# V-to-V assimilation in trisyllabic words in French

## Evidence for gradience and locality*

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We investigate the extent of regressive vowel-to-vowel assimilation in trisyllabic words in French. Sixty existing words were inserted in a carrier sentence, each containing /a/ in word-initial unstressed position, and /a/ or /i/ in word-medial unstressed and word-final stressed positions. Acoustic measurements taken at the midpoint of vowels showed that /a/ in word-initial position was less fronted and more open than /a/ in word-medial position when the vowels were followed by a final front vowel. The degree of fronting of /a/ word-initially was greater when the vowel was followed by a front vowel in both medial and final positions. These results suggest that vowel-to-vowel assimilation in trisyllabic words in French is a gradient and local effect of the final front stressed vowel on the vowel immediately adjacent to it.

**Key words:** anticipatory assimilation; Vowel Harmony; gradience; phonetics; phonology



## 1. Introduction

Word-level vowel-to-vowel assimilation (henceforth, VVA) is considered the phonetic basis of vowel harmony in French, which is defined as “the influence of the vowel of a stressed syllable on the pronunciation of a mid vowel in a preceding open syllable” (Walker 2001: 54–55). When the vowel of the word-final primary stressed syllable is a high or a high-mid vowel, the preceding mid vowel is expected to assimilate in height

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to the following stressed vowel, as in (1a) and (2a). Conversely, when the stressed vowel is a low or mid-low, the preceding mid vowel becomes mid-low, as in (1b) and (2b):

(1) a. *aim-er* /eme/ "to love"
    b. *aim-able* /ɛmabl/ "lovely"

(2) a. *au-to* /oto/ "car"
    b. *au-tomne* /ɔtɔn/ "fall"

The phonetic mechanism of this harmony pattern is acoustically real, and is best understood as "variations in tongue height along with related displacement of the tongue position along the front–back axis" (Nguyen & Fagyal 2008: 1). The effect of the word-final stressed vowel on the preceding vowel is non-morphologically conditioned (contrary to Dell 1973 and in support of Tranel 1987), likely unrelated to word frequency, and represents an instance of fine phonetic variation encoded in native speakers' mental lexicon. Thus, in light of Examples (1a) through (2b), vowel harmony in French is regressive assimilation anchored in gradient lingual coarticulatory patterns, with the final vowel as the trigger and the preceding vowel as the assimilating vowel.

Previous studies, however, almost exclusively focused on harmony in disyllabic tokens. Reports on VVA in longer words are rare and somewhat contradictory. In trisyllabic words, for instance, at least two assimilatory patterns seem to operate: (1) none of the preceding vowels assimilates to the final vowel (Example (3a)), and (2) assimilation is local, affecting only the vowel of the penultimate syllable, but not the vowel of the word-initial suffix (Examples (3b, c, and d)). In addition, the second scenario seems irregular, as in some cases, such as the word *territoire* "territory" (3e), the penultimate rather than the final vowel seems to trigger the local assimilatory effect: "This word is exceptional in that the vowel causing the harmony is not the stressed vowel, but the penultimate /i/" (Walker 2001: 110).

(3) a. *orgueil* /ɔʁgœj/ "pride" > *orgueilleux* /ɔʁgœjø/ "proud" (Tranel 1987: 61)
    b. *clair* /klɛʁ/ "clear" > *éclairer* /ekleʀe/ "to clarify"
    c. *code* /kɔd/ "code" > *décoder* /dekode/ "to decode"
    d. *aveugle* /avœgl/ "blind" > *aveugler* /avøgle/ "to blind"
    e. *terre* /tɛʁ/ "land" > *territoire*/tᴇʀitwaʁ/"territory" (Walker 2001: 54)

In light of these examples, one can conclude that the extent of VVA in long words remains little understood. As opposed to disyllabic words, morphological complexity arising from the presence of a prefix in trisyllabic words is likely to play a role. In addition, local assimilatory effects might not be tied to word-final stress. It is possible that the assimilatory effect of a front vowel, if any, operates regardless of the location of the triggering vowel in the word. Since actual realizations of VVA in trisyllabic words have not yet been studied acoustically, the present study is designed to investigate this phenomenon in a restricted and controlled set of existing words in French.

## 2. Research questions and hypotheses

In this study, we investigate the extent of regressive VVA in French, using acoustic phonetic methods in existing trisyllabic words with comparable phonetic structure. We follow previous work by Nguyen and Fagyal (2008) showing that VVA in disyllabic words is grounded in gradient coarticulatory patterns (see also Ohala 1994; Benus & Gafos 2007; Cole 2009).

Our first research question is whether there is extensive anticipatory coarticulation between the word-final stressed, or trigger, vowel (henceforth, V1) and the preceding target vowel (henceforth, V2) in a trisyllabic word, as has been shown for disyllabic words. Our second research question targets the prosodic domain of VVA, i.e. whether the assimilatory influence of the stressed vowel (V1) extends to the word-initial vowel (henceforth, V3).

Our hypothesis for the first research question is that, in agreement with previous findings on disyllabic words, there will be extensive local assimilation of V2 to V1 in longer words. Given that findings from previous studies do not authorize precise predictions of the extent of VVA in long words, we consider the second research question an empirical question that results from our experiment; nevertheless, there are expected answers for a restricted set of target words. We expect that if the domain of VVA is the word, we should find acoustic evidence of coarticulation triggered by V1 on both V2 and V3. If VVA is local and non-subject to feature-spreading rules, however, then vowels non-adjacent to V1 in long words would not show regressive assimilation to V1. In this case, one would more likely conclude that VVA in French is restricted to local coarticulatory assimilation, confirming observations in Examples (3b–e).

## 3. Methodology

A corpus of sixty trisyllabic French words was generated using the phonetic search feature of the electronic version of the *Petit Robert* dictionary (see Appendix for the complete word list). Words were either vowel or consonant-initial and each of the three syllables contained either /a/ or /i/ as their nucleus. Although we were primarily interested in observing the results of VVA in i-i-a and a-a-i type words, there were no entries of i-i-a type words in the dictionary. Therefore, we examined results from all words which contained /a/ in V1 position, of which we found sixty entries in the dictionary. Therefore, we are focusing in this study on words with /a/ in word-initial and word-medial positions, in order to compare the effect of the word-final trigger vowel (/a/ or /i/) on the same target vowel. Target words contained a variety of intervocalic consonants to make sure no single consonant or consonant type could exert a biasing coarticulatory influence on any of the target vowels. Additionally, although VVA has been defined as applying to mid vowels in French, we expect the phonetic mechanisms of VVA to be fundamentally the same when the target vowel is an open /a/ rather than a mid vowel. Thus, this experiment is based exclusively on /a/ as target vowels (V3 and V2) and /i/ vs. /a/ as trigger vowels (V1) in order to guarantee uniformity in acoustic information about the vowels in each position in the word.

The participants recruited for this first study were three native speakers of European French: 2 female speakers from the North East of France and 1 male speaker from the North-West of France, all exchange students at the University of Illinois. The speakers were recorded in the recording booth of the Phonetics Lab at the University of Illinois at Urbana-Champaign using an AKG C 520 head-mount condenser microphone, positioned 3–5 cm from the corner of the mouth. Words from the list were presented visually to the participants as a series of slides in Power Point which they were instructed to read aloud in a normal voice and volume, and at a normal speaking rate. The target word was first presented in the carrier phrase "*Il retape* (target word) *parfois*" ("He retypes (target word) sometimes"). The target word was then presented in isolation in the next slide, followed by a blank slide (see Figure 1 for an example of the series of slides). We will, henceforth, refer to the first presentation type as *in-sentence* and the second as *isolated* conditions. Two of these series were included for each of the 75 words, in randomized order, resulting in 4 tokens for each target word (2 in the in-sentence condition and 2 in the isolated condition), and an overall total of 300 combined tokens for the experiment. The experiment was self-paced: participants could determine the amount of time they took between each slide. One break was built into the presentation of the slides, and none of the participants took more than one five to ten minutes break to complete his/her readings. The experiment typically lasted about 15 minutes.

The acoustic analysis was performed in Praat. Syllable and phone boundaries were segmented using a Praat plugin implementing Jean-Philippe Goldman's EasyAlign automatic segmentation algorithm for French,[1] and were verified and corrected manually, if needed. A Praat script was used which measured the formant values in Hertz (Hz) at the midpoint of each of the three vowels in the target word; the midpoint was chosen as the location where the formant values would be measured in order to minimize any coarticulatory acoustic effects on the formant values from the neighboring consonants. These values were cross-checked manually for outliers, and the manually measured values were used as replacements for the outliers, if the outlier values were deemed to be incorrect. These changes amounted to less than one percent of all formant



1. Jean-Philippe Goldman's webpage is available at: http://www.unige.ch/lettres/linguistique/goldman/

values, and concerned primarily /i/ that was sometimes devoiced word-finally. For the purposes of statistical analyses, the vowel formant frequencies in Hz were converted to the perceptually more relevant auditory frequency scale, called Bark scale,[2] using Traunmüller's formula (Traunmüller 1990, cited in Nguyen & Fagyal 2008: 7).

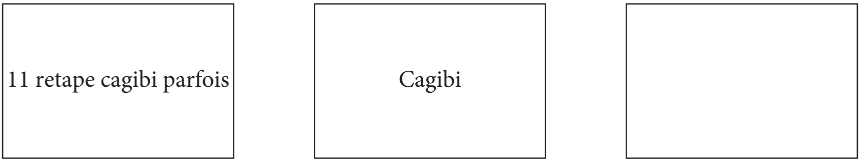


**Figure 1.** Example of the series of Power Point slides presented to the speakers to read aloud

## 4. Results

### 4.1 Extent of V-to-V assimilation influence in French

In order to test whether coarticulatory influence from the trigger vowel can extend to the left edge of the target word, words featuring /a/ as both target vowels (V3 and V2) and the two different trigger vowels (V1) were selected. Figure 2 shows V1, V2 and V3 formant frequencies measured at the vowel midpoints in a-a-i type words for each speaker and both conditions. F1 frequencies are plotted along the *y*-axis, F2 along the *x*-axis,[3] using the originally measured Hz scale. Ellipses represent productions of each vowel within two standard deviations. What we can observe immediately from these figures is that, for all speakers, the vowel space for V2 indicates, in general, lower F1 and higher F2 values than the vowel space for V3. In other words, /a/ is more closed and more fronted in word-medial than in word-initial positions before /i/ for all speakers.

Differences between the distributions of V3 /a/ and V2 /a/ in the two word conditions are shown in Figure 3. The corresponding distributions for the three speakers are distinguished by different shades and patterns. In each case, the left-hand pairs

2. The human auditory system's response to frequency is non-linear. A difference in 500 Hz between two sounds is perceived differently, for instance, below and above 2 kHz. In order to normalize for these discrepancies, the use of the Bark or Mel scales is recommended (Johnson 2003: 51; Stevens 2000: 237).

3. All formant plots were generated using JPlotFormants v1.4. The program can be downloaded from the following web site: http://www.linguistics.ucla.edu/people/grads/billerey/PlotFrog.htm

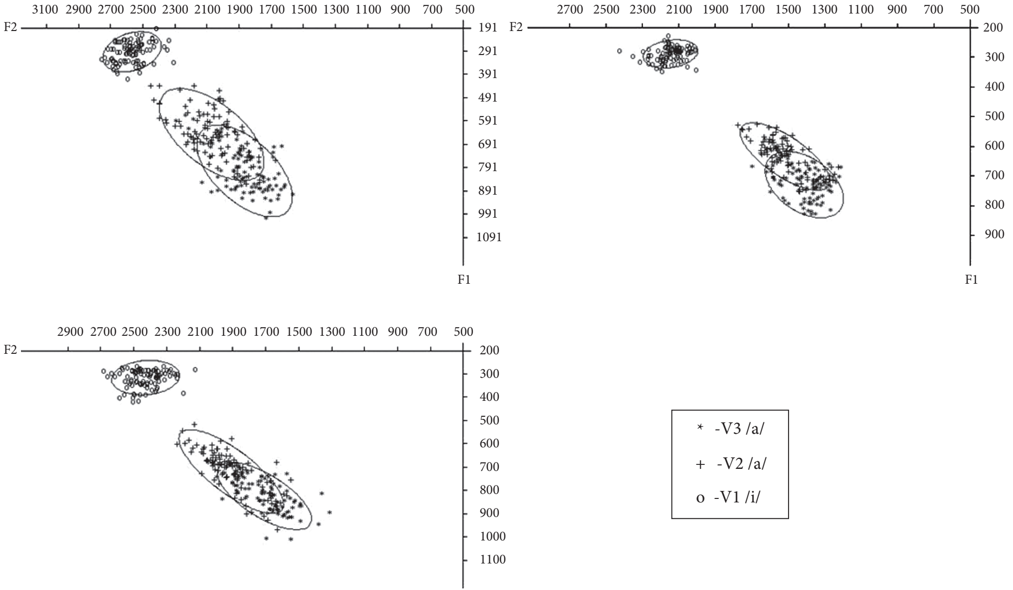


**Figure 2.** Plotted formant values in Hz and 2-standard-deviation ellipses for all vowels in a-a-i type words. Measurements from the *in-sentence* and *isolated* conditions are collapsed in for easier reading of the multiple data points

display the distribution for V3 /a/, with the leftmost plot of each pair corresponding to the in-sentence condition. The general tendency of lower F1 and higher F2 is again confirmed for V2 /a/ in comparison to V3 /a/. Given the negative correlation between F1 frequency and tongue height, and positive correlation between F2 frequency and fronting of the tongue body, these findings strongly suggest that V2 /a/ is more fronted and closed than V3 /a/ and, therefore, that V1 /i/ has, at the very least, an extensive coarticulatory influence on this word-medial vowel. However, the distribution of F1 values in isolated condition for speaker F2 and the distributions of F1 and F2 values for speaker M1 in both word conditions show subtle but clear differences, which called for inferential statistics.

We ran Paired Samples t-tests to verify statistically if /a/ in V2 was, on average, significantly more /i/-like than its corresponding counterpart in V3 (Hypothesis 1).[4] Statistics were calculated separately for each speaker, vowel type, formant, and word condition. Results of individual t-tests and descriptive statistics shown in Table 1 (see Appendix) confirm observations depicted in Figures 2 and 3: on average /a/ immediately preceding /i/ had significantly lower F1 and higher F2 than /a/ in word-initial position for each speaker and both word conditions. While in most paired comparisons, V3 and V2 were not correlated, which means that realizations of /a/ could be assumed to be independent in each syllable, in three out of four comparisons formant values in V3 and V2 showed weak but statistically significant correlation ($p < 0.05$) in speakers' F1 and M1 speech. This indicated that formant values in the two word conditions could not be collapsed and analyzed jointly, but rather word condition had to be kept as a separate independent variable in further statistical analyses.[5]

A comparison of V3 and V2 in a-a-i type words, as performed above, can help determine whether the word-final trigger vowel has a significant effect on the word-medial vowel, as we have just seen by observing the greater closing and fronting influence of V1 /i/ on V2 /a/ than on V3 /a/. However, this type of comparison cannot fully describe the extent of this influence, namely, whether V1 /i/ has *any* effect on the production of V3 /a/. Therefore, a comparison of V3 /a/ and V2 /a/ in a-a-i type words to those in a-a-a type words is needed, in order to observe possible differences due to the trigger vowels.

The plots in Figure 4 display F1 and F2 formant frequency ellipses within two standard deviations from mean values (denoted by the symbols indicated in the legend) of V3 /a/ and V2 /a/ in a-a-a and a-a-i words. We can observe, for all speakers, that



**4.** Statistical analyses reported in this paper have been performed using the software package SPSS 17.0.

**5.** Measurements from the *in-sentence* and *isolated* conditions are collapsed in Figures 2 and 4 for easier reading of the multiple data points and/or ellipses.

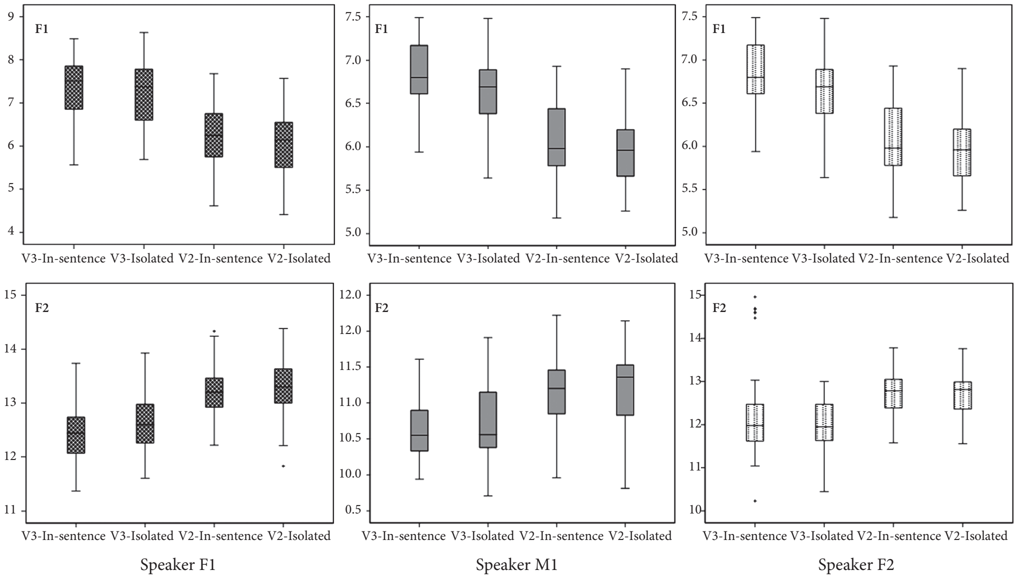


**Figure 3.** Boxplots of F1 and F2 formant frequency distributions in a-a-i type words for V3 /a/ (left boxplot pairs) and V2 /a/ (right boxplot pairs) in two word conditions (in-sentence and isolated)

V2 /a/ in a-a-i type words has a lower F1 and higher F2 than any of the other three instances of /a/. However, we can also observe that the mean of the word-initial V3 vowel in a-a-i words is not any higher or lower than the mean of the initial V3 vowel in a-a-a words. Taken together, these observations highlight the likelihood that word-medial V2 /a/ is more fronted and more closed than the other three vowels. This suggests that there is no regressive assimilatory influence of the trigger vowel V1 /i/ on V3 /a/ in the speech of any of the three speakers.

To test for the statistical significance of these tendencies, we conducted Repeated Measures ANOVAs[6] with position of target vowel (V3 and V2), type of trigger (/i/ and /a/), and word condition (in-sentence and isolated) as independent within-subject factors and F1 and F2 values as dependent variables. This 2x2x2 design yielded separate comparisons for each formant and speaker. The relative contribution of each source of variance tested is shown in Table 2 in the Appendix. Cells depicting statistically significant (at $p < 0.05$) single or joint factors are shaded.

For speaker M1, tests of within-subject effects revealed that for the first formant, there were significant main effects of position of /a/ in the word for the first formant ($F(1, 28) = 62.836$, $p < 0.001$), type of triggering vowel ($F(1, 28) = 14.197$, $p < 0.001$), and word condition ($F(1, 28) = 17.288$, $p < .001$). Among the interactions, only the interaction of the position of /a/ in the word and the type of trigger was significant ($F(1, 28) = 7.240$, $p < 0.012$), which means that the type of trigger had a different effect depending on which position the target vowel was placed in the word (initial or medial). It should also be noted that the joint interaction of position of /a/ in the word and word condition was not significant, but with more data points, it might approach significance ($F(1, 28) = 4.172$, $p < 0.050$). For the second formant, there was a widely significant main effect of the position of /a/ in the word ($F(1, 28) = 19.198$, $p < 0.001$), but neither the type of trigger vowel ($F(1, 28) = 3.646$, $p < 0.066$) nor word condition ($F(1, 28) = 2.608$, $p < 0.117$) contributed significantly to observed variance in the data.

For female speaker F1, the same tests revealed more significant interactions for both formants. For the first formant, there were significant main effects of position of /a/ in the word ($F(1, 28) = 29.282$, $p < 0.001$) and type of triggering vowel ($F(1, 28) = 12.140$, $p < 0.002$), but word condition had no significant main effect ($F(1, 28) = 2.379$, $p < .134$). Similar to speaker M1, only the interaction of the position of /a/ in the word and the type of trigger was significant ($F(1, 28) = 25.762$, $p < 0.001$), but in this



6. Prior to performing these analyses, we used Mauchly's test ($p > 0.05$) to test for the RM ANOVA version of equality of variances (see Field 2005: 427–482). As Mauchly's test returned non-significant results in each comparison, we assumed that the condition of sphericity was met in each case.

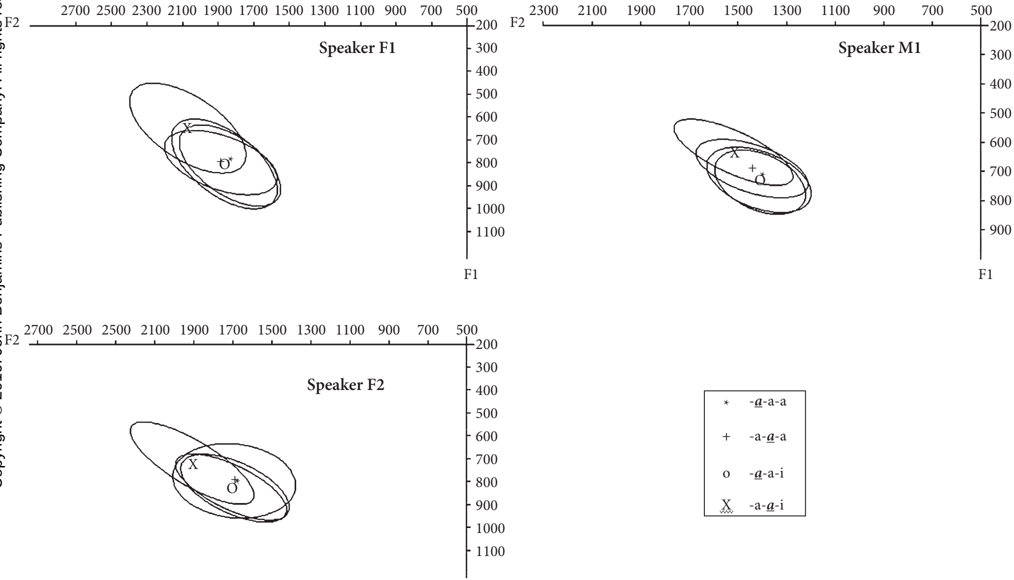


**Figure 4.** Two standard deviation ellipses and distribution means represented by the symbols listed in the legend in Hz for V2 /a/ and V3 /a/ in a-a-a and a-a-i type words. Measurements from the *in-sentence* and *isolated* conditions are collapsed in for easier reading of the multiple data points

speaker's speech both formants showed this effect. Again, type of trigger exerted a different effect on /a/ depending on its position in the target word.

In female speaker F2's speech, position of /a/ in the word ($F(1, 28) = 41.871$, $p < 0.001$), type of trigger ($F(1, 28) = 14.075$, $p < 0.001$), and word condition ($F(1, 28) = 7.241$, $p < .012$) were also significant. As opposed to the other speakers, these factors were significant for both formants. Besides the joint effect of position of /a/ and type of trigger ($F(1, 28) = 10.784$, $p < 0.003$) for the second formant, there was a significant three-way interaction between the three factors. The joint interaction of position of /a/ and word condition was also statistically significant ($F(1, 29) = 13.560$, $p < 0.001$) for the same formant. This means that for this speaker the type of trigger had a significantly different effect on /a/ in the front/back dimension depending on which position the target vowel (initial or medial) was placed in the word, as well as in which word condition (in-sentence or isolated).

To summarize, position of /a/ in the target word and type of trigger were significant within-subject factors for all speakers and all formants but the second formant in M1's speech. The interaction of these two factors was also significant for most speakers and dependent variables. Word condition has also contributed significantly to the observed variances, but less often and less unequivocally than the two other factors. Since the interaction between position of /a/ in the target word and type of trigger is of particular interest for answering our second research question (does V-to-V assimilation extend to the left edge of the word), we will now consider this interaction in greater detail.

Figure 5 displays, in Bark for each speaker, the interaction plots of mean F1 values in the top row and mean F2 values on the bottom row for the target vowel /a/ in two positions (V3 or V2) and with two different trigger vowels (/a/ or /i/) in the target words (a-a-a and a-a-i). For each pair of dots, the left-hand dot represents the mean of V3 /a/, while the right-hand dot represents the mean of V2 /a/. The dotted lines connect mean values of V3 /a/ and V2 /a/ when the trigger V1 is /i/ (a-a-i type words), while the solid lines connect mean values of these same vowels when the trigger V1 is /a/ (a-a-a type words).

In order to see a different effect of the trigger on /a/ in V3 than in V2 as a function of the type of trigger (/i/ or /a/), we should look for non-parallel lines. This is what we observe for both formants for all three speakers. As we can see, /a/ in V3 (word-initial) position was not at all affected by the type of trigger in four out of six cases. The two exceptions were the two female speakers, who seem to have fronted /a/ in both word-initial and word-medial positions in a-a-i type words (which is why mean F2 is higher for V3 /a/ in these words). However, the vowel /a/ was always significantly more closed (lower F1) and more fronted (higher F2) in word-medial position (V2) than in word-initial (V3) positions for all speakers.

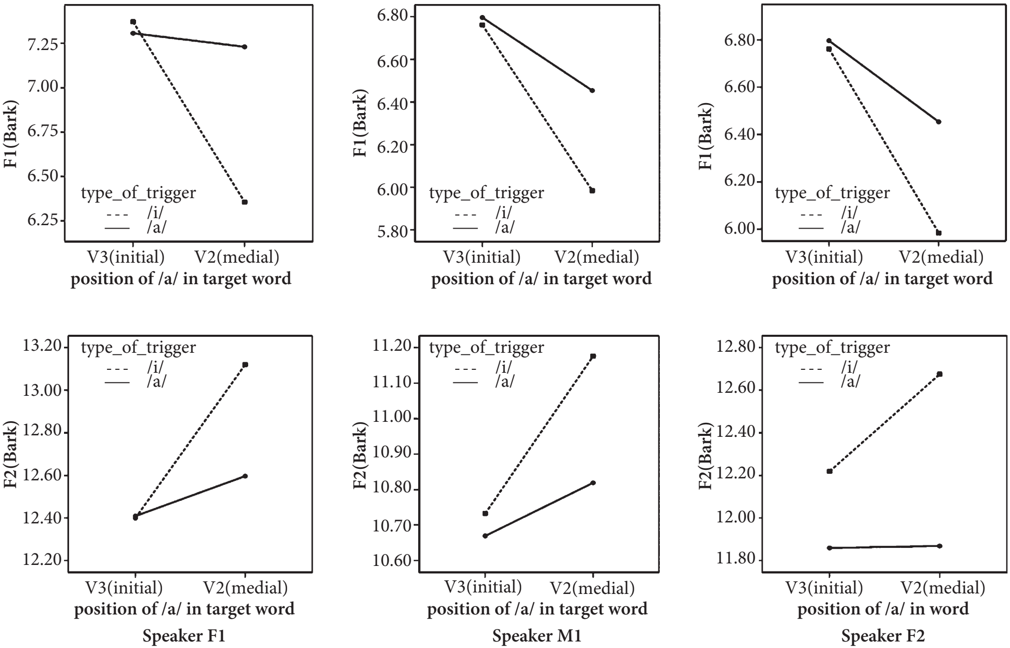


**Figure 5.** F1 and F2 distribution means in Bark for V3 /a/ (left in dot pairs) and V2 /a/ (right in dot pairs) in a-a-a and a-a-i type words in both conditions

## 4.2 Coarticulatory strength

A notable finding that we did not anticipate was evidence that the trigger vowel may have a gradient effect on the degree of regressive assimilation of the preceding vowel. Figure 6 displays the formant frequency distributions and means of V3 /a/ in all word types containing /a/ in their first syllable. As we can see, the fronting and closing influence of /i/ is slightly greater when the trigger is longer, in other words, when /i/ is both in final and in medial positions in the word. This increased effect is observed for all three speakers. However, speaker F2 seems more variable in terms of fronting of V3 /a/ across word types than the other two: we can see that there is some fronting and closing of word-initial V3 /a/ when /i/ is adjacent to it in type a-i-a words when compared to V3 /a/ in a-a-a type words. Nevertheless, these correlates are not as pronounced as when the /i/ trigger is "longer" in a-i-i words (i.e. when *both* V1 and V2 are comprised in the /i/ trigger).

Due to the small number of a-i-a type words in the corpus, we used non-parametric Independent Samples Mann-Whitney (2-tailed) tests to verify the statistical significance of these observations.[7] Results show that the first formant was, on average, significantly lower in V3 /a/ when it was followed by a "long" (a-i-i) front trigger than by a "short" (a-i-a) front trigger in two out of three speakers' speech. These were: speaker F1[8] (*Mdn* aii = 6.46, *Mdn* aia = 7.42; U = 378.5, $p < 0.001$, $r = -0.379$) and speaker M1 (*Mdn* aii = 6.37, *Mdn* aia = 6.57; U = 373, $p < 0.008$, $r = -0.311$). Formant values were not significantly different in the two contexts for speaker F2 (*Mdn* aii = 7.12, *Mdn* aia = 7.27; U = 574, $p < 0.28^{ns}$, $r = -0.127$).

Results for the second formant are even more convincing. The second formant was, on average, significantly higher in V3 /a/ in a-i-i type words that in a-i-a type words for all speakers. (Speaker F1: *Mdn* aii = 13.22, *Mdn* aia = 12.65; U = 430, $p < 0.005$, $r = -0.318$; Speaker F2: *Mdn* aii = 12.667, *Mdn* aia = 12.235, U = 451, $p < 0.017$, $r = -0.270$; Speaker M1: *Mdn* aii = 11.13, *Mdn* aia = 10.57; U = 343.5, $p < 0.003$, $r = -0.352$). Although the effect size is small in each case, these results confirm overall the gradient, essentially fronting, effect of a longer trigger on the preceding vowel in our target words.

7. Statistical significance of the Kolmogorov-Smirnov tests confirmed this choice: first and second formant values, indeed, showed non-normal distributions for both formant frequencies in all three speakers' speech.

8. Following conventions of reporting on the results of Independent Samples Mann-Whitney tests, we give the *median* (*Mdn*), the *U*, *p*, and *r* values for each test. Note that it is more appropriate to report on the *median* than the *mean* for non-parametric test, and *r* values allow gauging the effect size (Field 2005: 532).

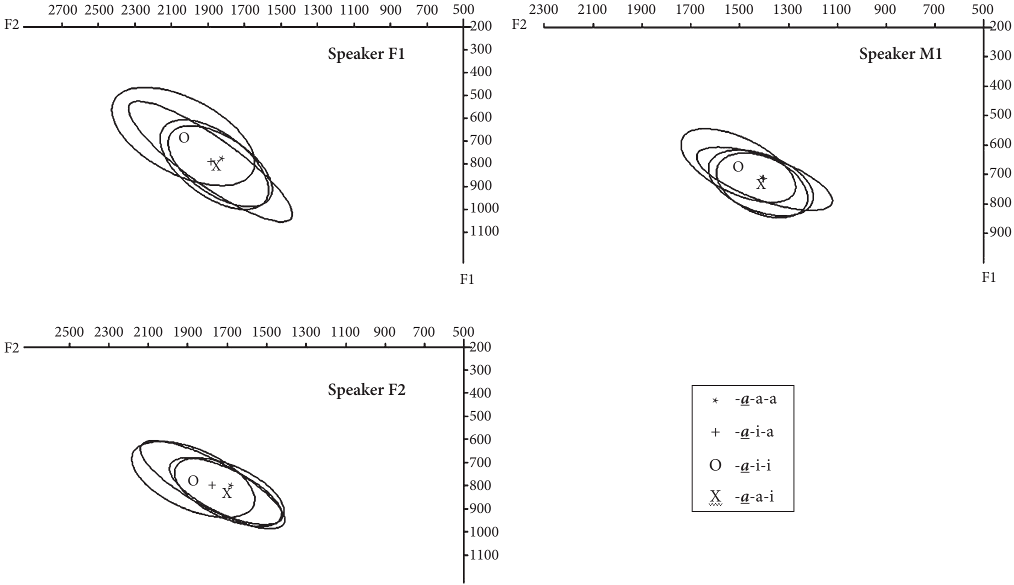


**Figure 6.** 2-standard-deviation ellipses and distribution means (represented by the symbols listed in the legend) in Hz for V3 /a/ in a-a-a, a-i-a, a-i-i and a-a-i type words

## 5. Discussion

In summary, based on the results of this experiment, we can say that the regressive assimilatory influence of the word-final front stressed vowel /i/ did affect the open vowel /a/ immediately adjacent to it. Thus, our hypothesis for the first research question is, confirmed: there is, indeed, extensive assimilation of V2 to V1 in trisyllabic words, as has been shown by previous studies for disyllabic words. However, the regressive assimilatory influence of the final vowel did not extend to the leftmost, word-initial /a/ in the target words. We must, therefore, conclude that regressive V-to-V assimilation appears to be a local phenomenon. Although further analyses of mid vowels are warranted, results reported here call into question any representation of VVA by feature-spreading rules or constraints relevant to the entire word as their domain of application. Our results seem more concurrent with the few examples of fronting of the penultimate vowel in trisyllabic words reported in Examples (3b–d) in the Introduction. The additional observation that regressive assimilation significantly increased in strength when the trigger vowel had a greater temporal extent lends further support to the interpretation that VVA is a gradient coarticulatory phenomenon (Nguyen & Fagyal 2008: 19–22).

Exemplar-theoretical representations of VVA can, very likely, account for these effects, as both local and long-distance assimilation can result in convergent regularities between fine phonetic detail and lexical representations, and thus lead to the incorporation of these details in native speakers' mental lexicon (see Cole 2009 for a discussion). Lack of evidence for long-distance assimilation in long words, such as we found in this corpus, would argue against formal accounts of the VVA phenomenon in French as the spreading of a single phonological feature to the leftmost edge of the word (Dell 1973; Casagrande 1984), or markedness constraints associated with the same prosodic domain (Durand & Lyche 2004).

How this local regressive assimilation interacts with prosodic structure, such as initial accent,[9] and how it fits in with other phonological phenomena in French, such as pre-tonic vowel raising, remains to be investigated (see Casagrande 1984). It is possible that local hyperarticulation due to initial accent in French could exert an influence on word-initial vowels in our target words.[10] However, long words in French have been shown to display variable initial accent placement (see Jun & Fougeron 2002), which means that initial accent might or might not have been realized in all target words used in this study. We have no evidence for systematic initial accent occurring



**9.** Initial accent (*accent initial*) in French refers to phrase-initial pitch prominence, whose realization is extremely variable. When it is realized, initial accent typically falls on the first or second syllable of a lexical word in an accentual phrase.

**10.** We thank one of the anonymous reviewers of this paper for this observation.

on all word-initial syllables in our corpus. Also, the prosodic status of initial accent in Parisian French is different from final stress, as the most recent phonological analyses represent the former at the level of the accentual phrase rather than the prosodic word (see Welby 2006). Thus, at this point it is unclear what our predictions of a possible effect of initial accent would be. Provided the initial accent is systematically realized, one could predict the some sort of an enhancement of /a/, i.e. the word-initial vowel becoming more /a/-like and therefore resisting the assimilatory effect of the word-final front vowel. This is a possible effect, but it requires targeted investigations, in which one of the test conditions is the absence or presence of initial accent. We leave the exploration of this question for future research.

The same is true for possible vowel reduction word-medially. Although one would not predict vowel reduction in word-medial unstressed syllables in this or other dialects of French spoken in France (see Valdman 1993: 30–31), experiments designed to separate out possible effects of position and assimilatory fronting would have to be carried out in order determine if fronting of V2 in our target words is due entirely to the following front vowel.

## 6. Conclusion

The current study showed that the only vowel subject to vowel-to-vowel assimilation in a trisyllabic word in French is very likely the word-medial vowel, the one adjacent to the word-final front trigger. Although important individual variations were observed with regard to fronting that need to be further investigated, this assimilatory pattern was robust and general across the three speakers and multiple real words. Results reported in this paper suggest that regressive vowel-to-vowel assimilation in long words in French exists, but it is a local assimilatory phenomenon rather than a word-level phonological process.



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## Appendix A

List of all trisyllabic words with /a/ in V1 position, and /a/ or /i/ in V2 and V3 positions (*Le Petit Robert électronique* or *electronic version of Le Petit Robert*):

| | | | | | |
|---|---|---|---|---|---|
| [a] [a] [a] | panama | padischah | canitie | agami | nagari |
| abaca | pataras | rabbinat | kamichi | amathie | panaris |
| ananas | patata | (7) | lapilli | apathie | pahlavi |
| apparat | tarama | | parisis | aphasie | paradis |
| baccara | (15) | [a] [i] [i] | sashimi | arrachis | ramassis |
| balata | | achylie | tassili | avachi | patati |
| baraka | [a] [i] [a] | alibi | (13) | avanie | safari |
| canada | assignat | ascidie | | avarie | salami |
| hamada | califat | athymie | [a] [a] [i] | canari | tabagie |
| kamala | habitat | atypie | abasie | gabarit | tatami |
| malaga | harissa | avili | abattis | hallali | (25) |
| nacarat | marina | cagibi | acabit | maladie | |



## Appendix B

Table 1. Means, standard deviations and results of Paired Samples *t-test* (two-tailed) for F1 and F2 of /a/ in V3 (word-initial) and V2 (word-medial) positions and in two word conditions: **p < = .001, *p < = 0.05, $^{ns}$ non-significant. Low F1 (in V2) and F2 (in V3) values are shaded in grey.

| | In-Sentence | | | | Isolated | | | |
|---|---|---|---|---|---|---|---|---|
| | V3 | | V2 | | V3 | | V2 | |
| | Mean | St.dev. | Mean | St.dev. | Mean | St.dev. | Mean | St.dev. |
| Speaker F1 | | | | | | | | |
| F1 | 7.29 | *.68* | 6.23 | *.72* | 7.21 | *.69* | 5.98 | *.79* |
| t-test | $t(48) = 7.408^{**}, r = -.049^{ns}$ | | | | $t(48) = 9.765^{**}, r = -.281^{*}$ | | | |
| F2 | 12.44 | *.52* | 13.19 | *.51* | 12.60 | *.53* | 13.25 | *.54* |
| t-test | $t(48) = -9.957^{**}, r = .142^{*}$ | | | | $t(48) = -9.991^{**}, r = .268^{*}$ | | | |
| Speaker F2 | | | | | | | | |
| F1 | 7.44 | *.48* | 6.54 | *.68* | 7.31 | *.47* | 6.42 | *.67* |
| t-test | $t(48) = 6.968^{**}, r = -.200^{ns}$ | | | | $t(48) = 7.397^{**}, r = -.021^{ns}$ | | | |
| F2 | 12.22 | *1.05* | 12.67 | *.53* | 11.95 | *.56* | 12.68 | *.53* |
| t-test | $t(48) = 2.875^{**}, r = .142^{ns}$ | | | | $t(48) = 7.177^{**}, r = .161^{ns}$ | | | |
| Speaker M1 | | | | | | | | |
| F1 | 6.81 | *.37* | 6.06 | *.44* | 6.65 | *.42* | 5.98 | *.43* |
| t-test | $t(48) = 8.345^{**}, r = -.183^{ns}$ | | | | $t(48) = 6.657^{**}, r = -.292^{*}$ | | | |
| F2 | 10.65 | *.44* | 11.11 | *.53* | 10.71 | *.53* | 11.19 | *.56* |
| t-test | $t(48) = -5.35^{**}, r = .254^{ns}$ | | | | $t(48) = -4.926^{**}, r = .240^{ns}$ | | | |

## Appendix C

Table 2. Within subject interactions in the Repeated Measures ANOVA design (position of target vowel x type of trigger x word condition) for F1 and F2 for each speaker. Statistically significant ($p < .05$) single and joint factors are shaded in grey.

| | Speaker F1 | | Speaker M1 | | Speaker F2 | |
|---|---|---|---|---|---|---|
| *factors* | *F1* | *F2* | *F1* | *F2* | *F1* | *F2* |
| position_in_word | p < 0.001 | p < 0.001 | p < 0.001 | p < 0.001 | p < 0.001 | p < 0.029 |
| type_of_trigger | p < 0.002 | p < 0.036 | p < 0.001 | p < 0.066 | p < 0.001 | p < 0.001 |
| sentence_position | p < 0.134 | p < 0.013 | p < 0.001 | p < 0.117 | p < 0.012 | p < 0.004 |
| position_a_in_word* type_of_trigger | p < 0.001 | p < 0.001 | p < 0.012 | p < 0.071 | p < 0.003 | p < 0.016 |
| position_a_in_word* sentence_position | p < 0.246 | p < 0.204 | p < 0.050 | p < 0.333 | p < 0.617 | p < 0.016 |
| sentence_position* type_of_trigger | p < 0.314 | p < 0.214 | p < 0.463 | p < 0.077 | p < 0.591 | p < 0.374 |
| position_a_in_word* type_of_trigger* sentence_position | p < 0.356 | p < 0.272 | p < 0.562 | p < 0.908 | p < 0.435 | p < 0.001 |