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PERCEPTUAL EXPLORATION OF AO IN DIACHRONIC AL > AU > AO > O[*]

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Abstract: The goal of the paper is to explore, by means of perceptual data, one of the possible intermediate steps, AO (Menéndez Pidal, 1968), in the diachronic sound change AL > AU > AO > O. AO is usually placed after the change AL > AU, as in Middle French (Bretos & Tejedor, 2015) and Middle Castilian (Menéndez Pidal, 1968). Ohala (1981) states that many sound change processes find their root in acoustic similarity, leading to signal misperception by the listener. Interestingly, AL and AU share similar acoustic information that can be misinterpreted (Recasens, 1996). In order to explore signal misperception in AL > AU > AO, and paying special attention to the transition AU and AO, ten subjects had to listen to the following stimuli AL, AO and AU uttered by a female Eastern Catalan speaker at two different speech rates, fast and slow. Subjects were forced to choose between AL, AU and AO in order to specifically explore AU categorization by the participants. Results show that AU can be perceived as AO. If AU is perceived as AO, then it may also be produced as such (Ohala, 1981), thus finding an opening for AO to emerge as another candidate in the sound change.

Keywords: diachronic, sound change, perception, acoustics

1 Introduction

The change AL > AU > O has historically been observed in the following Romance varieties: French (Vaissiere, 1996; Bretos & Tejedor, 2015), Castilian Spanish (Menendez Pidal, 1968), and Catalan (Recasens, 1996). Vulgar Latin already, albeit sporadically, presented cases of l-vocalization as in *cauculus* (Väänänen, 1963). In order to start the sound change, L should be velarized, which is acoustically similar to U in AU (Recasens, 1996). The sound change has another step, AU > O. Menendez Pidal (1968) makes a distinction between primary AU and secondary AU. The O which originated from a primary AU evolved from Latin AU > OU > O (*causa > cosa*, found in both Castilian and Catalan). On the other hand, the O which originated from a secondary AU is the result of Latin AL > AU > O *(altariu>otero*). Menendez Pidal (1968) also observed that the change from secondary AU > *O* yielded other candidates such as AO; however, O outlived the rest. According to Bretos and Tejedor (2015), French also yielded AO in the evolutionary path for l-vocalization: AL > AU > AO > O in words such as *alba > aube; cal(i)du > chaud; mal(i)fatius > mauvais* (Bretos &

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Tejedor, 2015). Both Menendez-Pidal (1968) and Bretos and Tejedor (2015) place the intermediate step AO after AU in AL > AU, but how did the change take place phonetically? I will briefly present two approaches that have tried to account for the change: the articulatory and the perceptual approaches. The present study will use concepts from both approaches to account for the historical sound change being explored.

As far as the articulatory approach is concerned, one can find Articulatory Phonology (AP) (Browman & Goldstein, 1992), which could, broadly speaking, account for this historical sound change by means of two articulatory mechanisms: *gestural overlap* and *gestural reduction*. For instance, l-vocalization, as in AL > AU, would be an example of consonant reduction, also known as *gestural reduction* in AP, where the tongue tip fails to complete the closure at the alveolar region of the palate. On the other hand, AU > O would be caused by *gestural overlap*, where two given articulatory configurations blend into one, thus yielding a new articulatory configuration which shares traits from the original ones. In addition, in this case, *gestural overlapping* would also be at work since labialization from the second element in AU, /w/, which is functioning at a different but simultaneous tier, would be exerting its own influence on the acoustic traits of the lingual configuration corresponding to the first element in AU, /a/, thus possibly reinforcing the percept of either AO or eventually O. Such an account is in line with what Penny (1993) describes as *reciprocal assimilation*, in which two phonemes blend into one intermediate pronunciation as in Latin *causa* > Spanish *cosa*.

However, the fact that the same articulatory configuration may be misinterpreted by the listener as one sound or another complicates matters further. This has already been proposed by Ohala (1981), which is the example of a perceptual approach to sound change. In our study, the ambiguous acoustic output of the lingual configuration for AU may be misinterpreted as AO. Ohala (1981) would add that coarticulation may be one of the reasons that distorts what the speaker intended to utter. For example, in the sequence /ut/ the acoustic output for /u/ is affected by /t/, thus yielding an acoustically more fronted back vowel than in isolated form. Speakers who are used to such coarticulatory effects are in a better position to discard such effects and thus interpret the acoustic information correctly. On the other hand, speakers who are not used to these effects may easily misinterpret it and fail to reconstruct the original intended sound.

Experimental research has been carried out to investigate the perceptual and production mechanisms of l-vocalization in various languages. For instance, Recasens (2012) states that there is some perceptual evidence that listeners hear a back rounded vowel when presented with a schwa+lateral sequence in Romance languages. In addition, Martin (2005) found perceptual evidence of listeners hearing AU when presented with AL in Romance languages as well. Both examples point at the fact that the historical sound change AL > AU has a perceptual component. Interestingly, perceptual evidence has also been found in Germanic languages such as English (Wong, 2013; Szalay et al., 2022) and Swiss German (Leemann et al., 2014), suggesting that the sound change may not be localized to only a specific family of languages and that there may be physical conditions on both speech production and perception triggering the sound change (Ohala, 1993). To the author's knowledge no previous research has been conducted focusing on the intermediate step "ao", which is why this present study will shed some light on this specific outcome in the historical sound change AL > AU > AO > O.

Having seen some examples of the possible articulatory, acoustic and perceptual underlying mechanisms of the sound change, I would like to draw the attention to the fact that

Menendez Pidal (1968) seems to suggest that the change from one intermediate sound to another may logically have implied a period of time in which different possible outcomes in the chain may have coexisted until one of them became the predominant candidate. It is beyond the scope of this study to account for the many variables outside the domain of perception which may have certainly conditioned the final outcome of the historical sound change. Gubian et al. (2023) suggest that a sound change is stochastic and speaker-specific in nature, which complicates matters when exactly determining the evolutionary path of any diachronic sound change. Their agent-based model (Cronenberg et al., 2023) provides the tools for investigating sound change, taking into account other factors than the strictly phonetic ones. For instance, they propose the existence of a speaker-specific phonology based on exemplars that may be the source of sound change processes. The speaker-specific phonology seems to be based on the speakers' experience with the specific sounds and lexicon in their own language. The present study deals with what Stevens and Harrington (2022) call the fine-grained (synchronic) phonetic biases. More specifically, what speakers of a language hear and how the same signal can be misinterpreted, thus triggering a possible sound change.

Based on Menendez Pidal (1968)'s observations about possible outcomes coexisting and utilizing perceptual data (Ohala, 1981), thus remaining in the more phonetic level of a sound change (Stevens & Harrington, 2022; Gubian et al., 2023; Cronenberg et al., 2023), I would like to explore the perceptual miscategorization of AU as AO in the AL > AU > AO > O sound change (Menendez Pidal, 1968; Bretos & Tejedor, 2015).

2 Method

2.1 Linguistic material

A perception forced-choice test was designed in which each stimulus had to be categorized as AL, AU or AO. The stimuli were obtained from a female speaker of Eastern Catalan in her 30's, saying the following words: *pal*, *pao* and *pau*, the phonetic transcriptions of which are: /pal/, /pao/ and /paw/. The reason why an Eastern Catalan speaker was chosen is because of the dark /l/ in this variety. Dark /l/s is a condition for l-vocalization to occur since dark /l/ and /w/ have similar acoustic patterns; that is, low F1 and F2 (Recasens, 1996). Ten repetitions were obtained for each token, which were inserted in the carrier phrase *Digues* __________ (Say __________). The speaker was instructed to read each sentence ten times at a self-chosen slow speech rate and then at a faster one. Faster rate, in this study, represents casual speech. The sentences were presented via PowerPoint. The subject was recorded with a Behringer XM2000 microphone connected to the mobile preamp audio interface M-Audio. EMU (Cassidy & Harrington, 2001) and Praat 6.3.10 were employed for signal processing. The sentences were sampled at 11,025Hz. The average duration of each group of stimuli (al-fast speech rate; ao-fast speech rate; au-fast speech rate; al-slow speech rate; ao-slow speech rate; au-slow speech rate) was calculated and then a representative of each group was selected for the perception test, which was the closest individual stimulus to the average duration in each group. The /p/ of the stimuli selected for the perception test was then manually removed in order to produce the following tokens: fast and slow *al*, fast and slow *ao*, fast and slow *au*.

2.2 Subjects

Ten subjects were recruited for the forced-choice test, all of whom reported they were bilingual speakers of both Spanish and Catalan. None of the subjects reported hearing problems. Six were women and 4 were men. Two subjects were in their 40's, four in their 50's and four in their 60's.

2.3 Experiment

Each stimulus was randomly presented five times with a total sum of 30 stimuli (6 stimuli x 5 repetitions). The ten subjects heard each stimulus through the same pair of headphones (SONY, MDR-ZX) connected to a laptop's internal soundcard (ASUS SonicMaster). Subjects had to complete a forced-choice test while the experimenter played each stimulus. The three options were AL, AO and AU. Each subject had 30 seconds to respond. No repetition was allowed. Miscategorization was analyzed using the average percentage of incorrect stimuli identification.

Chi-square test results were obtained from <https://www.socscistatistics.com/>.

4 Results

4.1 Phonetic context

The chi-square test indicates that the two variables (the phonetic context in the stimuli (AL stimulus, AU stimulus and AO stimulus) and the categories chosen by the listeners in the test (AL response, AU response and AO response) are associated with each other (X^2 (4, N = 300) = 231.7486, $p < .01$). The phonetic context has an effect on what listeners hear and it does so differently depending on the phonetic context. A summary of the results for each phonetic context can be found in table 1 (observed cell totals along with expected cell totals in parentheses). Miscategorization was present in AL, AU and AO. AL was miscategorized 5% of the times, AU 34% and AO 45%. AU was interpreted as AO (25%) and AO as AU (32%). In both cases the expected cell totals are very similar to the observed cell totals, indicating that the two phonetic contexts are very likely to be confused.

	AL response	**AU response**	**AO response**
AL stimulus	95 (39)	4 (34)	1 (27)
AU stimulus	9 (39)	66 (34)	25 (27)
AO stimulus	13 (39)	32 (34)	55 (27)

Table 1: contingency table for the three phonetic contexts: AL stimuli, AU stimuli and AO stimuli. The categories subjects chose when hearing one of the stimuli are in the top row (AL response, AU response and AO response). Observed cell totals along with expected cell totals in parentheses.

4.2 Speech rate

Generally, fast rate, representing a more casual speech in this study, yields higher miscategorizations (see table 2): slow (25.3%) vs fast (32.8%). More specifically, in two out of the three phonetic contexts: fast AL (8%) > slow AL (2%); fast AO (56%) > slow AO (34%). However, speech rate does not affect each phonetic context equally since the opposite pattern is observed in fast AU (28%) < slow AU (40%).

Stimuli	AL response	AO response	AU response
AL-slow	49	0	1
AL-fast	46	1	3
AO-slow	6	33	11
AO-fast	7	22	21
AU-slow	7	13	30
AU-fast	2	12	36

Table 2: contingency table in which the first column is the stimulus (AL slow/fast, AO slow/fast, AI slow/fast). The categories subjects chose when hearing one of the stimuli are in the top row (AL response, AO response and AU response).

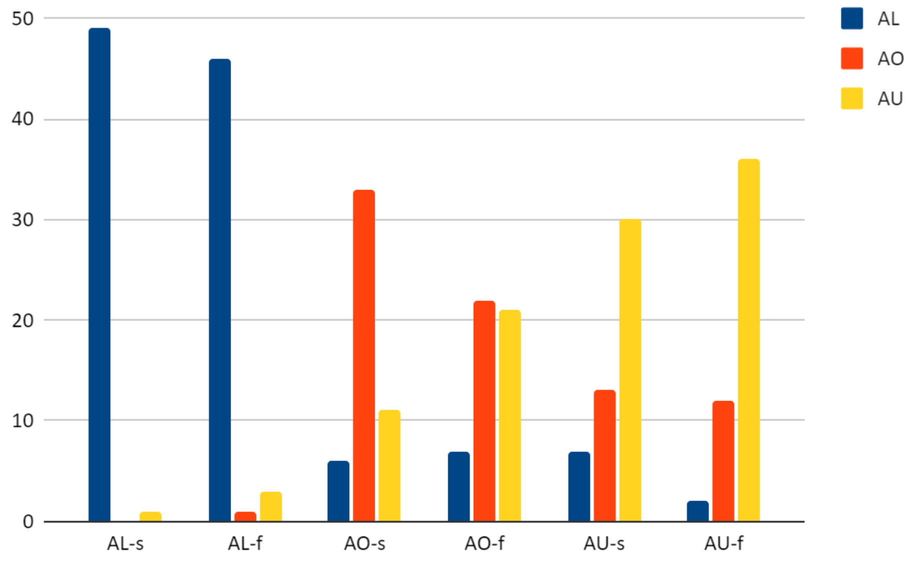

Figure 1: bar graph showing the results of the perception test by 10 subjects; y-axis shows number of times that the listeners chose AL (blue), AO (orange) and AU (yellow) for each stimulus; along the x-axis we find the labels of the stimuli used in the study (AL, AO and AU at different speech rates: fast and slow).

5 Discussion and Conclusions

The data points at the possibility of AU being perceived as AO. One cannot but wonder whether AU and AO coexisted, at least in the phonetic level but as time progressed, one of the candidates would stand out more than the other depending on factors other than the purely phonetic ones. If we take a look at Figure 1 again, we can see that overlapping exists between the three candidates but in different degrees. AL is heard as AU and AO but showing very low percentages of miscategorization, whereas AU and AO yield higher percentages of miscategorization. Also, a faster speech rate, representing more casual speech, yielded higher miscategorizations, which may hint at the possibility that it is harder for listeners to reconstruct the intended sound (Ohala, 1981; Recasens, 1996). Interestingly, AO can be interpreted as AU and vice versa, which hints at the possibility of a period of confusion while transitioning from one candidate to another.

Of note, and to complicate matters further, both phonetic context and speech rate interact. For instance, AU slow was more miscategorized than AU fast, which is the opposite pattern observed in the other two phonetic contexts, AL slow vs AL fast and AO slow vs AO fast. Such differences are probably due to the acoustic properties of the F2 transition, suggested by Recasens (1996). It seems that the combination of F2 transition and slow rate has increased miscategorization in this specific phonetic context, AU, which leaves an open door for further investigation into the effect of speech rate and phonetic context on the emergence of candidates in a sound change.

It is also interesting to see that the same stimulus can be perceived differently, which could be an example of what Gubian et al. (2023) call in their model the speaker-specific phonology, one of the sources of sound change. A preliminary analysis of the results for each participant revealed that categorization was by and large performed differently. If the sound is interpreted differently, then it could consequently be articulated differently as well, thus contributing to the sound change. If speaker-specific phonology were inexistent, then all the speakers in the perception test would perceive the same sound, but this is not so in the study.

One must bear in mind that we are drawing conclusions based on synchronic perceptual data, which is only an approximation how speakers at different periods of time perceptually behaved, influenced at the same time by many variables. The assumption that speakers today behave like speakers in the past should be taken with precaution. Agent-based models like the one proposed by Gubian et al. (2023) are trying to account for and represent sound change in a more realistic manner by incorporating into their model not only phonetic details from acoustic, articulatory and perceptual studies but also the concept of probability in order to explain sound change influenced by many other variables.

It is also critical to take into account the lexicon of a language in which the sound change takes place. For instance, results from phonetic analyses may indicate that a specific phonetic context may be more prone to sound change but such a change is not observed in the diachronic data due to its low frequency in the lexicon (Martin, 2005). Therefore, accounts on sound change based solely on phonetic analyses should be considered with precaution, since sound changes are affected by many other variables (Gubian et al., 2023).

One of the limitations of the present study, apart from accounting for diachronic sound changes using synchronic data, is having few subjects in the perception test. More subjects are required in order to obtain more robust results. In addition, an acoustic analysis of the different phonetic contexts at the two speech rates is needed in order to investigate how the two factors interact. Correlating the perception and acoustic information will undoubtedly help us understand the underlying mechanism of this specific sound change at the phonetic level, which would only be part of the explanation of the change as a whole, albeit key to understanding it. Further analysis of the responses of each of the participants in the study will be carried out in order to explore what Gubian et al. (2023) call in their model the speaker-specific phonology and the stochastic nature of a sound change.

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