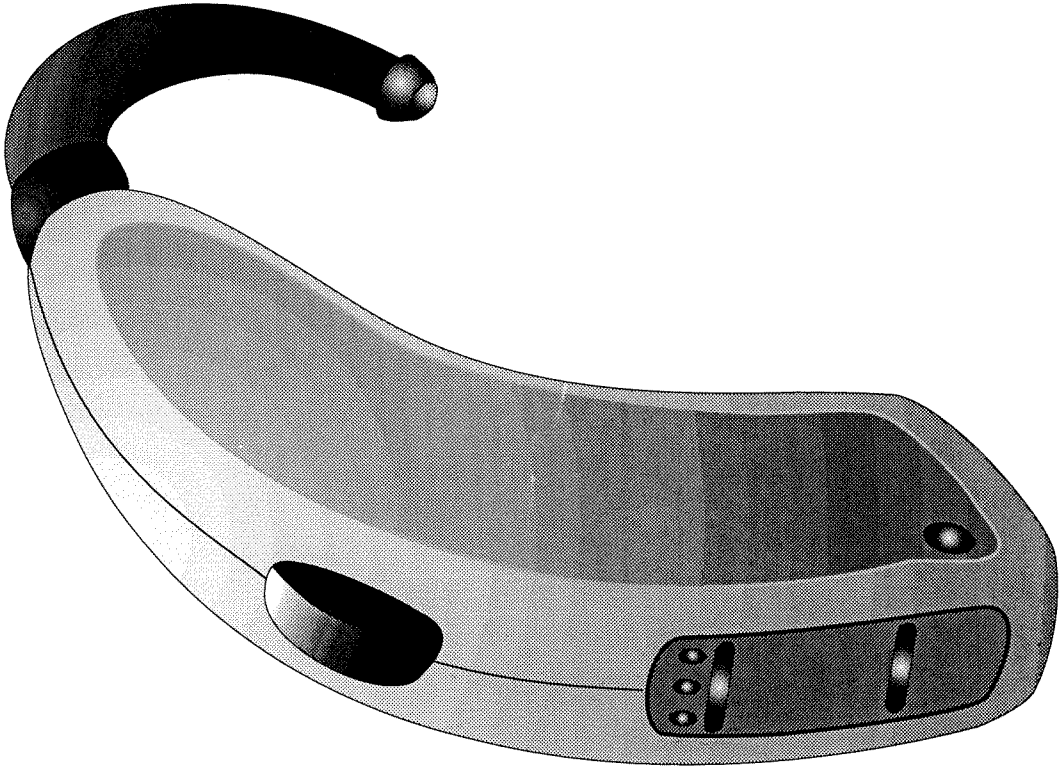

Chapter Seven

Evaluation Procedures

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INTRODUCTION

Today, evaluation procedures of whatever sort are seldom used for the selection of a hearing aid. Speech recognition and comparisons of hearing aids have given way to some form of prescriptive method, that is, to an *a priori* approach. Prescriptive approaches are even used for nonlinear aids, however imprecise the current algorithm. It is certainly better than the old ways, and improvement in technique is being made. If an evaluation procedure is used at all in selection, it is most likely a rating scale or some kind of needs assessment to determine listening problems, style bias, personal preferences, and prejudice. This chapter will focus on *a posteriori* evaluation procedures that may help the individual with hearing impairment and/or the audiologist gain insight into the utility of the hearing aid and its adjustment.

Part of the problem seems to be time, and its correlate, efficiency. Evaluation procedures need to be selected (or not selected) to meet the time constraints of the audiologist and the person with hearing impairment. The approach has to be interesting, informative, and utilitarian. If it is perceived as a waste of time, it should not be done. Determine the purpose of the evaluation procedure: ask yourself why you are doing it? What are you trying to accomplish? What do you need to know? Is it for purposes of client instruction? Do you want it to become part of the rehabilitation process? Do you want to use it for the adjustment and fitting of the hearing aid? Do you need to do it for documentation or justification of the selection process, or is it just out of curiosity (this is also a legitimate reason)? Whatever your purpose, make sure the tools you select in fact meet your needs.

To some degree, all evaluation procedures thus far devised are unreliable, particularly if used for hearing aid selection purposes. Denis Byrne's philosophy is that "the evaluation is for checking and refining the prescription rather than regarding the prescription as simply a starting point for the evaluation" (1). The following is a list of the evaluation procedures that can be selected. Some of these procedures are not well developed, while others are unnecessary. This chapter is a commentary and discussion about some of the tools that are available, and about their application.

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EVALUATION PROCEDURES

SPEECH TESTS AND MEASURES

RESPONSE TASKS
- Detection
- Discrimination
- Recognition
- Identification
- Comprehension
- Tracking
- Social Interaction

STIMULI
- Syllables
- Words
- Sentences
- Connected Discourse

COMMUNICATION CONDITION
- Listening in Quiet
- Listening in Noise
- Listening with Competing Speech
- Look and Listen
- Listening Through Telephony
- Listening by Recording
- Look and Listen by Television

SELF APPRAISAL APPROACHES
COMPARISON APPROACHES
QUALITY JUDGMENT
LOUDNESS JUDGMENT
NONSPEECH APPROACHES
MONAURAL VS. BINAURAL
SINGLE CIRCUIT VS. MULTIPLE CIRCUIT
AGE FACTORS
PERIPHERAL LOSS
PERIPHERAL-CENTRAL INVOLVEMENT

These evaluation procedures will be addressed under the following headings:

Evaluation for Purposes of User Instruction
Evaluation for Purposes of Rehabilitation
Evaluation for Purposes of Adjusting and Fitting the Hearing Aid
Evaluation for Purposes of Justifying the Selection of the Hearing Aid
Evaluation for other Purposes

EVALUATION FOR PURPOSES OF USER INSTRUCTION

Speech Discrimination

Two kinds of questions are asked: one by the audiologist, and the other by the potential hearing aid user. Both are really the same: what kind of signal processing is this person capable of? The person usually asks, "what percent of hearing loss do I have?" A sincere question, but one that needs to be turned around to ask, "what can I hear?" For the majority of potential users, the answer will be either a listener of manner of articulation or place of articulation. For the individual with the more severe loss, he or she may only process vowel and vowel-like information characterized by formant structure. For this person, no place information will be available and probably little, if any, manner information. The Nonsense Syllable Test (NST) is the most convenient way to address these fundamental questions.

The Nonsense Syllable Test

The NST is best done in quiet. All you are trying to do is determine what the person can hear under the best of circumstances. Twenty years of experience using this as a clinical tool suggests some practical applications (2). The audiologist can derive place and manner of articulation information from a limited set of phonemes (e.g., the voiceless and voiced stops, and selective voiceless and voiced fricatives). These may be all that is needed to derive the processing information or distinctive features one wants to demonstrate to the client. A set that we have found useful includes /p/, /t/, /k/, /b/, /d/, /g/ and /f/, /s/, /ʃ/, /v/, /z/, /ð/. The paradigm with which we became most comfortable was these phonemes in initial position concatenated with the vowels /*a*/ or /i/. Usually /*a*/ was used, but if the client had a more high-frequency loss, /i/, with its higher second formant, was more challenging and revealing of the limitations of signal processing for this individual. If the client has a more severe loss and limited ability to derive place information, the consonant-vowel (CV) paradigm using /*a*/ will reveal a listener who primarily processes manner information. If even manner of articulation is not derived, the clinician may want to try discrimination for vowels or semi-vowels and nasals. These demonstrations to the potential user are only useful if they reveal the ability to function partially. Responses that are near perfect or very limited in success

do not provide people with insights into their problems.

Nonsense syllable material can be presented monitored live voice or recorded (if the recording is of high quality). Paper and pencil responses can be used. A more convenient approach is to automate it via computer program. We have used a computer program that permits recorded presentation of the material, response through a touch-screen, and the derivation of confusion matrices to reveal error patterns. The computer, though an added expense, provides ease of presentation and scoring, and is easily managed by most listeners. The added feature of a confusion matrix makes it easier to explain errors to the listener (3).

The nonsense syllable approach that we use may be convenient and efficient, but it is by no means the most complete sampling of the array of features that could be used. It is a clinical tool primarily used for user instruction. If something more is needed, Resnick et al. provide an extensive NST consisting of consonant-vowel, vowel-consonant (VC), and consonant-vowel-consonant (CVC) syllables within three vowel contexts: /i/, /*a*/, and /u/ (4). The NST, when presented as a closed-set response task, is a true discrimination measure.

Telephony

In general, tests that merely provide percentage scores are not very helpful in user instruction. They may have other valid uses, but the user does not derive practical information. The one exception we have found to this is telephone communication via a hearing aid. Many individuals will need to know how they are going to function over the telephone (5). Since the telephone has a limited frequency response, even listeners with unimpaired hearing learn to use other clues to function successfully. Context is a big help when talking on the telephone. So too are the leading and trailing tails of the formant structure of the vowels, which suggest the associated consonant: something that people internalize when they are growing up and learning the rules of their language. It may not be perfect, but it has proven quite adequate for listeners who have unimpaired hearing. For many years, we have made it a practice to use sentence materials for testing clients for function on the telephone. The CID Everyday Speech sentence lists have proven convenient for this purpose (6). Rather than tabulate a formal percentage score based on the 50 key words, we estimate telephone success by categorizing the response to several sentences as "better than 90 percent," "80 percent," "70 percent," and so forth. Users seem to appreciate knowing approximately how well they will do on the telephone, and a percentage seems to be easy for them to understand in this context.

Peripheral-Central Involvement

Articulation Index formulae, now commonly used in the selection process, reflect intelligibility estimates based on the pure-tone audiogram of the individual and the assumption of a *normal* peripheral loss (7). Frequently, and especially among elderly persons, we find individuals whose speech recognition scores seem to be unusually low when compared to the pure-tone responses. There can be many reasons for this, including user motivation and elevated listener-response criterion, inappropriate selection of testing materials, and presentation technique. Most often it is a person with limited signal-processing ability, resulting from a malfunctioning cochlea and/or a central auditory involvement. The Articulation Index can provide an estimate of the speech understanding for an amplified signal, that is, the potential improvement to expect for an amplified signal based on the pure-tone audiogram (8). A reasonable assumption or rule of thumb, though not always accurate, is that if one ear fits the pure-tone audiogram expectation while the other does not, it is probably a peripheral problem with which the clinician is dealing. If both ears are well below expectation, he or she may have to contend with a central problem, although it could be the periphery that is not functioning well. If one follows clients long enough into their elderly years, one might be watching an ever-increasing central deficit if the pure-tone response is not changing. People need to have some indication of why they are having the problems in understanding they are having. The audiologist is obliged to provide some kind of answer. To complicate matters even further, there are individuals who function as expected for amplified signals in some situations and not in others. Sometimes, it is background noise for which the hearing aid cannot compensate, but for some individuals it may be a central phenomenon. The difficulty may be due to the individual's inability to function in competing speech situations, a common problem for those with central involvement (9,10).

It would be helpful if the Distortion Product Otoacoustic Emission (DPOAE) could provide us with more information about cochlear function, but at this point it is limited (11). A test of recruitment might suggest some-

thing about the signal-processing capabilities of the cochlea as might the Short Increment Sensitivity Index. For retrocochlear involvement, we have reflex decay, rollover (PI/PB) (12), and auditory brainstem response (13). For determining central involvement, there are a number of behavioral procedures at the brainstem level and the temporal lobe level, but these are somewhat limited in application if the speech deficit is too great. Still, some of these procedures might be useful in providing some insight into the problem (14). An observation we have made is that if the problem has a central component, the hearing aid(s) will have a much lower most comfortable level (MCL) setting than might be otherwise expected (with an otherwise adequate dynamic range). Those with a central component may only need the system "tweaked up a little bit."

Nonspeech Approaches

A lot of what we think of as central involvement may not be that at all. We cannot ignore the possibility of a central contribution to the overall problem and should not ignore it in our explanation to the client if we have reasonable evidence for such a condition. However, the so-called Speech Audiogram (SA) could explain many of the depressed speech scores that we see. It is a handy way to explain speech understanding in both quiet and in certain noise conditions. Audiologists frequently have the SA overlaid on the audiogram graph to facilitate discussion with clients about their potential. On the SA, clients can be shown where they fall beyond the point at which they can be reached even with a hearing aid, and what it will mean for understanding. Audiologists interested in pursuing this approach may refer to Humes and to Olsen et al. (15,16) and for a good review of speech discrimination among those with hearing impairment, to Levitt (17).

Although not often used anymore, a warble tone or narrow-band noise sound-field audiogram can demonstrate the functional gain (FG) that might be expected for aided response. A comparison is made with the unaided response. While real-ear probe microphone analysis measures what is being delivered near the eardrum, the sound-field audiogram is a way of showing functional improvement with a hearing aid, at least at the normally tested frequencies. This approach has some use for instructional purposes.

Self-Appraisal Scales

Most of the self-appraisal scales are useful for user instruction. They are not always reliable tools, but change in response should be expected over time. Listening and attitude about listening are dynamic processes that are ever changing. It often takes months to learn to successfully listen through a hearing aid. We should not expect responses to items on these scales to remain static. It should not matter. If used in the instructional phase, these scales provide an opportunity for discussion with users about future success and/or problems they will encounter with their hearing aid and communication. There is no one best scale for every situation. The clinician should choose one he or she is comfortable with and use it (18,19).

Evaluation for purposes of instruction is flexible and not very demanding in precision. What is done or not done in this phase of the hearing aid fitting depends upon the audiologist and the needs of the client. Some want information about how they are going to do, while others need reassurance that they are making the right decision. Evaluation during the instructional phase may provide insight, and may lead to a more tolerant and understanding hearing aid user. It can be part of the learning process.

EVALUATION FOR PURPOSES OF REHABILITATION

Intuitively, the audiologist wants to fit a hearing aid that will reproduce speech as faithfully as possible under all listening conditions, based on the limited signal-processing abilities of the prospective user. Speech has a range of about 40 dB from the weakest to the strongest phoneme. Changing the "normal" relationship of these phonemes degrades the intelligibility of these signals for the nonimpaired ear. The clinician's challenge is to modify (or degrade) this normal relationship so as to enhance the signal-processing capabilities of the defective ear and the listener with hearing impairment. We want the hearing aid to have the highest fidelity possible, but we need also to remember that we are dealing with low-fidelity ears.

It is quite common for users to exhibit reduced dynamic range as well as limited spectral resolution. How can we make people hear what they cannot physiologically hear? The answer, of course, is that we cannot. However, we can give them some degree of information that will permit the limited processing of speech signals. We can compress speech in a number of ways. We can peak clip it, if that will produce the best results. We can

emphasize certain parts of the spectrum while reducing other parts (a tuck here or there). It is a little like being a plastic surgeon for speech. Ultimately, we decide that we have enhanced or degraded the signal (depending on one's point of view) as much as possible based on *a priori* criteria. Now we want to find out whether it worked. Is there hearing aid benefit? Can we show benefit? How much benefit?

The dilemma is that it may take several months before we can truly see or recognize the results of our work (20). The user is not a reliable judge of improvement, at least not initially. Part of the reason it takes so long to internalize the new, and hopefully enhanced, signal is the user's memory for how speech is supposed to sound. The years of hearing loss have eroded the memory for the true target. In addition, persons with hearing impairment will never hear speech as they once heard it, no matter how good the reproductive capability of the hearing aid. The client needs to be able to understand these limitations in showing hearing aid benefit.

In some ways we have an easier task with the young child with hearing impairment as he or she tries to evolve the rules of language. This is not to minimize the difficulty in teaching the rules of language to this child, but rather to point out that the child is, in a sense, a *tabula rasa* when it comes to these rules. If we can provide a hearing aid that effectively differentiates the rules for the child, we have a chance for phonemic and prosodic success. Subsequently, getting a better hearing aid will not automatically improve that child's language. In fact, he or she will now have to deal with new or changed rules of language due to the new features being received. Without training, this might be a setback. Getting a better hearing aid for an adult should lead to automatic improvement, albeit over some unspecified period of time.

Adults, who developed their hearing loss years after the development of their language, will continue to have a built-in bias as to the speech code. The brain needs time to reorganize how it listens to or perceives speech. We are dealing with a process that often takes months to achieve. There is probably no quick fix for this problem. And yet, we hope to show hearing aid benefit in days or a matter of weeks. The longitudinal studies to address this problem have yet to be done. Can the process be speeded up by systematic listening (auditory training)? It would be nice if we could provide some kind of exercise program to build our speech perceptual muscles (e.g., listening to nonsense syllables, monosyllabic words, sentences). This probably is not realistic or helpful. For the adult with later-onset hearing loss, we are probably better off with enriched listening experiences for real speech communication.

What choices do we have to document hearing aid benefit? With a short training program, it may be possible to show potential for improvement with an NST. This will not reveal current hearing aid benefit or even future success. But if you need to show something right away, the NST might be helpful. It is of little real benefit to the client, and carry-over is expected to be limited.

Introspective techniques using rating scales, questionnaires, and interviews do little to effect hearing aid benefit, and are of limited use for documentation of benefit. Our current belief is that training in communication strategies is more important than anything else we can do for any individual with hearing impairment (21). Speech, particularly true discourse, is very complicated, and improvement is difficult to document. However, if one is really interested in effecting hearing aid benefit, contextual materials are necessary; they can provide both phonemic-processing exercise as well as the development of listening strategies.

The problem is not hopeless, but we need to recognize that methods of documentation of benefit are not adequately developed. What we need are before-and-after testing of something that is analogous to true discourse. The DeFilippo tracking procedure comes close to these criteria (22,23). The method can be used with individuals with all levels of hearing loss, although as the clinician moves beyond the severe range, he or she probably will need to permit lipreading. In addition, as the hearing loss becomes more severe, audiologists may find it necessary to change to materials that are more familiar to the listeners, (e.g., well-known stories). It is possible to add various types of background noise if they wish to address these issues. For the near-term foreseeable future, one would need to adopt protocols that meet the needs of both the audiologist and the client. For example, if the loss is mild, more difficult material may have to be used. Scoring could be the number of words repeated correctly in a given period of time, or the clinician could follow the recommended protocol. Subsequent materials need to match the initial ones used, and may be derived from the original source. Users should serve as their own controls. Thus, the before-test at the time of fitting is compared to after-tests to demonstrate improvement and supposedly its correlate, benefit.

EVALUATION FOR PURPOSES OF ADJUSTING AND FITTING THE HEARING AID

Do we obey our algorithms and adjust the hearing aid based on what we believe the user needs, or do we listen to our clients and try to make them comfortable and/or satisfied? A compromise probably is the best solution. We need to negotiate with our clients to determine what they will accept. Initially, the adjustment may not be what they will need or accept later on. That is why periodic follow-up within 2 to 4 weeks may be critical. Maybe we should be scheduling readjustment intermittently over a period of several months.

What type of evaluation tools will help? We still are trying to maximize hearing aid benefit. To do this, we will need to modify the features and controls of the instrument to provide the best possible signal processing. How much do we take away or give back to achieve the best (or temporarily best) results? Two approaches immediately come to mind: real ear probe measurements (REM) and functional gain. It is these nonspeech approaches that have superseded the Carhart comparative technique, which relied heavily on word recognition scores (24).

REM has become the method of choice in many clinics, including our own. Its use has revolutionized selection, fitting, and modification techniques. It can be utilized in all phases of hearing aid selection and fitting. There is no better way of determining what we are delivering near the eardrum. Output coupler measurements are no substitute for it (25), and it is easy to perform (26). It even should be done with multicircuit programmable units. The hearing aid adjusted (programmed) by computer still does not tell one what is happening at the eardrum, and REM is a good way to determine how close one has come to the target. It is a verification tool. There are a number of good review articles describing the myriad ways REM can be used to help in the selection, fitting, and modification process (27,28). These articles also describe the pitfalls if REM is not done carefully and consistently.

If time permits, the audiologist may want to backup his or her REM with FG testing, which was popularized by Pascoe (29). FG is the difference between unaided and aided sound-field thresholds obtained across the usual frequency testing range. It is a subjective approach still used in some clinics, but largely supplanted by the objective real ear measure. The one major disadvantage of FG is that it is a behavioral procedure, yet at the same time this is its one major advantage: because it is subjective, it reflects what the user actually hears (30,31). It is not recommended as a replacement for REM, but can be used to provide supplemental information suggesting the true effect of the hearing aid adjustment.

A word of caution about hearing aid adjustment: the setting is not synonymous with hearing aid benefit. Even if the setting agreed to on day 1 equals or nearly equals the setting on day 365, this does not mean that hearing aid benefit has been achieved. The audiologist still does not know how the person is using the information derived through the hearing aid. Comfort and acceptance tells one little about benefit. However, without the right adjustment there can be no benefit.

EVALUATION FOR PURPOSES OF JUSTIFYING THE SELECTION OF THE HEARING AID

The audiologist may feel he/she has good and sufficient reason for a particular hearing aid selection. Ultimately, it is the user who must accept the selection. Justification, of necessity, is based on the subjective impression of the user. An audiologist may counsel, educate, and even cajole clients as to what they think is best for them, and their influence is not trivial. All the tests being done to justify a binaural fitting, a multicircuit programmable unit, or any other selection will have to pass the final arbiter: the user. The tests may demonstrate the worthiness of the selection, and may be very helpful from an educational point of view. But the only method that meets the criterion for justification is the opinion of the user, best exhibited through systematic self-appraisal or satisfaction scales.

The euphoria of the initial fitting often is reflected in the satisfaction scales obtained from the user within the first couple of months after the fitting. As time goes on, and subsequent scales are done, the satisfaction may give way to the reality of hearing aid use: it will never be perfect (32). If the hearing aid is being used, it is most likely that derived benefit is improving. We need to reconcile this divergence: as benefit goes up, satisfaction may go down. This is a reflection of the expectations of the user, and probably not a reflection of the goodness of the fit. The self-appraisal/satisfaction scales represent the testimony of users as to their perception of benefit at a given point in time.

Which scales should be utilized? The ones that may be most useful and specifically related to hearing aid per-

formance and benefit are: Hearing Aid Performance Inventory (33), Profile of Hearing Aid Performance (34), and Hearing Handicap Inventory for the Elderly (35,36). Whichever is used, care needs to be taken in instructing the users and maintaining their interest and alertness throughout the process. Without these precautions, reliability may be jeopardized.

EVALUATION FOR OTHER PURPOSES

We are still concerned about evaluation for hearing aid selection and fitting, but we now want to try other approaches. Some of these other evaluation techniques are quite useful and, from an audiologist's point of view, interesting. There is much that can be done but maybe too little time in which to do it. There are a number of other approaches, and we can expect more as our knowledge and technology improves. Not all of these approaches will stand the test of time. Some will be ignored because it takes too much of our limited client time. We may want to adopt some of these approaches as part of our regular armentarium, or use an approach for a client on an as-needed basis.

We are moving steadily into the nonlinear age of hearing aids. The Independent Hearing Aid Fitting Forum (IHAFF) is directed toward the nonlinear aid, and part of its fitting protocol is a loudness test, the Contour Test (37). It uses warble tones in sound field (250 Hz–4000 Hz) and asks the listener to rate loudness on a 7-point scale with 1 = very soft to 7 = uncomfortably loud. If the IHAFF protocol is adopted for fitting, there will be a need to use this procedure. Loudness scaling may be helpful for the hypersensitive user (38,39).

Paired comparison techniques are interesting and may be useful, particularly when comparing circuitry performance for multiple program type hearing aids. Kuk recommends a 2–3-week listening trial with a new hearing aid for the inexperienced user before attempting this approach (40), which is time consuming and requires an attentive and inquisitive listener.

Quality judgments are being promoted as a means of fitting a hearing aid. Preminger and VanTasell, using continuous discourse, categorized speech quality into five areas for user rating: intelligibility, pleasantness of tone, loudness, listening effort, and total impression (41,42). The approach is worth trying. Some aspects of it might be incorporated into the clinician's overall approach.

If one were going to recommend assistive listening devices, the system should be evaluated with the user trying it. Usually REM and/or FG can be used. We really do not know what the client is receiving through a device unless we test for it.

We really have only just begun. What we will be doing for hearing aid selection and fitting 10 or 20 years from now may not be what we are currently doing. We need to be flexible and willing to try new approaches. We spent too many years locked into an approach that did not work well for us or our clients. Hopefully, we have learned our lesson.

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JOHN A. KOSLOWSKI, MS, has 10 years experience as an audiologist in clinical settings and in private practice. He received his Master's degree at the University of Wyoming, Laramie, Wyoming. Mr. Koslowski is currently a clinical audiologist at the VA Maryland Heathcare System, Fort Howard, Maryland.