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Lessons from the Past: Two Influential Articles in the Early History of Audiology

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Within a span of 8 months in 1946, two papers dramatically changed the course of audiology.

> A look at how these two formative papers—each by giants in our field—have stood the test of time. Specifically, are there some lessons here about how we might face the future of the profession in the years and decades to come?

In 1946 the profession of audiology was just emerging from WWII. Hearing aids were still primitive by today's standards, but—thanks to the Aural Rehabilitation Centers created by the Army and Navy during and after the war—hearing aid use became more common and more acceptable, at least by the veterans who were issued aids to counter the hearing losses sustained in the services.

Army Aural Rehabilitation Centers had been established in 1943 at four locations: Hoff General Hospital in Santa Barbara, Calif; Borden General Hospital in Chickasha, Okla; Deshon General Hospital in Butler, Pa; and the Walter Reed Army Medical Center in Washington, DC. The Navy established its Aural Rehabilitation Center at the Naval Hospital in Philadelphia. Each facility established its own system for dispensing aids, but the program at Deshon, headed by Raymond Carhart, certainly had the greatest long-term effect on the emerging profession of audiology.

During this same period (1943-1946), a group of scientists at the Psycho-Acoustic Laboratory (PAL) of Harvard University in Cambridge, Mass, and at the Central Institute for the Deaf (CID) in St Louis were carrying out fundamental acoustic and psychoacoustic studies of hearing and hearing loss for the National Defense Research Council, with special emphasis on hearing aids. As a part of their studies they visited the Military Rehabilitation Centers to coordinate their basic research with the actual dispensing operations in the field facilities.

At issue was a pressing question: What is the best way to fit hearing aids? Before WWII, the prevailing philosophy was divided. Some providers advocated manipulating the tone control to essentially complement the audiogram: that is, adjusting the frequency response of the aid to be inversely proportional to the degree of loss in the frequency region of the loss. This was termed "audiogram mirroring." Other providers felt that best results were achieved when the frequency response was essentially "flat," no matter the shape of the loss. It is well to remember, however, that in those days the frequency response of most hearing aids was neither very flat nor very flexible. The frequency response of the typical aid showed one or more prominent peaks, and the upper end of effective amplification seldom exceeded 3 kHz. Modest filtering yielded 3-4 tone control settings characterized by varying degrees of either low-pass or high-pass emphasis.

Finally, there were issues concerning speech audiometry, specifically the maximum word recognition score, sometimes referred to as the articulation score—what we now call the PB max. Almost everyone paid lip service to some form of speech audiometry because of its obvious relevance to human communication with or without a hearing aid, but there were major differences on how best to carry it out. These issues had been debated vigorously throughout the 1930s and early 1940s, but no consensus was visible on the horizon.

Then in 1946—within the space of 8 months—two controversial articles were published in *The Laryngoscope,* speaking to these issues. One was authored by a distinguished panel of auditory scientists at PAL and CID, headed by Hallowell Davis. It came to be called "The Harvard Report."[1] The other was authored by Raymond Carhart.[2] It is fair to say that the two papers reached quite different conclusions about some issues, and surprising agreement on others.

All of this happened over 72 years ago. The present article asks how the various recommendations in these two formative papers have stood the test of time, and what this history lesson might teach us today. Are there some lessons here about how we might face the future of the profession in the years and decades to come?

The Harvard Report



Hallowell Davis (1896-1992) was the lead author of the March 1946 paper, "The Selection of Hearing Aids,"[1] which later became known as "The Harvard Report." Davis was an associate professor of physiology and director of the Psycho-Acoustic Laboratory (PAL) at Harvard until 1946, when he moved to the Central Institute for the Deaf (CID) where he was a pioneer in the physiology of hearing and a director of research. In his career, he worked to build better hearing aids for combat veterans who had hearing loss, and his research included electrophysiology, behavioral psychology, and electroacoustic engineering. This interdisciplinary approach was embodied in his 1947 textbook with S. Richard Silverman of CID, Hearing and Deafness: A Guide for Laymen. Subsequent editions made it an important tool for students in the emerging field of audiology.

In March 1946, an article entitled "The Selection of Hearing Aids,"*1* and later called the "Harvard Report," was published in *The Laryngoscope*. The list of authors included some of the most distinguished names in the auditory sciences of that era: Dr Davis, C.V. Hudgins, R.J. Marquis, R.H. Nichols, G.E. Peterson, D.A. Ross, and S.S. Stevens). The 62-page report summarized

research on hearing aids completed during WWII at PAL and CID. The authors prefaced their findings by noting an area of disagreement with the Military Rehabilitation Centers:

"A point of view is expressed which is quite at variance with the current thought and practice at the [Army and Navy] Aural Rehabilitation Hospitals, and with the preconceived ideas of the authors themselves. It is the unorthodox nature of the point of view, and of some of our practical suggestions that justify the rather elaborate theoretical discussion."[1]

At PAL the investigators tested hearing-impaired persons by means of a "Master Hearing Aid," a device capable of simulating a wide variety of audiometric profiles and capable of simulating a number of amplification contours. Based on testing of 25 persons with impaired hearing they concluded as follows:

"The appropriate frequency characteristic for a hearing aid is not correctly indicated by current principles of "audiogram fitting" or "selective amplification." A uniform characteristic that can be varied by a tone control between "flat" and a moderate accentuation of high tones will provide the most satisfactory performance for all or nearly all cases of hearing loss."[1]

So much for selective amplification. The authors were equally uncomfortable with the concept of the individual "fitting" of a hearing aid:

"Individual detailed "fitting" is futile and illusory because of the variety of requirements to be met and the difficulty of evaluating the variables between which it is necessary to compromise. Reliable discrimination between instruments is achieved in only a minority of cases."[1]

The authors also addressed a number of issues related to the maximum word recognition score. They concluded that:

"In general the monosyllabic words grouped in the PB lists are probably the most satisfactory material with which to determine a patient's maximum articulation score. The basic limitation of this form of test is the rather low reliability of the scores with an untrained listener even when the technique of presentation is carefully standardized."[1]

Finally, the authors suggested a *new* technique perhaps prescient of today's adaptive techniques:

"Continuous discourse or disyllabic words can be presented at a constant level and the intensity of noise which brings the speech just to the threshold of intelligibility can be measured and the signal-to-noise-ratio calculated. Patients differ widely in the signal-to-noise ratio that they require for intelligibility. Most of them have much more difficulty than do normal listeners in discriminating words in the presence of noise..."[1]

Subsequent criticism of the Harvard Report centered on two issues. First the number of hearing-impaired persons tested was small (n=25). Second, they should have used actual hearing aids rather than the Master Hearing Aid, since the quality of the sound modified by the Master Hearing Aid would likely have been better than the same acoustic signal as modified by a real hearing aid of the time.

In summary, the authors of the Harvard report:

1. Saw no merit in either the concept of selective amplification or of detailed fitting of hearing aids;
2. Were only lukewarm about the importance of the maximum articulation score (now called the PB Max), and
3. Thought that a measure of the signal-to-noise ratio at which speech was just intelligible against a background of noise was an intriguing idea.

Raymond Carhart's Lecture and Paper



Raymond Carhart (1912-1975) was the author of the December 1946 paper, "Tests for Selection of Hearing Aids,"2 and is often called the "Father of Audiology." He received his degree in 1936 in Speech Pathology, Experimental Phonetics, and Psychology from Northwestern University, with his dissertation involving a mechanical model of the larynx. When Carhart was in the US Army during WWII, they asked him to head the aural rehabilitation program at Deshon Army Hospital in Butler, Pa. It was there, while assisting more than 16,000 hearing-impaired military personnel for the VA, that he helped popularize the idea of audiology as its own distinct research specialization. After WWII, Carhart returned to Northwestern to develop the country's first academic program in audiology, where he continued his research and headed the program until his death in 1975.

On May 31, 1946, Raymond Carhart presented an invited lecture at the annual meeting of the American Otological Society in Chicago. The title of the talk was "Tests for Selection of Hearing Aids," and it was subsequently published in the December 1946 issue of The Laryngoscope. It became a game changer. It is likely that Carhart was not in the best of moods that night in Chicago, since the Harvard Report had appeared in print only a month earlier in April 1946—and may have seemed to him like an attempt to undermine his concepts, based on experience with more than 16,000 service- men and women about how to dispense a hearing aid.

In seeking a rational basis for issuing an aid, he favored neither a flat response nor selective amplification. These were engineering concepts, but Carhart was not an engineer. He had trained in the speech sciences. Indeed, his doctoral dissertation concerned the fabrication and study of an artificial larynx. Not surprisingly, speech scientist Carhart decided that the most appropriate hearing aid was the aid that best helped the user understand what people around him were saying: the aid that produced the highest score on a test of speech recognition.

In describing the test battery which became the basis for the "hearing aid evaluation," Carhart wrote in his 1946 paper, "Tests for Selection of Hearing Aids":

"All tests utilized speech as the stimulus material—both to reduce testing time and because ability to hear speech is the auditory requirement of greatest importance to everyday life."[2]

In his paper Carhart summarized the test battery that he recommended for hearing aid fitting. Speech materials were employed to explore four dimensions of performance:

1. Sensitivity or effective gain, the threshold for spondee words with the aid set at a comfortable listening level (the Speech Reception Threshold or “SRT”);
2. Tolerance limit, the level at which pain, tickle, vibration, or dizziness is reached;
3. Signal-to-noise ratio (SNR), the noise level at which speech is just intelligible, and
4. Discrimination or distinguishing small sound differences (ie, PB max).

This was the procedure that he and his team had developed at Deshon. Within a few years in the civilian world after WWII, however, dimensions #2 (tolerance limit) and #3 (SNR) were abandoned, but #1 (SRT) and #4 (PB max) remained for many years the framework around which the conventional hearing aid evaluation (HAE) was constructed.

Some 72 years later, how well do these two papers align with present practices?

A Retrospective Look at The Harvard Report

On the matters of selective amplification and individual hearing aid fitting we would have to give the Harvard Report a poor grade. It took many years of controversy, but eventually technical progress made true selective amplification possible and the results have been reasonably positive. To be fair to the Harvard report, it is certainly the case that the hearing aids of 1946 were much less flexible than the hearing aids of today.

Relative to their conclusion that individual hearing aid fitting was not justified, many of today’s clinicians would argue that the fitting of hearing aids is one of the pillars of contemporary audiology. Both of these two issues, selective amplification and hearing aid fitting, are still alive and well.

Relative to the PB max as a useful tool for hearing aid selection, many would argue that the conclusion of the Harvard Report relative to lack of significant differences among aids stood the test of time very well. Here a good grade seems warranted.

Finally, we must give the Harvard Report a favorable mention for suggesting that a SNR concept might be a better way of understanding the range of individual differences in the ability to understand speech in difficult listening environments. This suggestion was promptly forgotten for the next 40 years, but has been revived by contemporary designers of a variety of novel speech-in-noise measures.

A Retrospective Look at Carhart’s Selective Amplification Approach

On the matter of selective amplification Carhart also missed the boat. He had just read the Harvard Report as he was preparing his own paper, and agreed that contemporary hearing aids offered only a limited range of frequency response characteristics. To his credit, however, he did not labor the point. He raised the issue only in a footnote.

Relative to his four-tiered hearing aid evaluation procedure, only two items—the SRT and the PB max—transferred successfully from the military environment to the civilian world, but for the next five decades Carhart’s concept of the individual hearing aid evaluation (HAE) dominated the clinical audiological treatment of people with hearing impairment.

Interestingly, one of the two items lost from the original military version of the HAE was the same idea proposed in the Harvard Report: the concept of the signal-to-noise ratio as a measure of speech understanding in the presence of competing noise. These ideas were resurrected only within the last 20-30 years by psychoacousticians who found them especially suitable for easily automated adaptive testing rules. In that time, several designers of clinical speech-in-noise tests have readily switched from percent-correct scores to signal-to-noise ratios (SNRs) with

considerable success.

What Is the Relevance of All This for the Contemporary Audiologist?

First, suspect the naysayer. Suspect the person who says “No, that will never work,” or “No, that will never happen.” Stranger things have *already* happened. If we could bring those distinguished PAL and CID scientists who collaborated on the Harvard Report back to life and showed them how selective amplification and painstaking hearing aid fitting have benefitted hearing aid users, there might just be a few shuffled feet and averted eyes.

Second, keep your mind open to new ideas. Welcome the SNR concept as a new, potentially valuable metric in the continuing search for a better understanding of the speech understanding problems of hearing-impaired persons.

Finally, suspect anyone who would censor the free flow of ideas and innovations in pursuit of better services for the hearing-impaired population.

Summary

In 1946, within a span of 8 months, two publications appeared which had a serious effect on the subsequent development of the profession. One, the Harvard Report, rejected the concepts of selective amplification and individual hearing aid fitting and was only lukewarm on the concept of speech audiometry. The other, by Raymond Carhart, presented the concept of the individual hearing aid evaluation (HAE) based on speech audiometric measures that he had developed during WWII. However, *only 2 of the 4 steps* in the original concept survived to “civilian life,” but they endured for the next half century.

Interestingly, both publications described a test of speech-in-noise quantified by the speech-to-noise ratio (SNR). This concept promptly dropped out of clinical audiological sight for several decades until revived by designers of modern speech-in-noise tests. The procedure lends itself well to adaptive testing procedures which can be readily automated.

Overall, one would have to conclude that Carhart’s article has had a greater long-term influence on the profession than the Harvard Report.

References

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2. Carhart R. Tests for selection of hearing aids. *Laryngoscope*. 1946;56(12):780-794.