Chapter 7

Visual and Audiovisual Speech Perception Training: Basic and Applied Research Needs

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Research needs in the area of visual and audiovisual speech perception training as they pertain to adults with an acquired hearing impairment are discussed.

The chapter is organized around five clinically relevant questions: (a) What is the most appropriate sensory modality for speech perception? (b) Can speech perception be improved through training? (c) Who is a candidate for speech perception training? (d) What type of speech perception training programs are most effective? and, (e) How do we evaluate the effectiveness of speech perception training programs? In each section short-term fundamental and applied research topics that require further investigation are identified.

It has long been recognized that speech-perception training constitutes an important part of services provided to individuals with a hearing loss who seek audiological rehabilitation services (e.g., Carhart, 1947; Deland, 1931/1968; Gaeth, 1979; Nitchie, 1930; O'Neill & Oyer, 1961). Even nowadays, speech-perception training continues to be an important component of the audiological rehabilitation programs (e.g, Binnie, 1991; Kaplan, Bally, & Garretson, 1987; Sanders, 1982; Sims, 1985). Two fundamental assumptions underlie this type of audiological intervention. First, it must be assumed that difficulties in speech communication are the cause of many of the handicaps encountered by individuals with a hearing loss. Moreover, it must be assumed that improvements in speech-perception will result in an amelioration in speech communication, which in turn will eliminate (or significantly reduce) many of the handicaps that accompany a hearing loss. Second, it must be assumed that the speech-perception competencies of some individuals can be improved through training. Over the years many aspects of speech-perception training have been investigated. However, there continues to be a number of basic issues that remain unresolved related to speech-perception training. This chapter will identify some fundamental and applied clinical issues that remain to be investigated in the area of visual and audiovisual speech-perception training.

Throughout this chapter the term *lipreading* is defined as: the process whereby visual sensory information is extracted from the articulatory movements available from a talker's lips, jaws, and adjacent facial musculature. *Speechreading* is defined as: "the process of perceiving spoken language using vision as the sole source of sensory evidence" (Boothroyd, 1988, p. 77). Hence, speechreading incorporates lipreading as well as the use of verbal and nonverbal associational cues (e.g., facial expression, situational and contextual cues) that may be related to the talker, the message, the environment as well as the cognitive processing abilities involved in the use of those cues (Jacobs, 1982). *Multimodal speech perception* will refer to situations where the speech cues are simultaneously available in more than one sensory modality (e.g., audio + visual, tactile + visual). Note that issues related specifically to *auditory speech perception* are discussed in Chapter 8 of the present monograph (Blamey & Alcántara, 1994).

The chapter is organized around five clinical issues related to speech perception training. Specifically the questions that are addressed in the present chapter are: (a) What is the most appropriate sensory modality for speech perception? (b) Can speech perception be improved through training? (c) Who is a candidate for speech perception training? (d) What type of speech perception training programs are most effective? and, (e) How do we evaluate the effectiveness of speech perception training programs? In each section an attempt is made to identify some clinical as well as some fundamental research issues that require further investigation. The chapter addresses the research needs related to adults with an acquired hearing loss. Although some of the issues discussed may apply to all populations (e.g., children, individuals with a profound congenital hearing loss), the specific needs of those other populations are not directly addressed in the present chapter.

WHAT IS THE MOST APPROPRIATE SENSORY MODALITY FOR (TRAINING) SPEECH PERCEPTION?

As a first approximation it is often assumed that speech perception is primarily an auditory phenomenon. However, several investigators have demonstrated that normal-hearing adults are influenced by visual speech information (e.g., MacDonald & McGurk, 1978; Massaro, 1987a; McGurk & MacDonald, 1976; Sumby & Pollack, 1954; Summerfield & McGrath, 1984) and even infants as young as 4 months of age can make use of visual information available in the speech message (e.g., Dodd, 1979; Kuhl & Meltzoff, 1982; Spelke, 1979). Moreover, it is known that many individuals with a hearing loss rely on visual cues to enhance their receptive speech communication skills. Furthermore, in most communicative settings the speech signal is simultaneously available in more than one sensory modality (e.g., auditory and visual). Given that the ultimate goal of speech perception training is to improve communication in everyday settings it would appear most appropriate to adopt a multimodal approach to speech perception (Braida, 1991; Massaro, 1987a; Summerfield, 1987, 1989). Unfortunately, at the present time the research that has been conducted in speech perception has primarily focused on unisensory speech-perception competencies.

Ideally, clinical practices should be based on sound theoretical foundations. A comprehensive model (or models) of multimodal speech perception would make it possible to predict an individual's speech perception performance in various communication settings. Also, comprehensive models should describe the fundamental processes involved in multimodal speech perception. At this time there are still many unresolved issues concerning the processes involved in multimodal speech perception.

Processes Involved in Multimodal Speech Perception

Recently there have been attempts to formulate models of multimodal speech perception (e.g., Braida, 1991; Grant & Braida, 1991; Massaro, 1987a; Summerfield, 1987, 1989). Although the specific processes involved in speech perception may differ across theorists, there is a general agreement that some basic operations are involved in multimodal speech perception (Massaro, 1987a, 1987b; Walden & Grant, 1993). Speech perception (unimodal as well as multimodal) involves the perceptual analysis and integration of the information extracted from the signal. Two issues related to the integration of speech information are particularly relevant to audiovisual speech perception. The first relates to the ***manner*** in which the information extracted from each sensory modality is integrated perceptually. Massaro (1987a) discussed this issue in terms of the dependent vs. independent evaluation of the features of speech in each sensory modality (see Figure 1). In the dependent model, the evaluation of the features of speech in one sensory modality is some function of the information available in other sensory modalities. In this model the result of the perceptual analyses made in one sensory modality (e.g., visual) may depend on whether the signal was also available in another (e.g., auditory) sensory modality. In the independent model, the evaluation of the features of speech extracted from one sensory modality would not be influenced by the information available in other sensory modalities. In this model, the result of the perceptual analyses made in one sensory modality (e.g., visual) would produce the same outcome regardless of whether the signal was presented visually-only or whether the signal was also comprised of information from another modality (e.g., auditory). In the absence of clear experimental findings most investigators favour the more parsimonious independent evaluation model (Braida, 1991; Massaro, 1987a; Summerfield, 1989). However, this issue requires further investigation.

The second issue related to multimodal integration centers around the ***stage*** at which the information extracted from different sensory modalities is combined. Specifically, the issue relates to the question: does integration occur before or after linguistic categorization/labelling (Summerfield, 1989)? Braida (1991) compared the Fuzzy Logical Model of Perception (FLMP: Massaro, 1987a) to

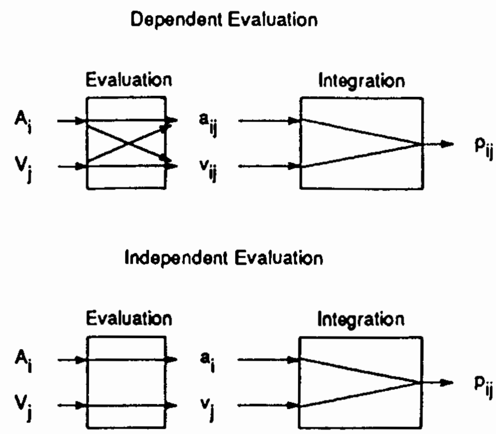

Figure 1. Illustration of dependent and independent models of multisensory integration of speech. From *Speech Perception by Ear and Eye: A Paradigm for Psychological Inquiry* (p. 153) by D.W. Massaro, 1987, Hillsdale, NJ: Lawrence Erlbaum Associates. Copyright 1987 by Lawrence Earlbaum Associates. Reprinted by permission.

two quantitative models of multimodal perception: a pre- and a post-labelling model of integration. In the FLMP, the information from each sensory modality is determined (in a probabilistic fashion) by the feature value of that stimulus for each of the possible responses. In the pre-labelling integration model, unimodal sensory data is assumed to be represented in continuous valued cues that are combined optimally before response labels are assigned. In the post-labelling model the responses that would be made under unimodal conditions are combined and a joint response is derived from the pair (Braida, 1991). To evaluate the three models of integration Braida (1991) analyzed the results from five previously reported investigations of auditory, visual, and multimodal consonant recognition. His analysis revealed that the most accurate predictions (for consonant recognition) were provided by the pre-labelling model. However, the author indicated that more research was required to demonstrate the accuracy of pre-labelling models for data obtained from individual subjects (as opposed to group results) and various types of speech stimuli (e.g., vowels, words, sentences). A better understanding of the basic principles involved in multimodal speech perception would have direct clinical applications in several areas of speech perception training, including: the identification of clients who would be candidates for a speech perception training program; the identification of the most appropriate sensory modality in which the program should be conducted; the selection of an optimal training paradigm (i.e., analytic vs. synthetic); and, the evaluation of the benefits of speech perception training programs. Those issues will be addressed in other sections of the present chapter.

Primary Sensory Modality in Multimodal Speech Perception

Most clinical conceptualizations of multimodal speech perception operate under the premise that speech perception is predominantly an auditory phenomenon whereby visual cues serve mainly to complement (or supplement) auditory speech perception (e.g., Binnie, 1974; De Filippo, 1979; MacLeod & Summerfield, 1987; Miller & Nicely, 1955). However, some investigators have suggested that, at least for some hearing-impaired individuals (e.g., those with a profound hearing loss), the primary modality for speech perception may be vision rather than audition (e.g., Erber, 1969, 1979; Seewald, Ross, Giolas, & Yonovitz, 1985; Tyler, Tye-Murray, & Lansing, 1988). There may be some benefit in developing conceptual models of multimodal speech perception in which auditory cues can serve to complement (or supplement) vision as the primary sensory modality for speech perception. Although this latter concept has been used to design some prosthetic devices for hearing-impaired individuals (i.e., tactile aids and cochlear implants) it has not been widely applied to issues related to speech perception training. There are some noteworthy exceptions in this regard. Erber (1969, 1979) and Garstecki (1981) outlined audiovisual speech perception training paradigms. One underlying premise of both training programs is that the speech signal, in the client's primary sensory modality for speech, should be degraded in order to optimize the use of the information available in the nondominant sensory modality.

At the present time, there does not exist a standardized procedure to assess the primary modality for speech perception among individuals who have a hearing impairment. However, recently there have been some attempts to develop procedures that would reveal an individual's primary sensory modality for speech perception. Renshaw, McConkey-Robbins, Miyamoto, Osberger, and Pope (1988) developed the HAVE (Hoosier Auditory-Visual Evaluation) test. In this test, monosyllabic words are presented audiovisually and the subjects are required to identify the test item in a three alternative forced choice response paradigm. The choices include the correct test word as well as two incorrect response alternatives: one of which is visually similar to the test word (i.e., the word initial consonants are homophenous) and one of which is auditorily similar to the test word. An analysis of the response patterns observed from a subject provides insights on whether the individual relies more on auditory or visual information to identify stimuli that are presented audiovisually.

Walden, Montgomery, Prosek, and Hawkins (1990) described a visual-biasing speech perception experiment. The authors generated a series of 14 synthetic speech stimuli that consisted of approximations of consonant-vowels which formed a /ba-da-ga/ perceptual continuum. The stimuli were presented under three different conditions: audio-only, audio signal paired synchronously with a video token of a talker uttering the syllable /ba/, and audio signal paired with a visual token of /ga/. For each condition the subjects were asked to label every stimuli as either a /ba/, /da/, or /ga/. The results revealed that the categorical phonemic boundaries differed across experimental conditions. Those findings indicated that the subjects' responses were biased by the presence of the visual stimuli. The authors found differences in the mean biasing effect observed for a group of normal-hearing subjects and a group of subjects with a sloping mild to severe hearing loss. A closer examination of the report suggests that different visual biasing patterns were observed among the group of hearing-impaired subjects. However, the published data did not make it possible to evaluate whether the procedure was sufficiently sensitive to identify an individual's primary sensory modality for speech perception. Further studies are required to investigate if the visual-biasing procedure (or a modification thereof) could be developed into a clinical test to assess the effects of visual cues in multimodal speech perception.

There may be some theoretical as well as clinical value in establishing whether there is always one primary sensory modality involved in multimodal speech perception. Moreover, it would be of interest to investigate whether the primary modality for speech perception differs among individuals who have a hearing impairment. A better understanding of this issue may have a significant influence on the development and selection of speech perception training paradigms for subgroups of clients who have a hearing impairment. For example, some clients may benefit from a multimodal training activity in which the audio signal was degraded in order to practice the extraction of visual cues. Conversely, other clients may benefit more from training activities in which the visual signal is degraded. At the present time there does not exist any experimental data on which to base clinical decisions concerning the sensory modality that would be most appropriate to use with individual clients during speech perception training programs. There is a need for further research concerning this aspect of multimodal speech perception.

CAN SPEECH PERCEPTION BE TAUGHT?

One of the most basic assumptions underlying all speech perception training programs must be that speech perception competencies can be improved as a result of training (Walden & Grant, 1993). At the present time there does not exist unequivocal evidence to support or reject this assumption. This section will present some evidence to suggest that speech perception may be an innate skill which is unlikely to be significantly altered as a result of perceptual training activities. Also, experimental evidence that demonstrates that speech perception performance can be improved as a result of training activities will be presented and discussed.

The Innate Hypothesis

The issue of whether speech perception is an innate or a learned skill has been (and continues to be) an important topic of discussion among individuals interested in speech perception theories. A detailed discussion of this issue is beyond the scope of this chapter. Suffice it to say that some theorists maintain that humans are uniquely pre-disposed to decode speech (for a review of this issue see: Kuhl, 1991; Logan, Lively, & Pisoni 1991; Mattingly, 1989; Miller, 1989; Strange, 1986). In addition, an analysis of the speechreading and audiovisual speech perception literature has led some investigators to hypothesize that speech perception performance may be innate or at least not easily amenable to changes following the completion of a training program (Montgomery & Demorest, 1988; Summerfield, 1989, 1992).

One puzzling (but consistent) finding that emerges from an examination of the visual speech perception literature is that there is a large amount of variability in speechreading performance among individuals, especially when the stimuli consist of words and sentences (e.g., Gagné, Tugby, & Michaud, 1991a; Grant & Braida, 1991; Hanin, 1988; Summerfield, 1989). Investigators have not been successful in identifying all of the underlying factors that may account for speechreading performance. Variables such as degree or onset of hearing loss, verbal ability, reading ability, visual memory, intelligence, cognitive processing styles, and socioeconomic status do not account for a large portion of the variance in the speechreading performance observed among individuals (for a review of the literature see: Berger, 1972; Jeffers & Barley, 1971; Montgomery & Demorest, 1988; Stoker & French-St. George, 1984; Summerfield, 1989). Summerfield (1983, 1989) suggests that sensory, perceptual, and cognitive skills may be necessary but they are not sufficient to account for speechreading performance variations. Moreover, speechreading experience does not account for the inter-subject variability observed in speechreading (Hanin, 1988; Summerfield, 1989). Some normal-hearing college students with no specific training in speechreading perform better than some individuals with an acquired hearing-impairment who presumably have normal language competencies and have relied on visual-speech perception to communicate for many years. These findings suggest that speech-reading may be determined by some innate (and yet to be identified) factors. Variables that have been shown to correlate with speechreading performance are the latencies of cortically recorded electrical potential evoked by a flash of light (Samar & Sims, 1983; Shepherd, 1982; Shepherd, DeLavergne, Frueh, & Clobridge, 1977). It should be noted that more recent studies have failed to replicate those findings consistently (Summerfield, 1992). According to Summerfield (1989, 1992) these results suggest that speechreading performance may be largely determined by neurophysiological factors that are not likely to be modified by perceptual training. More fundamental research is required to investigate the innateness of speech perception. The results of those studies may have direct implications for the provision of speech perception training programs. If speech perception is innate and speech perception performance is determined primarily by an individual's ("pre-wired") neurophysiologic make-up, speech perception training (in any sensory modality) may not constitute a very effective audiological rehabilitative service. It would be more cost-effective to focus treatment to other types of rehabilitation services such as the fitting and adjustment of sensory aids for speech perception, personal adjustment, and informational counselling, as well as communicative strategies.

The Learned Hypothesis

Clinical observations and anecdotal reports obtained from clients suggest that the communication skills of some individuals with a hearing impairment improve following the completion of a speech perception training program. Moreover, a review of the experimental literature indicates that, on average, subjects display modest improvements (typically approximately 10-15%) following the completion of a speech perception training program (e.g., Alcántara, Cowan, Blamey, & Clark, 1990; Danz & Binnie, 1983; Gagné, Dinon, & Parsons, 1991; Montgomery, Walden, Schwartz, & Prosek, 1984; Rubinstein & Boothroyd, 1987; Walden, Erdman, Montgomery, Schwartz, & Prosek, 1981; Walden, Prosek, Montgomery, Scherr, & Jones, 1977). Those results demonstrate that the perceptual processes involved in visual-speech perception can be modified as a function of training or experience. However, there still remains several unresolved issues related to visual and audiovisual speech perception performance and the effectiveness of speech perception training programs. These issues include experimental data, discussed above, that indicate that there is a wide range of variability in visual and audiovisual speech perception performances among individuals. As well, there is a large amount of intersubject variability in the amount of benefit provided by specific speech perception training programs. This latter issue is addressed in a later section of the present chapter.

Conclusion

The issue of whether speech perception abilities are innate or learned continues to be an important question that requires further investigation (Miller, 1989). There is a need for fundamental investigations that will lead to the identification of the basic processes involved in speech perception among individuals with normal-hearing. A better understanding of the basic processes involved in speech perception would provide a valuable framework for the development and evaluation of speech perception training programs. For example, valid theoretical models would make it possible to identify which components (if any) of the speech perception process are likely to improve through training exercises. Moreover, this information could serve to identify the clients that would be appropriate candidates for a speech perception training program. Speech perception training programs could be designed for clients who display less than optimal performance on specific aspects of speech perception that are amenable to treatment.

WHO IS A CANDIDATE FOR SPEECH PERCEPTION TRAINING?

The goal of perceptual training is to optimize one's overall receptive communication skills during interactive verbal communication. Hence, only individuals with a hearing loss *who do not display* ***optimal*** speech perception skills should be considered as candidates for speech perception training programs. One difficulty with determining candidacy for speech perception training in this fashion is that presently it is not possible to accurately predict the level of speech perception performance that can be expected from a client, given the individual's sensory capabilities (auditorily and visually) and the test conditions (e.g., level of auditory and visual noise) under which the task is performed. Hopefully, at some point in the near future it will be possible to generate predictions of audiovisual speech perception performances based on quantitative models of multimodal speech perception. Meanwhile, professionals must identify clients who are candidates for a speech perception training program. Given the complex nature of speech perception, it is likely that the identification of individuals who are candidates for speech perception training will be based on the results of tests that assess various aspects of speech perception performance. This section will address aspects of speech perception assessment that should be included in any test protocol designed to identify individuals who would be candidates for a speech perception training program.

All comprehensive test protocols designed to assess an individual's need for speech perception training should first answer one fundamental question: When compared to an appropriate reference group, does the individual's level of speech perception performance indicate that the completion of a perceptual training program could improve this person's speech perception performance? If the answer to this first question is yes, then the test results should make it possible to: (a) identify the specific objectives of the speech perception program; (b) determine the type of intervention program (e.g., analytic, synthetic, or both) that would be most appropriate for the client; and, (c) indicate in which sensory modality(ies) the training activities should be conducted (e.g., auditory, visual, or audiovisual). Some authors have proposed test protocols to assess a client's need for speech perception training (e.g., Binnie, 1976; Boothroyd, 1987; Erber, 1988; McCarthy & Culpepper, 1987; Owens, Kessler, Raggio, & Schubert, 1985; Schow & Nerbonne, 1982; Sims, 1985; Tyler, Preece, & Tye-Murray, 1986). In general, those test protocols are long and their efficacy has not been demonstrated experimentally. In most cases, the individual tests included in the assessment protocol have not been standardized and the psychometric properties of the tests are not available. The test results seldom provide specific guidelines concerning the type of speech perception training program (and activities) that would be most appropriate for the client. At the present time there does not exist a comprehensive assessment test protocol that can be used to determine candidacy for speech perception training in audiological rehabilitation. Minimally, all speech perception test protocols should assess both analytic and synthetic speech perception skills, as well as, auditory, visual, and multimodal speech perception performance.

Assessment of Analytic Skills

Several tests of analytic speech perception performance have been developed. In most cases these tests consist of some type of consonant recognition task (e.g., Binnie, Jackson, & Montgomery, 1976; Boothroyd, 1987; Erber, 1988; Hanin, Yeung, & Kishon-Rabin, 1990; Owens & Schubert, 1977; Tyler, Fryauf-Bertschy, & Kelsay, 1991; Tyler et al., 1986). In some cases the test stimuli were videotaped so that the test could be administered visually (and audiovisually) as well as auditorily (e.g., Binnie et al., 1976; Boothroyd, 1987; Tyler et al., 1991; Tyler et al., 1986). However, very often the psychometric properties (i.e., normative data), as well as measures of reliability, sensitivity, and specificity of those tests are not available. There is a need to develop analytic speech perception tests in every sensory modality. The Visual-Consonant Recognition Screening Test (Binnie et al., 1976) provides a good example of how the results obtained from an analytic speech perception test can be applied directly to the development of specific visual-speech perception training objectives. The test is very simple to administer and easy to score and interpret. However, normative data are required for this test. Moreover, the use of this assessment paradigm to evaluate auditory and multimodal consonant recognition should be explored.

Tyler et al. (1988) described a procedure that could be applied clinically to assess analytic speech perception performances. In this approach nonsense syllables were presented under two different conditions: visual-alone and audiovisually. The results of the confusion matrices obtained from each subject were used to compute the percent correct information transmitted for specific features of speech (e.g., place of articulation, duration, nasality) under each experimental condition. For each subject, the results obtained audiovisually were compared to the results obtained under the vision-alone condition. The results were used to measure the speech perception improvements observed when the auditory signal was combined with visual cues. The approach used by Tyler and his colleagues could be applied clinically. For example, the average percent of *visual* information transmitted for each feature of speech could be determined. It has been shown that there is not a strong relationship between degree of hearing loss and performance on visual-consonant recognition tasks (Benguerel & Pichora-Fuller, 1982; Jackson, 1988; Owens & Blazek, 1985; Walden, Prosek, & Worthington, 1974). Hence, perhaps the same standardized norms could be used for all the clients with an acquired hearing impairment, regardless of the extent of their hearing loss. In addition, the test could be used to assess audio-alone and audiovisual speech perception. An individual's audiovisual performance could be compared to the performance observed for the visual-alone and auditory-alone conditions. The improvement observed in the audiovisual condition would be compared to a range of improvements obtained from a reference group of subjects. With appropriate normative data (as well as standardized test materials) this testing procedure could provide valuable diagnostic information. Interactive laserdisc technology would make the test efficient and easy to administer (Tyler, 1994). Software programs could be developed to score the responses, compare performances to referenced (or predicted) norms, indicate if the client could benefit from an analytic speech perception training program, and provide specific objectives for training (in terms of features of speech and sensory modality).

Assessment of Synthetic Speech Perception Skills

In speech perception, synthetic (top-down, global) processing skills generally refer to how well an individual applies one's "knowledge of the world" to the interpretation and understanding of a message (Butler, 1984; Duncan & Katz, 1983). Synthetic speech processing skills have been shown to contribute significantly to speech recognition performance among adults with an acquired hearing loss (Boothroyd, 1988; Boothroyd & Nittrouer, 1988; Hanin, 1988). Given the complexity of this construct it is not surprising that there have been few successful attempts to develop test procedures to assess synthetic speech perception skills. In practice, investigators who have addressed this issue have operationally defined "knowledge of the world" as the ability to make use of information concerning the topic of the message as well as contextual cues and linguistic redundancies available in the speech signal. However, even this narrow definition of synthetic speech perception processing abilities is complex. For example, Boothroyd (1988) described five different types of linguistic redundancies that can facilitate speech perception (i.e., phonological, lexical, syntactic, semantic, and pragmatic). Presently, there does not exist any standardized clinical procedure to assess an individual's use of any one of those linguistic cues.

The SPIN test (Kalikow, Stevens, & Elliott, 1977) represents the most comprehensive attempt to design a standardized test to assess the use of synthetic processing skills in an *auditory* speech perception task. However, some investigators have reported that the SPIN test does not provide a sensitive measure of synthetic speech perception processing skills (e.g., Bilger, 1984; Owen, 1981). Presently, there does not exist any standardized test that can be used to assess synthetic processing abilities for stimuli presented visually-only or audiovisually. Considering the increasing use of synthetic speech perception training programs clinically, there is an urgent need to develop appropriate assessment procedures.

Several issues related to synthetic speech processing remain to be investigated before it will be possible to incorporate those aspects of speech perception into comprehensive assessment test protocols. First, conceptual models of synthetic speech perception skills must be developed. The inter-relationship between all the factors that comprise the construct of synthetic speech processing skills must be established (Lyxell & Rönnberg, 1992). Also, the relationship between analytic and synthetic speech perception skills must be investigated. Investigations reported by Hanin (1988), as well as Boothroyd and Nittrouer (1988), provide a good initial framework for this type of research. Concurrently, there is a need to develop standardized clinical procedures to assess aspects of synthetic processing. Given the complexity of this construct one approach may be to develop a general (screening) test of synthetic speech processing skills (the domain of which still remain to be determined). Other tests could be developed to assess specific synthetic skills (e.g., use of syntactic and semantic redundancies, use of contextual cues). Individuals who fail to perform within some pre-established reference norms on the screening test would complete a more thorough test battery that assessed sub-skills of synthetic processing abilities.

Tyler et al. (1986) developed two sentence-recognition tests: one test assessed sentence understanding without contextual cues and a companion test assessed sentence understanding with contextual cues (i.e., photographs were used to provide the subject with relevant contextual cues). Presumably, the difference in performance between the two tasks provide (at least in part) some measure of a subject's ability to make use of contextual cues. Similarly, Boothroyd and his colleagues developed a test procedure in which a sentence recognition task can be completed either with or without the knowledge of the topic of the sentence (see: Hanin et al., 1990). Again, a comparison of a subject's responses under both test conditions provides a measure of some aspects of synthetic processing skills. Gagné et al. (1991a, 1991b) described a speechreading test in which each test sentence was preceded by a captioned sentence. The captioned sentence was either unrelated or related to the test sentence. The authors of the test claim that the difference score (performance for the related sentences minus the performance for the unrelated sentences) provides a measure of how well a subject makes use of contextual cues. All those tests may serve as a general screening test of synthetic processing ability. However, standardized norms are not yet available for any of those tests. Moreover, the sensitivity and specificity of those tests remain to be demonstrated.

Other approaches to measure aspects of synthetic processing skills have been proposed. Montgomery (1991) described the Repeated Sentence Task (RST). The test consists of a visual-sentence recognition task in which the subject is requested to repeat as much of the elements of a sentence presented live-voice. The same sentence is repeated as many as 12 times or until the complete sentence is identified correctly. Conversational discourse analysis procedures are used to ascertain the types of synthetic strategies employed by the subject. Montgomery claims that an examination of the responses may reveal whether the subject used appropriate synthetic strategies and the response patterns may provide insights into the type of synthetic speech perception training that would be beneficial for the subject. Erber (1988) stressed the importance of incorporating (or simulating) interactive communication settings in assessing synthetic communication skills. The author described several test paradigms (e.g., TOPICON, ASQUE>>>, QUEST?AR), all of which involve some form of natural-like verbal exchanges between two individuals. It may be possible to develop some systematic procedures to examine the synthetic speech perception skills of individuals with a hearing impairment and their conversational partners. Moreover, some of the procedures described in this section could be developed into standardized tests to assess synthetic speech perception processing skills. The availability of micro-computers and video [laserdisc] technology has made it possible to incorporate various types of interactive communication exchanges into testing and training paradigms (e.g., Dempsey, Levitt, Josephson, & Porrazzo, 1992; Hanin et al., 1990; Tye-Murray, 1991, 1992b; Tye-Murray, Tyler, Bong, & Nares, 1988; Tye-Murray, Tyler, Lansing, & Bertschy, 1990). Thus, it should not be impossible to design systematic procedures to assess various aspects of speech perception performances using some close approximations of real life interactive communicative paradigms.

Assessment of Multimodal Integration

Clinically it would be of interest to assess the speech perception abilities of clients in various sensory modalities (auditory, visual, and audiovisual). Initially, a client's multimodal speech perception scores could be compared to normative data in order to determine whether the client is a candidate for speech perception training. Models of multimodal speech perception (discussed in a previous section) could guide the selection of an appropriate training program for individuals who display poorer than expected performances on an audiovisual speech perception test. For example, if a dependent model of multimodal speech perception is shown to be valid it is likely that multimodal speech perception training paradigms would be adopted for all clients since the information extracted in one sensory modality will be influenced by the information available in the other sensory modality. However, if an independent model of speech perception is shown to more accurately describe multimodal speech perception, then either a unisensory or a multisensory speech perception training program may be most appropriate for a given client. Individuals who do not perform as expected on the auditory or visual tests may benefit from a unisensory speech perception training program (either auditory, visual, or both separately). Clients who perform optimally on the unisensory tests but obtain a poorer than predicted score on the multimodal test may benefit from a training paradigm that emphasizes the integration of information from different sensory modalities. Specific guidelines concerning the appropriate sensory modality(ies) for speech perception training will have to wait for the development of valid models of multimodal speech perception.

At the present time there does not exist a well established procedure to assess multimodal speech perception clinically. However, the test of audio-visual speech-reception thresholds for sentences developed by MacLeod and Summerfield (1987, 1990) offers an interesting approach to the assessment of multimodal speech perception performances. The procedure is based on the test paradigm originally described by Plomp and Mimpen (1979) to measure auditory speech reception thresholds for sentences. The modifications reported by MacLeod and Summerfield involve a comparison of a subject's performance under two experimental conditions. Specifically, in this procedure the first step is to determine the signal-to-noise ratio (SNR) at which a subject obtains a score of 50% correct (for keywords) on an *auditory* sentence recognition task. Then the SNR at which the same subject obtains a score of 50% correct (for keywords) on an *audiovisual* sentence recognition task is determined. The difference in SNR between the two tasks is used to quantify the effects that visual cues provide in an auditory speech perception task. The authors report that their procedure provides reliable and sensitive estimates of auditory and audiovisual speech perception performances among adults with an acquired hearing loss (MacLeod & Summerfield, 1990).

Conclusion

The assessment of speech perception performance is a critical element of any speech perception training program. The short and medium term research objectives in this area of audiological rehabilitation must be the development and standardization of analytic and synthetic speech perception tests *in all sensory modalities.* Test development is a long and tedious procedure. The conceptual, methodological, and experimental processes involved in the development and standardization of tests have been described (e.g. Anastasi, 1982; Bilger, 1984; Cronbach, 1970; Nunnally, 1978; Sims, 1982). With time, tests that are shown to be reliable, valid, efficient, and sensitive while providing specific diagnostic information will be retained and incorporated into a comprehensive speech perception test protocol to assess candidacy for speech perception training.

ARE SPEECH-PERCEPTION TRAINING PROGRAMS EFFECTIVE?

Over the years several authors have described training programs (or components thereof) that were designed to improve the speech perception abilities of individuals with a hearing impairment. However, the effects of speech perception training programs on speech perception performance are not well established (Brown, Dowell, Martin, & Mecklenburg, 1990; Gagné, 1992; Ross, 1987; Tye-Murray, 1992a). At the present time there is very little experimental data to guide current clinical practice. This section briefly reviews findings that have been reported in three areas of speech perception training: analytic vs. synthetic training programs; visual vs. auditory vs. audiovisual speech perception training; and, computerized speech perception training programs. Then, some general issues that remain to be investigated concerning to the effectiveness of speech perception training programs are outlined.

Analytic vs. Synthetic Training

Several studies have demonstrated that analytic speech perception performance improves following the completion of an analytic speech perception training program (e.g., Lesner, Sandridge, & Kricos, 1987; Walden et al., 1981; Walden et al., 1977). However, the effect of analytic training programs on the perception of more complex speech material is not well established. Walden et al. (1977) reported that their intense analytic visual speech perception training program improved audiovisual sentence recognition scores as well as visual consonant recognition scores. Lesner et al. (1987) used a similar analytic training paradigm and confirmed that the training procedure resulted in some improvements in analytic visual speech perception performances. However, the authors failed to show that the speech perception training program improved the visual-sentence recognition performances of the subjects.

Some investigators have shown that training programs which incorporate activities designed to ameliorate synthetic skills result in improvements in speech perception performance (Danz & Binnie, 1983; Gagné, Dinon, & Parsons, 1991; Montgomery et al., 1984). Two studies have compared the relative effectiveness of analytic and synthetic speech perception training programs. In both studies the subjects were provided with either a synthetic-only speech perception training program or a combined analytic + synthetic training program (Alcántara et al., 1990; Rubinstein & Boothroyd, 1987). The results of those investigations indicated that both training paradigms resulted in some modest post-training improvements. Rubinstein and Boothroyd (1987) failed to show a difference between training methods. Alcántara et al. (1990) found that both approaches to training were beneficial. However, the results were dependent on the test materials that were used as outcome measures. Specifically, the improvements were greater on the tests that were similar to the type of training program that the subjects completed (see: Blamey & Alcántara, 1994). The inclusion of the analytic training resulted in improved scores on the analytic tests of speech perception. Subjects who participated in the analytic + synthetic speech perception training program displayed greater improvements on the tests that assessed synthetic-type speech processing skills. Studies that have investigated the effectiveness of various types of speech perception training programs have not provided definitive indications on whether analytic or synthetic speech perception training programs are more appropriate to improve the speech perception performances of adults with an acquired hearing impairment.

Presently, the relationship between performance on analytic and synthetic speech perception tasks is not well understood (Lyxell & Rönnberg, 1992). Hanin (1988) found that individuals who performed well on analytic speechreading tasks (i.e., visual-word recognition scores) also made better use of linguistic and contextual cues than those who were poor lipreaders. The author suggested that the amount of sensory information extracted from the message (i.e., an analytic skill) had an important impact on the ability to use synthetic speech processing strategies. Moreover, there does not appear to be a linear relationship between performance on analytic and synthetic speech perception tasks (Boothroyd, 1988; Gagné et al., 1991b). However, very little data has been reported on this issue. A better understanding of the relationship between analytic and synthetic type speech processing performances may provide some insights concerning the selection of an appropriate training approach (or the sequencing of training activities) for clients who display specific profiles of speech perception performance.

Sensory Modality

With few exceptions, most evaluative studies on the effectiveness of speech perception training programs have been conducted in a unisensory modality (either visual or auditory training). Walden et al. (1981) compared the effectiveness of an auditory-only and a visual-only analytic speech perception training program. Both experimental conditions resulted in improved audiovisual speech perception performances. Montgomery et al. (1984) investigated the effect of a synthetic-type audiovisual speech perception training program among a group of adults with an acquired hearing loss. As a group, the subjects displayed significant improvements in audiovisual sentence recognition scores after they completed the training program. The experimental data presently available does not provide a clear indication concerning the relative effectiveness of unimodal or multimodal speech perception training programs (Walden & Grant, 1993). More evaluative studies are needed to address this issue. As mentioned in a previous section, a better understanding of the processes involved in multimodal speech perception may provide some guidelines concerning the selection of an appropriate sensory modality for speech perception training.

Computerized Speech Perception Training Programs

In recent years many centers have incorporated materials recorded on video or laserdisc players into speech perception training programs. Often the recorded stimuli are under the control of microcomputer software programs which makes it possible to develop interactive speech perception training activities (e.g., Boothroyd, 1987; Dempsey et al., 1992; Gagné, Dinon, & Parsons, 1991; Hanin et al., 1990; Pichora-Fuller & Benguerel, 1991; Sims, 1988; Tye-Murray, 1992b; Tye-Murray et al., 1988; Tye-Murray et al., 1990). The reduction in the cost, and the increased availability of the equipment required for computer-based learning, as well as increasing requests for self-instructed learning programs from clients, will likely result in a greater use of computer-based (interactive) speech perception training programs in the future. Investigators have shown that some computer-based speech perception training programs can improve some aspects of speech perception performance (e.g., Boothroyd & Hnath-Chisolm, 1988; Gagné, Dinon, & Parsons, 1991; Hanin, Boothroyd, & Hnath-Chisolm, 1988; Sims, Von Feldt, Dowaliby, Hutchinson, & Myers, 1979; Tye-Murray, 1991). As with conventional speech perception training programs the results obtained thus far have been positive but modest.

There is a need for more research to evaluate the benefits and role of computer-based training programs in audiological rehabilitation (Lesner et al., 1987). At one level, many practical and basic human engineering issues related to interactive speech perception training remain to be investigated. There is a need to apply the findings of studies concerned with the effectiveness of computer-based learning in general to interactive speech perception training programs. Insights from the computer-based learning literature should make it possible to address some basic issues regarding computerized speech perception training programs. Issues that remain to be evaluated include: What type of instructions on how to complete the program should be given to the subjects? What type of response mode (e.g., keypunching vs. use of mouse vs. touch-screen monitors) is most readily accepted and efficient for most clients? How long should training exercises be (in order to maintain the client's level of motivation and optimize learning)? In addition, some issues related specifically to speech perception training programs require further investigations. For example: Do computerized self-instruction speech perception training programs constitute an effective substitute for conventional (clinician-initiated) training programs? Should those programs be used only as a supplement to conventional speech perception training? What client characteristics (e.g., computer literacy, speech perception performance level, personality traits) are most compatible with the successful use of computer-based speech perception training programs? Answers to those questions are required before the effectiveness and the role of computer-based speech perception training programs can be fully evaluated.

General Issues

A review of literature indicates that, on average, subjects display modest improvements following the completion of a speech perception training program. Those findings are reported regardless of the type of training program (i.e., analytic vs. synthetic vs. combined), the sensory modality (audio vs. visual vs.

audiovisual) in which the training programs are completed (e.g., Alcántara et al., 1990; Montgomery et al., 1984; Rubinstein & Boothroyd, 1987; Walden et al., 1981), or the type of training paradigms (clinician initiated or self-taught computer-based training programs) (e.g., Boothroyd, 1987; Dempsey et al., 1992; Gagné, Dinon, & Parsons, 1991; Sims, 1988). One question that arises is: What do clients learn during the speech perception training programs? One possibility is that clients learn to *extract* a similar amount of information from the signal independent of the type of training paradigm that is used to train speech perception. Another explanation may be that speech perception training programs do not teach specific speech perception skills. Rather they provide clients with an opportunity to develop *general strategies* for speech perception (Montgomery et al., 1984; Walden et al., 1981). It is possible that any training program provides similar opportunities for clients to develop those general speech perception strategies. Also, some investigators have suggested that post-treatment scores in speechreading may be attributable to the fact that subjects have become more familiar with the test procedures or test stimuli (e.g., Gagné, Dinon, & Parsons, 1991; Gagné, Parnes, LaRocque, Hassan, & Vidas, 1991; Lesner et al., 1987; Van Tasell & Hawkins, 1981). The issue of what is learned during the course of a speech perception training program is an important question which requires some investigation.

Although groups of subjects display modest post-treatment improvements on speech perception tests, a close examination of the literature suggests that there is a wide range of post-treatment improvements across individual subjects. Some subjects display very little benefit following the completion of a speech perception training program while other individuals show significant improvements (e.g., Gagné, Dinon, & Parsons, 1991; Montgomery et al., 1984; Walden et al., 1981; Walden et al., 1977). These findings reveal that not all subjects respond to a given treatment program in the same fashion. Few studies have investigated this issue. Walden et al. (1981) reported that the subject's motivation and the degree or duration of hearing loss could not account for the intersubject variability in their findings. It would be of interest to identify the factors (variables) that characterize the subjects who respond favourably to speech perception training. This information would have direct clinical applications. Specifically, it would provide some criteria for identifying clients who would be good candidates for speech perception training. Also, it would improve the quality of research designed to evaluate the effectiveness of training programs. For example, the relevant variables related to candidacy for speech perception training programs could be considered when subjects are assigned to either experimental or control groups. Additional research is required to identify subject-related variables that have an effect on the outcome of speech perception training programs.

In sum, presently there is no evidence to support any specific approach to speech perception training programs for adults with an acquired hearing impairment. Given that speech perception is a complex phenomenon it is unlikely that one speech perception training program would be equally effective for all individuals. It is more likely that some individuals would benefit most from one type of training program while other individuals would display greater improvements from another type of training program. Clinically, the question remains: "On what basis do we determine which specific type of speech perception training program will be most effective for an individual client?" A significant amount of fundamental and clinical research is required before a definite answer to this question can be provided.

HOW DO WE EVALUATE THE EFFECTIVENESS OF SPEECH PERCEPTION TRAINING PROGRAMS?

In the preceding section several research topics related to the need for evaluative studies on specific types of speech perception training programs were outlined. This section will identify some of the methodological issues that should be considered in designing investigations to evaluate the effectiveness of speech perception training programs. The issues discussed in this section are not exhaustive. Rather, they constitute some basic issues related to experimental designs and methodological approaches that must be considered when designing evaluative studies concerning the effectiveness of speech perception training programs. Discussions of research designs and methodological approaches that pertain more generally to research in audiological rehabilitation, in general, are presented in other chapters of the present monograph (see: Chapters 15, 16, and 17).

Perhaps the most critical part of any research project is the formulation of the research question (i.e., the hypothesis) to be investigated. The goals and objectives of evaluative studies should be specific and clearly defined. Ideally, the hypotheses developed for investigations related to the evaluation of a speech perception training program should be based on some theoretical model of the processes involved in speech perception. For example, speech perception training activities that stress the development and use of linguistic redundancies should have a greater impact on performances related to tasks that assess synthetic rather than analytic speech processing skills. Alternatively, research hypotheses may emerge from an examination of the stated or implicit objectives of a specific clinical intervention program. For example, the objective of a training program may be to improve audiovisual speech perception performances rather than unisensory speech processing skills. Hence, the research hypothesis should be formulated in a fashion that will make it possible to verify the specific objective of the training program. Often the questions addressed in research projects are not based on theoretical foundations or specific clinical objectives. For example, speech perception tests (word or sentence identification tasks) are often used to evaluate the effectiveness of training programs that were primarily designed to improve general communication skills such as use of coping or repair strategies.

Many of the decisions regarding methodological issues related to an evaluative research project will be determined by the a priori hypotheses formulated by the investigators (Hyde & Riko, 1994; Noh, Gagné, & Kaspar, 1994). Several authors have reported on some specific methodological issues that should be considered in designing investigations on the effectiveness of speech perception training programs (e.g., Blamey & Alcántara, 1994; Demorest & Erdman, 1994; Gagné, 1992; Hyde & Riko, 1994; Montgomery, 1994; Montgomery & Demorest, 1988; Walden & Grant, 1993). For example, the selection of subjects is important. First, the subjects recruited for an investigation should be representative of the population for whom the speech perception training program is intended. Moreover, the subjects assigned to the control or experimental groups should be matched on all the variables that may influence the outcome of the study. Variables that may be considered in recruiting subjects (or assigning individuals to specific groups) include: hearing status (in terms of type and degree of hearing loss as well as the onset and the duration of hearing loss); age, psychosocial variables, motivation, and personality traits; as well as analytic and synthetic speech processing skills. As mentioned in a previous section, a better manipulation of some non-hearing related variables is likely to reduce the intersubject variability observed in studies designed to evaluate the effects of specific treatment programs on speech perception. Hence, the results of those investigations will provide a better analysis of the "true" effects of the training program per se.

Investigations pertaining to the effectiveness of speech perception training programs should incorporate appropriate control groups as well as pseudo-treatment groups. The latter makes it possible to control for Hawthorn effects (whereby subjects perform better simply because they think they are undergoing some form of treatment) as well as the effects of familiarity with stimuli and test procedures that may be used both as training and evaluation measures (e.g., Blamey & Alcántara, 1994; Gagné, 1992; Gagné, Dinon, & Parsons, 1991; Lesner et al., 1987; Montgomery & Demorest, 1988; Van Tasell & Hawkins, 1981). The test procedures used to quantify the effects of a training program (i.e., outcome measures) are very critical in any evaluative investigation. First, whenever possible, the tests used should be standardized and have known psychometric properties. Also, in most cases, the outcome measures should include more than one test that measures the same aspect of speech perception (Montgomery, 1994; Montgomery & Demorest, 1988). The pre- and post-treatment test protocol should include measures that are directly related to the objective of the training paradigm and the research hypotheses (e.g., an analytic lipreading test should be included in the test protocol for studies designed to evaluate the effects of an analytic visual speech perception training program).

In most instances the objective of a speech perception training program is to improve speech perception in everyday life environments. Hence, efforts should be made to include speech perception tests that approximate communication in real situations as outcome measures. For example, the test protocol should include some measure of audiovisual speech perception performance. Moreover, there is a need to develop and include test procedures that assess the effects of speech perception training on interactive exchanges similar to those that occur in everyday settings. Finally, investigators should consider both the short-term as well as the longer-term effects of treatment programs. In most previous investigations, the post-treatment test protocol was administered soon (i.e., less than one month) after the subjects completed the speech perception training program. Hence, it was not possible to examine the long-term effects of the training program on speech perception performance (Gagné, 1992; Montgomery et al., 1984; Ross, 1987; Walden et al., 1977).

Finally, the metric used to define change or improvement (e.g., difference scores, possible improvement scores, percent possible improvement scores) is an important issue related to the selection of appropriate outcome measures for studies designed to evaluate the effectiveness of training programs. For a thorough discussion of methodological issues related to outcome measures in audiological rehabilitation the reader is referred to Chapter 16 of the present monograph (Montgomery, 1994).

CONCLUSION

For many years speech perception training programs have been a major component of the panoply of audiological rehabilitation services provided to individuals with an acquired hearing impairment. Clinical observations as well as anecdotal reports obtained from clients attest to the fact that many of those programs improve the communication skills of some individuals with a hearing loss. Also, some investigators have demonstrated experimentally that speech perception training does provide some benefits for some individuals. Yet, there remains a need for further investigation in almost all areas of speech perception training (Walden & Grant, 1993).

The present chapter identified many fundamental and applied issues that require further investigation in the area of visual and audiovisual speech perception training. There is an immediate need to identify clients who would benefit from this type of audiological rehabilitation services. Moreover, there is a need to evaluate the effectiveness of specific types of speech perception training programs. The longer-term research objectives in this area of audiological rehabilitation should be to develop a programmatic approach to the provision of speech perception training programs for individuals who seek audiological rehabilitative services (see: Hyde & Riko, 1994). Specifically, it would be beneficial to be able to determine the sequence in which the various rehabilitative services should be provided. Once those issues have been addressed it will be possible to investigate the cost-benefit aspects of various types of speech perception training programs. Presently there exists a burgeoning body of literature in the area of speech perception training. In some cases, previous investigators have provided models for the design of experiments in this area of research. However, there remain many issues that require further investigation. The future of research in visual and audiovisual speech perception training is very exciting and offers many challenges.

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