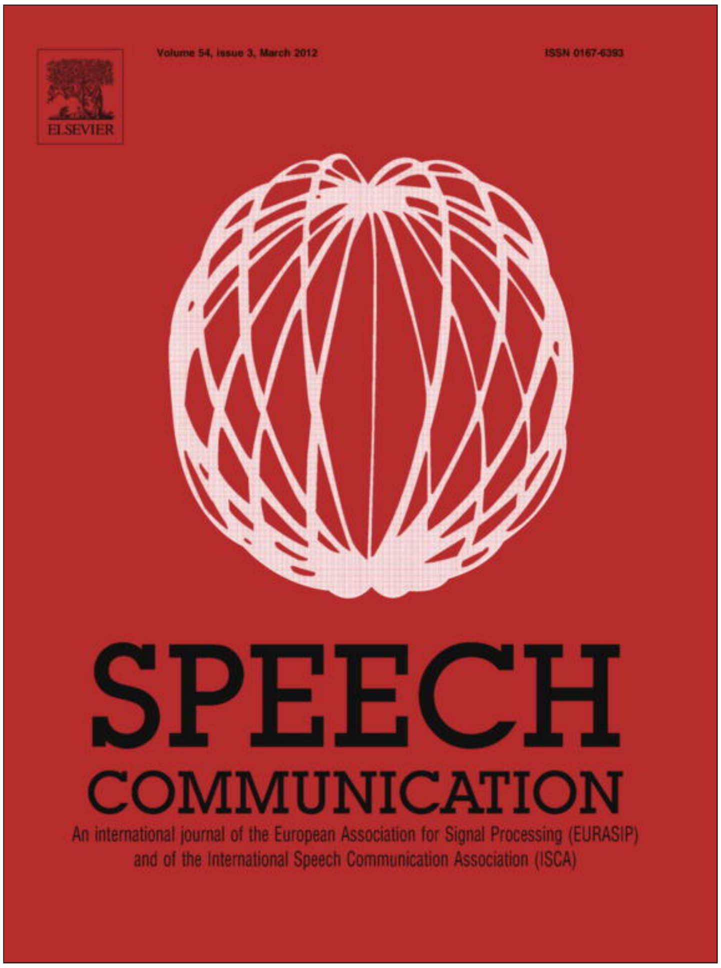
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A cross-language acoustic study of initial and final allophones of /l/

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Abstract

Formant frequency data for /l/ in 23 languages/dialects where the consonant may be typically clear or dark show that the two varieties of /l/ are set in contrast mostly in the context of /i/ but also next to /a/, and that a few languages/dialects may exhibit intermediate degrees of darkness in the consonant. F2 for /l/ is higher utterance initially than utterance finally, more so if the lateral is clear than if it is dark; moreover, the initial and final allophones may be characterized as intrinsic (in most languages/dialects) or extrinsic (in several English dialects, Czech and Dutch) depending on whether the position-dependent frequency difference in question is below or above 200/300 Hz. The paper also reports a larger degree of vowel coarticulation for clear /l/ than for dark /l/ and in initial than in final position. These results are interpreted in terms of the production mechanisms involved in the realization of the two /l/ varieties in the different positional and vowel context conditions subjected to investigation.

Keywords: Clear and dark /l/; Intrinsic and extrinsic allophones; Darkness degree; Vowel coarticulation; Spectral analysis

1. Introduction

There is a fairly good deal of information about the articulatory properties of contextual allophones of consonants thanks to extensive work on segmental coarticulation carried out during the last decades. Our knowledge about the articulatory properties of positional and prosodic allophones is more limited, although we have at present a reasonable amount of data on the mechanisms of consonant reinforcement and weakening in different syllable, word and utterance positions (Fougeron and Keating, 1997; Lavoie, 2001). There is, however, need for further investigation into how the phonetic realization of consonants varies with their placement within the word and the utterance from one language to another, and the extent to which the observed patterns of phonetic variability depend on the language-specific consonant articulatory characteristics. Along these lines, the present investigation will look into positional differences in the realization of /l/ in languages and dialects with clear and dark varieties of the alveolar lateral.

Traditionally two different varieties of /l/ have been identified, i.e., clear (/i/-like) and dark (/u/-like). As shown by the upper graphs of Fig. 1, the production of clear /l/ (right graph) involves tongue body raising and fronting and the formation of a single large cavity behind the primary dentoalveolar constriction, while dark /l/ (left graph) is articulated with different degrees of tongue predorsum lowering and of postdorsum retraction towards the uvular zone or the upper pharyngeal wall causing the cavity behind the primary constriction to split into an oral and a pharyngeal subcavities (Narayanan et al., 1997; Browman and Goldstein, 1995). A somewhat larger middle oral subcavity in the palatal region for the dark vs clear /l/ variety results from greater inward lateral compression (Narayanan et al., 1997). In addition to exhibiting more contact at the sides of the palate, clear /l/ may exhibit more laminal involvement than apical dark /l/ and thus, more central contact at constriction location (Zhou,

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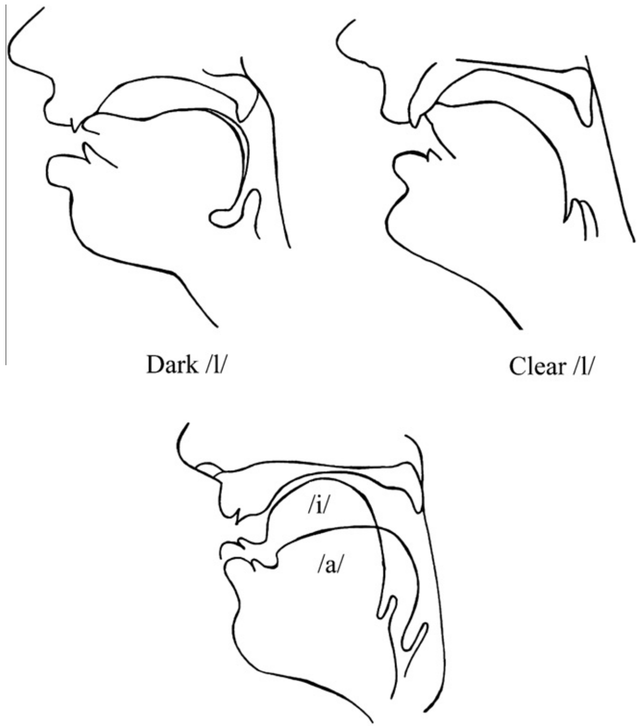

Fig. 1. Possible vocal tract configurations for dark /l/ and clear /l/ (top) and for vowels /i/ and /a/ (bottom).

2009); moreover, the place of articulation may be more anterior for the dark vs the clear cognate, i.e., dentoalveolar vs plain alveolar (see Recasens and Espinosa, 2005 for a literature review). A lower predorsum position for dark /l/ than for clear /l/ is expected to cooccur with more jaw lowering for the former vs latter consonant variety (see Lindblad and Lundqvist, 2003 regarding this issue).

These differences in tongue body configuration and cavity distribution yield very different F2 frequencies: a relatively high F2 about 1500–2000 Hz for clear /l/ and a lower F2 about 800–1200 Hz for dark /l/. The F2 frequency is a half-wavelength resonance of the back cavity system behind the primary constriction and decreases with tongue body backing (Fant, 1960; Stevens, 1998). As for the other spectral formants, F1 is typically higher for dark /l/ than for clear /l/, and appears to be positively related to the cross-sectional area of the lateral constriction which is greater for dark /l/ vs clear /l/ in line with differences in predorsum and perhaps jaw lowering between the two varieties of the consonant (Fant, 1960; Bladon, 1979). F3 may also be higher for strongly dark vs clear realizations of the alveolar lateral whenever the former are articulated more anteriorly than the latter along the dentoalveolar zone since this formant is associated with the cavity in front of closure location (Fant, 1960).

Languages and dialects differ as to whether they exhibit clear /l/ (French, German) or dark /l/ (Russian, Portuguese). Moreover, articulatory and acoustic data reveal that the darkness scale does not proceed categorically but gradually such that languages with one of the two /l/ types may show lighter or darker consonant qualities (Recasens, 2004). Thus, for example, among languages and dialects exhibiting dark /l/, the consonant is darker in Russian or European Portuguese than in present-day Eastern Catalan. Within this scenario, it seems advisable to classify languages and dialects depending on whether they are endowed with a strongly dark, a strongly clear or a moderately clear/dark variety of the consonant rather than just considering a binary distinction between clear and dark /l/. In the present paper, the binary classification advocated in descriptive studies will be refined based on the formant frequency values for /l/ in specific languages/dialects. If darkness degree proceeds gradually, several languages/dialects ought to exhibit intermediate darkness degrees in the consonant.

Allophonic differences between /l/ in syllable initial and syllable final position appear to be mainly associated with F2 which happens to show a higher frequency initially (where /l/ is clearer) than finally (where the lateral is darker). This is not surprising given that F2 is particularly sensitive to variations in tongue dorsum height and fronting that cue the darkness distinction. In most cases, this allophonic difference is relatively small and reflects a trend for consonants to be articulated with a somewhat higher and more fronted tongue position initially than finally (Recasens and Pallarès, 2004). On the other hand, the initial and final allophones of clear /l/ are expected to differ from those of dark /l/, both since the two consonant types exhibit very different acoustic qualities, and also because a more active involvement of the tongue dorsum during the production of dark /l/ than of clear /l/ renders the former consonant variety more constrained than the latter. Our initial expectation in this respect is that strongly dark /l/ should show similar dark realizations initially and finally and thus, ought not to be affected much by syllable position, while clear /l/ (and to some extent moderately dark/clear varieties of /l/ as well) ought to be more sensitive to differences in syllable position and, therefore, should allow for a larger spectral contrast between the syllable initial and syllable final realizations. This hypothesis is consistent with linguopalatal contact data for other anterior consonants revealing that articulatory differences as a function of syllable position vary inversely with differences in manner-induced degree of articulatory constraint, i.e., position-dependent differences are typically smaller for highly constrained lingual fricatives and trills than for less constrained stops and nasals, and also with articulatory and acoustic data indicating the presence of smaller coarticulatory effects from adjacent vowels on dark /l/ than on clear /l/ (Recasens and Pallarès, 2004; Recasens and Espinosa, 2005).

In some languages/dialects, the presumably universal spectral difference between the initial and final allophones of /l/ appears to be too large to be attributed solely to phonetic factors. In this case, the lateral consonant may be argued to exhibit a clear allophone in initial position and a dark allophone in final position. Traditionally, this scenario has been set in contrast with the one described above by ascribing the term ‘extrinsic’ to those allophones realized through different articulatory targets, and the term ‘intrinsic’ to those allophones which differ just in degree and are thus comparable to contextual phonemic variants (Ladefoged, 1965, 1968). In our study we depart from descriptive accounts of whether given language/dialects exhibit intrinsic or extrinsic allophones, and check whether F2 frequency differences between initial and final /l/ are clearly larger in the extrinsic vs intrinsic scenario. Our knowledge about the spectral differences between ‘extrinsic’ phonemic allophones occurring initially and finally, such as those of /l/, is scarce. The articulatory and acoustic characteristics of ‘extrinsic’ allophones for other consonant types have been described more precisely, e.g., the approximant vs stop realization of /b, d, g/ after a heterosyllabic phonetic segment allowing or blocking the passage of airflow in Spanish (Martínez Celdrán and Fernández Planas, 2007). Within this framework, the present study investigates the phonetic properties of the initial and final allophones of /l/ as a function of darkness degree in a considerable number of languages and dialects.

A detailed research plan to be developed in Sections 2 and 3 is outlined next. In the first place (Section 3.1), F2, F1 and F3 frequency values will be analyzed in order to elucidate language/dialect-dependent differences in /l/ darkness degree in the context of /i/, which is where the vocal tract and spectral characteristics of clear /l/ and dark /l/ are set in contrast most evidently (compare the vocal tract configurations for the two /l/ varieties in the upper graphs of Fig. 1 and that for /i/ in the bottom graph of the figure). In this vowel context condition, dark /l/ is expected to exhibit a higher degree of coarticulatory resistance than clear /l/. Therefore, while dark /l/ ought to keep to a large extent its typical low and back tongue body configuration, and thus a relatively constant low F2 frequency, next to this antagonistic high front vowel, the tongue body position for clear /l/ is expected to undergo raising and fronting in anticipation of the vowel in question and thus to come closer to the tongue body position for /i/. Formant frequency data for clear and dark /l/ in the context of /a/ will also be analyzed. The two consonant varieties ought to show a similar, relatively low F2 frequency in this vowel context given that some vowel-related predorsum lowering and postdorsum backing effect on clear /l/ should result in a similar tongue body configuration to that for dark /l/ (compare the graphs for clear /l/ and dark /l/ with that for /a/ in Fig. 1). In any case, in parallel to the /i/ context condition, clear /l/ next to /a/ ought to exhibit a somewhat higher and more anterior tongue dorsum and thus a higher F2 than dark /l/. Higher F1 and F3 frequency values for dark /l/ than for clear /l/ are expected to occur in the two vowel contexts. Data on darkness degree for /l/ in the two vowel contexts /i/ and /a/ will be collected in three positions, i.e., in symmetrical intervocalic word medial position (which allows measuring the vowel effects with a high degree of precision since the consonant is surrounded by two identical vowels in this case), in postpausal utterance-initial position and in prepausal utterance-final position.

Secondly, the spectral characteristics of initial and final /l/ will be determined by comparing F2 for the two consonant varieties utterance initially and utterance finally next to /i/ and /a/ (Section 3.2). This choice of positional conditions needs to be clarified. Utterance initial realizations match intervocalic syllable initial ones in that the two occur syllable initially as a general rule; in practice, however, the two positions differ phonetically in that utterance initial /l/ appears after a pause and next to a single contextual vowel while intervocalic /l/ is adjacent to two contextual vowels. In this paper, information on the spectral characteristics of syllable initial and syllable final /l/ will be analyzed in utterance initial and utterance final position. As shown later on in the paper, the intervocalic and utterance initial positions may be subsumed under the same label ‘initial’ to the extent that the spectral properties of /l/ are highly similar, though not identical, in the two cases. If the two allophonic realizations, i.e., initial and final, conform to the language-dependent consonant production requirements, our prediction is that there should be essentially a single positional allophone for strongly dark /l/ and two positional allophones for clearer varieties of the consonant. Moreover, languages and dialects exhibiting spectrally distant initial and final allophones and thus, a clear allophone in initial position and a dark one in final position will be identified. Since darkness degree is expected to proceed gradually across languages, it is also worth looking into the precise implementation of the consonant allophonic characteristics across languages/dialects sharing the same /l/ type. A comparison between the spectral values for initial and final /l/ and those for the consonant in intervocalic position will also be performed in order to ascertain the extent to which the spectral quality differences between the two former positions are triggered by initial clearing or by final darkening.

The degree of sensitivity to the vowel coarticulatory effects will also be evaluated by comparing the F2 frequency for /l/ next to the two vowels in all three positions, the main prediction being that dark /l/ should be more resistant to vowel coarticulation than clear /l/ and, therefore, that V-to-C effects should be less for the former consonant variety than for the latter (Section 3.3). The rationale underlying this hypothesis is that the degree of vowel coarticulation ought to proceed inversely with the degree of tongue body constraint for the consonant which, as indicated above, may be said to be directly conditioned by the degree to which the tongue dorsum adopts an /u/-like configuration. Therefore, the higher the degree of articulatory constraint involved in the production of /l/, the lesser the degree of vowel dependent coarticulation (see Recasens and Espinosa, 2005 for a more detailed account of the term ‘coarticulatory resistance’ applied to clear and dark /l/). Moreover, effects are expected to be larger from /i/ on /l/ than from /a/ on /l/ for reasons mentioned above. Consonant realizations exhibiting intermediate degrees of darkness could show intermediate degrees of vowel coarticulation.

The acoustic analysis will be performed on data for several languages/dialects which were recorded especially for the present research project and on data for other languages/dialects taken from literature sources. Most languages/dialects under analysis have been described as having a clear variety of /l/: Alguerese and Valencian Catalan (Recasens, 1996); Czech (Dankovičová, 1999); Danish (Grønnum, 2005, Tøndering, p.c.); Finnish, where darkness in /l/ has been characterized as vowel context dependent and the consonant appears to be clear rather than dark at least next to front vowels (Wiik, 1966; Iivonen, 2000, Reijo Aulanko, p.c.); French (Delattre, 1965; Tranel, 1987); German (Delattre, 1965; Kohler, 1977); Hungarian (Gósy, 2004); Italian (Bladon and Carbonaro, 1978; Recasens and Farnetani, 1994); Norwegian, where /l/ has been described as clear everywhere and also as dark after low and mid back rounded vowels (Kristoffersen, 2007, Simonsen, p. c.); Lengadocian Occitan (Wheeler, 1988); Romanian (Chitoran, p.c.); Spanish (Delattre, 1965; Navarro Tomás, 1972); Swedish (Lindblom, 2004; Lacerda, 2006). Other languages/dialects have been assigned a dark variety of /l/: Eastern Catalan, where the consonant appears to be moderately rather than strongly dark nowadays (Recasens, 1996); Leeds British English (Local and Carter, 2002); Majorcan Catalan (Recasens, 1996); European Portuguese (Cruz-Ferreira, 1995); Russian (Jones and Ward, 1969). A third group of languages/dialects has been characterized traditionally as having a clear allophone initially and a dark one finally: American English from the Midwestern region (Sproat and Fujimura, 1993); British English RP (Bladon and Al-Bamerni, 1976); Dutch (Warner et al., 2001); Newcastle English (Local and Carter, 2002). Other languages/dialects not included in the present paper match one of the above mentioned groups, e.g., Irish and Southern Welsh have a clear /l/ in all positions while Northern Welsh, Scottish and Australian English have a dark /l/ everywhere (Wells, 1982; Newton, 1996).

The following initials will be used throughout the paper for referring to the 23 languages/dialects under analysis: AE (American English), AL (Alguerese Catalan), BE (British English RP), CZ (Czech), DA (Danish), DU (Dutch), EC (Eastern Catalan), FI (Finnish), FR (French), GE (German), HU (Hungarian), IT (Italian), LE (Leeds British English), MA (Majorcan Catalan), NE (Newcastle English), NO (Norwegian), OC (Lengadocian Occitan), PO (European Portuguese), RO (Romanian), RU (Russian), SP (Spanish), SW (Swedish), VA (Valencian Catalan).

2. Method

2.1. Sentence material and speakers

Acoustic recordings of /l/ next to /i/ and /a/ were carried out utterance initially (/li, la/), utterance finally (/il, al/), and in intervocalic syllable initial position whether across a word boundary or word medially (/i(#)li, a(#)la/). The target consonant and the contextual vowel segments were embedded in real words and short meaningful sentences (see Appendix). A partial exception is American English where, according to the data source (Lehiste, 1964), the target words were read in the frame "Say the word ... instead" (see Appendix), and therefore word initial /l/ might have been affected by preceding /d/ and word final /l/ by a following high front vowel. As also indicated in the introductory sentence of the Appendix, no information about the precise positional conditions for word initial and word final /l/ in several languages/dialects (4) is available in the literature sources where the data have been taken from.

The sentence material was read a variable number of times by a variable number of male speakers whose age ranged between about 20–75 years and were about 30–50 years old for the most part. There were no noticeable differences in the voice quality of the speakers which might have had an influence on the formant frequency values and/or in the accuracy with which those values could be measured. The list of languages/dialects (16) grouped according to language family, together with the number of speakers and tokens, are presented next in alphabetical order.

(a) (Germanic)

Danish (5 Standard Danish speakers from Copenhagen, 5 tokens); Dutch (5 speakers of colloquial Dutch with some regional coloring, 3 tokens); German (4 speakers from Berlin, 5 tokens); Norwegian (4 Urban East Norwegian speakers, 5 tokens); Swedish (5 Standard Central Swedish speakers from Stockholm, 2–4 tokens).

(b) (Romance)

Alguerese Catalan (5 speakers, 5 tokens); Eastern Catalan (5 speakers, 5 tokens); Italian (5 Tuscan Italian speakers, 5 tokens); Majorcan Catalan (5 speakers, 7 tokens); Occitan (3 Standard Lengadocian speakers, 5 tokens); Romanian (4 Standard Romanian speakers from Bucharest, 5 tokens); Valencian Catalan (5 speakers, 7 tokens).

(c) (Slavic)

Czech (5 Standard Czech speakers from Prague, 3 tokens); Russian (3 Standard Russian speakers from Central Russia, 8 tokens).

(d) (Finno-Ugric)

Finnish (5 speakers from Helsinki, 5 tokens); Hungarian (8 speakers from Budapest, 2 tokens except for absolute final /il/ which was recorded 4 times in two different sentences).

Data for Eastern, Majorcan and Valencian Catalan were recorded by the author (Recasens, 1986; Recasens and Espinosa, 2005) and those for the other languages/dialects by several scholars mentioned in the Acknowledgements section. Recording were carried out in good laboratory conditions or in a quiet room at a 44.100 Hz sampling rate as a general rule.

Data for other languages/dialects taken from the literature (7) will also be subjected to evaluation. The corresponding sentence material is presented in the Appendix whenever available, and details on the number of speakers and tokens (also if available) and on the references where the data have been taken from are given below.

(a) (Germanic)

American English (3 Midwestern American English speakers (Lehiste, 1964)); British English RP (4 speakers (Bladon and Al-Bamerni, 1976)); Leeds and Newcastle English (4 speakers (Local and Carter, 2002)).

(b) (Romance)

French (6 Southern French speakers (Chafcouloff, 1985)); Portuguese (8 Standard European Portuguese speakers from Aveiro, 3 tokens (Marques, 2010)); Spanish (6 Standard Spanish speakers from Spain and one Colombian speaker (Quilis et al., 1979)).

Some of these languages/dialects taken from literature sources could not be analyzed in full due to the characteristics of the data samples: data for F1 and F3 were not available for British English RP and Leeds and Newcastle English, and those for F3 were absent for Portuguese; no estimate of speaker-dependent variability could be obtained for British English RP, Leeds British English, Newcastle English and Spanish since data for the individual speakers were lacking in this case; formant frequency data will be provided just for the /i/ vowel context for the Leeds and Newcastle English dialects, and for the utterance initial and utterance final positions but not for the intervocalic position for British English RP. At this point, it should also be stated that the spectral characteristics of /l/ could be affected to some extent by inherent language/dialect-dependent differences in contextual vowel quality, i.e., /a/ was especially front in Danish ([æ]), back in Swedish, American English and British English RP (ɑ), and long and tense in German ([a:]), while /i/ was long and tense in German ([i:]) and central in Russian ([ɨ]). As for the target consonant, the Norwegian data will be explored for clear /l/ in all positions and vowel contexts, and for dark /l/ after /a/ utterance finally; moreover, in view of the position restrictions for dark /l/ in this language, only data for clear /l/ will be shown in the tables and figures and submitted to all possible comparisons and to statistical testing.

2.2. Analysis procedure

The acoustic data were downsampled to 11.025 Hz for better visual inspection of the F1, F2 and F3 frequencies. Formant frequency data were measured at the /l/ midpoint after identifying the onset and offset of the consonant on simultaneous waveform and spectrographic displays. The acoustic period of the consonant was delimited by a period of low intensity formant structure and the edges of the higher intensity vowel formant transitions. Segmental boundaries for utterance final dark /l/ were hard to detect whenever the VC formant transitions proceeded gradually along the frequency scale. In this particular case, the segmental boundary was taken to occur at a point where the F2 transition levels out and the formant reaches a relatively stable state, its intensity decreases significantly and the consonant portion may be heard without (barely) any traces of the vowel.

Measurements of the first three formants were taken at the midpoint of the consonant on LPC trajectories using a 25 ms full-Hamming window and a minimum of 14 coefficients. Whenever the LPC trajectories were judged not to be reliable enough because they fell outside the center of the formant, formant frequencies were measured manually on the spectrographic displays with the help of a cursor. F3 at this temporal point could be cancelled or was hardly visible and thus hard to measure due to the appearance of a spectral zero between 2000 Hz and 3000 Hz (at about 1850–2000 Hz for dark /l/ according to Fant, 1960, and midway between 2500 Hz and 3000 Hz for the two /l/ types according to Bladon, 1979), which appears to be associated with the shunting cavity behind the tongue blade. The cancellation of the third formant occurred very rarely, i.e., less than 0.5% over the number of tokens for a given language/dialect.

Cross-speaker mean F2, F1 and F3 values as a function of vowel context and position are presented in Table 1 for all languages/dialects subjected to investigation.

2.3. Statistical analysis

One-way ANOVAs were performed on mean F1, F2 and F3 values across tokens for the individual speakers of those languages/dialects for which speakers' data were available (see Section 2.1). Separate statistical tests were carried out on /l/ next to /i/ and /a/ intervocalically, utterance initially and utterance finally in order to ascertain darkness degree in the consonant (Section 3.1), for /li/ vs /il/ and for /la/ vs /al/ so as to elicit possible allophonic differences between the two varieties of /l/ (Section 3.2), and for /ili/ vs /ala/, /li/ vs /la/ and /il/ vs /al/ in order to evaluate the degree of vowel coarticulation (Section 3.3). Two tests were run for each dependent variable, one involving data for all languages/dialects with 'language/dialect' as independent variable, and another one data for the two language/dialect groups with clear and dark /l/ using '/l/ variety' as factor; these test conditions will be referred as (a) (all languages/dialects) and (b) (two language/dialect groups) throughout the paper. Bonferroni pairwise comparisons were applied to the 'language/dialect' main effects for test condition (a), and the significance threshold was set at $p = 0.05$ in all statistical tests.

3. Results

3.1. Darkness degree

3.1.1. F2, intervocalic position

The upper left graph of Fig. 2 reports F2 frequency values for clear /l/ (unfilled bar) and dark /l/ (filled bar) in the sequence /ili/ averaged across languages/dialects. As expected, F2 exceeds 1500 Hz for clear /l/ (1714.83 Hz, sd = 189.26) and occurs around 1000 Hz for dark /l/

Table 1
Formant frequencies for /l/ as a function of language/dialect, vowel context and position. See Figs. 2 and 3 for standard deviations of the mean F2 frequency values

	F2						F1						F3					
	/li/	/ili/	/il/	/la/	/ala/	/al/	/li/	/ili/	/il/	/la/	/ala/	/al/	/li/	/ili/	/il/	/la/	/ala/	/al/
American English (AE)	1272	892	760	992	895	858	325	425	433	353	420	500	2458	2417	2547	2605	2447	2575
Alguerese Catalan (AL)	1621	1599	1620	1431	1327	1491	298	291	312	421	472	436	2489	2410	2506	2588	2560	2694
British English RP (BE)	1600		1000	1120		860												
Czech (CZ)	1518	1425	1021	1139	992	968	342	318	393	392	461	471	2458	2343	2335	2469	2410	2303
Danish (DA)	1717	1786	1617	1591	1593	1531	264	257	298	294	299	354	2707	2817	2625	2756	2733	2643
Dutch (DU)	1800	1729	821	1181	1131	924	266	266	319	458	477	605	2726	2789	2645	2477	2471	2729
Eastern Catalan (EC)	1123	1453	1060	1025	1072	1024	249	273	322	362	497	483	2420	2469	2463	2601	2585	2575
Finnish (FI)	1539	1517	1409	985	986	995	288	284	344	430	469	530	2530	2436	2324	2325	2469	2326
French (FR)	1682	1830	1748	1525	1340	1512	230	261	226	299	356	307	2584	2718	2683	2630	2583	2608
German GE)	1618	1734	1557	1363	1316	1498	218	221	299	331	359	444	2518	2434	2386	2303	2284	2403
Hungarian (HU)	1642	1700	1343	1126	1083	1202	258	291	339	385	428	425	2410	2405	2429	2421	2467	2279
Italian (IT)	1629	2094	1559	1394	1231	1391	280	278	308	393	463	374	2519	2716	2614	2674	2610	2712
Leeds British English (LE)	1012	1024	1024															
Majorcan Catalan (MA)	989	1228	1016	929	1084	973	380	365	395	449	565	458	2799	2733	2922	2867	2825	2935
Newcastle English (NE)	1588	1359	1140															
Norwegian (NO)	1724	1681	1604	1486	1128	1181	315	300	324	324	333	364	2526	2439	2563	2513	2503	2501
Occitan (OC)	1748	1886	1630	1413	1220	1487	241	243	261	324	403	354	2452	2511	2504	2532	2492	2526
Portuguese (PO)	1046	1003	1096	879	871	1116	302	277	295	369	413	336						
Romanian (RO)	1580	1722	1461	1280	1136	1295	265	265	287	352	413	477	2556	2609	2573	2492	2333	2397
Russian (RU)	964	1023	922	972	938	887	328	343	394	362	402	549	2658	2586	2487	2793	2698	2302
Spanish (SP)	1800	1630	1960	1560	1500	1520	320	300	300	470	340	360	2760	2600	2760	2680	2600	2500
Swedish (SW)	1709	1765	1531	1383	1180	1189	260	272	282	293	361	377	2738	2762	2681	2577	2486	2442
Valencian Catalan (VA)	1368	1982	1264	1150	1165	1121	380	365	395	449	565	458	2799	2733	2922	2867	2825	2935

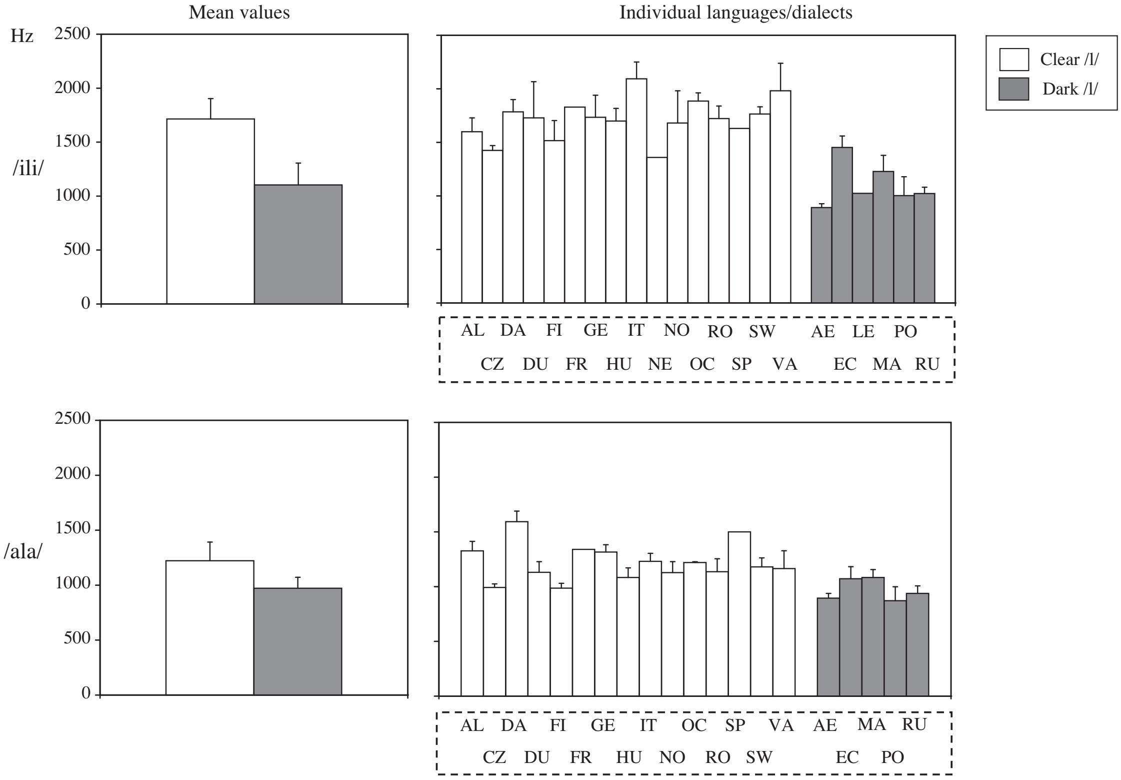

Fig. 2. (Left) Cross-dialectal F2 frequency values for clear /l/ and dark /l/ in the sequences /ili/ (top) and /ala/ (bottom). (Right) The same data plotted as a function of language/dialect. Error bars reflect the degree of speaker-dependent variability and correspond to one standard deviation; they are not shown for languages/dialects for which literature sources provide no speaker-dependent information. See Section 1 regarding the language/dialect initials appearing below the bars.

(1103.73 Hz, sd = 202.72). This F2 difference between the two varieties of /l/ turned out to be significant for both conditions (a) and (b) referred to in Section 2.3 ($F(17,68) = 20.96$, $p = 0.000$; $F(1,84) = 77.57$, $p = 0.000$).

The upper right graph in the figure plots F2 values for /ili/ for all languages/dialects included in the ANOVA according to whether they have been assigned traditionally a clear or a dark variety of /l/. Languages/dialects exhibiting extrinsic allophones according to literature sources have been grouped with those with clear /l/ (Dutch, Newcastle English) or with dark /l/ (American English) depending on whether their /l/ is clear or dark in intervocalic syllable initial position. The first thing to notice about the graph is that the F2 frequency range is larger for clear /l/ (735 Hz, i.e., 1359–2094 Hz) than for dark /l/ (561 Hz, i.e., 892–1453 Hz) meaning that the former variety is more variable across languages/dialects than the latter; moreover, differences between the two /l/ types turned to be greater at the upper rather than at the bottom extremes of the frequency range, i.e., 641 Hz and 467 Hz, respectively. Out of 65 significant pairwise comparisons for test condition (a), 46 occurred between all languages/dialects with clear /l/ and those with dark /l/ except for Eastern Catalan in some cases. Significant effects between languages/dialects with the same /l/ type were found to hold only twice for the dark /l/ group and 17 times for the clear /l/ group (the latter involved mostly Italian and Valencian Catalan which, as shown in the figure, exhibit the highest F2 frequency of all languages/dialects).

It looks then that Eastern Catalan, i.e., the dialect exhibiting the highest F2 of all languages/dialects with dark /l/, deviates from the general pattern in overlapping with some of the languages/dialects exhibiting a clear variety of the consonant. As suggested in Section 2.1, this dialect may be characterized as having a moderately dark consonant variety. In principle, a few languages/dialects with clear /l/ could qualify as candidates for a moderately clear variety of the consonant, i.e., Czech, Newcastle English and perhaps Finnish (see Fig. 2, upper right graph).

The bottom left graph of Fig. 2 reports cross-language/dialect F2 data for clear /l/ and dark /l/ in the sequence /ala/. In parallel to the /i/ context condition, F2 is higher for clear /l/ (1221.9 Hz, sd = 170.31) than for dark /l/ (972.11 Hz, sd = 99.70). Even though the difference is smaller than the one occurring in the high front vowel context, ANOVAs run on the data for intervocalic /l/ next to /a/ yielded a main effect of /l/ variety in the case of both test conditions (a) and (b) ($F(17,68) = 16.86$, $p = 0.000$; $F(1,84) = 30.09$, $p = 0.000$).

According to the bottom right graph of Fig. 2 and in parallel to the /i/ contextual condition, clear /l/ exhibits larger frequency ranges across languages/dialects than dark /l/, i.e., 607 Hz (986–1593 Hz) for the former variety and 213 Hz (871–1084 Hz) for the latter. Moreover, also analogously to the /i/ context, F2 differences between the two consonant varieties are larger at the upper extreme (509 Hz) than at the lower extreme (115 Hz) of the frequency range. Standard deviation values indicate the existence of less variability for /l/ next to /a/ (bottom right graph) than next to /i/ (top right graph), thus meaning that speakers differ among themselves to a larger extent in the latter vs former vowel environment. A less apparent dichotomy between the two /l/ varieties next to /a/ than in the context of /i/ is in agreement with the finding of less significant differences between pairs of languages/dialects with clear /l/ and dark /l/ in the former vs latter vowel context condition, i.e., significant differences next to /a/ occur in 27 out of 48 cases and involve mostly American English and Portuguese. On the other hand, significant effects between pairs of languages/dialects exhibiting the same consonant variety occurred only once in the case of dark /l/, and 20 times in the case of clear /l/ (the latter involved mostly Danish which is the language with the highest F2 frequency). The bottom right graph also shows some F2 frequency overlap between dark /l/ in Eastern and Majorcan Catalan and clear /l/ in Czech and Finnish.

3.1.2. F2, initial and final position

The F2 frequency difference between clear /l/ and dark /l/ also holds in utterance initial and utterance final position in the /i/ context condition (Fig. 3, top left graph). Mean values across languages/dialects amount to 1640.14 Hz (sd = 109.00) and 1067.61 Hz (sd = 114.18) for clear /l/ and dark /l/ before /i/, and to 1428.47 Hz (sd = 296.79) and 979.79 Hz (sd = 122.37) for clear /l/ and dark /l/ after /i/. F2 frequency differences between the two /l/ varieties achieved significance for both conditions (a) and (b) initially ($F(17,68) = 19.52$, $p = 0.000$; $F(1,84) = 202.07$, $p = 0.000$) and finally ($F(17,68)=27.52$, $p = 0.000$; $F(1,84) = 46.39$, $p = 0.000$). Post-hoc tests yielded more significant differences between language/dialect pairs with clear /l/ and dark /l/ in initial position (57 out of 61 cases with the partial exception of American English; see Fig. 3, upper middle graph) than in final position (58 out of 87 cases involving all languages/dialects except for those with clear /l/ and a low F2, i.e., Czech and Dutch, Valencian Catalan to a large extent, and presumably British English RP and Newcastle English; see Fig. 3, upper right graph). There were also significant differences within the clear /l/ group involving languages/dialects with low F2 frequency values, i.e., Valencian Catalan utterance initially (4 cases) and those mentioned above utterance finally (28 cases).

As for the /a/ context condition, mean F2 frequencies for clear /l/ and dark /l/ across languages/dialects amount to 1320.36 Hz (sd = 183.60) and 959.39 Hz (sd = 56.64) in utterance initial position, and to 1260.28 (sd = 237.67) and 971.71 Hz (sd = 104.54) in utterance final position (Fig. 3, bottom left graph). The prepausal realization of

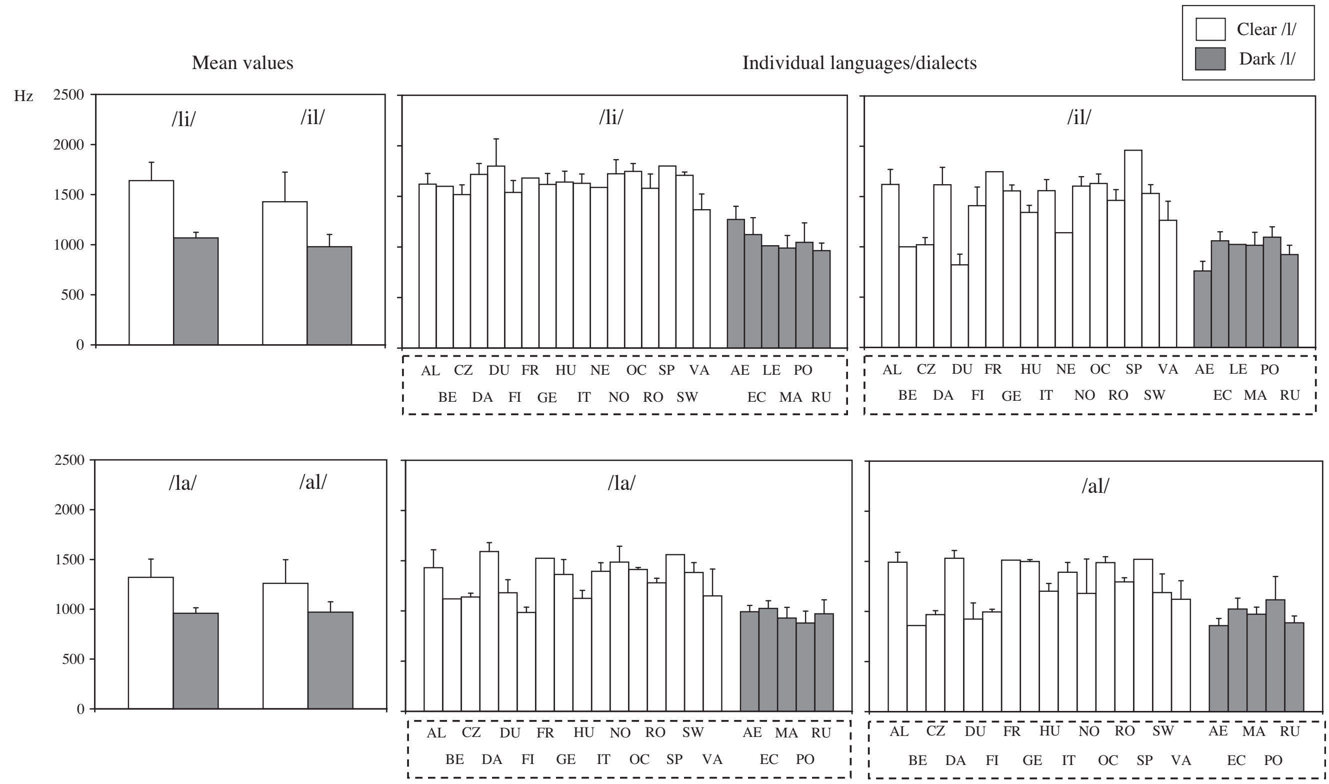

Fig. 3. (Left) Cross-dialectal F2 frequency values for clear /l/ and dark /l/ in the sequences /li/ and /il/ (top) and /la/ and /al/ (bottom). (Right) The same data plotted as a function of language/dialect. Error bars reflect the degree of speaker-dependent variability and correspond to one standard deviation; they are not shown for languages/dialects for which literature sources provide no speaker-dependent information. See Section 1 regarding the language/dialect initials.

Norwegian dark /l/ after /a/ turned out to be as heavily dark as it is in Russian or American English (929.6 Hz, sd = 99). Differences between the two /l/ varieties were significant for the two sequences /la/ and /al/ in the case of condition (a) ($F(17,68) = 15.49$, $p = 0.000$; $F(1,84) = 58.83$, $p = 0.000$) and of condition (b) as well ($F(17,68) = 10.98$, $p = 0.000$; $F(1,84) = 18.69$, $p = 0.000$). According to the bottom middle graph of the figure, there was a considerable number of significant differences between languages/dialects with clear /l/ and dark /l/ in initial position (40 cases out of 56), which involved all languages/dialects of the latter group and most languages/dialects of the former one save for those exhibiting low F2 frequency values (Czech, Dutch, Finnish, Hungarian and Valencian Catalan, and presumably British English RP). In comparison to the scenario in initial position, there were only 26 out of 48 significant differences in final position which occurred between all languages/dialects with dark /l/ and all languages/dialects with clear /l/ excluding those exhibiting a low F2, i.e., mostly Czech, Dutch, Finnish, Hungarian, Norwegian, Swedish and Valencian Catalan, and presumably British English RP as well (see Fig. 3, bottom right graph). There also were significant effects between languages/dialects with clear /l/ both initially (16) and finally (22) involving essentially the languages/dialects showing the highest F2 (initially, finally: Alguerese Catalan, Danish) and those showing the lowest F2 (initially, finally: Czech, Finnish; finally: Dutch).

3.1.3. F1, F3

Fig. 4 (top left graph) plots mean F1 data for intervocalic /l/ in the context of /i/ and /a/. As expected, this formant frequency values run opposite to those for F2, i.e., F1 is higher for dark /l/ than for clear /l/ next to /i/ (336.7 Hz, sd = 63.71; 280.8 Hz, sd = 33.76) and next to /a/ (459.5 Hz, sd = 69.78; 413.3 Hz, sd = 71.95). Data for the two /l/ varieties in utterance initial and utterance final position plotted in the top middle and right graphs of the figure reveal a similar pattern. F1 frequency differences between clear /l/ and dark /l/ achieved significance for /ili, li/ in both test conditions (a) and (b), and for /ala, la, il, al/ in condition (a) but not in condition (b).

As for F3 (Fig. 4, bottom left graph), there is a trend for dark /l/ to exhibit higher values than clear /l/ intervocalically in the context of /a/ (2638.6, sd = 161.07; 2521.7 Hz, sd = 139.21) but not next to /i/ (2551 Hz, sd = 140.26; 2581.4 Hz, sd = 164.17). Data for the utterance initial and utterance final positions plotted in the bottom middle and right graphs of the figure reveal a similar trend. F3 differences reached significance for /ala, la/ in test conditions (a) and (b), and for /ili, li, il, al/ in test condition (a) but not in condition (b).

3.2. Allophones

3.2.1. Initial and final position

In order to investigate whether the languages/dialects under study exhibit ‘intrinsic’ or ‘extrinsic’ allophones of /l/, Fig. 5 (top left graph) plots mean F2 frequency differences between utterance initial and utterance final /l/ in the context of /i/ for the two varieties of the consonant. Bars in the graph reveal the existence of a larger position-dependent F2 difference for clear /l/ than for dark /l/ (211.67 Hz vs 87.82 Hz) which is in accordance with our initial hypothesis that dark /l/ should be more resistant to position-dependent spectral differences than clear /l/. According to the statistical results, position-dependent differences in F2 frequency between the two /l/ varieties

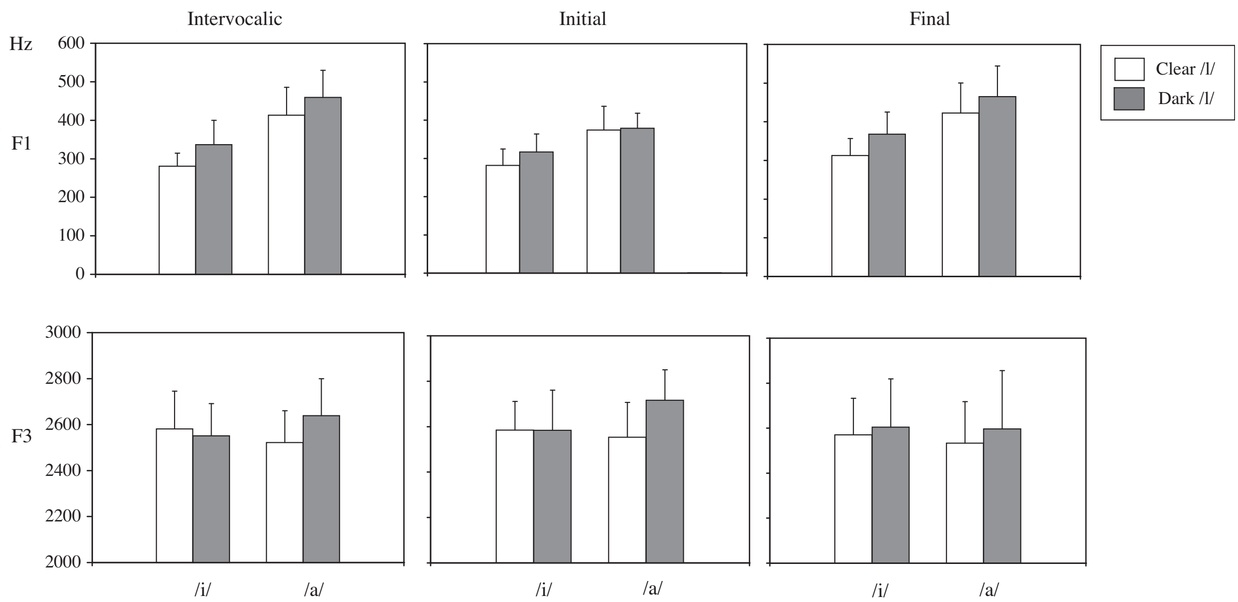

Fig. 4. Cross-dialectal F1 and F3 frequency values for clear /l/ and dark /l/ next to /i/ and /a/ in intervocalic, utterance initial and utterance final position. Error bars correspond to one standard deviation.

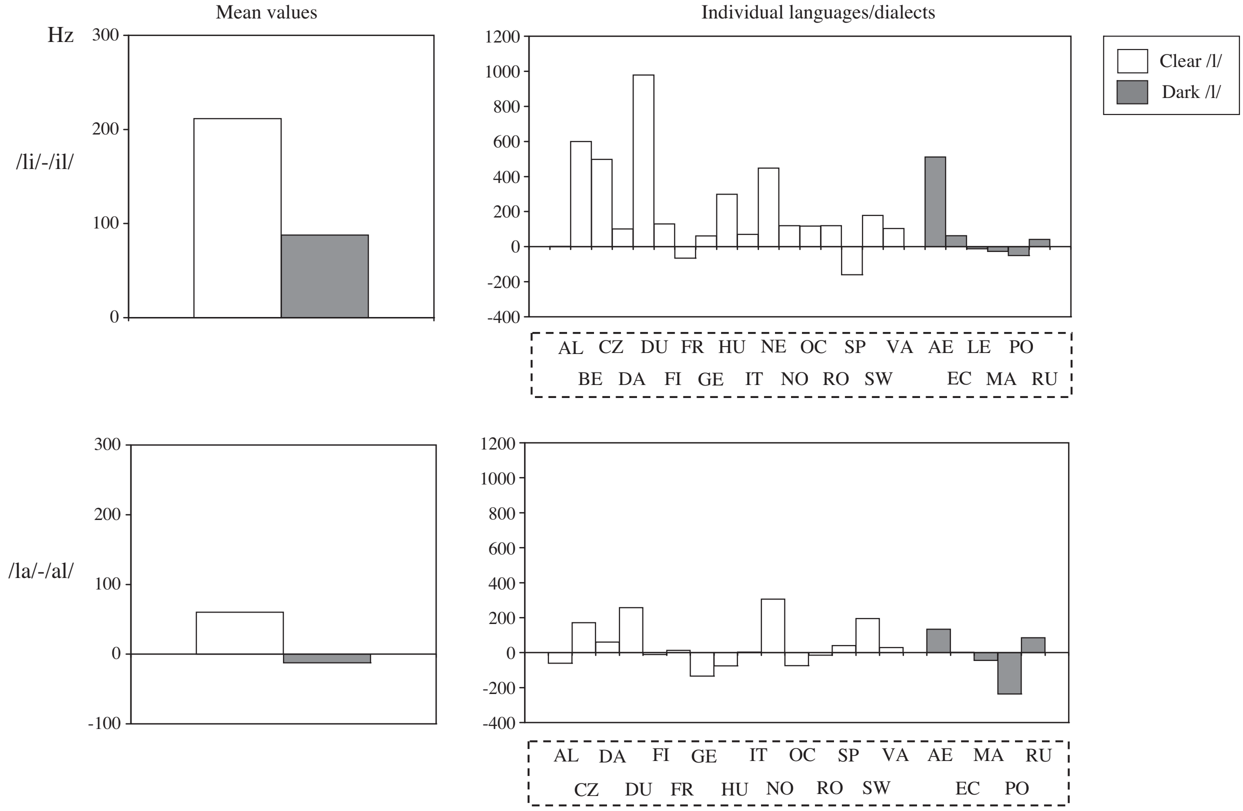

Fig. 5. (Left) Cross-dialectal F2 frequency differences between /li/ and /il/ (top) and between /la/ and /al/ (bottom). (Right) Data plotted as a function of language/dialect. See Section 1 regarding the language/dialect initials appearing below the bars.

achieved significance for both conditions (a) and (b) ($F(17,68) = 161.46$, $p = 0.000$; $F(1,84) = 7.00$, $p = 0.000$). As pointed out in Section 3.1.2, the differences of interest are associated mostly with considerably higher F2 frequency values for clear /l/ than for dark /l/ in utterance initial position.

The top right graph of Fig. 5 reveals that most languages/dialects, i.e., 17 out of 22, have a higher F2 initially than finally in the /i/ context condition. Moreover, the size of this positive difference may vary from one language/dialect to another: it is less than 200 Hz as a general rule, slightly above this figure in Hungarian (299 Hz), above 400 Hz in American English, British English RP, Czech and Newcastle English (512, 600, 497 and 448 Hz, respectively), and about 1000 Hz in Dutch (979 Hz). Pairwise comparisons reveal that significant differences involve essentially those languages/dialects showing the largest position-dependent F2 frequency contrast, i.e., Dutch (17), Czech (13) and American English (10). It could be then concluded that an F2 difference below 200/300 Hz corresponds to the situation in which initial and final /l/ qualify as phonetically conditioned 'intrinsic' allophones, while an F2 difference about 400 Hz or higher (as in English dialects, Czech and Dutch) is appropriate for a scenario where two distinctive 'extrinsic' allophones are available.

As revealed by the bottom left graph of Fig. 5, initial F2 also exceeds final F2 for clear /l/ in the /a/ context condition (60.1 Hz) while this is not the case for dark /l/ (−12.3 Hz). Moreover, the two position-dependent means turned out to be significantly different in the case of both conditions (a) and (b) ($F(17,68) = 4.54$, $p = 0.000$; $F(1,84) = 5.92$, $p = 0.017$). Analogously to the scenario for /i/ described above, these data are in agreement with the predicted trend for the clear variety to exhibit larger position-dependent differences than the dark one. As referred to in Section 3.1.2 and in parallel to the scenario for the /i/ context, larger position-dependent differences for clear /l/ than for dark /l/ in the context of /a/ should be attributed to an especially high F2 for clear /l/ utterance initially.

Data for the individual languages plotted in the bottom right graph of Fig. 5 show small differences between the F2 values for initial and final /l/ in the /a/ context condition which oscillate between slightly positive, slightly negative or practically zero depending on the language/dialect taken into consideration. In any case, several languages/dialects exhibit larger position-dependent differences than others, i.e., Dutch and Norwegian (with a higher F2 initially than finally by 258 Hz and 306 Hz) and Portuguese (with a higher F2 finally than initially by 237 Hz).

3.2.2. A comparison with the intervocalic position

A way to ascertain whether extrinsic allophones are conditioned mainly by the utterance initial or the utterance final position is by eliciting the extent to which F2 for /l/

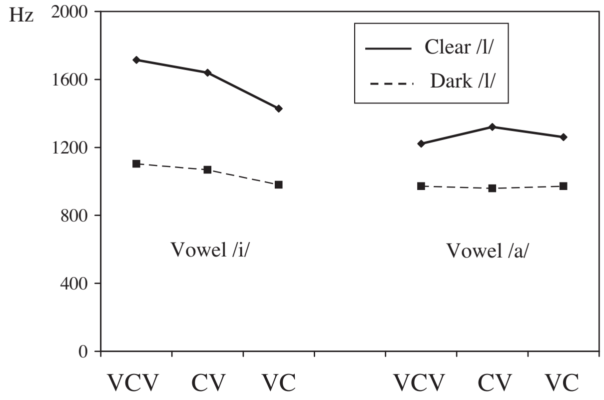

Fig. 6. Cross-dialectal F2 values for clear /l/ and dark /l/ plotted as a function of position and vowel context.

in these two positions deviates from the F2 frequency values for /l/ in the reference intervocalic position. Thus, the larger the deviation value, the higher the chances that the spectral difference between utterance initial and utterance final /l/ is to be attributed to one position or the other. Cross-language/dialect F2 data in the context of /i/ plotted in Fig. 6 (left side) indicate the presence of lower values utterance initially (CV) and utterance finally (VC) than intervocalically (VCV), as well as utterance finally than utterance initially, for the two varieties of /l/ and more so for the clear than for the dark variety of the consonant. Moreover, the top and bottom left graphs in Fig. 7 show that this position-dependent difference is mainly associated with those languages/dialects exhibiting extrinsic allophones, and therefore an especially dark realization in final position in the case of languages/dialects with clear /l/ in the top left graph (Czech, Dutch, Newcastle English, as well as British English RP for which no intervocalic data were available), and with an especially clear realization in initial position in the case of languages/dialects with dark /l/ in the bottom left graph (American English). It deserves to be seen whether preceding /d/ is fully or partially responsible for this especially clear realization of /l/ in American English (see Section 2.1). While not showing extrinsic allophones, Valencian Catalan and Italian (Fig. 7, top middle graph) as well as Eastern Catalan (Fig. 7, bottom middle graph) show considerably lower F2 values initially and finally than in intervocalic position. Data for the remaining languages/dialects plotted in the top and bottom right graphs of Fig. 7 exhibit slightly higher F2 values intervocalically and initially than finally or similar F2 frequencies in all three positions as a general rule. It may thus be concluded that the dichotomy between a clear initial allophone and a dark final allophone is associated mostly with F2 lowering in final position in Czech, Dutch and Newcastle English (also in British English RP), and with an F2 frequency increase in initial position in American English. In Italian, Valencian Catalan and Eastern Catalan, /l/ is somewhat darker initially and finally than intervocalically.

In contrast with the /i/ context condition, /l/ in the sequences /ala/, /la/ and /al/ in Fig. 6 (right side) shows small F2 frequency variations across the three positions of interest.

3.3. Coarticulation

Fig. 8 (top left graph) plots mean cross-language/dialect vowel coarticulation values for intervocalic /l/ obtained by

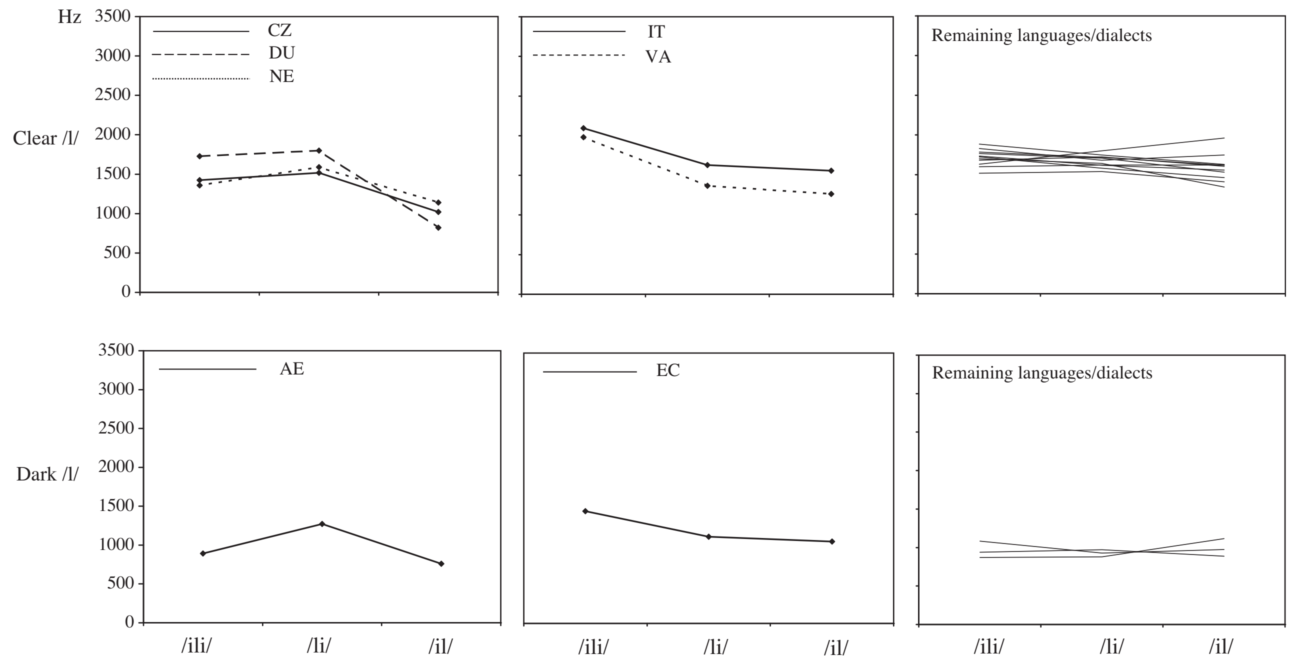

Fig. 7. Position-dependent F2 frequency patterns in the /i/ context condition. (Left) Languages/dialects with extrinsic allophones. (Mid) Languages/dialects with a lower F2 utterance initially and finally than intervocalically. (Right) Languages/dialects with no position-dependent F2 differences or with a slightly higher F2 utterance initially than utterance finally.

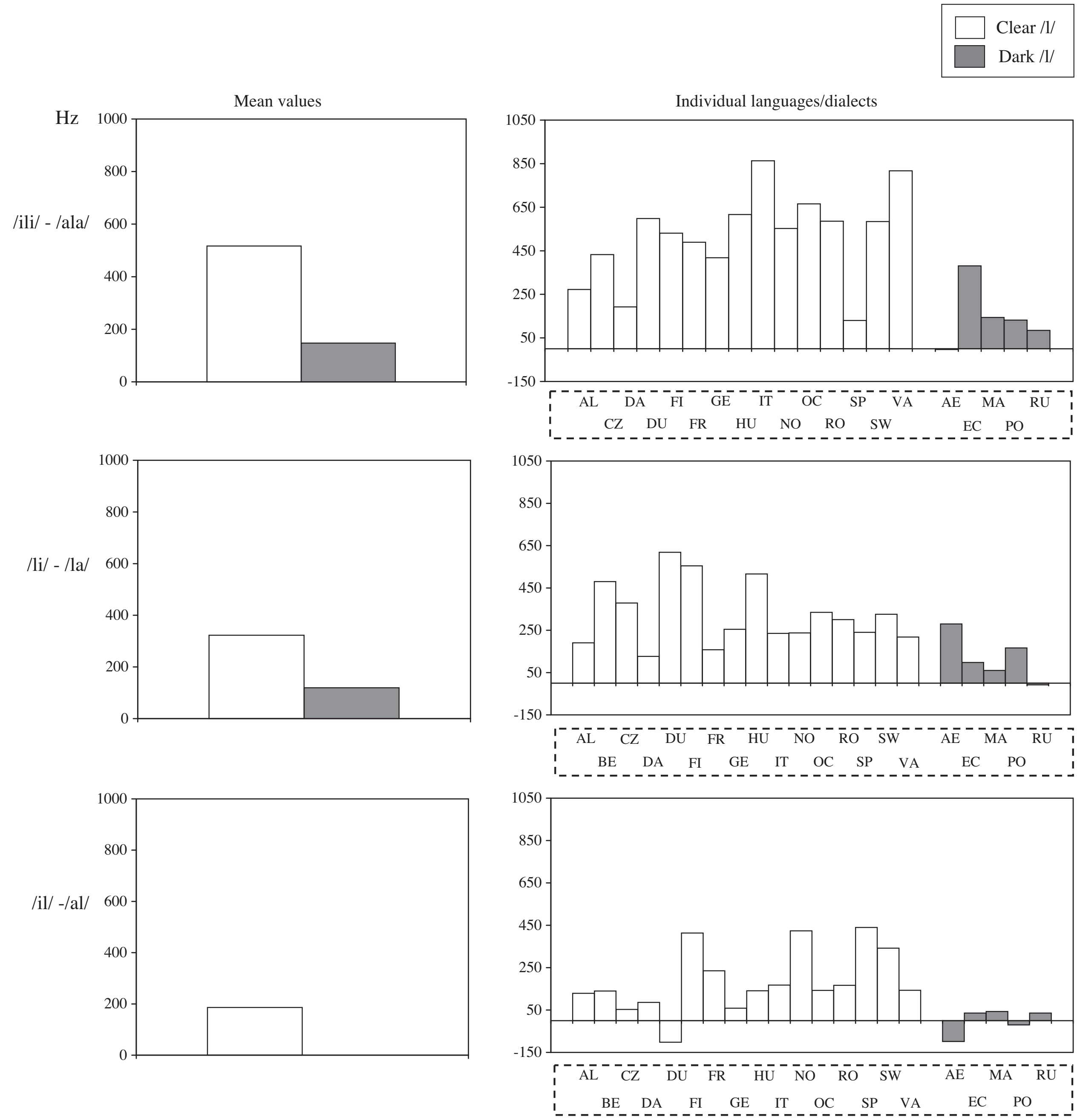

Fig. 8. (Left) Cross-dialectal F2 frequency differences for /l/ between /ili/ and /ala/ (top), /li/ and /la/ (middle) and /il/ and /al/ (bottom). (Right) The same data plotted as a function of language/dialect. See Section 1 regarding the language/dialect initials.

subtracting the F2 frequency for the consonant in the sequences /ili/ and /ala/. As expected, vowel-related distances are much larger for clear /l/ (516.6, sd = 205.54) than for dark /l/ (147.6, sd = 142.76). Vowel-dependent coarticulation differences between the two varieties of /l/ achieved significance according to ANOVAs for the two conditions (a) and (b) ($F(17,68) = 10.61$, $p = 0.000$; $F(1,84) = 49.59$, $p = 0.000$).

Frequency values for all languages/dialects plotted in the top right graph of the figure show greater ranges for the clear variety of /l/ (130–863 Hz) than for the dark one (−3/381 Hz). Significant differences were found to hold for pairs of languages/dialects exhibiting a clear and a dark variety in most cases (34) with the exception of Alguerese Catalan, Czech and Danish (and presumably Spanish) which allow for little coarticulation in spite of having a clear /l/ variety, as well as of Eastern Catalan which allows for larger vowel effects than the other languages/dialects with dark /l/. Significant differences between language/dialect pairs within each /l/ category occurred only 9 times for clear /l/ and were absent for dark /l/.

According to the middle and bottom left graphs of the figure, while being larger for clear /l/ than for dark /l/, coarticulatory differences between /li/ and /la/ and between

/il/ and /al/ are smaller than those occurring in intervocalic position. This holds for the two consonant varieties, i.e., the coarticulatory distance between /i/ and /a/ for clear /l/ amounts to 323 Hz utterance initially (sd = 147.89) and to 186.2 Hz utterance finally (sd = 150.18), while that for dark /l/ amounts to 119.3 Hz initially (sd = 109.79) and to −0.8 Hz finally (sd = 60.17). These coarticulation values also indicate the presence of less vowel coarticulation finally than initially for the two varieties of the consonant. ANOVAs run on the position-dependent differences in vowel coarticulation for clear /l/ and dark /l/ yielded a main effect of language/dialect for condition (a) (initial, $F(17,68) = 7.78$, $p = 0.000$; final, $F(17,68) = 4.59$, $p = 0.000$) and of consonant variety for condition (b) (initial, $F(1, 84) = 26.16$, $p = 0.000$; final, $F(1,84) = 13.29$, $p = 0.000$).

As revealed by the data plotted in the middle and bottom right graphs of the figure, post-hoc analyses yielded the existence of significant differences between those languages/dialects with 'clear' /l/ exhibiting most vowel coarticulation (Dutch, Finnish Hungarian and perhaps British English RP in initial position; Finnish, Norwegian, Swedish and perhaps Spanish in final position), and languages/dialects with dark /l/ showing least vowel coarticulation (all languages/dialects except for American English in initial position). There were also significant differences between languages/dialects with clear /l/ exhibiting maximal F2 coarticulation (see above) and those showing least coarticulation (Alguerese, Danish and Valencian Catalan and possibly French in initial position; Dutch in final position).

A related issue is what acoustic changes (and therefore what articulatory mechanisms) account for the position-dependent differences in coarticulatory sensitivity just referred to. In parallel to the method applied in Section 3.2.2, a suitable way to explore the F2 changes in question is by evaluating the discrepancy in formant frequency between utterance initial /l/ and utterance final /l/, on the one hand, and intervocalic /l/, on the other hand.

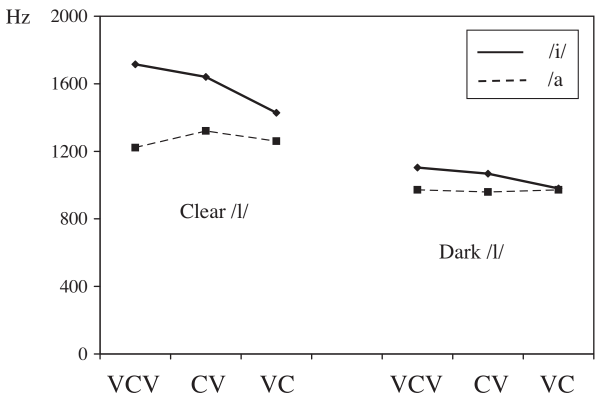

Fig. 9. Cross-dialectal F2 values for /i/ and /a/ at consonant midpoint plotted as a function of /l/ variety and position.

As for clear /l/, Fig. 9 (left side) reveals that a smaller distance between /li/ and /la/ than between /ili/ and /ala/ is associated with a 74.7 Hz F2 decrease in the /i/ context (/ili/ 1714.83 Hz, sd = 189.26; /li/ 1640.14 Hz, sd = 109.00) and a 98.46 Hz F2 increase in the /a/ context (/ala/ 1221.9 Hz, sd = 170.31; /la/ 1320.36 Hz, sd = 183.60). On the other hand, /il/ and /al/ come closer to each other than /ili/ and /ala/ since F2 lowers by 286.3 Hz finally vs intervocalically in the context of /i/ (/ili/ 1714.83 Hz, sd = 189.26; /il/ 1428.47, sd = 296.8), while increasing by 38.38 Hz also finally vs intervocalically in the context of /a/ (/ala/ 1221.9 Hz, sd = 170.31; /al/ 1260.28 Hz, sd = 237.67). Less vowel coarticulation initially and finally than intervocalically is then mainly associated with a continuous F2 decrease in the /i/ context condition.

As for dark /l/ (Fig. 9, right side), coarticulatory differences in initial position are comparable to those in intervocalic position since /l/ decreases very slightly by 36.12 Hz in the /i/ context (/ili/ 1103.7 Hz, sd = 202.7, /li/ 1067.6 Hz, sd = 114.18) and by 12.72 Hz in the /a/ context (/ala/ 972.1 Hz, sd = 99.7, /la/ 959.39 Hz, sd = 56.64). In parallel to the /i/ context condition, less F2 coarticulation finally than intervocalically is related to a F2 decrease in the /i/ context condition, i.e., F2 for /l/ lowers by 123.94 Hz next to /i/ (/ili/ 1103.7 Hz, sd = 202.7, /il/ 979.8 Hz, sd = 122.37) and basically undergoes no changes next to /a/ (/ala/ 972.1 Hz, sd = 99.7, /al/ 971.7 Hz, sd = 104.54).

4. Summary and discussion

F2 values for /l/ in the sequence /ili/ (also in the sequence /li/ and to some extent in /il/ as well) support descriptive accounts classifying the languages/dialects subjected to analysis in the present investigation according to whether they exhibit a clear or a dark variety of /l/: clear /l/ is found in Alguerese Catalan, British English RP, Czech, Danish, Dutch, Finnish, French, German, Hungarian, Italian, Newcastle English, Norwegian, Lengadocian Occitan, Romanian, Spanish, Swedish and Valencian Catalan; dark /l/ occurs in areally dispersed languages/dialects, i.e., Mid Western American English, Leeds British English, Majorcan Catalan, Portuguese and Russian. This grouping also holds in the /a/ context condition though less clearly than in the context of /i/ which is in line with differences in articulatory compatibility between the consonant varieties and the vowels in question.

The F2 formant frequencies for the two consonant varieties are set in contrast quite robustly both regarding the splitting boundary and the frequency ranges. The splitting boundary between clear /l/ and dark /l/ appears to be located somewhere around 1300–1400 Hz in the /i/ context and roughly at 1000 Hz in the /a/ context. The F2 frequency range is greater for clear /l/ than for dark /l/, which is in line with differences in articulatory constraint between the two consonant varieties, and may extend up to 2000 Hz and 1500 Hz for clear /l/ and to 1500 Hz and 1000 Hz for dark /l/ in the context of /i/ and /a/, respectively. Larger ranges for the two varieties of /l/ in the context of /i/ vs /a/ should be attributed to the specific relationship between the articulatory realization of the consonant and vowel segments; indeed, as shown in Fig. 1, while /a/ shares a low tongue dorsum position with dark /l/ since both phonetic segments are produced with predorsum lowering and tongue body retraction and to some extent with clear /l/ as well, the lingual gesture for /i/ is highly antagonistic to that for dark /l/ and affects considerably the articulatory configuration for clear /l/. F1 shows higher values for dark /l/ than for clear /l/ mostly next to /i/, while differences between the two /l/ types also hold for F3 mostly in the /a/ context condition.

Judging from the overlapping F2 frequency scenario in the intervocalic position in the context of /i/ and to some extent of /a/ as well, several languages/dialects could be characterized as having a moderately clear or a moderately dark (rather than a purely clear or purely dark) variety of the consonant. Indeed, /l/ could be moderately clear mostly in Czech and Newcastle English and perhaps Finnish, and moderately dark in Eastern Catalan. This finding is in support of darkness degree in /l/ proceeding gradually rather than categorically across languages and dialects. /l/ is expected to be realized through an intermediate articulatory configuration between the two /l/ types in languages/dialects where it exhibits intermediate degrees of darkness.

The paper also reports a general trend for F2 for initial /l/ to exceed F2 for final /l/ in line with position-dependent differences in articulatory configuration, i.e., a higher and more anterior tongue body position for the consonant in the former position vs the latter. Most languages/dialects show an F2 frequency positional difference below 200–300 Hz and may thus be characterized as having ‘intrinsic’ allophones. Other languages/dialects exhibit a larger F2 difference between the initial and final positions and thus, ‘extrinsic’ allophones. When compared to the scenario in intervocalic position, extrinsic allophones appear to be associated with final darkening in Czech, Dutch and Newcastle English (also in British English RP) and with initial clearing in American English. While not exhibiting extrinsic allophones, another group of languages/dialects are special in allowing for somewhat darker realizations of /l/ utterance initially and/or utterance finally than intervocalically (Italian, Eastern and Valencian Catalan). In agreement with literature descriptions, Finnish and Norwegian are also special in showing contextually determined positional allophones, i.e., F2 for /l/ is relatively low next to /a/ in Finnish and F2 for utterance final dark /l/ after /a/ in Norwegian is typical of a strongly dark variety of the consonant.

The two positions differ in degree of vowel coarticulation as well, i.e., there is less coarticulation utterance finally than utterance initially presumably for two reasons: utterance initial /l/ but not utterance final /l/ is subjected to anticipatory vowel coarticulation; a darker realization of /l/ involving a decrease in constriction degree and dorsopalatal contact in utterance final position next to /i/ causes the articulatory configuration of the alveolar lateral to approach that occurring next to /a/.

The allophonic and coarticulatory scenario allows setting apart the two varieties of /l/ in a more or less clearcut way. As for the allophonic issue, F2 frequency differences as a function of position are larger for clear /l/ than for dark /l/ in line with differences in articulatory constraint between the two consonant varieties, i.e., speakers hold a relatively fixed tongue dorsum configuration in the case of the more highly constrained dark vs clear variety of the alveolar lateral. Position-dependent differences in vowel coarticulation (intervocalic > utterance initial > utterance final) turned out to also be much larger for clear /l/ than for dark /l/ in line with the same differences in articulatory constraint just referred to, i.e., higher tongue dorsum requirements for dark /l/ vs clear /l/.

To recapitulate, data reported in this paper provide strong support for several hypotheses. First, they speak clearly in favor of both the subdivision of languages/dialects into two groups depending on whether they have a clear or a dark variety of /l/, and the existence of intermediate darkness categories. Secondly, they confirm a subdivision of positional allophones of /l/ into ‘intrinsic’ and ‘extrinsic’ while showing that the latter may be associated with the initial or the final position depending on language/dialect. Thirdly, several findings are consistent with differences in articulatory constraint between the two /l/ types, i.e., less F2 variability and coarticulation and smaller allophonic differences for dark /l/ than for clear /l/. Finally, the three positions subjected to investigation differ in F2 frequency and in degree of vowel coarticulation in the progression intervocalic > utterance initial > utterance final mostly due to differences in articulatory configuration during the consonant associated with the vowel /i/.

Future research needs to address possible language/dialect-dependent differences in the temporal implementation of clear /l/ and dark /l/. In the first place, the extent to which the degree of tongue body lowering and backing anticipation with respect to the apical raising gesture for dark /l/ depends on the darkness degree in the consonant. Secondly, whether the probability that closure formation for dark /l/ occurs after the voicing period in prepausal position increases with darkness degree in the consonant. While the latter characteristic has been shown to take place in American English (Browman and Goldstein, 1995), it does not seem to apply to Majorcan Catalan in spite of the two dialects exhibiting a strongly dark /l/ variety.

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Appendix A

The list of recorded sentences is appended below in the original language orthography and with English glosses, except for several language/dialects for which information about the sentence material is lacking (British English RP, Newcastle and Leeds English, French), and for Russian for which sentences are provided in phonetic transcription.

(a) (Germanic languages)

American English (/li/ say the word 'lee' instead; /il/ say the word 'feel' instead; /la/ say the word 'lush' instead; /al/ say the word 'dull' instead). Intervocalic data next to /i/ were recorded across words ending in -ly and exhibiting several vowels before /l/ (silly, holly), while those next to /a/ were gathered across words ending in -low and showing several vowels before /l/ (e.g., swallow).

Danish (/li/ liter af vin "liters of wine"; /i#li/ i litervis "lots of liters"; /il/ tænde en grill "light a grill"; /la/ latter er godt "laughter is well"; /a#la/ af latter skabt "of laughter created"; /al/ tænk på et tal "think of a number").

Dutch (/li/ lied van jou "that is nice of you"; /i#li/ die lieve man "that nice man"; /il/ de weg naar tiel "the way to the city of Tiel"; /la/ laat maar "just let it go"; /ala/ geld nalaten "leave behind money"; /al/ ann de paal "on the pole").

German (/li/ Lisa ist hier "Lisa is here"; /i#li/ nie liegen wir da "we never lie/couch there"; /il/ da ist schon Kiel "there is Kiel already"; /la/ Lara ist hier "Lara is here"; /a#la/ nah lagen wir da "we lay close together"; /al/ da ist der Stahl "there is the steel").

Norwegian (/li/ lia er der "the slope is there"; /i#li/ i lia der "in the slope there"; /il/ det er en bil "it's a car"; /la/ laget er der "the team is there"; /a#la/ ta laget der "take the team there"; /al/ det er en jarl "it's an earl").

Swedish (/li/ lite men gott "little but good"; /i#li/ vi lider här "we suffer here"; /il/ säg om dil "repeat the word 'dil'"; /la/ ladan är bra "the barn is good"; /ala/ Wallander här "Wallander is here"; /al/ säg om dal "repeat the word 'dal'").

(b) (Romance languages)

Alguerese, Majorcan and Valencian Catalan (/li/ litres de llet "liters of milk"; /i#li/ engolí/engolir líquid "he swallowed/to swallow liquid"; /il/ en/ne venen mil "they sell a thousand of this"; /la/ laca molt/assai bona "very good varnish"; /a#la/ visità/visitar l'àtic "he/she visited/to visit the top floor"; /al/ no li fa mal "it does not hurt him/her").

Eastern Catalan (/li/ lis diu "he/she says the word iris"; /i#li/ fi lis "fine iris"; /il/ diu fil "he/she says the word 'thread'"; /la/ las diu "he/she says the word 'weary'"; /a#la/ pa lat "large bread"; /al/ diu pal "he/she says the word 'stick'").

Italian (/li/ Lido de Bra "Lido de Bra"; /i#li/ i lidi qua "the shores are there"; /il/ ripeta dil "repeat the word 'dil'"; /la/ lato di Bra "side from Bra"; /a#la/ la ladra qui "the woman thief is here"; /al/ ripeta dal "repeat the word 'dal'").

Occitan (/li/ libres de dròlles "children's books"; /ili/ en equilibri "in equilibrium"; /il/ un camp de milh "a corn field"; /la/ lach de vaca "cow milk"; /ala/ lo camin s'alarga "the path gets wider"; /al/ li fa pas mal "it doesn't hurt him/her").

Portuguese (/li/ litro de água "liter of water"; /ili/ má bílis "bad bile"; /il/ palavra com til "word with a tilde"; /la/ laca de cabelo "hair lacquer"; /ala/ grande sala "a large hall"; /al/ pão com sal "bread with salt").

Romanian (/li/ litru de vin "liter of wine"; /i#li/ şi litera "and the letter"; /il/ încă un kil "one more kilo"; /la/ latră din nou "barks again"; /a#la/ ca lacrima "like the tear"; /al/ vede un cal "sees a horse").

Spanish (/li/ lima es una palabra "'file' is a word"; /la/ lava es una palabra "'washes' is a word"; /il/ digo la palabra vil "I say the word 'mean'"; /al/ digo la palabra coral "I say the word 'coral'". Data for intervocalic /l/ were recorded in words with /Vli/ and /ilV/ (feliz "happy", valido "court favorite") and in words with /Vla/ and /alV/ (alaba "he/she praises", Pilar (female name)).

(c) (Slavic languages)

Czech (/li/ lidem se zdá "people suspect"; /i#li/ pri lidech stál "he supported people"; /il/ na mesíc vyl "he howled to the moon"; /la/ Lada se má "Lada is lucky"; /a#la/ za Ladou stál "he stood behind Lada"; /al/ na mesíc dal "he took the moon seriously".

Russian (/lɨ/ [ˈlɨsɨj nʲe ˈrat] "the bald one is not glad"; /la/ [ˈlada zaˈʃla] "Lada has stopped by"; /i#lɨ/ [i ˈlɨsɨj ˈrat] "and the bald one is glad"; /a#la/ [za ˈladu ˈrat] "I am glad for Lada"; /il/ [a iˈvan xaˈdʲil] "but Ivan walked there"; /al/ [iˈvan nʲe ˈznal] "Ivan did not know").

(d) (Finno-Ugric)

Finnish (/li/ listasin ne "I made a list"; /ili/ kili meni "a billygoat went"; /il/ toistapa sil "repeat with that"; /la/ lato on tuo "that is a barn"; /ala/ kala uisi "a fish would swim"; /al/ toista sammal "repeat the word 'moss'").

Hungarian (/li/ lidérc van ott "there is a cacodemon"; /i#li/ mi listát írunk "we are writing a list"; /il/ ez damil "this is a line", ez a fa szil "this is an elm"; /la/ lakat a szó "the target word is lock"; /a#la/ a lakat zár "the lock fastens"; /al/ ismerős a dal "the song is familiar").

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