Vowel and Consonant Contrasts

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要　旨

教師の大切な役割の一つは何を教えるかという選択をすることである。発音指導に関しては機能的荷重（Functional Load: FL）の潜在的役割が考えられる。英語の発音教材の中で Brown（1988）と Catford（1987）によって作成された母音と子音対立の FL ランキングは長年にわたり高く評価されているものである。本論文はその FL ランキングの歴史と背景さらに作成手法について述べ，筆者の用法基盤アプローチを用いた FL ランキングの記述例を紹介すると同時にこのアプローチがどのような分析を可能にするかを提示したい。

キーワード：母音と子音対立，機能的荷重，英語発音，発音教材，諸英語

Keywords: Phoneme oppositions, functional load, English pronunciation, pronunciation teaching, world Englishes

1　Introduction

The concept of functional load (FL) has attracted the attention of researchers interested in pronunciation teaching and learning over the decades. Consequently, it is relevant to explicitly state what FL refers to as well as to review its interpretations and applications. FL was initially formalized in the 1930s by the Prague School as: “The degree of utilization of a phonological opposition for distinguishing different meanings of words in a given language" (Vachek et al., 2003, p. 82). A reformulation often cited by pronunciation researchers comes from King (1967, p. 831) who distilled the concept down to "the extent and degree of contrast between linguistic units, usually phonemes". Of critical importance, King recognized the central role of textual frequency "as well as, or instead of, the mere lexical utilization of phoneme oppositions" when estimating FL (Catford, 1988, p. 4). The two FL rankings of British RP (hereafter BRP) phoneme contrasts created by Brown (1988) and Catford (1987) still used today by applied linguistics researchers are based on this formulation of FL. Brown, for instance, deferred to King's conception when devising his ranking and Catford identified using text frequencies as a preferred method of estimation, although one he was not able to pursue.

Both Brown and Catford proposed FL as a means by which to objectively calculate relative importance and thus identify priorities for efficient implementation of pronunciation training. To this end, they provided the field with FL measures of BRP phoneme contrasts with which to undertake the task. Munro and Derwing (2006, p. 522) further stimulated interest in FL among researchers with an exploratory study that used the Brown and Catford rankings to investigate how useful FL could be as "a means of predicting accentedness and comprehensibility ratings". Subsequently, Kang and Moran (2014, p. 177) used the rankings to assess how phonological errors affect oral assessment and Suzukida and Saito (2019, p. 6) used them to determine which "segmental features are crucial for L2 comprehensibility judgments". Results from each of these studies led the researchers to conclude that "high FL" contrasts have a statistically significant impact on listeners' ratings of comprehensibility while "low FL" errors did not.

Encouraged by findings like these, Munro and Derwing (2015) include the replication and expansion of FL investigations in their prospectus for pronunciation research in the 21st century. Sewell (2021, p. 5) proposes broader potential applications and presents cogent arguments for the usefulness of FL as an informative heuristic in "assessing questions of language acquisition and language teaching, and relating them in turn to language usage and language change". Notably, Sewell also acknowledges the need to reevaluate the "go-to" resources, meaning the lists prepared by Brown and Catford, in light of modern corpus data and statistical modeling in order to supplement existing FL measures in ways that reflect contemporary analytical methods as well as globalized and localized usage of English.

This manuscript addresses these concerns as follows. First, it provides a critical review of Brown (1988)[1] and Catford (1987)[2] whose FL rankings are most often used by researchers. Second, it presents FL rankings for vowel and consonant contrasts obtained from a modern, usage-based, corpus-driven study intended to replicate work of Brown and Catford (to the extent possible).

2 Review of referential FL rankings

Researchers today continue to rely on the FL rankings of BRP vowel and consonant contrasts created by Brown and Catford (Hyeseung Jeong & Bosse Thorén, 2019; Kang & Moran, 2014; Munro & Derwing, 2006; Suzukida & Saito, 2019). Thus, the first task of this manuscript is to elucidate what Brown and Catford did precisely. In particular, proper understanding implies that the origin of their data must be identified without ambiguity as must the manner in which this data was analyzed in order to produce their rankings.

2.1 Brown's work

Brown (1988, p. 593) centers his discussion of FL around the "dilemma" confronted by teachers as to which features "merit precious class time". In his survey of the literature, he reviews proposed interpretations researchers have made when applying FL to the task of describing linguistic systems and the process of sound change, observing an untapped potential application to the area of language teaching. Relating to this specific domain, Brown (1988, p. 596) confines his concerns to BRP phoneme pairs which, according to him, "are often conflated by learners"[3] and enumerates 12 factors to consider when applying the construct to pronunciation teaching. These factors pertain to aspects at both the segmental and lexical levels. Regarding segmental aspects, factors encompass the cumulative frequencies of phoneme pairs and probabilities of occurrence of individual phonemes, phonotactic constraints along with acoustic and articulatory similarity. At the lexical level, considerations include lexical frequency, the number and frequency of minimal pairs (MPs) associated with a given contrast along with grammatical function and context of use of members of MPs.

After touching upon each of these factors in turn, Brown (1988, p. 603) concludes that "cumulative frequency and the abundance of MPs would seem to be the most important" and proposes "a rank ordering of [B]RP phonemes often conflated by learners". The rank is arranged in two 10-point scales, one for vowels and one for consonants, with 10 representing the pairs of greatest priority. However, Brown does not explain the origin of the data or the methodology he employed.

It is within reason to presume that the frequency data comes from Denes (1964)[4], whose work Brown referred to when reporting cumulative frequencies for some phonemes. Yet, attempts made to reconstruct Brown's ranking from Denes' data fail. For example, multiple phoneme pairs are clustered at some ranks, giving the impression that some pairs, for example /e, æ/ and /æ, ʌ/, have equal cumulative frequencies and the same number of MPs. This is not the case[5].

2.2 Catford's work

Catford (1987, p. 88) describes frequency and FL as two principles that can be used to make "a deliberate selection of items to be taught". Frequency, he explains, "is the number of times that a phoneme or phonemic opposition occurs per thousand words of text". However, he fervently explains his inability to conduct any sort of frequency analysis, abandoning this approach in favor of a *type-based* one. He explicitly cautions that textual frequency was not taken into account in any way to create his rankings. Summing up, in Catford's own words:

> "No doubt, it would have been better to do the count in a more complete and reliable way (nowadays using a computer) than going systematically through one's own inventory of phonological word forms. It was because I assumed for a very long time that someone else would do, or had done, a better job, that my data remained so long unpublished! So far as I know, however, nobody has done so up to now. I wish they would!" (Catford, 1988, p. 19)

Catford's adoption of a *type-based* approach means that his FL rankings reflect the existence of MPs for given contrasts, independent of the frequency with which speakers use them. FL "is represented by" the number of words (i.e., the types) or the number of pairs of words that it serves to keep distinct (Catford, 1987, p. 88). This means that his method gives equal value to all words, whether common words such as "say", "sit", "sick", and "soap" or rare words such as "sib" (which he tells us may be known only to Scots like him) or "cepe" (which he tells us he failed to include because he did not know it at the time). With this in mind, the compilation of his FL rankings was approached by first identifying phonemic oppositions "that differ from each other by one or two distinctive features" and then listing all the simple phonological monosyllables in his own pronunciation that embody those oppositions. Furthermore, Catford (1988, p. 19) is forthright in pointing out that the measures he provides are "a *personal* count, with the limitations and idiosyncrasies that that implies" (italics in the original). In order to work through all the possible combinations in a systematic manner, he filled in a matrix for each initial consonant with vowels listed down the left side and final consonants across the top. Oppositions were found by comparing matrices.

The *Relative Functional Load* list provided in Catford (1987) contains 158 phonological oppositions—57 initial consonants, 44 final consonants, and 57 vowels. The contrast that differentiated the largest number of words was assigned a value of 100% and the work done by other contrasts was measured related to it.

2.3 Challenges and opportunities for replica studies

As shown, these antecedent works have set up certain expectations when it comes to this kind of FL research. Specifically:

- There is consensus that vowel and consonant contrasts matter in instruction (Brown, 1988; Catford, 1987) and assessment (viz., Kang & Moran, 2014; Munro & Derwing, 2006; Suzukida & Saito, 2019). In the case of instruction, the presentation of phonemes as contrasts (rather than isolated individual items) enhances and facilitates the identification and learning of the elements of the sound system. In the case of assessment, it is proposed that phonemic contrasts play a role in intelligibility and comprehensibility.
- There is consensus that MPs matter in linguistic theory (Levis & Cortes, 2008) and in instruction (Brown, 1988; Catford, 1987). In linguistic theory, MPs embody the functional role of phonemes as "bearers of meaning in the given language" (Vachek et al., 2003, p. 120). MPs are "one of the most commonly used forms to demonstrate phonemic categories in any language" and have been a "mainstay" for teaching pronunciation and assessing spoken language production, as Levis and Cortes (2008, p. 197) observe. In instruction, both Brown and Catford implicitly value MPs, perhaps disproportionately, as they single out the number of MPs (as types) as the basis for FL rankings.
- There is consensus that sequencing matters in learning and assessment. Textbooks,

course syllabi, and curricula embody decisions made by materials designers and teachers as well as administrators regarding the order in which selected features should be taught. Leveling schemes like CEFR are indicative of a perceived hierarchy of mastery with higher levels encompassing those skills associated with lower levels. Rubrics are an example of learning and assessment tools which associate qualitative descriptors of perceived degree of aptitude and scalar evaluations such as advanced-intermediate-novice. It is worth noting that major commercial ELT textbook publishers such as Cambridge University Press, PearsonELT, and Oxford University Press have adopted corpus-based approaches to production since the 2000s and market their products as following selection and sequencing that better reflect actual language use.

- There is a consensus that FL measures that reflect usage frequency can be useful in guiding selection and sequencing in the domain of pronunciation teaching. Brown (1988) prefaces his work with a mention of this issue when he refers to the dilemma teachers must confront regarding what merits precious class time. Catford expresses a similar view when he proposes frequency and FL as two guiding principles for selection. Munro and Derwing (2006, p. 530) echo these sentiments based on findings from their study, suggesting that FL "provides a framework for deciding" how to allocate instructional resources.

This review of the Brown and Catford rankings has made some challenges for replica studies apparent. One point of challenge is the provenance of the data, which is unknown in Brown's case and unretrievable in Catford's case. The analytical procedures present another challenge since there are ambiguities and gaps in Brown's explanation while Catford's approach of counting MPs has been superseded, as he hoped.

We are thus provided with an opportunity to devise a methodological approach which meets the expectations just discussed and replicates the intentions (rather than the procedures) of Brown and Catford. The next section elaborates upon the present study.

3 The present study

The present work takes impetus from the substantial number of studies which adopt information-theoretic approaches to the estimation of FL (e.g., Oh et al., 2015; Surendran

& Niyogi, 2003, 2006; Wedel et al., 2013). This approach, first formulated by Hockett (1955), quantifies the amount of information conveyed by language in terms of *Shannon's entropy* (Shannon, 1948). Hockett (1966, p. 8) proposed that a phonemic system has "a job to do" and that it is possible to quantify the work done by a given constituent by comparing the entropy of the system with and without that constituent. Surendran and Niyogi (2003, 2006) demonstrated the usefulness of this approach in estimating the information value of a wide range of linguistic units including phonemes, phonemic contrasts, tone, stress in various languages. Results from cross-linguistic information-theoretic FL analyses of phonological components reported by Oh and colleagues (2015) have contributed data-driven insights to discussions regarding the organization of the mental lexicon and Wedel and colleagues (2013) have provided statistical evidence of FL as a factor in diachronic sound change.

3.1 Data set

The data set used in this study was curated from the British Academic Spoken English (BASE) corpus (https://www.reading.ac.uk/acadepts/ll/base_corpus/). The corpus contains 1.64 million running words sampled from university contexts, specifically recordings of 160 lectures and 39 seminars in a variety of departments. For the purposes of the present investigation, the highly frequently recurring words (HFWs) were identified and phonemic transcriptions were manufactured. Gilner and Morales (2020) document the rationale and procedures undertaken for the lexical analyses. Suffice it to say, the rationale draws on the well-attested phenomenon of high-frequency vocabulary (Biber & Conrad, 2010; Faucett et al., 1936; Nation, 2001; Schmitt & Schmitt, 2014; Sinclair, 1991) along with the well-documented frequency effects in learning (e.g., Ellis, 2002; The Five Graces Group et al., 2009) as well as speech processing and cognition (e.g., Brysbaert et al., 2018; Divjak & Caldwell-Harris, 2015). Procedural details on the manufacture of the phonological word forms are described in Gilner (2020). A review of these previous works will demonstrate that utmost care was taken to overcome the difficulties of working with electronic corpora and that particular attention was paid to achieving reliable and consistent phonemic transcriptions, including the development of custom software[6].

3.2 Calculation of FL

As mentioned previously, two entropy measures are calculated: one that corresponds to the information or entropy of the system containing all of its constituents and one that corresponds to the entropy of the system without a given constituent. The difference between the two measures corresponds to the FL of the particular constituent. Equation 1 calculates the entropy of the system—the measure $H(L)$—in terms of the probability of word-forms (p_{w_i}) as a factor of the recurrence of a word in a corpus.

$$\mathrm{H(L)} = -\sum_{i=1}^{N_L} p_{w_i} * \log_2(p_{w_i})$$

Equation 1. Amount of information or entropy in language L

The FL of a phoneme pairing φ-ψ is defined as the difference between the entropy $H(L)$ of the initial system and the entropy $H(L^*_{\varphi\psi})$ of the system where two sounds have merged, as shown in Equation 2.

$$FL_{\varphi,\psi} = H(L) - H(L^*_{\varphi\psi})$$

Equation 2. Functional load of the contrast between two phonemes φ and ψ

3.3 Complementary measures

In the presentation of results that follows, two complementary normalization measures are presented alongside the raw FL measures, namely DRN and LDRN. DRN, or dominant relative normalization, expresses FL as a fraction of the constituent with the highest FL. This is the method generally found in the literature (e.g., Catford, 1987; Gilner & Morales, 2020; Herdan, 1958). LDRN, or least dominant relative normalization, expresses the FL of each constituent as a magnitude of the one with the lowest FL. Note that these two measures express equivalent ratios as shown in Equation 3.

a) $$DRN_\varphi = \frac{X_\varphi}{X_M} = \frac{LDRN_\varphi}{LDRN_M}$$

b) $$LDRN_\varphi = \frac{X_\varphi}{X_m} = \frac{DRN_\varphi}{DRN_m}$$

Equation 3. Equivalent relationships between DRN and LDRN

4 Results

The results presented here are based on 1,493,460 phonemic transcriptions, manufactured according to the phonological specifications provided in Upton (2004). According to Upton's specifications, BRP has 21 vowel phonemes and 24 consonant phonemes and, thus, the maximum number of possible vowel contrasts is 210 (= $\frac{21 \times 20}{2}$) and the maximum number of possible consonant contrasts is 276 (= $\frac{24 \times 23}{2}$). The data set instantiated 137 vowel contrasts and 198 consonant contrasts. The top 40 contrasts, the maximum number that could be fit on one page, are presented in the tables in this manuscript. Interested readers can find complete results in the companion spreadsheet available on ResearchGate.

4.1 Vowel contrasts

Table 1 indicates a rather uneven distribution of work among the vowel contrasts. LDRN values show that the top ranked /ɪ - æ/ obtains an FL that is 12.67 times greater than the 40th ranked /eɪ - ɜː/. DRN values further expose some stark differences in the relative amount work carried by contrasts. The 5th ranked contrast does 55.72% of the work that the 1st ranked contrast. The relative decrease continues down the list: the 10th ranked does 34.47% of the work that the 1st does, the 15th ranked does 19.03%, the 20th ranked does 15.69%, the 25th does 13.20%, the 30th does 11.33%, the 35th does 8.90%, and the 40th does 7.89% of the top ranked contrast. In other words, the decrease in relative amount of work is steady with markedly larger decreases at the top of the ranking.

Closer scrutiny reveals a dominant role of certain vowel phonemes. The phoneme /eɪ/ participates in 9 contrasts (among the top 40), 7 of which are among the top 20. Furthermore, several of these involve phoneme pairs that are rather similar in articulatory terms. The phonemes involved in the 2nd ranked contrast /eɪ - ʌɪ/ differ along only one primary dimension, that of degree of tongue retraction. The phonemes involved in the 10th ranked contrast /eɪ - ɛː/ differ in terms of tongue height and lengthening. The phoneme /i/ participates in 9 contrasts, 3 of which are among the top 20. The phoneme /ɔː/ participates in 8 contrasts, 6 are among the top 20. The phonemes /əʊ aʊ ɪ/ participate in 6 contrasts, the latter of which has 3 among the top 20. The phoneme /ʌɪ/ participates in 5 contrasts, 4 of which are among the top 20.

Several other contrasts are rather similar in articulatory terms. Twelve of the 40

Table 1. FL ranking of the top 40 vowel contrasts in BRP

Rank	Phoneme contrast		FL	DRN	LDRN
1	ɪ	æ	0.0655	100%	12.67
2	eɪ	ʌɪ	0.0500	76.38%	9.68
3	eɪ	ɑ:	0.0377	57.58%	7.30
4	ɛ:	ə	0.0376	57.43%	7.28
5	eɪ	ə	0.0365	55.72%	7.06
6	eɪ	ɔ:	0.0325	49.67%	6.29
7	ɔ:	ɪ	0.0303	46.27%	5.86
8	ʌɪ	ɑ:	0.0288	44.03%	5.58
9	ʌɪ	ɔ:	0.0236	36.09%	4.57
10	eɪ	ɛ:	0.0226	34.47%	4.37
11	ʌɪ	i	0.0195	29.81%	3.78
12	ɔ:	ɑ:	0.0182	27.75%	3.52
13	eɪ	i	0.0143	21.80%	2.76
14	i	ɜ:	0.0129	19.72%	2.50
15	ɔ:	u:	0.0125	19.03%	2.41
16	eɪ	əʊ	0.0120	18.26%	2.31
17	ɔ:	æ	0.0117	17.86%	2.26
18	ɪ	aʊ	0.0107	16.26%	2.06
19	æ	ɛ	0.0104	15.95%	2.02
20	u:	ɪə	0.0103	15.69%	1.99
21	ɪ	ɛ	0.0102	15.64%	1.98
22	i	əʊ	0.0097	14.79%	1.87
23	ɛ	ɒ	0.0091	13.96%	1.77
24	i	ɛ:	0.0091	13.85%	1.75
25	i	u:	0.0086	13.20%	1.67
26	əʊ	aʊ	0.0085	12.91%	1.64
27	eɪ	ʌ	0.0080	12.16%	1.54
28	aʊ	u:	0.0077	11.78%	1.49
29	ɛ	ʌ	0.0077	11.76%	1.49
30	ʌɪ	ɜ:	0.0074	11.33%	1.44
31	i	ɪə	0.0068	10.42%	1.32
32	æ	aʊ	0.0068	10.33%	1.31
33	ɔ:	i	0.0067	10.27%	1.30
34	i	aʊ	0.0067	10.23%	1.30
35	aʊ	ɪə	0.0058	8.90%	1.13
36	ɪ	ʌ	0.0056	8.54%	1.08
37	ɪ	əʊ	0.0056	8.48%	1.07
38	ɔ:	əʊ	0.0055	8.44%	1.07
39	əʊ	ɪ:	0.0055	8.38%	1.06
40	eɪ	ɜ:	0.0052	7.89%	1.00

differ primarily in terms of degree of tongue height. This is notably the case for the 1st ranked contrast between the high-front and low-front phonemes. Other anterior-based examples include the contrasts ranked 10th, 13th, 19th, 21st, and 24th. The highest ranked contrast between posterior-based phonemes is ranked 9th. Other examples are ranked 12th, 15th, and 38th. Four of the top 10 contrasts involve phonemes that differ primarily in terms of tongue retraction. The 2nd ranked contrast involves two anterior-closing diphthongs whose initiating segments occupy opposite quadrants in the mid zone of vowel space. Similarly, the contrasts ranked 4th, 5th, and 6th pair mid-front with mid-central and mid-back phonemes.

4.2 Consonant contrasts

Table 2 indicates an uneven distribution of work among the consonant contrasts. LDRN values show that the top ranked /n - z/ obtains an FL that is 8.51 times greater than the 40th ranked /z - m/. DRN values further expose some stark differences in the relative amount work carried by contrasts. The 5th ranked contrast does 45.16% of the work that the 1st ranked contrast. The relative decrease continues down the list: the 10th ranked contrast does 31.78% of the work that the 1st does, the 15th ranked does 25.00%, the 20th ranked does 18.18%, the 25th does 16.94%, the 30th does 14.57%, the 35th does 13.82%, and the 40th does 11.75% of the top ranked contrast. In other words, the decrease in relative amount of work is steady with larger decreases at the top of the rank. It is worth noting that the >50% threshold used to classify high FL in recent studies (viz., Kang & Moran, 2014; Munro & Derwing, 2006; Suzukida & Saito, 2019) would be satisfied by the top 4 contrasts in this ranking (and the top 5 in the case of vowel contrasts).

Closer scrutiny reveals a dominant role of certain consonant phonemes. The phoneme /w/ participates in 9 contrasts (among the top 40), 5 of which are among the top 20. The phoneme /n/ participates in 8 contrasts, 7 of which are among the top 20. The phoneme /t/ participates in 8 contrasts, 6 of which are among the top 20. The phoneme /z/ participates in 6 contrasts, with 4 among the top 20. The phoneme /m/ participates in 6 contrasts, 1 of which is among the top 20.

The contrasts in this table tend to involve rather distinct phonemes which differ in terms of both manner and place of articulation. Only seven out of the 40 contrasts in Table 2 involve phonemes that are relatively similar. The phonemes involved in the contrast ranked 5th, for example, differ only in voicing. The 6th ranked contrast pairs the

Table 2. FL ranking of the top 40 consonant contrasts in BRP

Rank	Phoneme contrast		FL	DRN	LDRN
1	n	z	0.0770	100%	8.51
2	t	n	0.0742	96.35%	8.20
3	t	z	0.0687	89.24%	7.60
4	t	j	0.0566	73.49%	6.26
5	t	d	0.0348	45.16%	3.84
6	z	f	0.0282	36.65%	3.12
7	n	f	0.0270	35.01%	2.98
8	n	l	0.0259	33.60%	2.86
9	d	j	0.0255	33.12%	2.82
10	t	f	0.0245	31.78%	2.71
11	w	b	0.0234	30.39%	2.59
12	n	w	0.0199	25.86%	2.20
13	n	g	0.0199	25.82%	2.20
14	n	s	0.0197	25.58%	2.18
15	w	ð	0.0193	25.00%	2.13
16	w	h	0.0186	24.13%	2.05
17	w	s	0.0159	20.65%	1.76
18	z	d	0.0152	19.80%	1.69
19	t	m	0.0151	19.59%	1.67
20	h	b	0.0140	18.18%	1.55
21	n	m	0.0139	18.07%	1.54
22	w	g	0.0138	17.89%	1.52
23	w	m	0.0136	17.70%	1.51
24	j	h	0.0133	17.24%	1.47
25	v	p	0.0130	16.94%	1.44
26	s	m	0.0130	16.92%	1.44
27	w	d	0.0125	16.26%	1.38
28	t	s	0.0125	16.19%	1.38
29	t	h	0.0122	15.86%	1.35
30	l	ʧ	0.0112	14.57%	1.24
31	s	g	0.0112	14.54%	1.24
32	z	v	0.0108	14.06%	1.20
33	θ	ʧ	0.0108	13.99%	1.19
34	l	θ	0.0108	13.98%	1.19
35	s	ð	0.0106	13.82%	1.18
36	f	m	0.0103	13.41%	1.14
37	w	ʃ	0.0100	13.02%	1.11
38	d	v	0.0095	12.36%	1.05
39	s	k	0.0091	11.80%	1.00
40	z	m	0.0090	11.75%	1.00

voiced alveolar and voiceless labiodental fricative while the 32nd ranked contrast involves the voiced labiodental and the voiced alveolar fricatives. The 8th ranked contrast pairs the lateral approximant with the alveolar nasal. The 21st ranked contrast involves the bilabial and alveolar nasals. The 11th and 22nd ranked contrasts involve the voiced labial-velar approximant paired with the voiced bilabial stop in the former case and with the voiced velar stop in the latter case.

At this point, the objectives of this manuscript stated in the Introduction have been accomplished. The review of the work of Brown and Catford exposed some obstacles to replication and prompted the design and implementation of an updated approach to the production of FL rankings. The present study produced FL rankings for 137 vowel and 198 consonant contrasts of BRP estimated from usage metrics in the BASE corpus, the top 40 of which were introduced here. The companion spreadsheet available through ResearchGate provides the field with the complete results.

5 Addendums

This section includes three addendums which serve to further contextualize the results of this study. The first addendum addresses the issue of relative frequency of recurrence among the words that form MPs. Next, readers are guided through some observations regarding how to interpret differences in past and present FL rankings. Lastly, the FL rankings for vowel and consonant contrasts in General American English (GAE) are presented.

5.1 Balanced vs unbalanced MPs

Given the role that MPs play in the of estimation of FL, a shared concern among researchers has been accounting for the frequency of use of the words that form MPs. Intuitively, it seems sensible to consider that all things being equal, “a contrast which distinguishes two frequent forms is more significant than one which distinguishes two infrequent forms, or a frequent from an infrequent one.” (Catford, 1988, p. 4, citing Greenberg [1958]). This concern is understandable since, depending on the line of inquiry, the relative contributions of lexical items might need to be taken into consideration when interpreting results. It is thus important to acknowledge that methods of estimating FL intended to reflect the variable of relative contribution have not yet been devised. This means that MPs formed between two words with similar probability of occurrence, between a highly recurrent word and a rarely recurrent one, or two words of low probability of occurrence all contribute equally to the FL estimation.

The methodology adopted for the present investigation goes some way toward addressing this issue. Recall that the FL values are derived from the MPs formed among HFWs. A consequence of this methodological decision is the exclusion of MPs involving words with low probability of recurrence in the corpus as a whole while, at the same time, narrowing the magnitude of differences in probabilities among the words included. In this way, the FL rankings presented here might provide interested readers with a means by which to explore the hypotheses put forward by Levis and Cortes (2008, p. 205) regarding "the effect of frequency on using minimal pairs".[7]

5.2 Catford's ranking in light of the findings from the present study

As the differences in data and methodology impede meaningful comparison of the results obtained from this study with the rankings produced by Catford, this addendum is provided simply to orient those readers familiar with Catford's rankings with the extent of the differences. Table 3 presents a list of the top 40 initial consonant contrasts provided in Catford's ranking including the DNR values obtained from this usage-driven, information-theoretic approach to calculation in the rightmost column.

The divergences in FL measures are immediately obvious, as expected. Some of the pairs obtain low or nil FL when usage probabilities are taken into consideration. Twelve contrasts on this list obtain an FL <1.0%, including three of the top 5. Recall that an FL of 0.00% reflects an absence of MPs in the data set. Researchers using FL to investigate comprehensibility have followed Munro and Derwing (2006) in applying a threshold of >50% to distinguish between to "high FL errors" and "low FL errors". Results from the present study indicate that three of the contrasts on this list satisfy the criterion of FL >50% and only one among them, namely /n – l/, was a variable of interest in the comprehensibility studies just mentioned.

Some of the differences in results at the top of the list merit particular attention. The contrasts /b – p/, /k – p/, and /t – p/ are ranked 2nd, 3rd, and 4th, respectively, on Catford's list. They obtain very little or nil FL in the present investigation. This seems somehow counterintuitive since examples of MPs for each of these three contrasts come easily to mind. In other words, they are type-rich contrasts and this type-richness creates a (false)

Table 3. Catford's list of initial consonants and DRN values from the present study

Rank	Phoneme contrast		Catford (1987)	Present study
1	h	k	100%	4.32%
2	b	p	98%	0.00%
3	k	p	92%	0.90%
4	t	p	87%	0.00%
5	h	p	85%	6.63%
6	s	h	85%	19.94%
7	l	ɹ	83%	9.24%
8	d	b	82%	1.99%
9	t	s	81%	35.84%
10	t	k	81%	6.91%
11	d	l	79%	14.32%
12	f	p	77%	4.67%
13	w	b	76%	67.28%
14	d	ɹ	75%	7.26%
15	t	d	73%	100.00%
16	g	b	71%	1.78%
17	f	h	69%	0.89%
18	s	f	64%	8.62%
19	n	l	61%	74.39%
20	n	m	59%	40.00%
21	d	g	56%	0.66%
22	n	d	53%	20.80%
23	s	ʃ	53%	17.85%
24	g	k	50%	10.21%
25	w	g	49%	39.60%
26	n	ɹ	41%	8.14%
27	d	ʤ	39%	0.72%
28	t	ʧ	39%	2.11%
29	s	ʧ	37%	0.09%
30	g	ʤ	31%	0.00%
31	b	v	29%	0.00%
32	ʃ	ʧ	26%	1.89%
33	f	v	23%	8.67%
34	w	v	22%	0.00%
35	s	θ	21%	8.79%
36	j	ʤ	21%	0.00%
37	d	ð	19%	6.13%
38	ʧ	ʤ	19%	0.00%
39	t	θ	18%	6.14%
40	f	θ	15%	2.99%

perception of high FL. When usage metrics are used to estimate FL, however, it turns out that intuitions stemming from type-based perceptions do not coincide with actual language use.

5.3 FL rankings for vowel and consonant contrasts in General American English (GAE)

Until now, the field has had access to rankings reflective of a single English variety, namely, BRP. This section presents FL rankings for vowel and consonant contrasts for General American English (GAE). The data set was curated from the MICASE corpus (Simpson et al., 2002), which functions as a companion to BASE and contains close to 200 hours of academic speech from university departments. Analytical procedures mirror those described previously regarding the BRP rankings. The results presented here are based on 1,350,474 phonemic transcriptions of the dominant vocabulary identified in the MICASE corpus manufactured according to the phonological specifications provided in Yavaş (2006). According to these specifications, GAE has 16 vowel phonemes and 24 consonant phonemes and, thus, the maximum number of possible vowel contrasts is 120 ($=\frac{16 \times 15}{2}$) and the maximum number of possible consonant contrasts is 276 ($=\frac{24 \times 23}{2}$). The data set instantiated 86 vowel contrasts and 195 consonant contrasts. The top 40 contrasts, the maximum number that would fit on one page, are presented in the tables below. Interested readers are reminded that they can find complete results in the companion spreadsheet.

5.3.1 Vowels contrasts

Table 4 indicates a rather uneven distribution of work among the vowel contrasts. LDRN values show that the top ranked contrast /eɪ - aɪ/ obtains an FL that is 16.16 times greater than the 40th ranked /ɪ - ʌ/. DRN values further expose some stark differences in the relative amount work carried by contrasts. The 5th ranked contrast does 44.20% of the work that the 1st ranked contrast. The relative decrease continues down the list: the 10th ranked does 22.60% of the work that the 1st does, the 15th ranked does 16.41%, the 20th ranked does 13.22%, the 25th does 9.20%, the 30th does 8.21%, the 35th does 7.09%, and the 40th does 6.19% of the top ranked contrast. In other words, the decrease in relative amount of work is steady with markedly larger decreases at the top of the rank.

Closer scrutiny reveals a dominant role of certain vowel phonemes. The phonemes

Table 4. FL ranking of the top 40 vowel contrasts in GAE

Rank	Phoneme contrast		FL	DRN	LDRN
1	eɪ	aɪ	0.0583	100%	16.16
2	ɪ	æ	0.0554	95.03%	15.36
3	eɪ	ə	0.0357	61.28%	9.90
4	ɪ	ɔ	0.0274	47.10%	7.61
5	æ	u	0.0258	44.20%	7.14
6	aɪ	i	0.0231	39.60%	6.40
7	eɪ	i	0.0191	32.70%	5.28
8	i	oʊ	0.0184	31.56%	5.10
9	ɔ	ɑ	0.0181	30.98%	5.01
10	eɪ	oʊ	0.0132	22.60%	3.65
11	ɪ	aʊ	0.0128	21.92%	3.54
12	ɪ	ɛ	0.0101	17.40%	2.81
13	ɛ	ɑ	0.0100	17.12%	2.77
14	æ	ɛ	0.0096	16.55%	2.67
15	oʊ	aʊ	0.0096	16.41%	2.65
16	æ	ɔ	0.0088	15.10%	2.44
17	ɛ	ʌ	0.0088	15.08%	2.44
18	eɪ	ʌ	0.0088	15.08%	2.44
19	i	u	0.0087	14.90%	2.41
20	i	aʊ	0.0077	13.22%	2.14
21	aʊ	u	0.0075	12.79%	2.07
22	æ	aʊ	0.0071	12.23%	1.98
23	aɪ	ʊ	0.0066	11.37%	1.84
24	aʊ	ɑ	0.0062	10.70%	1.73
25	oʊ	u	0.0054	9.20%	1.49
26	æ	i	0.0052	8.86%	1.43
27	ɔ	oʊ	0.0050	8.63%	1.39
28	ɔ	aʊ	0.0050	8.63%	1.39
29	aɪ	ɛ	0.0050	8.62%	1.39
30	aɪ	ɑ	0.0048	8.21%	1.33
31	ɛ	ɜ	0.0047	8.06%	1.30
32	eɪ	ɔ	0.0046	7.90%	1.28
33	oʊ	ə	0.0043	7.32%	1.18
34	aɪ	oʊ	0.0042	7.24%	1.17
35	eɪ	ɪ	0.0041	7.09%	1.15
36	aɪ	u	0.0040	6.87%	1.11
37	ɪ	oʊ	0.0038	6.53%	1.06
38	eɪ	u	0.0038	6.46%	1.04
39	ɪ	ɜ	0.0036	6.26%	1.01
40	ɪ	ʌ	0.0036	6.19%	1.00

/eɪ ɪ oʊ/ participate in 8 contrasts among the top 40. The phoneme /aɪ/ participates in 7 contrasts. The phonemes /aɪ aʊ/ participate in 7 contrasts. The phonemes /æ i ɔ oʊ ɛ u/ participate in 6 contrasts.

Several contrasts are rather similar in articulatory terms. Eight of the 40 differ primarily in terms of degree of tongue height. A prominent example is the 2nd ranked contrast between the high-front and low-front phonemes. Other anterior-based examples include the contrasts ranked 7th, 12th, 14th, 26th, and. The highest ranked contrast between posterior-based phonemes is ranked 9th. Other examples are ranked 25th and 27th.

5.3.2 Consonant contrasts

Table 5 indicates an uneven distribution of work among the consonant contrasts. LDRN values show that the top ranked /t - z/ obtains an FL that is 7.73 times greater than the 40th ranked /z - m/. DRN values further expose some stark differences in the relative amount work carried by contrasts. The 5th ranked contrast does 54.66% of the work that the 1st ranked contrast. The relative decrease continues down the list: the 10th ranked contrast does 36.89% of the work that the 1st does, the 15th ranked does 29.07%, the 20th ranked does 23.20%, the 25th does 19.54%, the 30th does 16.97%, the 35th does 15.49%, and the 40th does 12.94% of the top ranked contrast. In other words, the decrease in relative amount of work is steady with larger decreases at the top of the rank.

Closer scrutiny reveals a dominant role of certain consonant phonemes. The phoneme /n/ participates in 9 contrasts (among the top 40), 8 of which are among the top 20. The phoneme /w/ also participates in 9 contrasts (among the top 40), 6 of which are among the top 20. The phoneme /t/ participates in 8 contrasts, 5 of which is among the top 20. The phoneme /m/ also participates in 8 contrasts, 1 is among the top 20. The phonemes /z s/ participate in 6 contrasts, with 3 and 2 in the top 20 respectively. The phonemes /d f g h/ each participate in 4 contrasts among the top 40.

The contrasts in this table tend to involve rather distinct phonemes which differ in terms of both manner and place of articulation. Only four out of the 40 contrasts in Table 5 involve phonemes that are relatively similar. The contrast ranked 5th, for example, pairs voiced and voiceless alveolar plosives. The 10th ranked contrast pairs the alveolar nasal and lateral approximant while the 16th ranked contrast involves the alveolar lateral approximant and alveolar approximant. The 8th ranked contrast pairs the lateral approximant with the alveolar nasal. The 22nd ranked contrast involves the bilabial and

Table 5. FL ranking of the top 40 consonant contrasts in GAE

Rank	Phoneme contrast		FL	DRN	LDRN
1	t	z	0.0723	100%	7.73
2	n	z	0.0713	98.62%	7.62
3	n	t	0.0680	94.01%	7.27
4	t	j	0.0616	85.15%	6.58
5	t	d	0.0395	54.66%	4.22
6	d	j	0.0331	45.73%	3.53
7	n	ɹ	0.0312	43.12%	3.33
8	z	f	0.0270	37.38%	2.89
9	n	s	0.0270	37.34%	2.89
10	n	l	0.0267	36.89%	2.85
11	n	w	0.0245	33.95%	2.62
12	n	f	0.0239	32.99%	2.55
13	t	f	0.0233	32.26%	2.49
14	w	b	0.0211	29.19%	2.26
15	w	ð	0.0210	29.07%	2.25
16	l	ɹ	0.0193	26.66%	2.06
17	w	h	0.0191	26.48%	2.05
18	n	g	0.0181	25.02%	1.93
19	w	m	0.0171	23.59%	1.82
20	w	s	0.0168	23.20%	1.79
21	t	m	0.0161	22.22%	1.72
22	n	m	0.0158	21.81%	1.69
23	m	ɹ	0.0145	19.99%	1.55
24	z	d	0.0142	19.68%	1.52
25	h	b	0.0141	19.54%	1.51
26	w	d	0.0132	18.27%	1.41
27	j	h	0.0130	18.01%	1.39
28	w	ʃ	0.0130	17.95%	1.39
29	v	p	0.0125	17.22%	1.33
30	s	ð	0.0123	16.97%	1.31
31	s	g	0.0121	16.74%	1.29
32	m	s	0.0121	16.72%	1.29
33	m	b	0.0120	16.54%	1.28
34	w	g	0.0116	16.03%	1.24
35	t	s	0.0112	15.49%	1.20
36	t	h	0.0108	14.89%	1.15
37	m	f	0.0102	14.14%	1.09
38	l	g	0.0097	13.46%	1.04
39	z	v	0.0096	13.23%	1.02
40	z	m	0.0094	12.94%	1.00

alveolar nasal phonemes.

6 Closing remarks

FL has long held the interest of applied linguists, yet the go-to resources for teachers and researchers remain FL rankings for BRP published in the 1980s. The review provided in this manuscript of the steps taken to create those rankings has demonstrated the need for new approaches to the production of these resources. The corpus-driven methodology described here is one alternative and the results have provided a very different portrayal of the relative amount of work undertaken by vowel and consonant contrasts than that obtained from type-based methods (such as the one used by Catford). In addition, differences in results obtained for BRP and GAE indicate that FL appears to be a system-specific phenomenon, highlighting a venue of inquiry worthy of pursuit. The methodology used in the present study can be replicated, thereby, facilitating the expansion of the rankings available. A welcome outcome of this study would be further investigation into the development and application of FL rankings in order to broaden and deepen understanding of the role FL plays in communication and, perhaps, speech processing. The companion spreadsheet available on ResearchGate provides complete results of the two varieties discussed here as well 8 other varieties, namely, Canadian English, East African English, Hong Kong English, Indian English, Irish English, Jamaican English, Philippine English, and Singapore English.

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Notes

1 This work was reproduced as Brown (1991).

2 The steps taken to create the Relative Functional Load list provided in this work are described in Catford (1988).

3 Brown's paper offers no further explanation or empirical support for his choice of pairs.

4 Denes (1964) provides phoneme frequency metrics obtained from analyses of an electronic corpus compiled from two phonetic readers containing a total of 23,052 words composed of

72,210 phonemes transcribed according to a BRP pronunciation model.

5 For example, pairs /e, æ/ and /æ, ʌ/ are both given a rank of 10. According to Denes (1964), adding cumulative frequencies from Table 2 and number of MPs from Table 7b yields 233.34 = ((2.81 + 1.53) + 229) and 119.2 = ((1.53 + 1.67) + 116), respectively.

6 This work was supported by JSPS KAKEN Grant Number JP16K02776.

7 The BASE-UK-DOVO word list is available at https://leo.aichi-u.ac.jp/~gilner/wordlists.html. This file contains frequency and part-of-speech information.

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