Methods for measuring intelligibility of closely related language varieties

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Introduction

The exact number of known living languages varies from 5,000 to 10,000, depending on one's definition of 'language'. An even larger number of dialects are spoken worldwide. Many of these languages and dialects (from now on taken together as 'languages' or 'varieties') are so similar that they are mutually intelligible to varying degrees, even without prior contact or formal instruction. Speakers of such different yet related languages sometimes communicate each speaking their own language. Haugen (1966) introduced the term semicommunication for this kind of communication. Other terms used are receptive multilingualism, semibilingualism, non-convergent discourse, asymmetric/bilingual discourse, and inherent intelligibility. Examples of observed semicommunication can be found in Zeevaert (2004).

For various reasons it may be interesting to establish the degree to which a speaker of one variety understands the speech of another closely related variety, for instance to resolve issues that concern language planning and policies, second language learning, and language contact. Unbiased data about distances between varieties and detailed knowledge about intelligibility can also be critical for sociolinguistic studies. Varieties that have strong social stigmas attached to them could unrightfully be deemed hard to understand (Wolff 1959; Giles & Niedzielski 1998). The relationship between attitudes and intelligibility is not a straight forward one, but advances in the field of linguistic distances and intelligibility testing provide sociolinguists with objective data to resolve conflicts that arise concerning varieties on a standard-nonstandard continuum. Knowledge about mutual intelligibility is also needed for standardisation and development of new orthographies in communities where no standardised orthography exists.

To investigate intelligibility, a large number of tests have been developed that make it possible to express degree of intelligibility in a single number, often the percentage of input that was correctly recognized by the subject. The aim of the present chapter is to give an overview of methods for measuring intelligibility of closely related languages and to discuss the advantages and disadvantages of the various methods. We focus on spoken language comprehension, but many tests can also be applied to the comprehension of written language.

The experimental and methodological considerations relevant for intelligibility testing have a great deal in common with those relevant for studies in various other areas of sociolinguistics. For example, efforts must generally be taken to control the context of speech production or speech perception as much as possible while keeping the recording or listening condition as natural as possible. A number of techniques have been developed within the area of experimental methods for the study of language variation. It is not uncommon to use more than one method to study a linguistic phenomenon, as each method has its shortcomings. Sociolinguists and dialectologists have devoted much attention to giving technical descriptions of linguistic varieties, and exploring general questions about language attitudes and stereotypes. However, in recent years there has been an increasing focus on perceptual sociolinguistics with the aim of gaining concrete explanations and theories about the mental processes behind perception of linguistic variation (e.g. Preston 1999; Long

and Preston 2002; Thomas 2002; Clopper 2004). Researchers have shown a growing interest in uncovering what linguistic and non-linguistic features listeners react to when asked to make judgments of speakers and their speech. Methods include experimental designs using systematically manipulated speech to isolate the desired aspect of perception to be investigated (e.g. Fridland and Bartlett 2004) or manipulation of listeners expectations (Niedzielski 1999) as well as statistical correlations between acoustical measurements and reactions to perception experiments (e.g. Clopper and Pisoni 2004). For an overview of experimental methods for the study of language variation see Nagy (2006).

Human spoken language is extremely robust and native subjects are generally successful in getting the speaker's intentions even if the input speech is defective, for example in cases of language or speech pathology, foreign accents, and computer speech, and even in noisy conditions. Listening to a closely related language is similar to other situations where the speech input is non-optimal and we assume that no special mechanism is involved in decoding this kind of speech. This means that methods for investigating mutual intelligibility can also be taken from other disciplines, for example in the area of speech technology, second language acquisition and speech pathology.

General methodological considerations

This section gives an overview of methodological considerations that should be made when designing an intelligibility investigation. Factors are discussed that may influence the results and that should either be avoided or taken into consideration when interpreting the results. Topics dealt with are the test material, selection of speakers and subjects, and the characteristics of the task to be carried out by the subjects.

Test material

To carry out an intelligibility test one needs recordings of languages that can be used as listening material. The choice of test material depends on the aim of the investigation and can vary along a number of dimensions: style (spontaneous or read, formal or informal), number of speakers involved (monologues, dialogues), linguistic entity (isolated words, sentences, texts), complexity (difficult, easy) and subject matter (daily life, science, society, technique, politics etc.). If the intelligibility of more languages is compared, great care should be taken to keep these factors constant when collecting material for tests.

It is important that the texts represent the languages to the same extent. A way to control the material is to use translations of the same text in all test languages. This mostly means that the usage of read speech is necessary, while it may be preferable to use spontaneous speech since this simulates a natural situation to a larger degree. A good compromise may be recordings of semi-spontaneous speech, where the material is controlled to some extent, such as in map tasks (cf. Anderson et al. 1991; Brown et al. 1984; Grønnum 2009) or picture description tasks, where speakers have to carry out some task that demands speech production in a controlled setting. However, the use of (semi-)spontaneous speech makes it impossible to use the same texts and questions for the different test languages so that the results are less comparable.

When using translations, a text in one of the test languages is often translated into the other test languages. However, there is a risk that the translators may tend to

stick too closely to the original text when choosing words and expressions for the translations. To make sure that one of the test languages does not get a special status, a solution is to use translations from a language that is not one of the test languages or, alternatively, to use source texts from each of the test languages. In this way frequent words and constructions are more likely to be represented to the same degree in all test languages. Frequent words are more easily recognized than infrequent words (Luce and Pisoni 1998).

Other word characteristics are also known to influence intelligibility and should therefore be controlled for. Words with a high neighbourhood density are often more difficult to recognize than words with few competitors. A word's neighbourhood density can be defined as the number of words that deviate from the target word by just one sound (Luce & Pisoni 1998). A word like *elephant* has no neighbours and is not easily mistaken for another similar word, while the word *cat* has a total of 30 neighbours, for example *bat, kit* and *cap* and can therefore easily be confused with another word.

Word length should also be considered. Studies have shown that longer words are more easily recognized than shorter words (Wiener and Miller 1946; Scharpff & Van Heuven 1988). This is attributed to the relationship between word length and the number of neighbours. Longer words have fewer neighbours than shorter words (Vitevitch & Rodriguez 2005). Furthermore, redundancy increases with word length, and this is assumed to enhance intelligibility as well.

The speech fragments selected for the intelligibility test are generally supposed to represent the language as a whole. If the sample is large enough, for example a complete text, one may assume that it represents a random sample of the test language. However, it is important to be aware that one single unintelligible word or sound may disturb the picture so that in fact the intelligibility of the whole speech sample becomes lower. Smaller fragments (word lists, restricted sets of sentences) call for some control. For example, one can make sure that the material is phonetically and lexically balanced, i.e. in accordance with the statistical distribution of the words and phonemes in the language.

When the same stimulus is presented more than once there may be a learning effect (priming). Therefore the same stimuli should not be presented more than once to the same subject. This contradicts the fact that it is desirable to use the same stimulus material when comparing the intelligibility of more languages. The solution is to use a Latin square design where each subject hears a proportion of the stimuli in each of the test languages, and yet hears stimuli in each of the languages in equal proportions, and never hears the same stimuli twice (see Table 1). A disadvantage is that often many groups of subjects are needed, four groups in the example in Table 1.

Table 1. Example of a Latin square design with the languages A-D, stimuli 1-4 and test versions I-IV.

	Test version			
Languages	I	II	III	IV
A	1	2	3	4
B	2	3	4	1
C	3	4	1	2
D	4	1	2	3

Speakers

Speech comprehension is affected by speaker characteristics. Some speakers are more intelligible than others, for example because of differences in voice quality, precision of articulation and reading ability (Hazan & Markham 2004). The sex of the speaker seems to play a role as well, female voices in general being more intelligible than male voices (Bradlow et al. 1996). Speaker characteristics may also vary across educational level, age and social class. If the aim of an investigation is to compare the intelligibility of several languages, one should select speakers with similar voice characteristics and background. If the design of the experiment allows it, more than one speaker could be used per language variety, so that effects of variability between speakers will average out. If the intelligibility of only two languages is compared in a listening test one could opt for a bilingual speaker to make the stimuli. To be sure that the speaker sounds native in both languages, a voice line-up could be arranged (Hilton et al. submitted).

Subjects

The task performance of human subjects is always somewhat variable. Humans may be influenced by unwanted factors such as motivation to carry out the test task and previous experience with the test language. Also, a certain relationship between attitudes and intelligibility has been found in previous research. The fact that Danes understand Swedish better than Swedes understand Danish, for example, is often explained by less positive attitudes among Swedes towards the Danish language, culture and people than visa versa (Delsing & Lundin Åkesson 2005; Gooskens 2006). Therefore, if researchers wish to test the intelligibility of a language without the influence from attitudes, they may exclude subjects with strong positive or negative attitudes or aim to match the subject-groups so that they have (approximately) the same attitudes towards the test language.

The subjects should be representative for the group of people to be tested as far as educational level, intelligence, age, gender, social class, geography, language background and experience with the test language is concerned. In order to control for these factors it is important to select a well-defined group of subjects, for example an equal number of male and female high school pupils between 17 and 18 years, who are born and raised in a specific place and who have no prior experience with the test language.

To control for all the above-mentioned subject characteristics, an intelligibility test is often accompanied by a questionnaire that the subject has to fill in. Here questions are asked about personal background (age, gender, places of living, language background of the subjects and the parents of the subject, schooling etc.), about the attitude towards the test language (e.g. ‘How beautiful does language X sound on a scale from 1 (beautiful) to 5 (ugly)?’) and experience with the test language (e.g. ‘How often do you hear/speak/read/write language x on a scale from 1 (never) to 5 (every day)?’). The answers to the questionnaires can be used to exclude certain subjects from further analysis because they do not meet all subject criteria.

Task

When designing a listening task to establish the level of intelligibility in a group of people, it is important to take into account the limitations of the task offered. The task can be either too easy or too difficult and both situations should be avoided since they make it difficult or impossible to interpret the results.

If the task is too easy and the subjects answer all questions correctly, this will result in a ceiling effect whereby a measurement cannot take on a value higher than some limit or 'ceiling'. This will make it hard to interpret the results. There are several ways to avoid ceiling effects. The intelligibility of the speech sample can be made more difficult by manipulating the signal by means of filtering or signal compression techniques or by adding noise. Another way to make the task more difficult is to put the subjects under time pressure either by asking them to perform the task as quickly as possible or to give them only a limited amount of time to answer. In addition, reaction time can be measured. This gives a more precise measurement and even though all subjects answer all questions correctly there may still be a difference in the time it takes to correctly comprehend the various stimuli.

It is important to build in a reference condition in the experiment with native speakers listening to their own language as control group to check that the task is not too difficult. It should be kept in mind, however, that even under the most favorable circumstances, native subjects will mostly make mistakes. If the task is too difficult the percentage correct answers may be so low that it is difficult to interpret the results (floor effect). Furthermore, the subjects may get frustrated and decide not to finish the test. The task is for instance too difficult if it does not take the memory limitations of subjects into account. Therefore too complex tasks or too long sentences should be avoided. Also the limitations of the specific subject group should be taken into account (e.g. illiteracy, hearing loss and visual handicaps). For some groups of subjects it may form a hindrance if they have to use the computer to perform the task. In reaction time experiments it should be taken into consideration that right-handed persons generally respond faster to verbal stimuli with their right hand than with their left hand and vice versa for left-handed persons (Rastatter & Gallaher 1982).

Methods for measuring intelligibility

In this section we first present methods for measuring overall intelligibility of complete spoken varieties and give examples of investigations where these methods were used. A major division can be made between investigations where subjects are asked how well they *think* they understand the other language (opinion testing) and investigations testing how well subjects *actually* understand the other language (functional testing). At the end of the section methods are presented for determining the role of single linguistic phenomena for intelligibility.

Intelligibility can be measured at several levels of the linguistic hierarchy from sounds to larger entities like words, sentences and whole texts. When testing overall intelligibility, preference may be given to the text level since this is closer to reality where subjects are mostly confronted with whole messages. However, the word level is very central, since it is the key to speech understanding. As long as the subject correctly recognizes words, he will be able to piece the speaker's message together. By testing isolated words it becomes possible to pinpoint the role of specific sounds for the intelligibility. Therefore some tests are restricted to the word level.

Opinion testing

An easy and efficient way to get a quick impression of the intelligibility of a language is to ask subjects to rate along scale(s) how well they think they understand the language at hand. It may provide a shortcut to functional intelligibility tests and in

addition it provides information about peoples subjective ideas about the intelligibility of languages. The results should be interpreted with some care, however, as a person's reported language behaviour may not be in line with his or her actual language behaviour.

Without speech samples. The simplest kind of opinion testing involves no speech fragments. An example of such an investigation is Haugen (1966). In the first large investigation on the mutual intelligibility between the three closely related Scandinavian languages, Danish, Norwegian and Swedish, he sent questionnaires to three hundred persons in each of the three countries. Three questions explored the informants' opinion concerning the level of mutual comprehension:

1. When you met an X for the first time, how well could you understand him? (not at all - with great difficulty - had to listen intently - all but a few words - understood everything)
2. Do you now understand X speech without difficulty (no - yes - fairly well)
3. When you speak with X, how well do they understand you? (same alternatives as under 1.)

An advantage of this paper-and-pencil method is that no speech material has to be selected. Furthermore, it is possible to abstract from individual speakers who may influence the results because of specific voice characteristics and speaking styles. On the other hand it is uncertain whether respondents are actually able to judge intelligibility without speech samples. They may never or rarely have heard the language or not remember how well they understood the speaker. The consequence may be that the respondents base their opinions on some extra-linguistic factor such as their positive or negative attitudes towards the country and its speakers, political borders, desirable answers or the geographical distance to the place where the language is spoken.

With speech samples. An example of a investigation using speech samples to test intelligibility is Tang & Van Heuven (2007). Recordings of the same text, the fable 'The North Wind and the Sun', in 15 Chinese dialects were presented to 24 subjects from each of the places where the dialects were spoken. For each dialect they were asked to indicate how well they believed monolingual subjects of their own dialect would understand the speaker on a scale from 0 ('They will not understand a word of the speaker') to 10 ('They will understand the other speaker perfectly'). Also with this approach it is uncertain whether subjects are actually able to make the judgments on an objective linguistic basis without being influenced by non-linguistic factors.

Functional testing

Doubting the validity of intelligibility judgments, most researchers prefer to test actual speech comprehension. The disadvantage of this approach is that it is in general difficult to abstract away from individual speakers and test situations. In addition, an effort must be made to avoid priming effects, ceiling effects, too heavy memory load and other unwanted effects. These considerations often make it rather time consuming both to develop suitable tests and to carry out the tests themselves.

Content questions. In order to simulate a test situation that is as close to reality as possible, a number of investigators have tested intelligibility by means of questions about the content of a text. The intelligibility of a language variety is expressed as the mean percentage of correct answers given by the participants chosen for the task.

The questions about the texts must be formulated with great care. They should cover the content of the whole text as well as possible and not measure memory, general knowledge or intelligence of the subject. Correct answers to the questions must also be well-defined. This is not always an easy task and may force the researcher to distinguish between different degrees of correctness, for example 'completely correct', 'partly correct' and 'incorrect'. A more objective solution is to use multiple choice questions where the subject has to choose between a limited number of possible answers. An additional advantage of this method is that the answers can be corrected rather easily, either manually or automatically by computer. A disadvantage of multiple choice questions is that it may be difficult to find distracters that are not too easily excluded by the subjects. Furthermore, the use of multiple choice questions is rather unnatural, since people are mostly not given several possible replies in a natural situation where intelligibility is required.

Translations. Another way of testing the intelligibility of a text is to have the subjects translate it. Intelligibility is then expressed as the percentage of correctly translated words. An advantage of this method compared to content questions is that the researcher does not have to formulate questions about the text which may sometimes be a difficult task (see above). All words in the text count to the same degree even if the text is not completely understood and the general knowledge of the subject only plays a limited role.

For the researcher, it is may be difficult to decide whether translations should be counted as correct or incorrect and the choice may be rather subjective. For example a Danish person may translate Swedish *piga* 'maid' into the Danish cognate *pige* 'girl' that has only a partly overlapping meaning. Furthermore, some subjects may have difficulty translating since for them it not a natural task to perform. The ability to translate appears to involve far more than mere intelligibility and it may draw heavily on the subjects memory. Therefore the text must be presented in short chunks with pauses in between where the subject can write down the translation.

An example of a translation task is Gooskens, Beijering & Heeringa (2008) who tested the intelligibility of the fable 'The North Wind and the Sun' in 18 Nordic language varieties among subjects from Copenhagen. The six sentences of the fable were presented sentence by sentence to the respondents with each sentence in another variety. To avoid learning effects the same respondents should not hear the same sentence twice and since all sentences from the 18 varieties should be presented, a total of 18 groups of respondents were tested. In addition to the intelligibility scores, distances between standard Danish and each of the Nordic language varieties were measured at the lexical level and at different phonetic levels. In order to determine how well these linguistic levels can predict intelligibility, the intelligibility scores were correlated with the linguistic distances and a number of regression analyses were carried out. The results show that for this particular set of closely related language varieties phonetic distances are a better predictor of intelligibility ($r = -.86$) than lexical distances ($r = -.64$). For other language pairs the relative contribution of various linguistic levels may be different.

Another possibility to avoid memory problems is to have the respondents translate a collection of isolated words that is representative for the test language, for

example a random selection or words selected from a frequency list. The correction of the translations may be even more difficult than in the case of whole texts since words may have more meanings when they are presented out of context. Furthermore, respondents often make spelling errors that might make it unclear to the researcher whether the respondent has actually understood the test word.

Kürschner, Gooskens & Van Bezooijen (2008) tested the intelligibility of 384 frequent Swedish words among Danish subjects via the internet. The translations were automatically categorized as right or wrong by the computer through a pattern match with expected answers. The answers which were categorized as wrong were subsequently checked manually by a Danish mother tongue speaker. Responses which deviated from the expected responses due to a mere spelling error were counted as correct identifications. Spelling errors were objectively defined as instances where only one letter had been spelt wrongly without resulting in another existing word. So, for example the mistake in *ærende* (correct *ærinde*) 'errand' is considered a spelling mistake and therefore counted as correct (only one wrong letter without resulting in another existing word), while *aske* (correct *æske* 'box') was not counted as correct because the mistake results in an existing word meaning 'ash'. Some Swedish words have more than one possible translation. For example the Swedish word *brist* 'lack' can be translated into Danish *brist* or *mangel*, both meaning 'lack'. Both translations were counted as correct. In the case of homonyms, both possible translations were accepted as correct. For example, Swedish *här* can be translated correctly into Danish *hær* 'army' or her 'here'. The aim of the investigation was to determine to which degree various linguistic factors contribute to the intelligibility of Swedish words among Danes. The word-intelligibility results were correlated with eleven linguistic factors. The results show that many different linguistic factors may influence intelligibility. The highest correlation was found in the negative correlation between word intelligibility and phonetic distances. Also word length, different number of syllables than in Danish, foreign sounds not present in Danish, neighbourhood density, word frequency, orthography, and the absence of the prosodic phenomenon of 'stød' in Swedish had a significant influence on the level of intelligibility.

The words can be presented in a context where part of the message may be printed out with blanks for selected words only. For example, Van Bezooijen & Van den Berg (1999) played semi-spontaneous samples of various Dutch varieties to different groups of subjects from The Netherlands and Belgium. The texts were written down in Standard Dutch but the nouns were replaced by dotted lines of the same length. The subjects were asked to write the missing words on the lines while listening to the recordings. There were considerable differences in intelligibility among the tested varieties and intelligibility depended to some extent on the geographic background of the listeners. An advantage of this test type is that it is easy to make sure that the correct translation is given. However, this approach makes it uncertain which role the (written) context plays in the interpretation of the words.

To make it easier to correct the responses, multiple choice tests are often used in which respondents are asked to select the best possible translation out of the choices from a list. It is difficult to construct such a test, since the choice of distracters determines how difficult the test is and it is often not possible to select the same distracters in more languages. To solve this problem, Tang & Van Heuven (2009) determined word-intelligibility by having subjects perform a semantic categorization task whereby words had to be classified as one of ten different pre-given semantic categories such as 'body part', 'plant', 'animal', etc. For instance, if the subject hears the word for 'apple', s/he should categorize it as a member of the category 'fruit'.

Here, the assumption is that correct categorization can only be achieved if the subject correctly recognizes the target words. Since there are as many as ten semantic categories, the role of guessing is negligible. It is a disadvantage of this method that only words from predefined categories can be tested.

Van Heuven & Van Bezooijen (1995) provide an overview of methods for quality evaluation of synthesized speech. Here it is mostly tested how well subjects understand synthesized speech in their own native language. We will discuss two of the translation tasks that have also been used for testing the intelligibility of natural languages. The advantage of these methods in comparison with the translation task mentioned above is that the test words are presented in a controlled spoken context. The results are easy to score by hand or automatically. The tests are easy to adapt to new test languages but the number of words that can be tested in one test session is more limited that in the case of isolated words.

A set of semantically unpredictable sentences (SUS) were compiled by Benoit, Grice & Hazan (1996). These sentences consisted of five different, common syntactic structures with words randomly selected from lexicons with frequent, 'mini-syllabic' words (smallest words available in a given category). The SUS-sentences can be automatically generated using five basic syntactic structures and a number of lexicons containing the most frequently occurring short words in each language. The syntactic structures are simple and the sentence length does not exceed seven words (eight for English because of the auxiliary in questions) in order to avoid saturation of the subjects' short-term memory. The sentences have normal word order and prosody but do not permit the subject to predict the identity of content words from sentence semantics or situational context. For example, in a semantically anomalous sentence such as *He drank the wall* the syntactic structure is correct. Subjects receive cues as to syntactic category only but other than that they will not be able to make any further predictions about word identity by means of semantic or syntactic contextual cues. Since words are tested in different positions in the sentence, word segmentation is an essential feature assessed by this test. Intelligibility can be expressed as the percentage correctly translated (content) words, but the simplest and fastest way to score results is to only take into account the sentences that are entirely correctly translated. This easy-to-obtain score is strongly related to word score. Gooskens et al. (in press) presented Danish and Swedish SUS-sentences to Danish and Swedish subjects in order to test the mutual intelligibility as well as the intrinsic intelligibility of the two languages.

The SPIN-test (Speech Perception in Noise) is a list of sentences that test word intelligibility (Kalikow, Stevens & Elliot 1977). The subject translates only the last word in a number of short spoken sentences. Since the position of the target word is pre-given, word segmentation problems are minimal. There are two types of materials in the SPIN test. One type presents target words that are highly predictable from the earlier context as in *He wore his broken arm in a <u>sling</u>* (target underlined). The other type presents words that are not predictable from the context, as in *We could have discussed the <u>dust</u>*. Wang (2007) showed that the high predictability part of the SPIN test was more sensitive to differences between speaker and subject groups with different degrees of listening comprehension in English than the low predictability part. The test is easy to adapt to new test languages and but the number of words that can be tested in one test session is more limited that in the case of isolated words.

Recorded text testing. A special problem arises when a researcher wants to test the mutual intelligibility of languages that he does not master himself. For such a situation the recorded text testing (RTT) method has been developed. This method was first used in the fifties to establish the mutual intelligibility of American Indian languages (Voegelin & Harris 1951; Hickerton, Turner & Hickerton 1952; Pierce 1952). Casad (1974) and Nahhas (2006) give detailed overviews of the steps that should be taken to carry out a test with RTT. The standard method uses a short text recorded from a speaker of the speech variety to be tested. The subject hears the text, with questions in his own mother tongue about the text interspersed following the portion which contains the answer to the question. The subjects are required to answer these questions.

An alternative approach to the standard RTT question format is the RTT retelling method that requires subjects to listen to a narrative that has been broken down into natural segments of one or two sentences each and to retell the recorded text, segment by segment, in their L1 (see Kluge 2007). In this way the subjects do not have to answer specific comprehension questions. For each segment the number of correctly retold core elements are counted and the segment scores are added up to obtain the overall score for a given RTT text.

The main advantage of the RTT retelling method, when compared to the standard RTT question method, is the fact that comprehension of an entire text is tested, rather than that of selected sections only. A second major advantage is that in many more traditional societies, retelling a story is more appropriate and less threatening than answering questions. An additional advantage is that this method does not require the design of comprehension questions and the translation of these questions into the speech varieties of the communities under investigation. The most important disadvantage is that it is very time consuming both to develop the test and to count the number of correctly retold segments.

Reaction times. In cases where the test language is very similar to the language of the subjects, an off-line intelligibility task where responses are to be given after subjects heard test passages, may be so easy that most answers are correct, resulting in a ceiling effect. There is a need, therefore, to use more sensitive testing procedures. Reaction time is a possible response measure that might improve the sensitivity of an intelligibility test. The assumption is that the faster the subjects react, the better the intelligibility. To ensure the credibility of the experiment, the lexical decision task needs to be followed by a second meaning-identifying task.

Reaction time can be measured by means of software applications that measure temporally accurately to within a few milliseconds. It registers when a subject performs a certain action, for example a vocal response, pressing a button on the computer keyboard or touching the computer screen, which makes it suitable for various groups of test subjects, including children. Response times cannot be measured precisely via the internet and therefore this method is not suitable for web-based experiments.

Various tasks can be used to measure overall intelligibility using reaction times. In a sentence-by-sentence listening task subjects listen to sentences and push a button whenever they are ready for hearing the next sentence (e.g. Ralston et al. 1991). Comprehension is checked afterwards. In a sentence verification test (e.g. James et al. 1994), subjects decide whether short sentences are true statements or not (e.g. *Mud is dirty* and *Rockets move slowly*). Impe (2010) used a lexical decision task where the subjects had to decide as quickly as possible - by means of pushing a 'yes- or no-

button' - whether the stimuli (200 existing and as many non-existing words in 10 Dutch language varieties) were meaningless or meaningful Dutch words.

Observations. It can be argued that by its very nature intelligibility is a quality that cannot easily lend itself to quantitative measurement. Probably it is possible to achieve certain pragmatic communicative goals even with a low degree of understanding. Comprehension depends on interactive cooperation, something that does not emerge in artificial test situations. Comprehension may be better in its natural context than in an artificial one because a specific setting reduces the number of possible interpretations. Börestam Uhlmann (1994) taped some thirty inter-Scandinavian arranged conversations between Danes, Norwegians and Swedes aged 18-25 who were unaccustomed to the others' languages. She was first of all interested in which kind of strategies the participants used to improve mutual intelligibility, such as rephrasing, elaborate explanation, use of English, repairing and interruptions, either to clarify something or to make certain that the message had been correctly understood. Her analysis of the result is mainly qualitative, but she also showed that it is possible to quantify the results by for example counting the number of reparations and misunderstandings. Zeevaert (2004), observed real Nordic meetings and made a quantitative analysis of turn taking as well as length and frequency of pauses.

A disadvantage of this approach is that speakers and subjects are well able to conceal misunderstandings and to adapt their language to the conversational partner so that it may be difficult to express exactly how well the speakers understand each other. It also asks for a large effort from the researcher because he has to make a detailed analysis of the conversation.

Performance task. A way of simulating a natural communicative situation is a performance task. For example, Van Heuven & De Vries (1981) tested the intelligibility of various versions of foreign-accented speech by means of a performance task. Dutch subjects listened to recordings of Dutch accented utterances produced by a Turkish speaker who was asked to describe a number of simple actions (e.g. someone puts a spoon in a glass). The subjects were asked to perform the actions described by the speaker as quickly as possible. The mean reaction time of the correctly performed actions was the measure of intelligibility. The aim of the investigation was to investigate the role of phonic and non-phonic factors in the intelligibility of foreign accented speech through an experimental approach. The results showed that phonic factors are more important than non-phonic factors. This is the same result that was later found for Danish listeners' comprehension of Norwegian syntactic and phonological features (Hilton, Gooskens & Schuppert submitted).

The advantage of this method is that it measures a intelligibility in a communicative situation. However, the fact that the subjects have to perform the actions described limits the variation in syntactic constructions and words that can be included.

Testing with the aim of determining the role of linguistic factors

So far methods for measuring intelligibility have been discussed that can be used to measure overall intelligibility, i.e. languages as a whole. However, sometimes the aim of intelligibility testing is to assess the contribution of single linguistic phenomena to

intelligibility. For example, very little is known as yet on the specific contributions of single sounds to overall intelligibility.

One approach when aiming at identifying specific factors that influence intelligibility is an error analysis on the test results. For example, Kürschner at al. (2008) carried out correlations and logistic regression analyses with the results of an experiment on the intelligibility of 384 Swedish words among Danes as the dependent variable and eleven linguistic factors that have been found to contribute to L1 intelligibility in earlier studies as independent variables. In this way they could make conclusions about the relative importance of these for intelligibility. Phonetic distance turned out to be the most important predictor of intelligibility followed by word length.

Another way of investigating the role of specific linguistic factors is the experimental method. By keeping the effects of all factors but one constant, and systematically varying the characteristics of the latter, any difference in intelligibility must be caused by the variations in the target module. If, for example, we wish to test the hypothesis that Danish is poorly understood by Swedes due to the presence of *stød* (a voice characteristic creating phonological contrasts not present in Swedish), we can remove the *stød* from recordings of Danish. If Swedes understand the manipulated version better than the original version, *stød* must be causally related to the intelligibility of Danish.

If diagnostic testing is used to investigate the role of specific sounds, the most purposeful approach is to test intelligibility of isolated words, since at sentence level or higher levels poor intelligibility is difficult to trace back to specific sources. If the words are presented in a sentence, the context or the situational redundancy is likely to make up for poor intelligibility.

Various diagnostic tests can be used to pinpoint linguistic factors that influence intelligibility. These factors may be found at all linguistic levels (segmental, prosodic, morphological and syntactic). Many of the functional tests that have been discussed in the previous section may also be used for diagnostic purposed in adapted forms and they are connected to the same advantages and disadvantages.

The results of investigations of the relative importance of various linguistic factors for the intelligibility may be used to develop a model of intelligibility. As we have seen, intelligibility tests involving human subjects is often labour-intensive and involves many considerations. It also yields noisy data. It would therefore be helpful if we had an objective way of predicting intelligibility that would not involve actual testing. Since languages differ in many dimensions such as sound inventories, prosody, vocabularies, morphology and syntax, such a measure would involve linguistic distance measurements at different linguistic levels. However, we still lack information about how to weigh these dimension in order to develop a measure that can predict intelligibility. If for example word order differences hardly compromise the communication between speakers of two languages while small differences between the sound systems make the mutual intelligibility difficult, then differences in phonology must be weighted much more in the computation of the linguistic distance than syntax. So far, no complete model of intelligibility exists, but Gooskens et al. (2008) have shown that at an aggregate level phonetic distances measured by means of the Levenshtein algorithm (Heeringa 2004) in combination with lexical distances expressed as the percentage of non-cognates (historically non-related words) can predict intelligibility to a large extent (.81 percent explained variance). Morpho-syntax may also play a role in the intelligibility though to a smaller degree than phonology (Hilton et al. submitted). A refined model may improve the predictive

power, but it should be realized that non-linguistic factors such as attitudes and previous experience may also play an important role.

Comparing methods

In the preceding section a number of methods for measuring intelligibility have been presented. Unfortunately, it is not possible to give an answer to the questions which methods is best. The choice of the method to be used in an investigation depends on a large number of practical factors such as time and funds available and the background of the subjects. Even with sufficient time and money and subjects who are able and patient enough to undergo complicated and lengthy tests, the choice of method still depends on the precise aim of the investigation.

But apart from these considerations, does it still matter which method is used? In order to shed some more light on this point we need to know whether the same persons who achieve high scores in one test also achieve high scores in another test when all other factors are kept constant. A few researchers compared the results of different methods of measuring intelligibility. These comparisons are valuable because they give an impression of the importance of choosing a specific method. Doetjes (2007) investigated the effect of six different test types on the measurement of the intelligibility of Swedish among Danes. The same text was tested in six different test conditions: true/false questions, multiple choice questions, open questions, word translation, summary and short summary. The percentages of correct answers decreased from 93.0% for the true/false questions to 66.2% for the short summaries. This shows that at this point in time it is not possible to give an absolute answer to the questions how well subjects understand a language and caution should be taken when comparing results from different investigations. When comparing various previous investigations on Swedish-Danish mutual intelligibility, for example, we see very different results, probably due to the use of different texts and tasks and the different backgrounds of the subjects. However, it is notable that Danes for example always have higher scores on the Swedish intelligibility tests than vice versa. This indicates that it may not be possible to express how well a language is understood in an absolute sense, but that it may be possible to compare the relative intelligibility of various languages as long as the test conditions are kept as constant as possible.

Maurud (1976) tested mutual intelligibility between the Scandinavian languages by means of word tests and content tests on the same texts. He found correlations between the test results between r =.6 and .8 for various groups of subjects. Tang & Van Heuven (2009) tested the mutual intelligibility of 15 Chinese dialects by means of functional intelligibility tests at word and sentence level and compared these with each other and with opinion scores and objective distance scores at the lexical and the phonological level. They found correlation between the opinion scores and the functional scores between r = .7 and .8. The same results were found for correlations between functional and opinion tests on the one hand and objective measurements on the other hand. The authors conclude that mutual intelligibility should preferably be tested by means of functional sentence intelligibility tests. The correlation between word-intelligibility and sentence intelligibility was very high (r =.9) but sentence intelligibility reflected traditional Chinese taxonomy better than word intelligibility does. So, comparisons of various tests show rather high correlations, but still a large amount of unexplained variance is left. Even though there is a large overlap, different tests measure different aspects of intelligibility.

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