other hand, bilinguals with poor production skills will also be poor at both perception and self-perception because they are unable to match their own productions with the auditory targets in others' speech. However, bilinguals with intermediate production skills will, in large measure, perform better at perception and self-perception than production, because, as hypothesized earlier, the ability to compare one's own speech with auditory targets in others' speech is essential in developing accurate production skills.

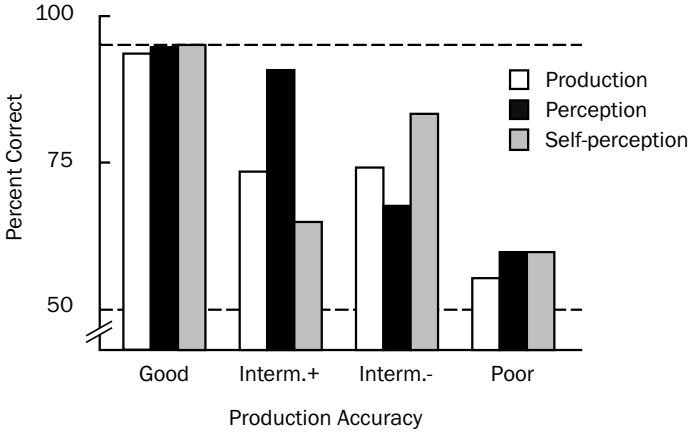

Figure 2. *Production, perception, and self-perception accuracy for Korean-English bilinguals. Dashed lines indicate an average for production and perception performance for English monolinguals (96.39 in production and 94.26 in perception) and Korean monolinguals (50.39 in production and 50.37 in perception).*

2. SELF-PERCEPTION AS A LINK BETWEEN PERCEPTION AND PRODUCTION. Testing these predictions, we asked the same bilinguals to return and perform a word identification task on their own speech to obtain a measure of self-perception. A bilingual's self-perception score was thus defined as the ability to perceive one's own speech identically to the way English monolinguals did in experiment 2. The stimuli and procedure in this experiment were identical to the production rating task performed by English monolinguals in experiment 1. Self-perception scores were available for fourteen bilinguals.

2.1. RESULTS AND DISCUSSION. Chi-square tests comparing perception, self-perception, and production data confirmed our predictions (see Figure 2). More specifically, representing asymptotic performance, the bilinguals whose productions skills are good (N=6) are equally good at perception and self-perception [χ^2=0.80, p>0.05]. Furthermore, the bilinguals whose production skills are poor (N=4) are equally poor at perception and self-perception [χ^2=3.12, p>0.05], performing at chance level and therefore marking the beginning of second-language development. Overall, in both of these stages of second-language learning, perception is completely aligned with production.

The role of self-perception in the developing relationship between perception and production is however most salient in scores of bilinguals with intermediate production skills; i.e., where most of the learning occurs. Of the four bilinguals with intermediate production skills who returned to perform this task, two performed better at perception than production (*Interm.+* group). Indeed, as was predicted, their self-perception and production scores are identical (p>0.05) and intermediate in accuracy. The other two bilinguals in this group performed better at production than

perception (*Interm.-* group). Identical to their production accuracy ($p>0.05$), self-perception accuracy of these bilinguals tended to exceed their perception scores [$\chi^2=3.49$, $p=0.06$]. Implicit in these results is the claim that self-perception, or the ability to distinguish one's own productions from others' speech, is essential in the development of production abilities. Indeed, the bilinguals in the *Interm.+* group belong in the developmental stage in which their self-perception ability is improving, thus enabling them, with more experience, to attain native-like accuracy in a second language. Conversely, the bilinguals whose production surpassed perception accuracy, a somewhat surprising outcome of this study, are good self-perceivers. Being able to perceive their own speech accurately thus enables them to produce sounds accurately. However, these bilinguals may be less likely to attain native-like accuracy in production because, in addition to a good self-perception ability, accurate production should perhaps be grounded in accurate perception.

3. GENERAL DISCUSSION AND CONCLUSIONS. Of the three hypotheses entertained in the introduction, overall this study supports the hypothesis that accurate production is contingent on accurate perception in a second language, and that perception and production abilities may not necessarily be aligned. Indeed, throughout the learning process, perception precedes production. However, we propose that self-perception is important and perhaps even essential in the development of accurate production skills. In fact, self-perception, as both an auditory and articulatory feedback mechanism, may be a necessary link between speech perception and speech production. That is, without self-perception, or the ability to compare one's own attempts at speech with the speech production of others, and regardless of whether such a comparison occurs at an auditory (e.g., Flege 1995) or articulatory (e.g., Best 1995) level, second-language learners may not be able to link auditory perceptual targets with their own articulation efforts. The influence of self-perception may also explain situations where on the surface it appears that production precedes perception. In actuality, as self-perception data demonstrate, accurate production is nevertheless still perceptually based (Newman 1998).

An important implication of this conclusion for speech processing in general and second-language research in particular is that self-perception is essential in learning sounds, enabling speakers to gradually approximate their production ability to their perception ability. Subjecting this hypothesis to more rigorous testing in both first- and second-language research may further illuminate the relationship between perception and production in speech processing.

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