RIASE

CONSTRUCTION OF A SCREENING INSTRUMENT FOR MOTOR SPEECH DISORDERS:
STANDARDIZATION OF PHONETICALLY BALANCED TEXT "O SOL"

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ABSTRACT

Aging, neurodegenerative diseases or brain injuries are the main causes of motor speech disorders (MSD) which impacted on the communication effectiveness and quality of life of humans with more than 60 years. MSD's early identification is relevant to mitigate these effects. **Objective**: To ensure the psychometric criteria of validity, reliability and sensitivity of the European Portuguese (EP) phonetically balanced text (PBT) "O Sol" (The Sun) for the norm speakers. **Methodology**: 55 subjects spoken of the three EP dialects with ages between [18-58] years participated on the validity and sensitivity criteria. Secondly, 10 subjects spoken of central-southern EP dialect with ages between [19-50] years participated on the reliability criteria. Subjects read aloud the PBT "O Sol". Sound samples were captured with integrated Sony Linear PCM-D50 microphone recorder. International Phonetic Alphabet was used for transcription. **Results**: The PBT "The Sun" satisfied the seven construction pre-requisites of a PBT. It presented all EP phonemes and syllabic formats. For the three dialects, 6/38 phonemes presented significantly different absolute frequency averages ($p < 0.05$). Inter-examiner agreement and intra-examiner were 82% and 91.3%, $p < 0.05$, respectively. **Conclusion**: The PBT "O Sol" is valid, reliable and sensitive to dialectal variations of the EP.

Descriptors: Aging; reading-aloud task; motor speech disorders; phonetically balanced text

INTRODUCTION

Aging is a physiological process characterized by morphological, functional, biochemical and psychological changes. The number of people over 60 years of age doubled in last three decades. It is projected to these values remain until 2050. In Portugal, the number of people over 65 years of age increased by about 19.4%. There is an estimate 120 elderly for every 100 young people. Sedentary lifestyle is a high risk factor associated with aging. Chronic and neurodegenerative diseases' prevalence leads to changes in neurological, musculoskeletal, respiratory, laryngeal and articulatory systems. These changes can modify speech production and life's quality (INE, 2012; Kawai, et al., 2002; Mazini Filho, et al., 2010; OMS, 2012; Souza, et al., 2011).

Motor Speech Disorders (MSD) result from central nervous system (CNS) lesions that can have an affect on orofacial morphology and physiology, impairing speech production. MSD are characterized by changes in the speech production (e.g., slow or fast), voice (e.g., rough, breathiness and/or weak) and resonance (e.g., hypo- or hypernasal). These changes affect speech intelligibility and communication skills (Kempler & Van Lancker, 2002; Tjaden & Wilding, 2011).

MSD are categorized in three groups: dysarthria, speech apraxia and orofacial apraxia. Dysarthria refers to the inability to control the structures responsible for speech production. Dysarthria is characterized by voice changes, muscle weakness and articulatory effort. Speech apraxia is characterized by difficulty in voluntary muscle movements, programming and sequencing of speech sounds. Orofacial apraxia is the inability to perform voluntary movements of facial structure and swallowing movement (Borrie, 2011; Knollman-Porter, 2008; Vaz, Fontes & Fukujima, 1999).

Assessment of MSD is based on structured tasks (e.g., repetition, maximum effort and reading-aloud of words, sentences and texts) and unstructured tasks (e.g., spontaneous speech). The structured task reading-aloud is representative of spontaneous speech production. These task should be performed using a phonetically balanced text (PBT) built specifically for the language that is intended (Kempler & Van Lancker, 2002; Lowit-Leuschel & Docherty, 2001). The application of a PBT in subjects with MSD allows to study the impact of these pathologies on communication skills, specifically on speech production (Baken & Orlikoff, 2000; Lowit-Leuschel & Docherty, 2001).

"O Sol" (*The Sun*) (Patent Application No. nº 3093/2012) is the only one PBT for the European Portuguese (EP) and was built to be used as a reading-aloud task (Mendes, Moreira, Costa, Murtinheira & Jorge, 2014). PBT "O Sol" could be used as a screening instrument intended for early identification of MSD. Validity, sensitivity and reliability are psychometric criteria necessary for the construction of screening tools. These criteria are recommended by Scientific Advisory Committee of the Medical Outcome Trust and need be applied to the PBT "O Sol". (Frances & Glascoe, (n. d.); SACMOT, 2002). Validity determines whether an instrument assess what it's proposed to. Validity has three areas: content, construction and concurrent. Content validity verifies whether an instrument has its content appropriate to its purpose. Construct validity compares the results of an instrument to its theoretical assumptions. The phoneme occurrence frequency of a PBT should be compared with reference *corpora*. In case of PBT "O Sol", phoneme occurrence frequency was compared with the *corpora* PF_fone and FrePOP (Frequency of Phonological Objects in Portuguese) (Frota, Vigário, Martins & Cruz, 2012; Nascimento, Marques & Cruz, 1984; Mendes et al., 2014; SACMOT, 2002). Concurrent validity compares the results of an instrument with another validated instrument that has the same purpose (Frances & Glascoe, (n. d.); Mendes et al., 2009; SACMOT, 2002). Throughout this paper the term "segment" will be used want to phonetic segment (ie, receiver), either phonological segment (ie, phoneme). These segments are commonly called speech sounds, eg., vowels, consonants.

Sensitivity refers to the ability of an instrument to detect changes caused by external factors. The EP has three dialects: northern, central-southern and insular. PBT "O Sol" should be sensitive to these variations (Frances & Glascoe, (n. d.); Mendes et al., 2014).

Reliability determines how an instrument produces the same results, regardless of location, the examiner and the time interval in which it is applied (Ferreira, & Marques, 1998; SACMOT, 2002). Degree of reliability can be obtained by internal consistency (Cronbach's alpha – **α**) or by Intraclass Correlation Coefficient (ICC). Both reflect the variance ratio and the homogeneity of quantitative measures. Reliability can be also determined by intra and inter-examiner agreement, or by applying test-retest (in two moments). High degree of reliability increases professionals' and researchers' assurance to use an instrument (Ferreira & Marques, 1998; Maroco & Garcia-Marques, 2006; SACMOT, 2002; Terwee et al., 2007). It is intended that PBT "O Sol" has the same kind of results, regardless the examiner and/or the time interval in which it is applied.

For this study, the following objectives were defined:

- Check the content, construction and concurrent validity of PBT "O Sol":
    a) Ensure compliance with all the seven pre-requisites of a PBT for EP.
    b) Ensure similar phoneme occurrence frequency to spontaneous speech, having the reference of PF_fone and FrePOP *corpora*.
    c) Compare results to an identical instrument.

- Check the sensitivity of the PBT "O Sol" to the variations of three EP dialects (i.e., northern, central-southern and insular).

- Check the reliability of PBT "O Sol" using:
    a) Intra-examiner agreement for equivalence degree.
    b) Inter-examiner agreement for stability degree.

It is relevant to provide health professionals with skills and tools to perform an early identification of MSD. MSD have impact on social and communication skills and quality of life. The application of a valid, reliable and rapid instrument allows the assessment, diagnostic and development of an effective plan treatment for each patient. (Kempler & Van Lancker, 2002; Tjaden & Wilding, 2011; Villaseñor-Pineda & Montes-y-Gómez, 2004).

METHODS

Subjects

55 norm-speakers spoken of the three EP dialects (i.e., northern, central-southern and insular), 14 males and 41 females, with ages between [18-58] years participated on the validity and sensitivity procedures of this study (see Table 1).

Gender	EP dialect			
	N	CS	I	Total
M	5	7	2	14
F	15	16	10	41
Total	20	23	12	55

Table 1. Sample characterization.
Legend: (N) northern dialect; (CM) central-southern dialect;
(I) insular dialect.

Secondly, 10 norm-speakers spoken of central-southern EP dialect, 5 males and 5 females, with ages between [19-50] years participated on the reliability criterion.

Both subject samples were selected according to following criteria: 1) ages between 18 and 65 years; 2) EP monolingual speaker; 3) at least elementary school graduation; 4) no speech problems, language and communication, verified by a licensed speech therapist; 5) robust physical health; 6) absence of smoking, alcohol and drug consumption; and 8) no cold or respiratory problems on recording days.

Procedures

Subjects read twice the PBT "O Sol" (2009 Version) in a seated position. The first reading trial was in silent voice. The second trial was performed with a comfortable pitch, intensity and speech rate.

Reading-aloud tasks were collected by speech-language therapists and 4th year students of Speech Therapy Major of Health Science School of the Polytechnic Institute of Setubal (ESS-IPS). Recordings were performed at subjects' home or the Advanced Vocal Function Laboratory of Health Sciences School of Polytechnic Institute of Setubal. Noise ambient level was below 50dB (Titze, 2000), measured by a sound level meter Center 325 (IEC 651 Type-II). Sound samples were captured with Sony Linear PCM-D50 (96KHz/24bit) integrated microphone recorder. They were converted to mp3 format and were phonetically transcribed with International Phonetic Alphabet.

Three types of validity were verified: 1) content, 2) construct, and 3) concurrent validity. Content validity was verified using seven PBT construction pre-requisites: 1) contain all language phonemes, specifically of the EP language; 2) have all phonemes with the same relative occurrence frequency of spontaneous speech; 3) contain all syllabic formats; 4) present text cohesion; 5) have an appealing theme without childish or scientific characteristics; 6) be written in a simple language, to facilitate the understanding, and reading-aloud task; 7) be brief to avoid fatigue. For construct validity, the mean phonemes' absolute and relative occurrence frequencies (i.e., Fa and Fr, respectively) productions were calculated. Fr was compared with the Fr of the *corpora* FrePOP and PF_fone, and mean deviation was calculated. Mean deviations above 0.5 were considered within the threshold of acceptance (cut-off). Mean deviation less than 0.5 indicated Fr lowers than the *corpora*. For concurrent validity, the phonemes' Fa of the PBT "O Sol" should be compared with other EP PBT.

For dialect sensitivity, Fa and Fr of each phoneme were calculated and compared among the three EP dialects.

For the reliability, inter-examiner agreement was performed by having two examiners transcribed each subject. Intra-examiner agreement was performed by having an examiner transcribed each subject in two different moments, with a minimum interval of one month. For both reliability procedures the phonemes' Fa and Fr were calculated.

For the statistical analysis, dialectal sensitivity of the PBT "O Sol" was performed with One-Way Anova. For the reliability, inter-examiner agreement was analyzed with a *t*-test and intra-examiner agreement with a Pearson's correlation coefficient. α was set at .05.

For data analysis, Microsoft Office Excel 2007 and Statistical Package for Social Sciences (SPSS) - Version 20 was used.

RESULTS

Validity

Concerning content validity, the PBT "O Sol" respected the seven pre-requisites for the construction of a PBT. The PBT "O Sol": 1) presented the 38 phonemes of the EP; 2) contained all phonemes with the Fr similar occurrence to the EP FrePOP and the PF_fone *corpora*; 3) contained the 12 syllabic formats of the EP, being the consonant+vowel format the most common; 4) presented textual cohesion; 5) presented an appealing theme, without childish or scientific characteristics, even though contained words such as *helium*, *hydrogen* and *gravitational*; 6) had

a simple language, to facilitate the reading-aloud task; 7) had an average reading duration of 1 minute, i.e., avoided fatigue.

For construct validity, the PBT "O Sol" presented 38 phonemes of the EP. Fr of 30/38 phonemes of the PBT "O Sol" was equal to or above the threshold of acceptance, i.e., 78.9 % of phonemes had a Fr within 0.5 of at least one of the *corpora*. [a, ɨ, ẽ, w̃, p, k, v, ʃ] presented Fr values below the acceptance threshold for both *corpora*. Twenty-two phonemes presented Fr means equal or above the acceptance threshold for the two *corpora*. [e, o, ũ, n] presented Fr means closer to the acceptance threshold of FrePOP and above the PF_fone *corpus*. [ɾ] presented a value close to threshold of acceptance of PF_fone and above FrePOP. [i, b, ʀ] presented Fr means below the threshold of acceptance of PF_fone, but it was close to FrePOP.

For vowels and glides, the Fr mean of 14/18 were similar or above the acceptance threshold of both *corpora*. [a, ɨ, ẽ, w̃] presented a Fr mean below the two *corpora* (see Figure 1).
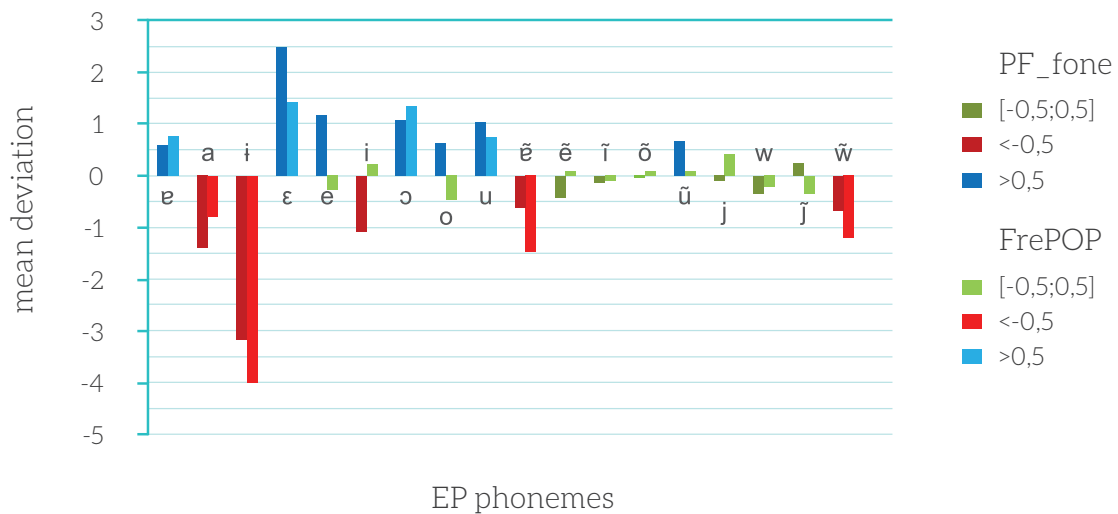

Figure 1. Mean deviation of the vowels and glides Fr of the PBT "O Sol", PF_fone and FrePOP

For consonants, Fr means of 7/9 occlusives of the PBT "O Sol" presented values equal or above both *corpora*, except [p, k] that were below. Regarding fricatives, 4/6 presented equal or above the acceptance threshold of both *corpora*, except [v, ʃ]. All liquid consonants (5/5) presented equal values or above the acceptance threshold for both *corpora* (see Figure 2).
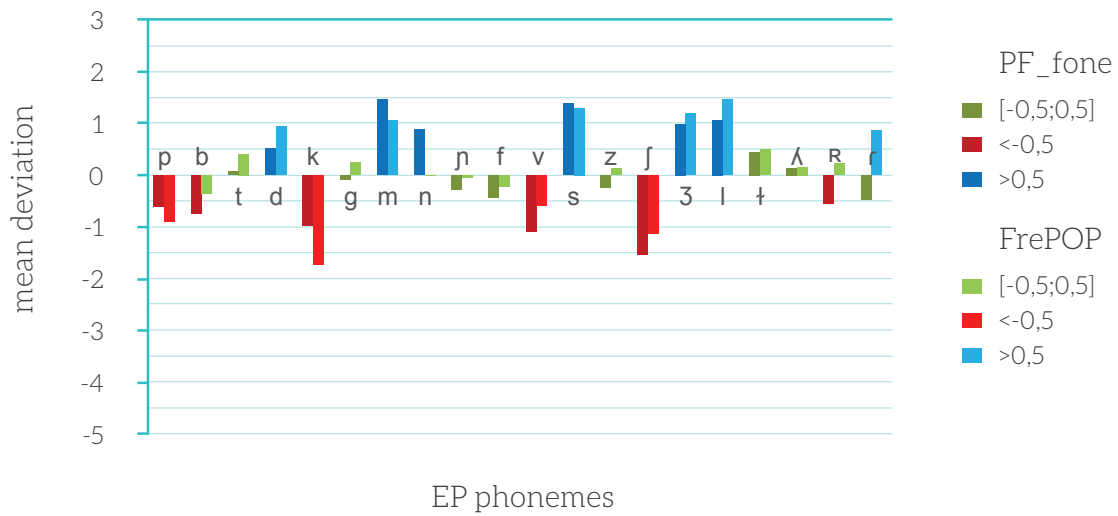
Figure 2. Mean deviation of the consonants Fr of the PBT "O Sol", PF_fone and FrePOP

Concerning concurrent validity, Fa and Fr of the PBT "O Sol" were not compared with other PBT, because there was no other one built for EP.

Sensitivity

Dialectal sensitivity of the PBT "O Sol" was calculated by comparing the productions of 55 norm-speakers of the three EP dialects. These values varied in all phonemes, except for [b, ʀ] which presented the same values for the three dialects. [ɨ, i, ĩ, j, ʃ, ʒ] presented Fa means significantly different ($p < .05$) for the three dialects. Central-southern dialect presented a Fa mean of [ɨ, j] higher then northern and insular dialects. Northern dialect presented a Fa mean of [i, ĩ] higher then central-southern and insular dialects (see Table 2).

Concerning occlusive, fricative and liquid consonants, the Fa means were similar for the three dialects, with the exception of [ʃ, ʒ] that presented significant differences ($p < .05$). Central-southern dialect presented a Fa mean of [ʃ] higher then northern and insular dialects. Northern dialect presented a Fa mean of [ʒ] higher then central-southern and insular dialects (see Table 3).

Phonemes	EP DIALECTS						F	p value
	N		CS		I			
	Fa	Fr	Fa	Fr	Fa	Fr		
ɐ	50,00	10,85	49,09	10,66	50,00	10,96	1,04	0,36
a	14,67	3,19	14,91	3,24	14,58	3,20	0,34	0,71
ɨ	9,76	2,12	12,32	2,67	9,92	2,17	4,68	0,01*
ɛ	16,52	3,59	16,45	3,57	16,42	3,60	0,13	0,88
e	8,52	1,85	8,82	1,91	8,58	1,88	0,36	0,70
i	26,33	5,73	23,14	5,02	21,67	4,75	9,54	0,00*
ɔ	10,33	2,25	10,59	2,30	10,67	2,34	0,67	0,52
o	7,29	1,58	6,91	1,50	7,00	1,53	1,49	0,24
u	40,00	8,69	40,09	8,70	38,75	8,43	1,62	0,21
ɐ̃	8,38	1,82	9,27	2,01	8,33	1,83	1,95	0,15
ẽ	6,10	1,32	5,64	1,23	6,25	1,32	0,58	0,56
ĩ	3,00	0,65	2,23	0,48	2,92	0,64	7,12	0,00*
õ	4,05	0,88	4,05	0,88	3,92	0,86	0,60	0,55
ũ	4,05	0,88	4,00	0,87	4,08	0,90	0,81	0,45
j	8,67	1,87	12,14	2,63	11,25	2,46	5,58	0,01*
w	2,24	0,48	2,14	0,46	2,00	0,44	0,26	0,78
j̃	4,48	0,97	4,32	0,94	4,25	0,93	0,17	0,84
w̃	2,00	0,43	2,00	0,43	2,08	0,46	1,85	0,17

Table 2. Absolute and relative frequencies of vowels and glides of the PBT "O Sol" for the three EP dialects and *p-values* for One-way Anova.

Legend: (N) northern dialect; (CS) central-southern dialect; (I) insular dialect; (Fa) absolute frequency; (Fr) relative frequency; (*) $p<.05$; (#) values equal

Phonemes	EP DIALECTS						F	p value
	N		CS		I			
	Fa	Fr	Fa	Fr	Fa	Fr		
p	10,10	2,19	10,09	2,19	10,00	2,19	0,38	0,69
b	3,00	0,65	3,00	0,65	3,00	0,66	.	#
t	26,14	5,68	26,05	5,66	26,08	5,72	0,60	0,55
d	24,14	5,24	23,86	5,18	23,92	5,24	0,90	0,41
k	12,00	2,61	12,05	2,62	12,08	2,65	0,78	0,46
g	5,19	1,13	5,00	1,09	5,17	1,13	2,34	0,11
m	20,14	4,37	20,00	4,34	20,08	4,40	0,77	0,47
n	11,14	2,42	10,91	2,37	10,92	2,39	2,47	0,10
ɲ	2,05	0,44	2,00	0,43	2,00	0,44	0,80	0,45
f	4,05	0,88	3,95	0,86	4,00	0,88	1,27	0,29
v	4,24	0,92	4,00	0,87	4,17	0,91	2,20	0,12
s	22,76	4,94	22,95	4,98	23,25	5,10	2,78	0,07
z	5,43	1,18	5,32	1,15	5,17	1,13	0,36	0,70
ʃ	18,52	4,02	21,95	4,76	19,17	4,20	13,20	0,00*
ʒ	10,29	2,23	6,68	1,46	9,42	2,06	13,22	0,00*
l	14,57	3,16	14,45	3,14	14,83	3,25	0,54	0,59
ɫ	5,14	1,12	5,45	1,18	5,17	1,13	0,59	0,56
ʎ	2,05	0,44	2,00	0,43	2,08	0,46	0,81	0,45
ʀ	3,00	0,65	3,00	0,94	3,00	0,66	.	#
ɾ	30,14	6,55	29,82	0,43	30,08	6,59	2,18	0,12

Tabela 3. Absolute and relative frequencies of consonants of the PBT "O Sol" for the three EP dialects and p-value for One-way Anova.

Legend: (N) northern dialect; (CS) central-southern dialect; (I) insular dialect; (Fa) absolute frequency; (Fr) relative frequency; (*) p<.05; (#) values equal

Reliability

The inter-examiner agreement was 82%, 31/38 phonemes did not differ between the two examiners. The vowels [ɨ, i, ẽ, e], the glide [j] and the consonants [ʃ, ʒ] presented significant differences (p <.05) (see Table 4). According to these results, the PBT "O Sol" showed a "strong equivalence".

The intra-examiner agreement, measured by a Pearson correlation, was R=.913, p <.05. This degree of correlation indicated a "strong stability" (Almeida & Freire, 2007) of the instrument.

Phonemes	t-test	*p* value
a	-0,595	0,751
ɨ	4,553	0*
ɛ	-1,811	0,66
e	-0,280	1
i	-3,681	0,006*
ɔ	-2,490	0,054
o	0,625	0,391
u	0,744	0,166
ẽ	2,264	0,029*
ẽ	-2,925	0,022*
ĩ	-0,097	1
õ	-0,404	1
ũ	-0,273	1
j	1,846	0,045*
w	-0,394	0,754
j̃	0,171	0,628
w̃	-1,124	0,343
p	-0,719	1
b	-2,354	#
t	-1,150	0,343
d	-2,590	0,174
k	-0,973	1
g	-2,354	#
m	-1,231	1
n	-2,381	0,343
ɲ	-2,354	#
f	-1,414	0,343
v	-2,354	#
s	-0,914	1
z	-0,367	0,836
ʃ	3,295	0,003*
ʒ	-3,778	0,003*
l	-0,610	0,828
ɫ	0,073	0,838
ʎ	-2,354	#
ʀ	-2,354	#
ɾ	-1,505	0,754

Table 4. Inter-examiner agreement of phonemes of the PBT "O Sol" and p-value for t-test.
Legend (*) p<.05; (#) equal results between the two examiners. T-test, value p<0,05

DISCUSSION

The main objectives of this study were to verify the validity, reliability and sensitivity of the EP PBT "O Sol" conceptualized to be a screening tool for early identification of motor speech disorders in adults. This required to apply "O Sol" to a sample of three EP dialects of norm speakers and ensure that psychometric criteria were guaranteed. The results of this study revealed that the TFE "O Sol" is a text that can be used as a reading-in-aloud structured phonatory task. It presented: 1) all 38 EP phonemes; 2) all phonemes with an occurrence frequency similar to spontaneous speech; 3) all EP syllabic formats; 4) textual cohesion; 5) an appealing theme without childish or scientific characteristics, even though has three words with less frequent semantic usage (i.e., *helium*, *hydrogen* and *gravitational*); 6) an accessible language which facilitates the reading task; 7) an average time reading of 60 seconds, i.e., it is brief enough to avoid fatigue. Therefore content validity was assured.

The 38 EP phonemes were presented in the "O Sol". 78.9% of the phonemes (30 in 38) had a Fr within the *corpora*'s PF_fone and FrePOP reference, i.e., spontaneous speech. Eight phonemes were below the established acceptance threshold (i.e., <0.5), compared to one of the *corpus*. 22 phonemes showed similar or above Fr average of the acceptance threshold of the two *corpora*. The average of Fr 14/18 vowels and glides the "O Sol" was similar or higher than both *corpora*'s acceptance threshold. The [a, ɨ, ɐ] and the glide [w] presented a Fr average below the one of the two *corpora*. The Fr average of 7/9 occlusives of "O Sol" had similar or higher values to the two *corpora*. The Fr average of 4/6 fricatives showed similar values to the acceptance threshold of both *corpora*, except for [v] and [ʃ]. All liquids (5/5) presented a Fr similar to or greater than the acceptance threshold of the two *corpora*. Small variations above or below the acceptance threshold were due dialectal variations or (un)consistency production. However, since the TFE "O Sol" hosted the most phonemes with the desired relative occurrence of the spontaneous speech, its validity construction was ensured.

The concurrent validity checks the degree to which an instrument's results correlate with other existing valid instrument. For the EP there is no other PBT, therefore the realization of concurrent validity was not possible to perform.

Regarding the dialectical variations, "O Sol" showed Fa average of [ɨ, i, ɪ, j, ʃ, ʒ] significantly different (*p* <0.05) for the three dialects. [ɨ, j] were more frequent in central southern dialect, while [i, ɪ] were more frequent in the northern dialect. For consonants, [ʃ] showed significant higher values in central southern dialect and [ʒ] in the northern. In short, this PBT was sensitive to dialectal variations that should not be considered articulation disorders, but acceptable in dialectal differences EP.

For reliability, inter-examiner agreement was 82% (i.e., greater than 80%), indicating a "strong equivalence". Intra-examiner agreement was 91.3%, showing, a "strong stability" (Almeida & Freire, 2007). The reliability of "O Sol" was guaranteed.

As for limitations, this study provided a reduced 55 norm speaker convenient sample, but still served to presented consistent results for the psychometric parameters. No doubt the sample size needs to be increased and be balanced in terms of age, gender, dialect and literacy. Secondly, as future project, it is intended to implement the same methodology in 60 to 90 MSD subjects with and without a diagnosis of neurogenic disorder, in order to delineate communicative indicators of a neurodegenerative disease (e.g., Parkinson's, Alzheimer's) and the resulting MSD (e.g., dysarthria, apraxia).

CONCLUSION

The PBT "O Sol" regards all seven pre-requisites for a PBT for EP, as well as presented all the phonemes and syllabic formats in the same occurrence frequency of EP spontaneous speech. Therefore, it ensured the content, concurrent and construction validity. Dialectal sensitivity was verified in all three dialects of EP: northern, central-southern and insular. Reliability was ensured through intra- and inter-examiner agreement, revealing strong equivalence and stability of the instrument, respectively. Therefore, the SACMOT (2002) psychometrics criteria for the construction of an assessment instrument were ensured. In the future, the PBT "O Sol" will be applied to a population sample with MSD, in order to verify its validity and reliability on the identification and categorization of these speech disorders.

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