French adaptation of the "Frenchay Dysarthria Assessment 2" speech intelligibility test

Alain Ghio, Laurence Giusti, Emilie Blanc, Serge Pinto

French adaptation of the "Frenchay Dysarthria Assessment 2" speech intelligibility test

Alain Ghio*, Laurence Giusti, Emilie Blanc, Serge Pinto

Aix-Marseille Univ, CNRS, LPL, Aix-en-Provence, France

*Corresponding author:

email: alain.ghio@lpl-aix.fr
Alain Ghio
Aix-Marseille Univ, CNRS
Laboratoire Parole & Langage
5 Avenue Pasteur
BP 80975
13604 Aix en Provence Cedex 1
France
Tel.: +33 (0)4 13 55 36 30
website: www.lpl-aix.fr/~ghio

Abstract

Objectives: Speech intelligibility can be defined as “the degree to which a speaker’s intended message is recovered by a listener”. Loss of intelligibility is one of the most frequent complaints in patients suffering from speech disorder, impairing communication. Measurement of intelligibility is therefore an important parameter in follow-up. We developed a French version of the "Frenchay Dysarthria Assessment, 2nd edition" (FDA-2), an intelligibility test recognized internationally in its English version. The present study details the construction of the test and its preliminary validation.

Materials and Methods: We first compiled a set of words and phrases in French, based on the criteria defined in FDA-2. In a second step, we validated the test in healthy subjects in normal and noisy conditions, to check sensitivity to speech signal degradation.

Results: The test proved valid and sensitive, as scores were significantly lower for noise-degraded stimuli.

Conclusion: This French-language intelligibility test can be used to evaluate speech disorder: for example, in dysarthria, head and neck cancer or after cochlear implantation.

Key-words: Speech Intelligibility; Speech Disorder; Dysarthria; Head and Neck Cancer; Speech Production Measurement

Introduction

In functional assessment of patients with speech disorder, intelligibility is a key parameter in, for example, dysarthria [1], head and neck cancer [2] or speech production after cochlear implantation. Speech disorders frequently impair quality of life in terms of communication, and may lead to social isolation [3]. Several speech perception assessment instruments are available to measure the severity of speech production disorder. Some apply to spontaneous speech, assessing comprehensibility: i.e., a listener's ability to interpret the meaning of an oral message produced by a speaker, without focusing on phonetic or lexical precision [4]. Intelligibility is defined more precisely as "the *degree* to which the speaker's intended *message* is recovered by the *listener* "[1]. Global intelligibility can be assessed on a predefined scale, such as the French *Batterie d'Evaluation Clinique de la Dysarthrie* (BECD) [5] for conversation, or the Nottingham SIR (Speech Intelligibility Rating) [6], which ranges from 1 (unintelligible) to 5 (intelligible for all listeners). Less globally and more analytically, the patient can be asked to read a list of words or phrases, and the examiner writes down what he or she has understood; the transcription is compared against the original list, and a score is calculated as the percentage of correctly understood items. In clinical consultation, there is usually just one examiner, but juries may be used for research purposes [7, 8].

In French, there are several lists, such as those of Lafon[1], Fournier[2] and Combescure[3], but these are more adapted for hearing loss. Peckels & Rossi's minimal pairs diagnostic test [9] is one of the oldest and most successful, but is little used clinically as it requires producing 216 words, which is too much for a patient with speech disorder. Kent et al.'s Single Word Intelligibility Test [10] was adapted and translated into French by Gentil [11] and later used by Auzou for the BECD [12] and by Crochemore & Vannier [13] for their *Test Phonétique d'Intelligibilité de la Batterie d'Evaluation Clinique de la Dysarthrie* (BECD) [5]. This is a standardized instrument widely used in France to assess dysarthria as a whole, and includes a fairly short intelligibility test involving production of 10 isolated words and 10 short phrases, directly adapted from the English-language Frenchay Dysarthria Assessment [14]. It is quick to administer, and provides an intelligibility score at almost the same time as the task is being performed, for which reason it is widely used in France. Regarding the words and phrases, however, this initial version had several limitations:

[1] www.college-nat-audio.fr/fichiers/img85a.pdf
[2] www.college-nat-audio.fr/fichiers/img91a.pdf
[3] www.college-nat-audio.fr/fichiers/img92a.pdf

1. Word frequency is not controlled: some words, such as "*grand*" ("big") or "*peur*" ("fear"), have high frequency and are therefore easier to understand than some rarer words, such as "*croche*" ("quaver") or "*clenche*" ("latch"), that may be harder to decode. Random extraction from the full list can thus give rise to easy or difficult working lists that are not at all equivalent and lead to non-reproducible results.

2. Spelling is not controlled: some words, such as "*paon*" ("peacock") or "thym" ("thyme") have irregular spellings; being moreover low-frequency, their spelling is liable to give rise to misreading, which needs to be avoided so that this is not counted as misarticulation.

3. Phonetics is not controlled: some words are clearly presented in quasi-minimal pairs, such as "*caché*", "*café*", "*cassé*", "*calé*", "*carré*", whereas "*boxeur*", for example, has no opposite number except "*docteur*", which is its closest relation. Moreover, the most frequent phonemes in French do not come in initial position: for example, [r], [v] or [l]. And finally, "*mouche*" is the only word containing the phoneme [u].

4. Phrases are repetitive, such "*l'enfant* ("the child") + verb": the listener's attention is quickly drawn exclusively to the verb, in what has become an isolated word recognition task, despite the intention of the test.

5. The corpus comprises 50 words and 50 phrases, which leads to a learning bias in examiners who use them on a regular basis.

A revised form of the test was produced in English: the FDA-2 [15]. We therefore aimed to adapt this intelligibility test to the French language, including the improvements made in version 2, while taking account of the specificities of French: a simple word-for-word translation would have made no sense. Firstly, then, the structure of the test was analyzed to disclose the criteria, which were then adapted for the French language.

French adaptation of the word list

Overall, the words used are frequent, with variable but controlled phonetic structure (target consonants in initial, middle or final place), and of varied grammatical type (nouns, adjectives, verbs).

Linguistic criteria of the English word list

Lexical frequency

The first selection criterion for words for the new FDA-2 corpus is lexical frequency: how often they figure in the language. The selected words all have a minimum frequency of 10 per million, according to Leech's database [16] taken from the British National Corpus.

This is an important improvement: in version 1 [5, 14], some words were rare and others frequent. In French, for example, "*clenche*" and "*croche*" have frequencies of less than 1 per million, whereas "*grand*" and "*peur*" have frequencies greater than 300 per million. Frequent words are known to be easier to recognize, and the list was not homogeneous in this regard, which has been corrected in version 2.

Phonetic structure

The phonetic structure of the words in the English corpus was analyzed, and formalized in the following manner:

Articulation site	Target phoneme	In initial position	In middle position	In final position	3-syllable	4-syllable
Bilabial	p	**p**et	peo**p**le	ma**p**	**p**assenger	**p**opulation
	b	**b**ig	ru**bb**ish	ca**b**	**b**eautiful	**b**ureaucracy

- Each English consonant occurs in initial (e.g., **p**et), middle (e.g., peo**p**le) and final (e.g., ma**p**) position in the short 1- or 2-syllale words,

- and in initial position in long words (e.g., **p**assenger, **p**opulation).

In this way, the authors had a total 116 words in English.

Grammatical types

In version 2, a word may be not only a noun but also an adjective or verb.

Application and adaptation of criteria for French

The new French word list used the on-line *lexique-3* application (www.lexique.org), controlling for:

- frequency: >10 per million;
- initial/middle/final position of consonants, with reference phonemes using all French consonants and the groups most frequently found in initial position;

- lists with 1-, 2-, 3- and 4-syllable words.

We also added other criteria for our corpus:

- A variety of vowels associated to the target consonants, to limit the risk of the examiner identifying the word just from the vowel, as he or she quickly becomes familiar with the words in the list. For example, in BECD version [5], "*mouche*" is the only word in the list featuring the phoneme [u].
- In long words, as late as possible a uniqueness point: i.e., the point at which one word becomes distinct from another. Thus, for example, "*vérité*" ("truth") is only distinguishable from "*véridique*" or "*véritable*" ("true") on the 3rd syllable.

Table 1 presents the full list of 101 words.

Table 1 about here

Adaptation of the phrase list for French

Overall, the selected phrases are non-repetitive, with varied morphosyntactic structure, varying tenses and modes, and including target words with variable but controlled phonetic structure.

Linguistic criteria for the English phrase list

The phrase corpus comprises 50 short phrases. E.g.:

Articulation site	Target phoneme	In initial position	In final position
Bilabial	p	You have to **pay** The front **porch**	Where's the **map**?
	b	Go to bed Where were you **born**?	Go and get a **cab**

Morphosyntactic structure

In version 1 [5], phrases were carrying phrases in which only the last word (always a verb) varied: e.g., "*L'enfant abrite*" ("The child shelters"), "*L'enfant dicte*" ("The child dictates"), "*L'enfant fraude*" (The child cheats"). In version 2, morphosyntactic structure has been changed completely: beginnings vary, and not all phrases include a verb.

Modes and tenses

Modes and tenses have also been diversified: sentences are not always indicative and tenses are not always simple present.

Target words

All phrases include a target word, although we do not know whether frequency was controlled. Some were also to be found in the word corpus, although with no apparent logic. On analysis, the targets words in the phrases met the same phonetic criteria as in the word list, with the same consonants and semi-vowels as target phonemes. The consonant groups, however, were not found, and the use of the target phonemes was not quite the same as in the word list: each appeared 3 times, twice in initial and once in final position.

Phrase beginnings

The more diverse beginnings and morphosyntactic structures make the phrases less predictable. The speaker's intelligibility is thus better tested than in the old version, where the listener had just to recognize a verb in the present tense.

Application and adaptation of criteria for French

Modes and tenses

Following the FDA-2 criteria, we diversified modes and tenses, unlike in the original test which used only the present indicative. Morphosyntactic structures are thus now varied. The corpus comprises 10 interrogative, 6 exclamatory, 10 imperative and 25 indicative sentences.

Phonetic distribution

Like in the FDA-2, our target-words follow a coherent phonetic distribution, with each consonant occurring in both initial and final position. Unlike in the word corpus, consonant groups were not included as target phonemes in the phrase corpus.

Supplementary criteria

We introduced certain criteria in addition to those of the FDA-2.

- Occurrence frequency: we selected target words with frequency >10/million, as in the word corpus.

- Choice of words: we selected target words not already in the word corpus, unlike in the FDA-2.

- Predictability: we sought to reduce phrase predictability by using each beginning twice, followed by grammatically different structures, such as a verb and a noun: "*Je ne veux pas changer*" ("I don't want to change"), and "*Je ne veux pas de thé*" ("I don't want tea"). The 51 phrases included 25 different beginnings (1 being used 3 times).

Table 2 presents the complete phrase list.

Table 2 around here

Material and methods

As the present test is under development, its intrinsic validity needed assessing: i.e., sensitivity and specificity. The specificity of the test is its capacity to isolate speakers with speech disorder; control subjects should therefore present good intelligibility. Sensitivity is the capacity to detect all speakers with speech disorder; subjects with speech impairment should therefore present low scores. Using groups of individuals already known to have or not have speech disorder, assessed against a gold standard, enables assessment of the test's capacity to predict dysfunction.

The procedure risks becoming circular if no gold standard is clearly defined, as is the case in speech disorder assessment, where objective criteria are lacking [17]. How can a new instrument be calibrated if the actual samples are ill-defined?

We therefore used a speech-in-noise experimental paradigm, as recommended elsewhere [18,19,20]. Test validity could thus be assessed using artificially degraded speech, enabling objective control of the degree of degradation and avoiding the statistical problems of speech disorder severity in controlling speech signal quality [19].

Borie et al. [20] examined the relation between speech processing in noise (signal degradation) and dysarthric speech (source degradation) in terms of intelligibility performance, and concluded that intelligibility performance for speech in noise correlates with intelligibility performance for dysarthric speech, suggesting similar cognitive-perceptual processing mechanisms.

List validation therefore used control speakers in normal and in degraded conditions to assess sensitivity to this difference.

Before recording or perception testing, all participants were informed of the aim of the research, and signed an informed consent form.

Speakers

Fifty native French speakers, free of ENT or neurologic issues, were recruited; 25 male, 25 female; mean age, 56±26 years (range, 19-89 years). Following the FDA-2 protocol, each speaker pronounced 10 words taken randomly from the list shown in Table 1 and 10 phrases taken randomly from the list in Table 2. Words and then phrases were presented sequentially on a computer screen. Readers were recorded in the Speech Experimentation Center (www.lpl-aix.fr/~cep) by an EVA2 device with AKG C1000S microphone. Phonédit software (www.lpl-aix.fr/~lpldev/phonedit) was used to splice each recording to isolate each word/phrase. These isolated stimuli were then extracted as audio files. Crest normalization was performed, applying constant gain throughout the signal on each recording by adjusting the maximal amplitude to a target of 90% of the signal dynamic (16 bits); in this way, all stimuli were at the same intensity level.

Speech samples

To check sensitivity to signal degradation, degraded speech samples were produced. There are several ways of doing this: adding white noise, colored (pink, brown) noise, speech-spectrum noise, or non-stationary cocktail-party noise. We chose to use white noise, known to degrade speech communication [21], based on uniform spectrum degradation (without a-priori). Signal-to-noise ratio was set at 1.66, corresponding to 4.4 dB, as this gave pretest scores of 40-60% correct word identification: i.e., intelligibility level of severe dysarthria (BECD [5]).

Sample perception assessment

A jury of 18 naïve listeners transcribed these stimuli, to validate the test on 2 hypotheses:

- >90% intelligibility for healthy listeners, according to the FDA-2 validation data in English;
- significantly lower scores for degraded stimuli.

Each stimulus (normal and noise-degraded) was heard by 3 listeners, to enhance reliability; The experimental material thus comprised 2 series (words, phrases) of 1,000 stimuli (50 speakers x 10 items * 2 conditions) for 3 listeners: i.e., 6,000 perception tests. Items and blocks were randomized to avoid listing bias; also, a given listener did not receive the same stimulus under both normal and noise-degraded conditions, to circumvent memory bias.

The perception tests were conducted in the Speech Experimentation Center on the multi-post perception station (http://www.lpl-aix.fr/~cep/fiches_instruments/

Fiche_instrument_TestsPercept_2016.pdf). The listener, wearing Sennheiser HD 415 phonic headphones, transcribed on the computer a mean 335 stimuli (words and phrases), using Perceval-Lancelot software [22] (www.*lpl-aix.fr/~lpldev/perceval*). Presentation intensity was preset by the listener to be comfortable and optimal for the task. Stimuli were repeated until the selected level was obtained. All stimuli, normal and degraded, were presented under the same conditions. Each item was presented once only, as the experimental conditions ensured good listening quality; a second hearing would not correspond to the ecological situation of an on-line intelligibility test. The listener wrote what he or she understood, even if this was only a few words in the case of phrases. If nothing was understood, the listener validated the item without writing anything.

Transcriptions were compared manually to the target word or phrase and scored as correctly or incorrectly understood. A speaker's intelligibility was represented by the number of items correctly transcribed, divided by the total number of item tested: perfect intelligibility would score 1, and total unintelligibility 0.

Results

Statistical analysis used R 3.4.2 software (www.r-project.org*)*.

In the normal condition, speakers' mean intelligibility for words was 0.960±0.087, versus 0.557±0.198 in noise (significant difference on non-parametric Wilcoxon-Mann-Whitney test; $p < 0.001$).

Intelligibility in noise calculated per word rather than by speaker increased with increasing word length (Figure 1): 0.39 for 1-syllable words, 0.47 for 1-syllable words with final schwa ("e"), 0.58 for 2-syllable words, 0.68 for 3-syllable words, and 0.83 for 4-syllable words. Scores according to word length in noise showed normal distribution (Shapiro-Wilks test; $p > 0.1$) with equivalent variances (Bartlett test; $p > 0.1$). Differences between groups (normal vs. noise) were significant ($p < 0.01$).

FIGURE 1 about here

In the normal condition, speakers' mean intelligibility for phrases was 0.978±0.037, versus 0.667±0.202 in noise (significant difference on non-parametric Wilcoxon-Mann-Whitney test; $p < 0.001$).

Discussion

The results confirmed the two study hypotheses: words and phrases were understood more than 95% of the time in normal conditions with normal speakers; and the corpuses were sensitive to signal degradation, with significantly lower scores under white noise, with 54% intelligibility for words, and 67% for phrases. Perceptual analysis thus confirmed test validity for control subjects.

Phrases showed better intelligibility than words, in both normal and degraded conditions. This was due to a quantity effect: as shown by Samuel [23] for phonemic restoration, more words, and thus more lexical information, provide more indices for the listener. Likewise, longer words were better understood. Using long words in an intelligibility test may be questioned, but diminished intelligibility for long words may reveal certain speech dysfunctions such as pneumo-phonatory malcoordination. Intelligibility should therefore be tested for both short and long words.

Analysis of results per word showed strong differences. For example, "*cri*" ("cry") and "*rue*" ("street") showed low intelligibility in the normal condition (respectively 67% and 75%); in noise, "*cri*" was unintelligible, and "*rue*" scored 39%. In contrast, "*fleur*" ("flower), "*amour*" ("love"), "*débarrasser*" ("clear"), "*décider*" ("decide"), "*population*" ("population") and "*téléphone*" ("telephone") showed 100% intelligibility in both normal and degraded conditions, successfully resisting signal degradation. For phrases, "*Où est cette île ?*" ("Where is this island?") was significantly less intelligible than other phrases, in both normal (77%) and degraded condition (18%), all others scoring ≥89% in normal condition and ≥31% in noise. Even so, these items scoring particularly low or high were not eliminated: the corpus is to be taken as a whole, with varying ease of understanding. It is rather the administration modalities that should be reconsidered, to avoid randomly presenting a series of "easy" or "difficult" items. We would advise, for example, reading 3 rather than just 1 list of 10 words/phrases and count the one with the intermediate score, so as to be more representative of diminished intelligibility. This, however, would increase administration time, and patient fatigue needs allowing for; a compromise has to be struck between exhaustive exploration and examination duration [24].

In our experience, words and phrases become better transcribed later in the test. There may be two reasons for this. The listener may develop a certain expertise during the exercise, getting increasingly better at restoring degraded messages. Or there may be a real learning effect over time: the same words, pronounced by different speakers, keep coming back and the listener

may come to recognize them as being part of the corpus, improving identification, even in noise. This improvement in intelligibility over time clearly shows the clinical problem of the therapist's habituation to the test.

In compiling the corpus of words and phrases some potentially useful options, such as including a larger number of items, were discarded in order to adhere to the principles of the original test and conserve the homogeneity required for international harmonization, as the original version is adapted and used in a large number of countries, not only in speech therapy practice but also for international research [25].

Conclusion

The present study aimed to precisely describe the French adaptation of the FDA2 intelligibility test, explain the choices made, present the lists and perform a preliminary validation. The objective was validated by testing in healthy subjects in normal and degraded situation. Scores plateaued in the control situation and were sensitive to speech degradation. This was induced artificially, by adding noise to normal speech, enabling initial validation and the requisite calibration. This procedure is not intended to replace true calibration on speech disordered subjects (head and neck cancer, dysarthria), which will be essential for complete validation.

Analysis of results inspired two suggestions for administration of this test:

- randomize within categories (7 short, 3 long words);

- administer 3 lists of 10 items and adopt the intermediate score.

Even so, an intelligibility test should ideally be based on a very large corpus, to circumvent the listener learning effect, but this would involve methodological requirements different from those of the work presented here. After validation, this intelligibility test adapted from the revised Frenchay Dysarthria Assessment 2 will be available in open access. In the spirit of open science, the lists are without copyright, and can be copied. A computerized version would also be worth developing.

Acknowledgments

The authors thank the CEP staff (www.lpl-aix.fr/~cep), and Carine André in particular, for conducting the perception tests.

Conflicts of interest

None

Références

1. Kent R. Intelligibility in speech disorders. Amsterdam/Philadelphia. John Benjamins. 1992.
2. Meyer TK, Kuhn JC, Campbell BH, Marbella AM, Myers KB, Layde PM. Speech intelligibility and quality of life in head and neck cancer survivors. Laryngoscope. 2004 Nov;114(11):1977-81
3. Fogle P.T., Essentials of Communication Sciences and Disorders, Jones & Bartlett Learning, 2nd edition, 2017 - 512 pages
4. Woisard V., Espesser R., Ghio A., Duez D. De l'intelligibilité à la compréhensibilité de la parole, quelles mesures en pratique clinique ? Revue de laryngologie, otologie, rhinologie, vol. 1, no. 134. 2013, p. 27-33.
5. Auzou P, Rolland-Monnoury V. *Batterie d'Evaluation Clinique de la Dysarthrie*. 1st ed. Isbergues: Ortho Edition; 2006.
6. Cox R.M., McDaniel D.M., Development of the Speech Intelligibility Rating (SIR) test for hearing aid comparisons, J Speech Hear Res. 32 (1989) 347–352.
7. Hustad K.C., The Relationship Between Listener Comprehension and Intelligibility Scores for Speakers With Dysarthria, Journal of Speech Language and Hearing Research. 51 (2008) 562. doi:10.1044/1092-4388(2008/040).
8. Walshe M., Miller N., Leahy M., Murray A., Intelligibility of dysarthric speech: perceptions of speakers and listeners, International Journal of Language & Communication Disorders. 43 (2008) 633–648. doi:10.1080/13682820801887117.
9. Peckels J, Rossi M. Le Test de diagnostic par paires minimales : adaptation au français du Diagnostic Rhyme Test de Voiers. Revue d'acoustique; 1973, 27:245-262.
10. Kent RD, Weismer G, Kent JF, Rosenbek JC. Toward phonetic intelligibility testing in dysarthria. J Speech Hear Disord. 1989, 54(4):482-499.
11. Gentil M. Phonetic intelligibility testing in dysarthria for the use of French language clinicians. Clin Linguist Phon. 1992;6(3):179-189.
12. Auzou P, Ozsancak C, Jan M, et al. Evaluation clinique de la dysarthrie : présentation et validation d'une méthode. Rev Neurol (Paris). 1998;154(6-7):523-530.
13. Crochemore E, Vannier F. (2001) Analyse phonétique de la parole dysarthrique. In : Les Dysarthries. Auzou P., Özsancak C., Brun V. (Eds) Masson, Paris,: 71-82
14. Enderby P. *Frenchay Dysarthria Assessment*. 1st ed. San Diego: College-Hill Press; 1983.

15. Enderby P, Palmer R. (2008) FDA-2: Frenchay Dysarthria Assessment. 2nd ed.Tex.: Pro-Ed.
16. Leech G, Rayson P, Wilson A. Word Frequencies in written and spoken English: based on the British National Corpus., Longman, Harlow, 2001.
17. Weismer, Gary. 2006. Motor Speech Disorders: Essays for Ray Kent. 1 edition. San Diego: Plural Publishing Inc.
18. Megan Mcauliffe, Martina SchaeferM, Greg A O'Beirne, Leonard Lapointe, Effect of noise upon the perception of speech intelligibility in dysarthria, Poster presented at the American Speech-Language and Hearing Association Convention, New Orleans, LA, US, pp. 18-21 nov 2009, https://ir.canterbury.ac.nz/handle/10092/3410
19. Fontan L, Tardieu J, Gaillard P, Woisard V, Ruiz R., Relationship Between Speech Intelligibility and Speech Comprehension in Babble Noise. J Speech Lang Hear Res. 2015 Jun;58(3):977-86. doi: 10.1044/2015_JSLHR-H-13-0335.
20. Borrie SA, Baese-Berk M, Van Engen K, Bent T. 2017, A relationship between processing speech in noise and dysarthric speech. J Acoust Soc Am. 2017 Jun;141(6):4660. doi: 10.1121/1.4986746.
21. Phatak S.A, Lovitt A., Allen J.B., Consonant confusions in white noise, J. Acoust. Soc. Am. 124 (2008) 1220–1233
22. André C., Ghio A., Cavé C., Teston B. PERCEVAL: a Computer-Driven System for Experimentation on Auditory and Visual Perception. International Congress of Phonetic Sciences (ICPhS), 2003, Barcelona, Spain. UAB, pp.1421-1424
23. Samuel A. Phonemic restoration: insights from a new methodology. J Exp Psychol Gen. 1981;110:474-494.
24. Robert D. Dysarthries et atteintes de la voix dans les affections neurologiques. In: Précis d'audiophonologie et de déglutition: Tome 2 – Les voies aéro-digestives supérieures. 1st ed. Solal; 2009:269-289.
25. Pinto S., Chan A. , Guimarães I. , Rothe-Neves R., Sadat J. A cross-linguistic perspective to the study of dysarthria in Parkinson's disease. Journal of Phonetics, 64 (2017) 156–167. doi:10.1016/j.wocn.2017.01.009.

	Articulation site	*1-syllable*	*1 + final schwa*	*2-syllable.*	*3-syllable*	*4-syllable*
	.	*Initial*	*18 words*	*middle 20 words*	*Initial 15 words*	*Initial 13 words*
[p]	bilabial	pain	soupe	appel	politique	population
[b]		bar	robe	habits	bâtiment	bénédiction
[m]		mer	pomme	amour	magasin	majorité
[f]	frica-tive	feu	gaffe	enfin	fatigue	fidélité
[v]		vin	rêve	envie	vérité	/
[t]	dental	temps	vite	autour	téléphone	télévision
[d]		donc	code	aider	décider	débarrasser
[n]		non	bonne	année	numéro	normalement
[s]	alveo-lar	sac	douce	aussi	solitude	sécurité
[z]		zut	chaise	hasard	/	/
[ʃ]	pala-tal	cher	bouche	échelle*	charité	/
[ʒ]		jour	rouge	agir	général	génération
[k]	velar	cœur	chèque	écart	qualité	conversation
[g]		goût	bague	égal	gouverneur	gouvernement
[l]	liqui-d	lac	balle	aller	légitime	laboratoire
[r]		rue	père	héros	relation	récupérer
[w]	semi-vowel	oui	/	avoir	/	/
[j]		hier	fille	ancien	/	/
[ɥ]		huit	/	enfuir	/	/
[ñ]		/	ligne	agneau	/	/

1-syllable words with initial consonant group:

[pl] plat	[pr] prêt	[bl] bleu	[br] bref	[fl] fleur	[fr] front	[tr] train	[dr] draps
[kl] clair	[kr] cri	[gl] glace*	[gr] grand	[sp] sport	[st] stop	[sk] ski	[vr] vrai

** final schwa [e]*

Table 1: French word corpus

	Articulation site.	**Initial position**	**Target word**	**Final position**	**Target word**
[p]	Bilabial	Fais comme tu peux	peux	Aura-t-il sa lampe ?	lampe
		Qui est parti ?	parti		
[b]		Regarde comme c'est beau.	beau	J'ai peur qu'il tombe !	tombe
		Tu as dit bonjour ?	bonjour		
[m]		C'est au milieu.	milieu	Qui est cet homme ?	homme
		J'ai besoin de manger.	manger		
[f]	Labio-dental	Mon fils est fâché.	fâché	Il avait soif.	soif
		Laisse-moi finir !	finir		
[v]		Fais la vaisselle.	vaisselle	Elles veulent des preuves !	preuves
		Laisse-moi la voiture.	voiture		
[t]	dental	Je ne veux pas de thé.	thé	Je suis en tête.	tête
		Il avait tout.	tout		
[d]		Qui est le dernier ?	dernier	Il faudra de l'aide.	aide
		Elles veulent déjeuner.	déjeuner		
[n]		Où est-il né ?	né	Aura-t-il la sienne ?	sienne
		Il est à nous.	nous		
[s]	alveolar	Elle fait semblant.	semblant	J'ai besoin de vacances !	vacances
		C'était super !	super		
[z]		Il ira au zoo.	zoo	Elle fait ses valises.	valises
[ʃ]	palatal	J'ai peur des chiens.	chiens	Prenez à gauche.	gauche
		Je ne veux pas changer.	changer		
[j]		Elle aime son jardin.	jardin	Mon fils est en voyage.	voyage
		Tu as mal joué !	joué		
[k]	velar	Elle aime conduire.	conduire	Va à la banque !	banque
		Tu as dit de courir.	courir		
[g]		Ce n'est pas gagné.	gagné	C'était une blague ?	blague
		Je suis de garde.	garde		
[l]	liquid	Va te laver !	laver	Où est cette île ?	île
		Ce n'est pas lui.	lui		
[r]		Il est en retard.	retard	Prenez vos affaires !	affaires
		Il faudra rentrer.	rentrer		
[w]	Semi-vowel	Regarde ces oiseaux !	oiseaux	/	
[J]		Tu as mal aux yeux ?	yeux	Il ira au soleil.	soleil
[ɥ]		C'est de l'huile.	huile	/	

Table 2: French phrase corpus

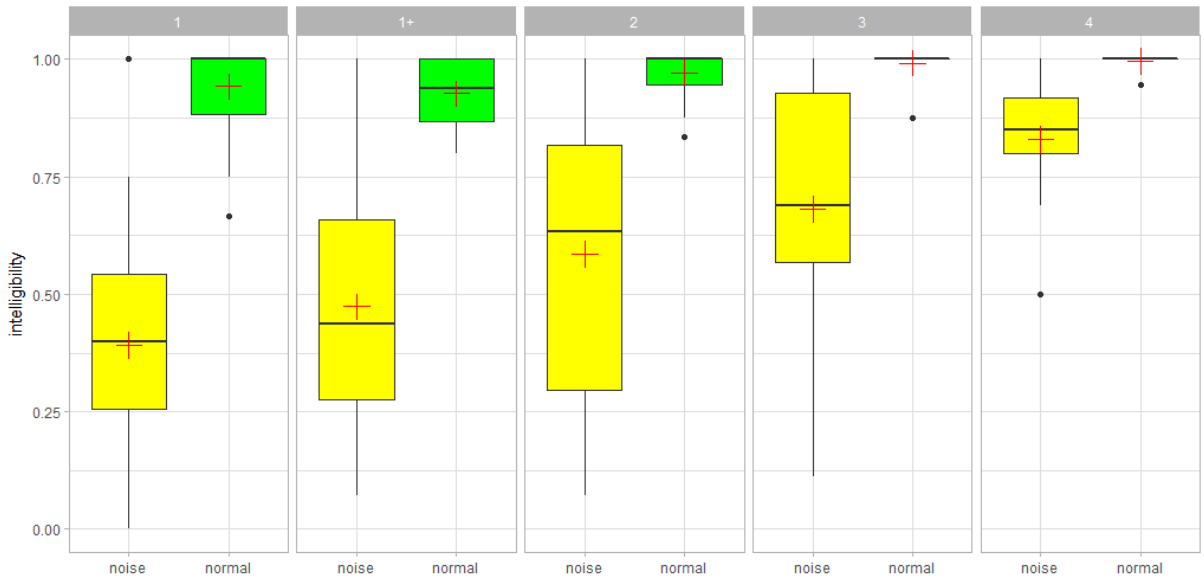

Figure 1: Intelligibility scores for words in normal and in degraded condition according to number of syllables