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Phonetic detail in Italian homophonic simplex and complex words

This study investigates whether Italian speakers encode varying degrees of morphological complexity of the homophonous sequences /stra/ and /ino/ through acoustic variation in production. Specifically, we compare the duration of /stra/ and /ino/ sequences when they are part of simplex words (e.g., *strategico* 'strategic', *destino* 'destiny'), productive affixes in transparent derivatives with an evaluative meaning (e.g., *strabello* 'extremely nice', *gattino* 'small cat'), and affixes in more opaque and lexicalized derivatives with non-evaluative meaning (e.g., *straripa* 'it overflows', *postino* 'mailman'). We find that morphemic /stra/ in transparent derivatives is systematically longer than the non-morphemic homophone, while the difference is not significant for /ino/. Within morphologically complex words, the more predictable the association of the affix with its base, the shorter the duration of the affix. We explain these results in terms of how easily the speakers associate specific meanings with given phonological forms.

Keywords: morpho-phonetic variation, Italian derivatives, homophones, acoustic detail, morphological complexity.

1. *Introduction. The phonetics of morphologically complex words*

According to recent research, morphological meaning systematically modulates the acoustic realization of words. In this review, we focus in particular on derivational morphology. An increasing amount of experimental and corpus evidence suggests that articulatory implementation is sensitive to words' internal morphological structure. For instance, Smith, Baker & Hawkins (2012) have shown that the same phonological sequence (e.g., /dɪs/) is articulated differently when it is comprised in complex forms as a real prefix (as in Eng. *discolour*) compared to when it corresponds to a pseudo-prefix (as in Eng. *distinctive*). In particular, words with genuine prefixes exhibit a longer and more peripheral /ɪ/ (lower F1, higher F2), a shorter /s/, and a longer VOT in the following plosive, thereby suggesting that morphological structure is reflected in consistent acoustic patterns. Further evidence comes from studies investigating the role of the relative frequency of derivatives with respect to their base in predicting affix phonetic reduction. For example, Hay (2003) has demonstrated that when a derived word is more frequent than its base and its internal segmentability is low (as in the case of Eng. *exactly*, close to lexicalization), its phonological constituents undergo greater phonetic reduction, as manifested for instance in increased /t/ deletion before the suffix *-ly*. Hay (2007), centered

on the production of *un-* in New Zealand English, similarly shows that prefix duration increases with the morphological transparency of the prefixed word: *un-* is significantly longer in transparent forms like *unburstable* than in opaque or lexicalized forms like *unfortunate*. The Segmentability Hypothesis (Hay, 2003; see also Bell, Ben Hedia & Plag 2020) therefore states that derivatives that are highly segmentable and transparent are less likely to undergo acoustic reduction than derivatives that are less segmentable and more lexicalized.

More recently, the effects of compositionality on acoustic duration have been further explored by Plag & Ben Hedia (2018), who have tested the duration of four English affixes (*un-*, *dis-*, *in-*, *-ly*) using data from the Switchboard corpus of spoken English. For *un-* and *dis-*, affix duration is positively correlated with word segmentability; by contrast, no systematic effects are found for *in-* and *-ly*. Several other studies have provided conflicting results, as reviewed in Stein & Plag (2022). By extending their investigation to three large corpora and eight different English derivational affixes, these authors explicitly challenge the reliability of segmentability/transparency as a consistent predictor of acoustic enhancement, while acknowledging that its influence is nonetheless observable in the data.

Repeated observations of phonetic reduction correlated with informational redundancy of linguistic elements (e.g. Kuperman & Pluymaekers, 2007) have suggested what Bell et al. (2020: 89) call the Informativity Hypothesis, which postulates that acoustic segments that are more informative for word recognition are produced with greater acoustic salience than less informative ones (see also Hanique & Ernestus, 2012). As Seyfart (2014: 143) pointed out, the informativity of a word type is the averaged probability with which a word will occur given each of the contexts that it can occur in. Usually-predictable words have low informativity, because they tend to provide less new information in actual communicative use. In contrast, usually-unpredictable words have high informativity, because in actual use they tend to be surprising and informative. For instance, in their study on English noun-noun compounds, Bell & Plag (2012) found that the probability of perceptual prominence is correlated with the informativity of that constituent, using both probabilistic and semantic measures. In particular, they show that in compounds, the level of informativity of N2 is decisive in placing an accent. The more informative second constituents are, the more they are probable to attract stress.

Unfortunately, studies on the morphology-phonetics interface have investigated a restricted number of languages, mostly Germanic (English, German and Dutch), and sporadically a few others (Pluymaekers, Ernestus & Baayen, 2005; Tomaschek, Plag, Ernestus & Baayen, 2019).

In this paper, we focus on Italian. Italian derivational morphology, with its rich array of phenomena, offers a good opportunity to test the role of segmentability and informativity in shaping the phonetics of morphologically complex words. Therefore, our aim is to investigate the production of word-initial /stra/ and word-final /ino/ in morphologically different words. These two sequences may be ambiguous in word recognition to the extent that they can be associated with

three different functions: (1) non-(derivational)morphemic segments, being part of the root of a word (such as in *strada* 'street') or part of the inflectional form of a non derived word (such as in *delfino* 'dolphin'); (2) affixes productively used in the expression of evaluative meanings – respectively, an intensifying prefix (*stra-*, as in *strabello* 'extremely beautiful/nice') and a diminutive suffix (*-ino*, as in *gattino* 'little cat/kitten'); (3) affixes used either in synchronically opaque forms (*stra-*, as in *straripa* '(it) overflows') or in the derivation of nouns with other derived semantic category (*-ino*, as in *postino* 'mailman'; cf. Rainer 2003). We explore whether the ambiguity for *stra-* and *-ino* is resolved by the speakers in production by manipulating the acoustic detail.

In what follows (§ 2), we first provide background information on the morphology of *stra-* and *-ino* derivatives in Italian, and then outline the research questions that guide the study.

2. *Homophony in Italian derivation*

Italian derivational morphology lacks bi-uniqueness: the same phonological form can correspond to different meanings due to the homophony of different affixes and homophony between affixes and parts of lexemes.

For instance, the final phonological sequence /ino/ appears in diminutives like *gattino* ('kitten', from *gatto*), in agent nouns such as *postino* ('mailman', from *posta*), in instrument nouns such as *cancellino* ('eraser', from *cancellare*), and in ethnic derivatives like *tunisino* ('Tunisian man', from *Tunisia*). The same segment /ino/ also surfaces in morphologically simplex nouns like *delfino* ('dolphin'), where it is homophonous with the aforementioned suffixes but etymologically unrelated.

As Merlini Barbaresi (2004: 266-267) explains, the suffix *-ino* displays a great semantic fragmentation and it has long been discussed whether its several functions are to be considered a case of homophony or polysemy. Following a series of previous studies on diminutive suffixes in Romance languages (Rainer 1990; Fortin & Rainer, 2022), Rainer (2023) conducts a thorough diachronic and comparative analysis on Italian, demonstrating that, although connected to the same Latin etymological form, the functions of diminutive, instrumental, and agentive affix developed simultaneously and independently in Italian, which suggests polysemy rather than homophony. Agentive, ethnic and instrumental *-ino* show a moderate productivity compared to diminutive *-ino*, and, in addition, its derivatives have a much lower semantic transparency than the diminutives (see § 3.1, Tab. 1).

Compared to *-ino*, initial *stra-* shows even more complexity. It bears intensifying meaning in words like *strabello*, 'extremely nice/beautiful' (from *bello*, 'nice/beautiful'); it forms parasynthetic verbs like *straripare* 'to overflow', derived from the noun *ripa (riva)*, 'shore', where the prefix bears the meaning of 'going out or over' something. A morphemic *stra-* is also present in prefixed but baseless forms like *strapazzo* 'wear out (v.)/ strain (n.)'. Finally, non-morphemic /stra/ is part of the root of simplex words like *strabismo* 'strabism'.

Studies conducted over non-evaluative prefix *stra-* (Corona, Maniglia & Pisegna, forthcoming) highlight that its form originated as an "incrocio di etimi" (Pisani, 1967), i.e. a crossing of different etymons converging into a single form throughout their phonological evolution. In fact, the Italian form *stra-* in parasynthetic verbs like *straripare* or nouns like *strapazzo* emerges from a convergence of an array of Latin prefixes whose meaning is somewhat related to motion, i.e., *extra*, *trans*, and *ultra*. This original prefix is no longer productive synchronically and, for contemporary Italian speakers, its morphosemantic transparency is low or null. In opposition to that, the evaluative prefix *stra-* is extremely productive and has high morphosemantic transparency (cf. § 3.1).

The present study aims to test whether the different morphological status of homophonic sequences /stra/ and /ino/ is encoded by speakers in production through systematic variation in the acoustic detail.

Two aspects are investigated. The first is whether true affixes (as in *strabello* and *gattino*) and pseudo-affixes (as in *strabismo* and *delfino*) are acoustically differentiated in duration. The second is whether, within derivatives, the morphological properties of words' morphosemantic transparency and affixes' productivity correlate with acoustic duration.

3. *Experiment*

3.1 Materials

For the purpose of our experiment, we selected a total of 30 Italian target word forms, 15 beginning with /stra/ and 15 ending in /ino/. Of these, 10 words with non-derivational forms of /stra/ and /ino/ (e.g. *strabismo*, *delfino*) were named Class 1 items; 10 words with derivational, evaluative *stra-* and *-ino* (e.g. *strabello*, *gattino*) were named Class 2 items; 10 words with derivational, non-evaluative *stra-* and *-ino* (e.g. *postino*, *strapazzo*) were named Class 3 items.

In selecting the experimental words, we tried to control for the phonetic and phonological characteristics of the context following (for /stra/) or preceding (for /ino/) the relevant sequences: the cluster positioned before or after the target sequence /stra/ or /ino/ was a (preferably plosive) consonant with an anterior place of articulation. Forms were also balanced for word length in number of syllables and stress position: we only admitted trisyllabic and quadrisyllabic words, stressed on the penultimate syllable.

Then, we looked for the corresponding lemmas of these forms in the GRADIT dictionary (De Mauro, 1999-2000) and ColFis corpus (Bertinetto et al., 2005), in order to eliminate diastratically or regionally marked forms.

Numeric indices of morphotactic transparency, morphosemantic transparency, productivity of the derivational process, lexical frequency and relative frequency were calculated for all Class 2 and Class 3 forms according to the procedures explained below. Lexical frequency was computed for Class 1 items.

The index of morphotactic transparency used in our study was adapted from Talamo, Celata & Bertinetto (2016), which in turn is based on the universal scale of Morphotactic Transparency developed by Dressler (2005) with the aim of describing the morphotactic phenomena that affect derivatives in the English language. Dressler's transparency scale is based on the principle of iconicity and biunique correspondence of form and meaning of the morphological units of complex words, and identifies eight degrees in total. In the scale used in this study, while maintaining the same classification criteria, we reduced the number of transparency degrees to better fit the analysis of the characteristics of *stra-* and *-ino* words. Therefore, we assigned to each selected form scale values from 1 = maximal opacity to 4 = maximal transparency. As reported in Tab. 1 below, for instance, we assigned 4 to forms such as *strabello*, and 1 to forms such as *strabiliante*.

Likewise, our scale of morphosemantic transparency was inspired by Talamo et al. (2016), too, and comprises four degrees in total (1 = maximal opacity, 4 = maximal transparency). In this case, in modifying the original scale, we took into consideration the distinction between memorized lexicon and non-memorized lexicon, and the distinction between morphemes modifying the information and morphemes transforming the information, following the work of Schwarze (2001) (for transparency indexes, see Corona & Tramutoli, in preparation). Thus, we still assigned 4 to forms such as *strabello*, and 1 to forms such as *strapazzo*.

Lexical frequency was extracted from the corpus of written Italian Web 20 (itTenTen), composed of 12,451,734,885 tokens. Moreover, following Plag & Ben Hedia (2018) we calculated the relative frequency (RF) of each word (Stein & Plag, 2022; Purse, Fruehwald & Tamminga, 2022). RF puts in relation the frequency of a specific form with that of its morphological correlations, and therefore it is an accurate measure of the transparency and productivity of morphologically complex words (Stein & Plag, 2022: 1). It is calculated by dividing the whole frequency of a derivative (Naff) by the frequency of its base (Baff). Lower values of RF thus correspond to derivatives in which the base is more frequent than the derived word; on the other hand, derivatives which occur more frequently than their base are associated with higher RF values. In the first case, the derivative is considered to be more transparent: the higher frequency of the base will make it easier for the speaker to recognize the base as a constituent of a complex derivative, which is then processed through its parts. These derivatives are also more productive. In the second case, the derivative is considered to be less transparent because, if it is encountered more frequently than its base, speakers will be less likely to recognize the word's constituents, which will discourage morphological decomposition (Plag & Ben Hedia, 2018; Stein & Plag, 2022).

Finally, we calculated the productivity of each derivational process based on Baayen (1992, 1994), which integrates the productivity index with a frequency index. In particular, productivity (P) is assessed on the basis of the hapax-conditioned degree of productivity, which is measured by taking into account the

total usage of a given affix and by relating to it the number of new forms[1]. In such an account, productivity assesses the probability of encountering a new word formed with the morphological process in question.

Table 1 presents the experimental words along with their classification (Class 1, 2, or 3) and their values for morphotactic transparency, morphosemantic transparency, productivity, relative frequency (RF), and lexical frequency (Fr). As shown in the table, Class 2 items are, on average, both morphotactically and semantically more transparent, are derived through more productive morphological processes, and exhibit lower RF values compared to Class 3 items.

Table 1 - *Experimental word set. Table legend: MT: morphotactic transparency; MS: morphosemantic transparency; P: productivity; RF: relative frequency; Fr: form frequency*

Class	*Sequence*	*Forms*	*MT*	*MS*	*P*	*RF*	*Fr*
1	/stra/	*strabismo* 'strabism'	/	/	/	/	7374
		stradina 'alley, small street'	/	/	/	/	42329
		stragista 'mass murderer'	/	/	/	/	5365
		strabuzzato 'goggle-eye'	/	/	/	/	455
		strategico 'strategic'	/	/	/	/	240735
1	/ino/	*zerbino* 'doormat'	/	/	/	/	8263
		destino 'destiny'	/	/	/	/	472181
		branzino 'seabass'	/	/	/	/	7303
		assassino 'murderer'	/	/	/	/	111244
		lamantino 'manatee'	/	/	/	/	567

[1] Baayen's P* (hapax-conditioned productivity) is a quantitative measure of morphological productivity that determines the probability that a hapax legomenon contains a given affix. It is calculated by dividing the number of hapaxes by the total number of occurrences of that particular affix.

Class	*Sequence*	*Forms*	*MT*	*MS*	*P*	*RF*	*Fr*
2	/stra/	*strabello* 'extremely nice'	4	4	180	1.18	324
		straduro 'extremely hard'	4	4		1.34	5
		stragiusto 'extremely right'	4	4		0.26	33
		strabevuto 'drunk, overdrunk'	4	4		0.51	10
		stratimido 'extremely shy'	4	4		0.9	3
2	/ino/	*topino* 'small mouse'	4	4	4	3.67	4206
		gattino 'kitten'	4	4		3.87	21568
		nasino 'small nose'	4	4		3.23	5637
		riposino 'nap'	4	4		3.15	4984
		nipotino 'grandchild'	4	4		4.07	14460
3	/stra/	*strapazzo* 'wear out, strain'	4	1	0	1.85	5364
		straripa '(it) overflows'	2	2		4.89	2403
		straforo 'outsize, on the sly'	4	1		2.67	1456
		strabiliante 'astonishing'	1	1		3.91	19822
		stravolgere 'overturn, upset'	4	1		4.34	27448
3	/ino/	*tubino* 'sheath dress'	4	2	0,8 (1)	3.41	7678
		postino 'postman'	4	2		3.54	19879
		spazzino 'garbage collector'	4	2		3.9	3711
		tunisino 'Tunisian man'	4	2		4.27	9765
		arrotino 'knife grinder'	4	2		5.21	3300

As Tab. 1 illustrates, all *stra-* and *-ino* forms from Class 2 show high morphosemantic transparency, scoring 4 out of 4 in our scale. Their morphotactic transparency scores accordingly. Conversely, both prefixed and suffixed forms from Class 3 show the lowest degrees of morphosemantic transparency (1-2), even when the morphotactic transparency is not rated correspondingly (specifically, see *-ino* Class 3, where the

morphotactic transparency is high, but the morphosemantic transparency is low). The table also clearly shows that, as discussed above, more transparent (Class 2) derivatives show lower RF values, while more opaque derivatives (Class 3) have higher RF. Productivity values' distribution matches this distinction between Class 2 and Class 3, too. It is null for Class 3 *stra-* and only modest for Class 3 *-ino*, while it is higher for Class 2 *-ino* and much elevated for Class 2 *stra-*.

Along with these values, we reported the form frequency (Fr) for each selected item in the table. Although form frequency is quite variable from item to item, it seems to suggest that the forms with higher productivity (especially in *stra-*) are not very frequent. This measure indexes the token frequency of the items, and not the type frequency, which would rather address productivity, which, as expected (Baayen, 1992), is in fact high.

For each item, we also took into account a number of phonetic and prosodic factors which can influence the variation of acoustic duration, such as Length (word length in syllables: trisyllables vs. quadrisyllables), Global speech rate (calculated as the number of syllables of each sentence divided by the sentence duration), Local speech rate (calculated as the number of syllables within the target word divided by the word duration), Base duration (the duration of the base of the derivative, or the word excluding the initial /stra/ or the final /ino/), Phonological neighborhood density (number of minimal phonological neighbors of the target word, manually extracted from itTenTen), Preceding word (whether the word preceding the target one was a stressed content word or a clitic), Preceding and following segment (the type of segment before and after the target sequence, grouped as anterior, posterior or non-lingual) and Distance from the sentence beginning (calculated as the number of words preceding the target item).

3.2 Recording, annotation, analysis

Fourteen Italian native speakers (7 female, 7 male; age range: 20–35 years) from Northwestern Italy were recorded while producing the target items according to the procedure described below. All were normal hearing and exhibited no speech or language impairments. The recordings were carried out in a quiet and low-noise setting at the University of Milan using a Zoom H4n Pro recorder (.wav format, 44.1 kHz, 16-bit). The words were presented to participants according to a gap-fill reading task in which Italian sentences containing a blank space were presented on a screen. Two candidate words were offered to complete the sentence, one of them being clearly the most suitable and the other inappropriate for semantic and/or syntactic reasons. Participants were instructed to mentally complete the sentence with the right word candidate and then read it aloud. This procedure minimized list-like reading effects, favored fluent speech, and encouraged access to the meaning of the sentence and the target word before production (cf. Bell et al., 2020). The 30 target items and 90 distractors (15 prefixed, 15 suffixed, 60 morphologically simple) were included in the reading task. The sentence list was manually randomized to ensure that at least three filler sentences occurred between

any two target sentences. The list of the 30 sentences containing the target items is reported in the Appendix. Initial annotations were generated semi-automatically with ELAN via BAS-WebMAUS Basic (word and phoneme tiers), followed by manual correction and alignment refinement in Praat. An additional manual tier marked the /stra/ and /ino/ intervals within target words. Acoustic duration (ms) of /stra/ and /ino/ portions of each experimental item was extracted using Praat scripts and then manually verified.

The final dataset comprised 410 tokens (209 /stra/, 201 /ino/). The descriptive and quantitative analyses of acoustic duration were carried out in R (R Core Team, 2024). Measurement outliers were excluded based on the interquartile range (IQR) method in R, removing values beyond 1.5 below the first quartile and values 1.5 times above the third one. For the quantitative analysis of the data, we run linear mixed-effects models in R using the *lmerTest* package (Kuznetsova, Brockhoff & Christensen, 2017) and post-hoc comparisons of estimated marginal means using the *emmeans* package (Lenth, 2021) with p-values adjusted for multiple comparisons using the multivariate t method (adjust = "mvt"). Visualizations were produced using the *emmeans* and the *ggeffects* (Lüdecke, 2018) packages.

In order to answer our research questions, namely whether true and pseudo-affixes differ acoustically in duration, and whether morphosemantic transparency and affix productivity correlate with duration, we ran two separate analyses. First, the analysis was carried out on a subset which included only Class 1 and Class 2 items (see § 4.1); then, a subset containing only Class 2 and Class 3 was analyzed (see § 4.2). In both analyses, linear mixed-effects models included all the relevant morphological and prosodic factors described in § 3.1 (i.e., Sequence /stra/ or /ino/; Class for the first analysis and Relative Frequency for the second one; Word form frequency; Global and local speech rate; Base duration; Word duration; Phonological neighborhood density; Preceding word; Preceding and following segment; Distance from the sentence beginning). Full models were then simplified through stepwise model selection using the step function from the *lmerTest* package (Kuznetsova et al., 2017), so that only the variables and interactions that were significant were maintained into the final formulas. With this approach, we were able to investigate whether morpho-phonetic effects on duration emerged even when several other phonetic and prosodic control variables were taken into account. This allowed us to identify the contribution of morphological features among that of other co-varying acoustic and prosodic factors, providing a clearer view of possible morpho-phonetic influences on duration.

4. *Results*

4.1 Non-affix vs. affix (Class 1 vs. Class 2)

In Experiment 1, we compared the realizations of the items in Class 1, i.e., the simplex word group, and Class 2, i.e., the transparent and productive derivatives with evaluative meaning.

We ran a linear mixed-effects model in which the duration of the sequence was the dependent variable. The main predictor was the categorical variable of Class (Class 1 and Class 2). Further control variables included were: Sequence, Length, Word form frequency, Global speech rate, Local speech rate, Base duration, Phonological neighborhood density, Preceding word, Preceding and following segment and Distance from the sentence beginning. Moreover, to control for the possible differences between the initial vs. final sequence, we modelled all possible two-way interactions between the factor Sequence and all other model factors. Finally, speaker ID and item were included as random intercepts in the model. The reduced model, obtained through stepwise selection, included speaker as random intercept (formula: ~1 | speaker), 8 significant main effects and 5 significant two-way interactions, as reported in Table 2.

Table 2 - *Summary of the linear mixed-effects model to predict stra- and -ino sequence duration in the non-affix (Class 1) and affix (Class 2) groups. Only significant main effects and interactions are reported*

	Estimate	*t value*	*Pr(>|t|)*
Intercept	622.00	14.84	<.0001
Sequence (ino)	14.84	7.58	<.0001
Class (2)	15.06	3.84	<.001
Local SR	-69.99	-22.01	<.0001
Base duration	-0.36	-10.54	<.0001
Previous segment	39.94	2.50	<.05
Follow. segment	-35.48	-3.39	<.001
Distance	15.13	4.01	<.0001
Phon. neighbors	3.13	2.38	<.05
Sequence:class	-25.20	-2.91	<.01
Sequence:length	111.23	5.68	<.0001
Seq.:base dur	-0.53	-9.85	<.0001
Seq.:follow.seg	46.80	3.10	<.01
Seq:distance	-18.55	-3.58	<.001

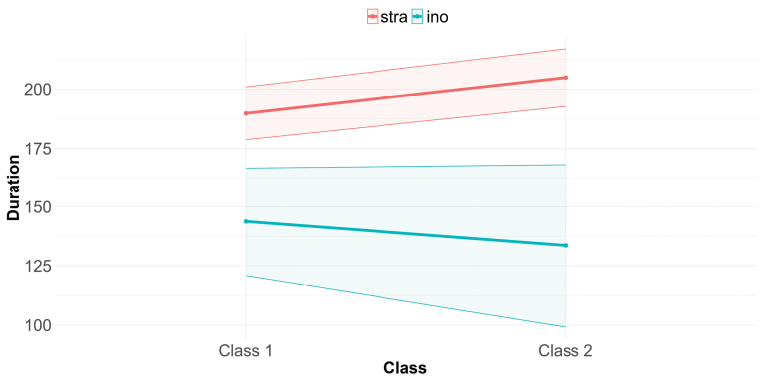
Several control factors turned out to significantly affect the duration of /stra/ and/or /ino/ sequences. Specifically, when Local speech rate increased, the sequence duration decreased; when the Base was longer, the sequence was shorter; the effect was stronger in /ino/ than /stra/ words. Previous and following segments also influenced the variation of the sequence duration (duration increased when the previous segment had a posterior place of articulation and when the following segment was lingual; these variations were significant for /stra/ words only). The further away the sequence occurred from the start of the sentence, the longer it was predicted to be, which is probably an effect of domain-final prosodic lengthening; the effect was significant only for /stra/ words. A denser phonological neighborhood caused increased duration of the sequences. Finally, /ino/ showed a

significant difference in duration from trisyllables to quadrisyllables, while /stra/ words did not.

Most importantly for our research question, the model highlights a significant main effect of the Class factor and a significant two-way interaction between Class and Sequence: the sequence duration increases significantly from Class 1 to Class 2, i.e., from the non-affixed to the affixed words; /stra/ and /ino/ are predicted 15.06 ms longer when they function as true affixes than when they are part of morphologically simplex words.

Moreover, the significant interaction of Class and Sequence indicates that the effect of Class is different across /stra/ and /ino/ (Fig. 1). A post-hoc comparison reveals that the increase in duration between Class 1 and 2 is significant in /stra/ words (β=15.1; *t ratio*=3.84; p<.001), where the prefix is 15.1 ms longer than the non-prefix sequence. The estimated marginal mean duration was 189.83 ms for Class 1 (95 % CI [178.70, 200.95]) and 204.89 ms for Class 2 (95 % CI [192.77, 217.02]). The difference is not significant for /ino/ words (β= -10.1; *t ratio*= -1.33; p=0.1), where the true prefix is on average 10.1 ms shorter than the non-prefix sequence.

Figure 1 - *Acoustic duration of* /stra/ *and* /ino/ *sequences as a function of Class*



4.2 Homophonous affixes (Class 2 and Class 3)

In a second analysis, we investigated whether the morphological properties of *stra-* and *-ino* in highly transparent (Class 2 items) and opaque derivatives (Class 3 items) were reflected in the acoustic detail. To that aim, log-transformed relative frequency (RF) was used as a predictor in the model. Log-transformation was applied to normalize the right-skewed distribution of RF values due to the presence of very high values for high-frequency derivatives (e.g., *nipotino*, 'grandchild'), and very low values for less frequent derivatives with high-frequency bases (e.g., *stragiusto*, 'extremely right'; see Tab. 1). Fixed and random factors were the same as in the previous analysis (§ 5.1) with the exception of Word form frequency, which was excluded due to high collinearity with RF ($r(272) = .81, p<.001$).

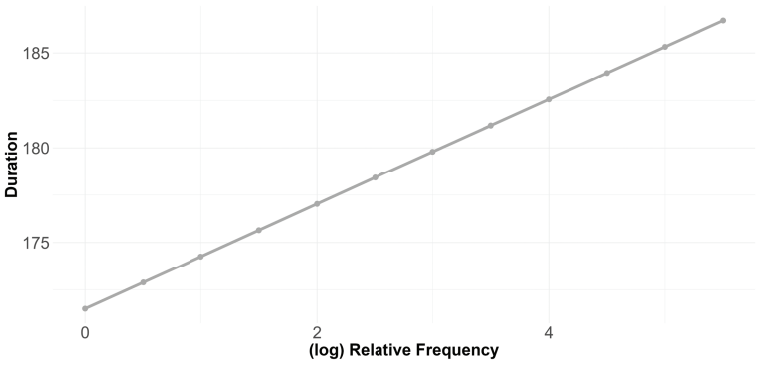
A simpler version of the model was obtained through stepwise model selection. The reduced model included speaker as random effect (formula: ~1 | speaker), 10 significant main effects and 6 significant two-way interactions, as reported in Tab. 3.

Table 3 - *Summary of the linear mixed-effects model to predict stra- and -ino sequence duration in derivatives. Only significant main effects and interactions are reported*

	Estimate	*t value*	*Pr(>|t|)*
Intercept	752.37	15.92	<.0001
log.RF	2.76	2.05	<.05
Lenght	75.30	5.87	<.0001
Local SR	-78.97	16.19	<.0001
Base duration	-0.44	-9.16	<.0001
Preceding word	39.26	2.22	<.05
Distance	13.21	5.56	<.0001
Phon. neighbors	-8.89	-2.10	<.05
Sequence:length	73.50	3.43	<.001
Seq.:phon. neighbors	9.69	2.17	<.05
Seq.:local SR	19.40	3.49	<.001
Seq.:base dur	-0.30	-3.68	<.001
Seq.:follow.seg	55.32	4.60	<.0001
Seq:distance	-9.11	-2.44	<.05

Several control factors had a significant effect on affix duration: Length, Base duration, Local speech rate, Preceding word (affixes were longer if the preceding word was a clitic), Distance from the beginning of the utterance, Following segment, Phonological neighbors, often in interactions with Sequence, indicating that the effects could be different in *stra-* vs. *-ino* words.

Figure 2 - *Estimated marginal means of Affix duration by RF*



Most relevant to our focus, the model reported a main effect of RF, reproduced in Fig. 2: increasing RF values corresponded to *longer* affix duration (β = 0.08, 95 %

CI [0.0031, 0.15]). The estimated value is very small, and this must be taken into account when interpreting the robustness and generalizability of the effect. However, the effect suggests that derivatives with lower transparency and lower productivity (higher RF) were longer than derivatives with higher transparency and higher productivity (lower RF). The effect was equally present in *stra-* and *-ino* words.

5. *Discussion*

This study has analyzed durational variations of Italian non-morphemic /stra/ and /ino/ sequences and their homophonous affixes to investigate whether homophony in derivational morphology is resolved by the speakers in production through manipulation of the acoustic detail. More specifically, we have asked whether there are systematic differences in duration between (1) morphemic and non-morphemic sequences, and (2) *stra-* and *-ino* affixes in derivatives with high vs. low degree of segmentability, transparency and productivity. Our analyses highlighted significant morpho-phonetic effects on duration, with some differences between the two sequences, as it will be discussed in detail below. Crucially, the modeling approach adopted showed that morpho-phonetic effects emerged even when a range of other predictors known to influence duration were included in the models, many of which also reached significance. Our results thus acknowledge that variation in duration arises from the interaction of multiple factors, and that morphological complexity contributes to this variation, even if its effect might be relatively subtle. Among the limits of the current study, we acknowledge that, although the models are mathematically well-specified and convergent, the factor estimates should not be regarded as definitive, given the high number of predictors relative to the limited number of observations. A corpus-based investigation based on this preliminary exploration is already in progress and will allow determining the generalizability of the estimated effects.

Concerning the first point, the analysis presented in § 4.1 has shown that there may be a significant difference in duration between non-morphemic and morphemic sequences: some morphemic sequences are systematically longer than the corresponding non-morphemic ones. Importantly, the effect of morphology is significant after controlling for many other potential predictors of durational variation, including several prosodic, segmental and frequency factors. This suggests that, besides well-known phonological and lexical effects, morphological meaning still has an effect on how the speakers pronounce words. This result is in line with recent research on Germanic languages, showing that morphological structure and phonetic implementation are not independent of each other, as reviewed in § 1. As outlined by several authors (e.g., Plag, Homann & Kunter, 2017; Seyfarth, Garellek, Gillingham, Ackerman & Malouf, 2018; Tomaschek et al., 2019), similar results directly challenge the traditional feed-forward theories of phonology-morphology interaction (e.g., Chomsky & Halle, 1968; Kiparsky, 1982) and layered psycholinguistic models of speech production (e.g., Levelt, 1999) which assume that higher-level grammatical

information and information about word-internal morphological structure are not available at the articulatory stage and, therefore, cannot account for morphologically-related systematic acoustic variation.

In our data, the morphological effect is unequally distributed across words: it is mostly carried by /stra/ words, while the difference is not significant for /ino/ words. Both the direction of the effect (true affixes longer than homophonic sequences) and the uneven distribution between /stra/ and /ino/ words are aspects worth further discussion.

It has been argued that a duration increase in true affixes might indicate that the speakers enhance or hyperarticulate a phonological sequence when it bears a morphological function, while the same sequence is comparatively reduced or hypoarticulted when it is part of a simplex word. This view is in line with both the Segmentability and the Informativity Hypothesis outlined in § 1: sequences that are more meaningful or informative tend to show greater articulatory enhancement and less phonetic reduction than less informative sequences. Consistently with this view, previous studies have found longer acoustic durations of derivational prefixes (e.g., Smith et al., 2012) and suffixes (e.g., Seyfarth et al., 2018). These explanations support the communicative function of phonetic detail, in that speakers would employ fine acoustic variation to enhance morphological constituents in order to facilitate recognition and interpretation from the listeners (Jaeger & Buz, 2017; Smith et al., 2012; Smith & Hawkins, 2012; Stein & Plag, 2022).

The absence of a similar effect for /ino/ words runs against this view. To maintain the Segmentability Hypothesis, one could argue several possible explanations. Firstly, the position of the sequence in the word could play a role: word-initial position is where phonetic information is more salient and crucial for word recognition (Smith et al., 2012). Secondly, segmental composition may have influenced the results: /stra/ is intrinsically longer than /ino/ (on average, 246 ms vs. 207 ms) and this might have enhanced the probability of finding a significant variation effect. It is also possible that segments in /ino/ show morpho-phonetic variation in dimensions other than duration, such as vowel quality, as reported for instance by Smith et al. (2012) for [ɪ] in *mis-* and *dis-*, which was more centralized in pseudo-prefixes rather than in real-prefix homophones (see Celata & Rossi, forthcoming, for further evidence on how multiple temporal and spectral properties interact in signaling morphosemantic differences). Additionally, unlike *stra-*, *-ino* undergoes resyllabification and stress assignment, making the suffix fully integrated into the derivative; this could potentially reduce duration changes related to morphological structure. Finally, *-ino* being a suffix includes an inflectional marking which bears *grammatical* meaning, and this might have obscured the potential effects of its *derivational* meaning. Further analyses are necessary to explore these hypotheses.

However, the Segmentability Hypothesis still appears not to be able to explain the second point of interest in our analysis, namely, the gradient effect of transparency and productivity in the analysis of Class 2 and Class 3 derivatives. Recall that, as shown in Tab. 1, Class 2 items not only tend to show lower RF values than Class 3 items, but they are also more transparent morpho-semantically and originate from

more productive derivational processes than Class 3 items. As we explained in § 3.1, we used in our analysis RF as a cue of transparency and productivity.

Our results on derivatives highlighted a main effect of RF on duration. Specifically, we observed that higher values of RF correlated with longer affix duration; on the other hand, lower RFs matched with shorter affixes. This result does not align with the Segmentability Hypothesis (cf. § 1) nor with a communicative explanation of morpho-phonetic variation, based on which we would have expected a *negative* correlation between affix duration and RF.

The difficulty in interpreting the effect of RF is not new. Stein & Plag (2022), in a large corpus study of eight different English affixes, found that RF effects on duration do not emerge consistently across a large number of affixes (with one exception). Moreover, for the case in which RF has a significant effect on duration, this was negative (higher segmentability correlated with longer duration) consistently with the Segmentability Hypothesis.

We believe that, better than the Segmentability Hypothesis, the Informativity Hypothesis (§ 1) can exhaustively explain our findings. The central notion of the Informativity Hypothesis (which makes this Hypothesis go one step beyond pure segmentability or compositionality issues) is the probability with which a certain affix or constituent occurs in a certain context, in our case with a specific base. When this probability is high, the association of the affix with the base is more predictable for the speakers, and, as a consequence, more segmental reduction occurs. In our dataset, the probability of the association of the nominal base *gatt-* and the diminutive suffix *-ino* (to form *gattino*) is higher than the probability of association of the nominal base *post-* and the agentive suffix *-ino* (to form *postino*), due to higher productivity of diminutive *-ino*, compared to agentive and ethnic *-ino* (see Tab. 1). By contrast, if the probability of matching an affix with a base is low, the form-meaning association is less predictable for the speakers, therefore more informative, and consequently the affix is longer. Affixes in Class 3 complex words are semantically more informative than affixes in Class 2 words, and therefore comparatively longer in production.

In this sense, we suggest that RF indexes informativity, besides compositionality: if lower RF corresponds to less informative items, then the shorter duration of affixes in forms like *gattino* compared to *postino* aligns with the expectations. In other words, since Class 3 affixes have lower productivity than Class 2 affixes, they are less probable, and therefore less expected, i.e. more informative. As a consequence of their higher informativity, they are produced with longer duration. Conversely, Class 2 evaluative suffixes have a higher productivity, thus are more probable to occur in complex words; they have lower informativity, and therefore shorter.

In sum, the overall pattern emerging from our analyses suggests that morpho-phonetic durational variation is more closely tied to the property of affixes' semantic informativity with respect to their base, rather than to the internal compositionality of derivatives. The Informativity Hypothesis is apparently able to explain both of our results: the categorical opposition between simplex and complex forms and the gradient effect of productivity and transparency in morphologically complex words.

6. *Conclusions and outlook*

In this study, we presented a phonetic investigation of Italian homophonic affixes and non-affix sequences. We found that the duration of word-initial /stra/ and word-final /ino/ displayed systematic variation in relation to the morphological complexity of the words in which they appeared. The *stra-* prefix was found to be longer than its non-morphemic homophone at the beginning of simplex words; within derivatives with the same phonological form, the degree of informativity between the base and the morpheme was found to be positively correlated with an increase in the duration of the affixes.

Although based on a relatively small dataset of read speech, this pilot study provides initial evidence for the role of morphological information influencing speech production mechanisms of homophonic sequences in Italian. The results motivate further investigation using a larger dataset and additional affixes. Future work will also have to incorporate non-durational acoustic measures, such as intensity, F0, and vowel formants, to assess whether non-temporal features show the effects of morphology besides acoustic duration. Moreover, extending the research on additional speech styles, including spontaneous and narrative speech, could help us determine whether discourse-related and contextual factors play a role in the acoustic realization of homophonic affix and non-affix sequences. Finally, further extensions of this research could also explore how Italian listeners use acoustic variation to disambiguate homophones in real time speech processing.

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Authors' contribution

Contributor's roles (where multiple contributors share the same role, their names follow an alphabetical order): conceptualization: Celata, Corona, Meluzzi; data curation: Nese, Rossi, Tramutoli; formal analysis: Rossi; funding acquisition: Celata, Corona, Meluzzi; investigation: Corona, Nese, Rossi, Tramutoli; methodology: Celata, Corona, Rossi; project administration, resources, and supervision: Celata, Corona, Meluzzi; visualization: Rossi; writing – original draft: all contributors; writing – review & editing: Celata, Corona, Rossi, Tramutoli.

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Appendix

Experimental sentences containing the target items that were presented to the speakers accompanied by 90 distractor sentences:

1. Per lo strabismo mette gli occhiali
2. Per lo strabello solo lusinghe
3. Per lo strapazzo dorme in poltrona
4. La bella stradina blocca il passaggio
5. Il pane straduro si dà agli uccellini
6. Il fiume straripa dopo la pioggia
7. La bomba stragista non porta vantaggio
8. Un fine stragiusto non porta vantaggio
9. Passò di straforo non senza vantaggio
10. Con occhio strabuzzato riguarda la scena
11. Con sguardo strabevuto non devi guidare
12. Con mossa strabiliante conquista la folla
13. Il piano strategico garantisce il successo
14. Il bimbo stratimido non esce di casa
15. Volendo stravolgere sparigliamo le carte
16. Trovi lo zerbino fuori dalla porta
17. Trovi un bel topino fuori dalla gabbia
18. Trovi un bel tubino fuori dalla stanza
19. Con il destino non si può mai sapere
20. Con il gattino non si può mai sapere
21. Con il postino non si può mai sapere
22. Faccio il branzino con le patate
23. Cola il nasino col raffreddore
24. C'è lo spazzino con i rifiuti
25. Un bell' assassino fa molta paura
26. Un bel riposino fa molto piacere
27. Un bel tunisino fa molto couscous
28. Il grosso lamantino passa nella vasca
29. Il caro nipotino passa col triciclo
30. Il solito arrotino passa col carretto