DOI: 10.17469/O2102AISV000020

LORENZO CIAURELLI, ARAVIND NAMASIVAYAM, GRAZIANO TISATO, PASCAL VAN LIESHOUT, CLAUDIO ZMARICH

Consonantal and vocalic gestures in the articulation of the Italian glides /j/ and /w/ at different syllable positions

From a phonological point of view, four glides (or approximants) exist in Italian: /j/, /w/, [i̯] and [u̯]. Glides still raise a lot of questions, from the definition of the necessary and sufficient features for their identification (Chitoran, Nevins, 2008), to their characterization at the acoustic and articulatory levels of speech production (Gick, 2003). In this paper, in order to describe the articulatory features of Italian glides, we analyzed the kinematics of both consonantal and vocalic gestures involved in the production of /j/ and /w/, by using 3D electromagnetic articulography (EMA; Carstens Medizinelektronik GmbH). The results show similar articulatory features for both glides in the way they differentiate themselves from corresponding vowels [i] and [u].

Key words: glides, kinematics, articulatory features, diphthong.

Introduction

Italian glides present a number of questions, ranging from the definition of their phonological nature (phonemic vs. allophonic status), to their phonetic and articulatory features (vocalic vs. consonantal, greater vs. lesser degree of constriction than corresponding vowels). In the phonological literature (Marotta, 1988; Nespor, 1993; Schmid, 1999; Bertinetto, Loporcaro, 2005) [j] and [w] are considered phonemes (/j/ and /w/) when placed in a word's initial position (onglides) preceding a vowel (V) as in "iodio" and "uomo". In contrast [i̯] and [u̯] are treated as positional, non-syllabic, allophones (offglides) of the corresponding vowels /i/ and /u/ as in "daino" and "auto". Onglides, also known as "semiconsonanti", are the non-nuclear elements of rising diphthongs, whereas offglides, also known as "semivocali", are the non-nuclear elements of falling diphthongs.

From an articulatory perspective, one can distinguish three different theoretical approaches which have tried to deal with the problem of glides characterization. The "Featural Hypothesis" and the "Structural Hypothesis" are the best known. Proponents of the first view (Nevins, Chitoran, 2008) assume that glides like /j/ and possibly /w/ are less vocalic than vowels like /i/ and /u/ because of their greater constriction degree. Proponents of the second view (Gick, 2003) assume that the glides /j/ and /w/ and their allophones can be characterized by the timing relationship between their gestural components, due to the position they occupy in the word (or syllable), without having to specify their features directly. The third view (Maddieson, 2008), states that glides are characterized by the absence of a stable acoustic or articulatory target position, although they cannot be considered intrinsically transitional.

According to the "Structural Hypothesis", Browman and Goldstein (1992; 1995) have identified two gestural syllable position effects through which one can identify the properties of allophones in final or initial syllable positions: a) syllable position-specific timing between different tautosegmental[1] gestures (a property of gestural configuration); b) final reduction (a property of gestural scaling). Assuming that glides consist of two gestures (Sproat, Fujimura, 1993), namely a C-gesture (consonantal in nature) and a V-gesture (vocalic in nature), they can be distinguished by analyzing the behavior of their component gestures in different syllable positions. As to the English glides /j/ and /w/, empirical studies have shown that the C-gesture of initial allophones is greater in magnitude than the C-gesture in final allophones, and it temporally precedes the V-gesture, whereas in final allophones, C- and V-gestures are phased more closely together. Ambisyllabic allophones behave somewhat in between the characteristics found for initial and final allophones. In other words, final allophones are more vowel-like and initial allophones are more consonant-like (Gick, 2003).

In past years, Italian glides have mostly been studied by means of acoustic analysis, which does not always provide clear information on the actual gestural configurations of their production. Further, acoustic analysis was found to be unsuitable to identify some constituent differences between glides and vowels. For example, Salza, Marotta & Ricca (1987) showed that onglides can be distinguished from corresponding vowels by mean of acoustic duration (/j/ and /w/ are shorter than /i/ and /u/ respectively), whereas offglides ([i̯] and [u̯]) were similar in duration to unstressed vowels.

There is only one preliminary articulatory study on Italian glides using the Reading EPG system (Calamai, Bertinetto, 2006). The authors found that global tongue-palate contacts tends to be more extended in /i/ compared to /j/ and in /u/ compared to /w/. These results, albeit quite unexpected and at odds with findings from English glide productions (Nevins, Chitoran, 2008), are not unrealistic. Indeed, as Maddieson and Emmeroy (1985) have demonstrated, there is a wide cross-linguistic variability in the production of glides, due to underlying differences between glides and homorganic vowels. However, the EPG methodology used in the study of Calamai and Bertinetto (2006) is not particularly suited for studying articulatory behaviors in glides because EPG does not indicate which part of the tongue contacts the palate nor does it record lips movements, which is a constituent gesture of /w/ and /u/. Moreover, EPG cannot track the transition from syllable nucleus (in this case /a/) to glides. In contrast, 3D electro-magnetic articulography (EMA) is a more reliable instrument for this type of research (van Lieshout,

[1] In the Articulatory Phonology framework *tautosegmental gestures* refer to the internal organization of segment, that is to those overlapping gestures which characterize the segment.

Merrick & Goldstein, 2008) since it can track the movements of multiple articulators in a 3D space and with a higher temporal resolution (200 Hz against the 100 Hz of EPG).

In this paper we will try to shed light on the different hypotheses put forward in the previous works in this area. As stated by Featural Hypothesis, and at odds with Calamai and Bertinetto (2006), we expect to find a greater constriction degree for glides (Marotta, 1988; Bertinetto, Loporcaro, 2005). Moreover, by analyzing the steady-state and transitional portions of glides and vowels, we want to verify whether glides lack a stable target position (Maddieson, 2008). Finally, we want to study whether there is a cross-linguistic variability in the production of glides (Stone, Lundberg, 1996; Maddieson, Emmeroy, 1985).

In order to verify whether Italian glides are more vowel- or consonant-like we studied the movements of specific articulators used in the production of /j/ and /w/ by means of three parameters: a) extent of constriction degree; b) duration of steady-state portion of articulation; c) duration of transition from glide to syllable nucleus. We analyzed a wide set of articulators possibly involved in the production of glides, then, based on preliminary analysis, we discarded those that were found unsuitable for characterizing allophonic variations of glides (e.g. front-back movements of tongue). The articulators studied in this paper were tongue body for /j/ and tongue back with lips (upper & lower) for /w/, similar to previous work in this area (Gick, 2003).

In this paper, we will focus on a selection of Ciaurelli's (2015) data; a preliminary analysis of the production of one participant from the same dataset was presented in Zmarich, van Lieshout, Namasivayam, Limanni, Galatà & Tisato (2011).

1. *Methods and Materials*

1.1 *Participants*

The ten participants (8 females and 2 males, average age 32 years) involved in the experiment were all fluent speakers of Italian as their first language. They were all Italian students living in Toronto for a short period of time and they were recruited by flyers and word-of-mouth and paid for their participation. To avoid a bias due to the influence of regional Italian dialects, we were careful not to include people coming from Campania and Emilia-Romagna. This was done because there is a tendency for extreme diphthongization and for producing actuals diphthongs as hiatuses ([ˈpje.de] vs [ˈpi.e.de]) in Campania and for spirantization of the /w/ in words like "auto" and "attuale" in Emilia-Romagna (Telmon, 1997).

In this paper, we only present data from 5 female participants (average age 27 years). The five participants (subj2, subj4, subj5, subj6 and subj8) were chosen for the completeness of their data (there was no problem during recording sessions) and the clarity of their pronunciation. We will only refer to words containing onglides, offglides and vowel targets as I-words and U-words. As we already presented data for subj2 on U-words previously (Zmarich et al., 2011), we will not present these data here.

All participants were asked to complete a short questionnaire about general demographic data and to sign a consent form. All of them have normal vision and no history of hearing or speaking difficulties. The study was approved by the Health Sciences Research Ethics Board at the University of Toronto.

1.2 Instrumentation

We used an AG500 articulograph (Carstens Medizinelektronik, GmbH) setup at the Oral Dynamics Lab (ODL) in the Department of Speech-Language Pathology at the University of Toronto to record kinematic and acoustic data from the participants. The AG500 allows for 3D recordings of articulatory movements inside the vocal tract by tracking the movement of transducer coils placed on the articulators in the following manner: 2 coils on the vermillion borders of the upper and lower lip respectively, 1 on the tongue tip (1 cm behind the actual tip of the tongue), 1 on the tongue body (2 cm behind the tongue tip coil location), 1 on the tongue back (at least 1 cm behind tongue body location), 1 on the lower incisors of the lower jaw. We also recorded head motion by placing additional coils on subject's forehead, bridge of the nose and left and right skin covering the mastoid. This allowed us to afterwards correct the movement of articulators for head motion. Acoustic recordings were made with a 44 kHz sampling rate at 16 bits using a supplementary headset microphone connected to a solid-state audio recorder, which was synchronized with the kinematic signals. These are standard procedures developed at the ODL (Henriques, van Lieshout, 2013).

Two different sets of measures were obtained using the INTERFACE program (Tisato, Cosi, Drioli & Tesser, 2005). The movement patterns used for analyzing /i/, /j/ and [i̯] were:

- Tongue body vertical (TB_VERT, i.e. the position in high-low dimension of the coil on the tongue body).

For /u/, /w/ and [u̯] we used:

- Tongue back vertical (TBACK_VERT, i.e. the position in high-low dimension of the coil on the tongue back).
- Lip opening (LIP_OPEN, i.e. the vertical distance between the coils on the vermillion border of upper and lower lip).

For each of these component gestures associated with glides and vowels we calculated mean and standard deviation (SD) values for the following parameters:

- extent of constriction degree (i.e. the spatial value – in millimeters – of the position of the TB_VERT or TBACK_VERT or LIP_OPEN coils, represented in Figure 1 by green and red triangles).

– Duration of steady-state portion of articulation (i.e. the value of the temporal interval representing the difference between the two red or green arrows in Figure 1; these arrows were automatically detected by INTERFACE as temporal locations where the velocity of the movement under examination reached a threshold of 15% of the maximal velocity); in other words the arrows enclose only the portions of the articulatory trajectory characterized by a zero or very low velocity (i.e., the steady state).
– Duration of transition from glide to syllable nucleus (i.e. the value of the temporal interval representing the difference between the second arrow of a steady-state portion and the first arrow of the following steady-state portion); in other words, the arrows enclose only the portions of the articulatory trajectory characterized by a non-zero or low velocity.

Finally, after manually segmenting the speech signal (Salza, 1991), we made acoustic measurements of segment duration by using Praat software (Boersma, Weenink, 2009).

1.3 Stimuli

In order to elicit the production of the target glides and vowels by the participants we set up a series of short sentences. The target segment "I" and "U" (we will use the capital letters to refer to both glides and vowels) were added to vowels [e], [ɛ], [o] and [a] in order to produce hiatuses and diphthongs. All targets (hiatuses and diphthongs) were inserted in the carrier phrase "Ha detto X chiaramente" ("he said X clearly"), where X is the word containing the targets. Each sentence was repeated twice over one session, and there were 3 sessions using a normal, habitual rate and 3 other sessions using formal, slow rate, for a total of 408 sentences. All sequences were presented in random order to the participants on a computer screen using *Direct RT* (Jarvis, 2008), a stimulus presentation program. In order to obtain the stimuli at slow rate, we made participants listening to questions prompting for an answer that would put contrastive focus on the target word. The Table 1 shows the words contained in the carrier phrase.

Due to the small sample of participants statistical analysis was performed on each participant separately.

In order to better compare the kinematic values for I and U segments, we normalized the kinematics values for each articulator by subtracting the peak value achieved for each parameter for the vocalic targets /i/ and /u/ produced in isolation ("Ha detto i/u chiaramente") from the peak values achieved for the I and U targets in the carrier. Then, we performed a statistical analysis separately for I-words ("mia" and "maiale) and U-words ("tua", "attuale", "auto" and "baule").

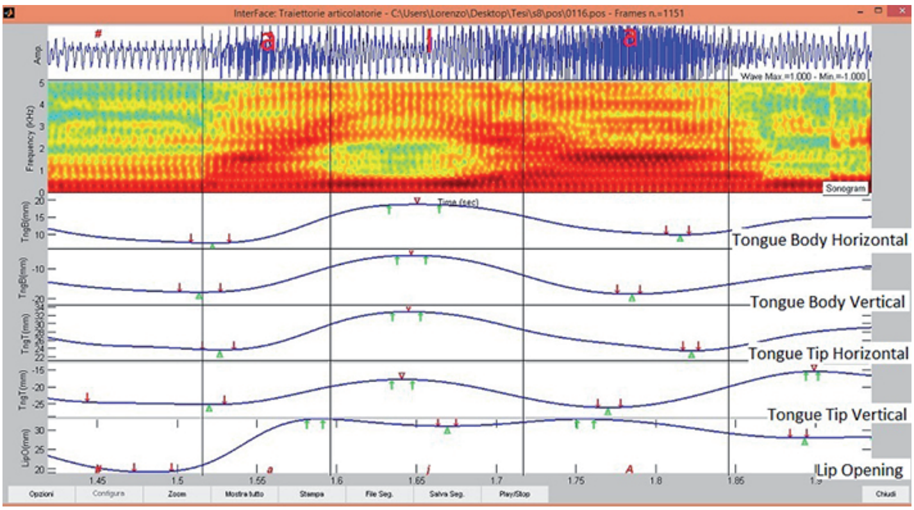
Table 1 - *Words contained in carrier phrase ("Ha detto X chiaramente") sorted by target segment, position and syllabic status*

Segments	Contextual vowels	Hiatus (V.V)	Onglide (GV)	Offglide (VG)	Hiatus (V.V)
u/w	a	tua /'tu.a/	attuale /at.'twa.le/	auto /'aw.to/	baule /ba.'u.le/
i/j	a	mia /'mi.a/	maiale /ma.'ja.le/	mai /'mai/	faina /fa.'i.na/

In order to study the differences between glides and homorganic vowels, we made the following comparisons: a) "mia" vs. "maiale"; b) "faina" vs. "mai"; c) "tua" vs. "attuale"; d) "baule" vs. "auto". In this way, we were able to analyze the transition from glides to vowel nucleus (and vice versa) as well.

Regrettably, we were unable to analyze the offglide-vowel opposition for I-words ("mai" vs "faina"), as the preliminary analyses showed that vertical movement of the tongue dorsum of [i̯] in "mai" was strongly influenced by the production of the velar stop /k/ which followed in the sentence carrier ("Ha detto mai chiaramente").

Figure 1 - *Screenshot of APmanager tool of INTERFACE showing the /aIa/ segment of the word "maiale". From top to bottom: 1) waveform; 2) Spectrogram; 3) Trajectories of selected articulators, from top to bottom: a) Tongue Body Horizontal; b) Tongue Body Vertical; c) Tongue Tip Horizontal; d) Tongue Tip Vertical; e) Lip Opening. The red and green triangles represent maximum and minimum positions in the trajectory of articulators respectively. The flanking red and green arrows locate the point where velocity of the movement reaches a threshold of 15% of maximal velocity (i.e. a relatively stable portion of a trajectory, referred to as a steady-state portion)*



2. *Results*

Table 2 shows the acoustic durations of glides and vowels. A Student's t-test was performed on acoustic durations, with I-words as factor. No statistical significance was found among I-words. A one-way ANOVA was also performed on acoustic durations, with U-words as factor. The difference among U-words was significant for all participants (subj4: f-ratio = 181.447, p-value < 0.001; subj5: f-ratio = 84.815, p-value < 0.001; subj6: f-ratio = 27.853, p-value < 0.001; subj8: f-ratio = 147.716, p-value < 0.001). A Bonferroni post-hoc pairwise analysis showed that for all subjects the acoustic duration for /u/ in "tua" was significantly greater than the duration for /w/ glide in "attuale" (subj4: p-value < 0.001; subj5: p-value < 0.001; subj6: p-value = 0.002; subj8: p-value < 0.001). We also found that the duration of /u/ in "baule" was significantly longer than [u̯] in "auto" for all subjects (subj4: p-value < 0.001; subj5: p-value < 0.001; subj6: p-value < 0.001; subj8: p-value < 0.001).

Table 2 - *Range, mean (s) and standard deviation of acoustic durations of I- and U- targets*

Subject	*Word*	*Target*	*Range*	*Mean*	*Std*
SUBJ_2	mia	/i/	0.097	0.162	0.038
SUBJ_2	maiale	/j/	0.093	0.160	0.034
SUBJ_4	mia	/i/	0.120	0.145	0.033
SUBJ_4	maiale	/j/	0.064	0.122	0.019
SUBJ_4	tua	/u/	0.065	0.131	0.016
SUBJ_4	attuale	/w/	0.038	0.084	0.013
SUBJ_4	baule	/u/	0.045	0.185	0.012
SUBJ_4	auto	[u̯]	0.029	0.073	0.010
SUBJ_5	mia	/i/	0.112	0.124	0.034
SUBJ_5	maiale	/j/	0.054	0.133	0.018
SUBJ_5	tua	/u/	0.086	0.137	0.026
SUBJ_5	attuale	/w/	0.044	0.046	0.012
SUBJ_5	baule	/u/	0.069	0.161	0.021
SUBJ_5	auto	[u̯]	0.060	0.077	0.018
SUBJ_6	mia	/i/	0.169	0.175	0.069
SUBJ_6	maiale	/j/	0.147	0.150	0.046
SUBJ_6	tua	/u/	0.128	0.150	0.047
SUBJ_6	attuale	/w/	0.097	0.088	0.034
SUBJ_6	baule	/u/	0.116	0.220	0.041
SUBJ_6	auto	[u̯]	0.090	0.106	0.028
SUBJ_8	mia	/i/	0.042	0.141	0.010
SUBJ_8	maiale	/j/	0.037	0.139	0.012
SUBJ_8	tua	/u/	0.068	0.149	0.019
SUBJ_8	attuale	/w/	0.029	0.076	0.009
SUBJ_8	baule	/u/	0.069	0.191	0.024
SUBJ_8	auto	[u̯]	0.030	0.074	0.009

Figure 2 shows the /i/-normalized Tongue Body Vertical (TB_VERT) values for the I-targets in the I-words. A Student's t-test was performed on TB_VERT, with I-words as factor. The normalized value for /i/ in "mia" was significantly greater than the value for /j/ in "maiale" for three subjects (subj4: t = -3.729, df = 21.192, p-value = 0.001; subj6: t = -3.420, df = 17.830, p-value = 0.003; subj8: t = -2.630, df = 18.318, p-value = 0.017).

Figure 2 - */i/-normalized Tongue Body Vertical (TB_VERT) values (mm) for I-words "maiale" and "mia"*

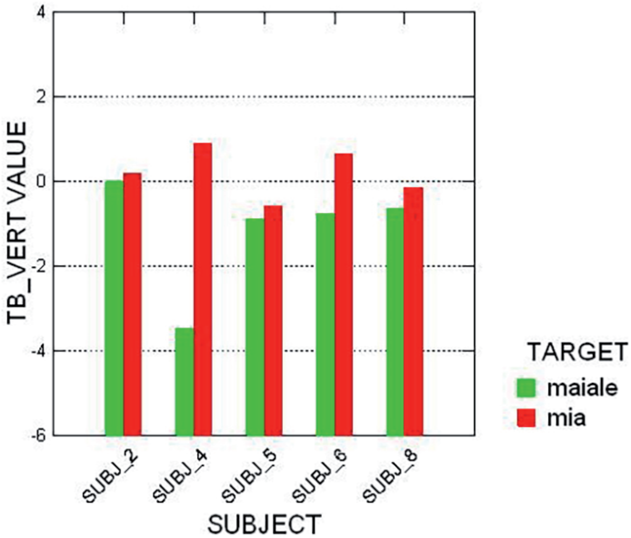


Figure 3 shows the /u/-normalized Tongue Back Vertical (TBACK_VERT) values for the U-targets in "attuale" and "tua". A one-way ANOVA was performed on TBACK_VERT with U-words as a factor. The difference for the U-words was significant for all participants (subj4: f-ratio = 30.680, p-value < 0.001; subj5: f-ratio = 29.085, p-value < 0.001; subj6: f-ratio = 28.808, p-value < 0.001; subj8: f-ratio = 7.313, p-value = 0.001). A Bonferroni post-hoc pairwise analysis showed that for 3 subjects the normalized value for /u/ in "tua" was significantly greater than the value for /w/ glide in "attuale" (subj4: p-value = 0.005; subj6: p-value = 0.001; subj8: p-value = 0.003). We also found that as for subj4 the normalized value for /u/ in "baule" was greater than the value for the [u̯] glide in "auto" (p-vaue < 0.001), whereas for subj6 (p-value < 0.001) that value was significantly greater for the[u̯] glide than for /u/.

A one-way ANOVA was performed on LIP_OPEN with U-words as a factor, but no significant differences were found.

We also studied the durations of the steady-state intervals of articulatory movements, that is the temporal interval where the velocity of articulator movement is lower than 15% of the maximal velocity.

Figure 4 shows the durations of TB_VERT steady-state for I-targets in "mia" and "maiale". A Student's t-test was performed on TB_VERT with I-words as factor. All participants produced a significantly longer steady-state for /i/ in “mia” than for /j/ in “maiale” (subj2: t = -3.946, df = 13.251, p-value = 0.002; subj4: t = -4.181, df = 11.074, p-value 0.002; subj5: t = -2.940, df = 11.065, p -value = 0.013; subj6: t = -3.251, df = 10.231, p-value = 0.008; subj8: t = -2.630, df = 12.823, p-value < 0.001).

Figure 3 - */u/-normalized Tongue Back Vertical (TBACK_VERT) values (mm) for U-words “attuale” and “tua”*

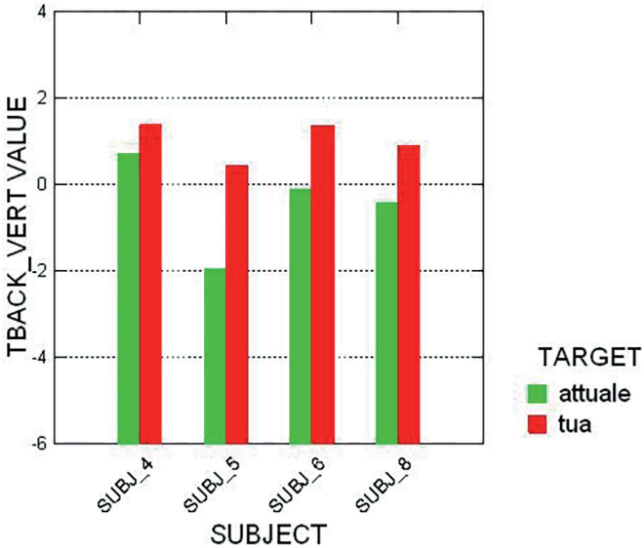


Figure 4 - *steady-state duration (ms) for TB_VERT for I-targets in “mia” e “maiale”*

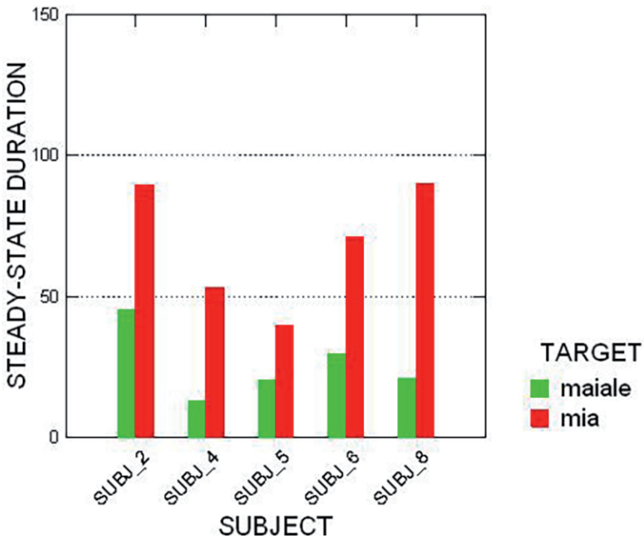
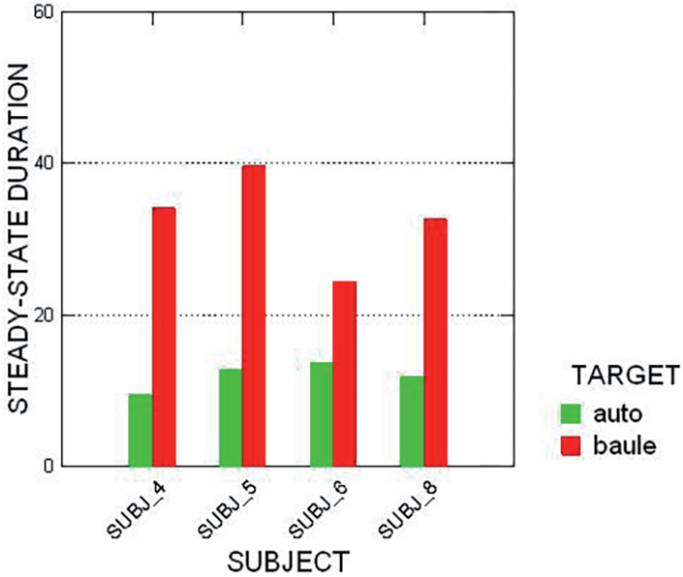


Figure 5 shows the durations of TBACK_VERT steady-state for U-targets in "baule" and "auto". A one-way ANOVA was performed on TBACK_VERT with U-words as a factor. The difference in U-words was significant for all participants (subj4: f-ratio = 17.363, p-value < 0.001; subj5: f-ratio = 54.434, p-value < 0.001; subj6: f-ratio = 20.874, p-value < 0.001; subj8: f-ratio = 10.573, p-value < 0.001). A Bonferroni post-hoc pairwise analysis showed that for all participants the steady-state portion for /u/ in "baule" was significantly longer than for [u̯] in "auto" (subj4 and subj8: p-value = 0.001; subj5 and subj6: p-value < 0.001). As for the onglide-vowel contrast, the steady-state portion for /u/ in "tua" was significantly longer than for [u̯] in "attuale" only for subj8 (p-value = 0.006).

Further a one-way ANOVA was performed on LIP_OPEN with U-words as a factor, but no significant differences were found.

Figure 5 - *steady-state duration (ms) for TBACK_VERT for U-targets in "auto" e "baule"*

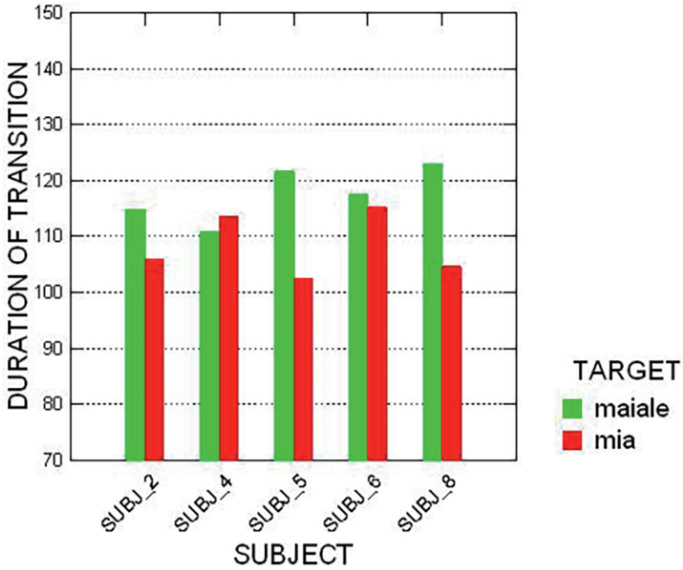


We analyzed the duration of the transitions from vowels to glides (or vice versa) as the distance between two contiguous steady-states (that is from I to /a/ and for U to the following and preceding /a/; see Figure 1).

Figure 6 shows the values of duration of transitions for I-words. A Student's t-test was performed on TB_VERT with I-words as factor. For 3 out of 5 subjects the transition from /j/ to /a/ in "maiale" was significantly longer than the transition from /i/ to /a/ in "mia" (subj2: t = 2.079, df = 21.877, p-value = 0.05; subj5: t = 2.563, df = 21.823, p-value = 0.018; subj8: t = 5.418, df = 14.768, p-value < 0.001). A one-way ANOVA was performed on TBACK_VERT and LIP_OPEN with U-words as factor. The difference among U-words was significant for just one subject and only for TBACK_VERT (subj4: f-ratio = 72.440, p-value < 0.001). A

Bonferroni post-hoc pairwise analysis showed that for this subject the transition from /w/ to /a/ in "attuale" was longer than the transition from /u/ to /a/ in "tua".

Figure 6 - *duration of transition (ms) from I-target to /a/ for TB_VERT in I-words*



3. *Discussion and Conclusion*

The aim of this study was to gain a better understanding of the nature of Italian glides and how they contrast with homorganic vowels. Specifically, we wanted to verify, by means of a kinematic analysis, whether glides are more vowel- or consonant-like and whether there is any difference between I and U glides with respect to their component gestures (in this case, only for U-targets, because they are constituted by both tongue and lips gestures). To this end, we analyzed the behavior of specific articulators involved in glides and vowel productions using 3 parameters: a) constriction degree; b) duration of steady-state portion; c) duration of transition from glides to syllable nucleus. The main findings show that for both onglides, the vertical position of the tongue (tongue body for I, and tongue back for U) distinguishes onglides from the corresponding vowels, in the sense that both vowels /i/ and /u/ show a greater degree of constriction than /j/ and /w/ onglides respectively. These results are at odds with data from English (Ladefoged, Maddieson, 1996; Stone, Lundberg, 1996;) but comparable with the findings of Calamai and Bertinetto (2006) in Italian speakers who showed smaller tongue-palate contact for the onglides when compared to the homorganic vowels.

We also found that the offglide [u̯] is distinguished from its corresponding vowel predominantly by a difference in the duration of the steady-state portion. In fact, all participants produced the /u/ segment with longer duration of the articulatory steady-state portion than the [u̯] segment, whereas only two out of four participants distinguished /u/ from [u̯] by showing a different value for constriction degree (for one of the subjects, constriction degree was greater in the vowel than in the glide, whereas for the other subject constriction degree was greater in the glide than in the vowel).

The duration of transition was found to be longer for /j/ than for /i/ for three subjects out of five and for /w/ than for /u/ for just one subject. No significant difference was found with regard to offglide-vowel opposition ([u̯] vs /u/).

Finally, no significant results were found for lip gesture movements (LIP_OPEN) involved in the production of U-targets.

In trying to interpret these results, we have to take into account some limitations of the current experimental design. The greater constriction degree found for /i/ and /u/ vowels with respect to /j/ and /w/ glides could be due to the fact that full vowels analyzed here carried lexical stress. However, one could also interpret this result as a reflection of the assumed hypo-articulated nature of glides. Furthermore, as Maddieson and Emmeroy (1985) have demonstrated, there is a wide variability in production of glides across the languages, which could perhaps account for the difference found between Italian and English glides.

Although these limitations prevent us from making some general statements about the difference between I and U offglides, the behaviors of /w/ and [u̯] show a clear differentiation in the way they contrast with homorganic vowels. In fact, the onglide-vowel contrast is triggered by a difference in constriction degree, whereas the offglide-vowel contrast is based on a difference in steady-state duration. Following Salza, Marotta & Ricca (1987) and Marotta (1988), one could consider the [u̯] offglide as a non-stressed vowel as the only significant difference with respect to the /u/ vowel is in duration, both articulatory (steady-state) and acoustically. This finding, together with the finding on transition duration between glides and vowels, might suggest that glides are not inherently transitional (Maddieson, 2008), and it could depend on underlying differences between glides and homorganic vowels (Maddieson, Emmeroy, 1985).

Although the comparison between acoustic and articulatory analyses is beyond the aims of this study, the results from acoustic analysis seem to confirm the previous statement. In fact, although both onglides (/j/ and /w/) can be differentiated from the homorganic vowels (/i/ and /u/) by means of articulatory steady-state duration, only /w/ can be differentiated from the homorganic vowel by means of overall acoustic duration as well. So it could be accounted for by a difference in shift from vowel to glide for /i/ and /u/.

Finally, the fact that no significant results were found for lip opening in differentiating /w/ and [u̯] from vowels seems to suggest that for U-glides, the primary articulator is the tongue (i.e. the tongue back movement in high-low dimension). However, a preliminary analysis on horizontal lip movements (not included in this paper) seems to reveal an important role of lip protrusion in U-glides production that needs further exploration.

4. *Future Perspectives*

In this paper we have presented only a selection of the data that were collected originally. A next step will be to investigate further claims made by Gick (2003). To this end, we will analyze the onset of glides' constituent gestures in order to verify the hypothesis stated by Browman and Goldstein (1992; 1995) about gestural syllable-position effects.

Further analyses would be necessary to determine the syllabic role of Italian glides. Following Hsieh and Goldstein (2015) one could analyze the temporal behaviour of gestures in glides to determine the gestural organization of complex onset and complex coda sequences considering that:

- onset consonants are hypothesized to be coupled in-phase to the following vowel and anti-phase to each other (Fowler, 2015), whereas;
- coda consonants are hypothesized to be sequential, with the first coda consonant coupled in anti-phase mode to the preceding vowel and following consonants coupled anti-phase to preceding consonant.

Given these assumptions, we will be able to directly compare onglides and offglides and to gain some insight into their gestural organization.

Bibliography

Bertinetto, P.M., Loporcaro, M. (2005). The sound pattern of Standard Italian, as compared with the varieties spoken in Florence, Milan and Rome. In *Journal of the International Phonetic Association*, 35(2), 131-151.

Boersma, P., Weenink, D. (2009). Praat: Doing phonetics by computer. Version 5.1.20 [Computer program]. Retrieved 31.10.09.

Browman, C.P., Goldstein, L. (1992). Articulatory phonology: an overview. In *Phonetica*, 49(3-4), 155-180.

Browman, C.P., Goldstein, L. (1995). Gestural syllable position effects in American English. In Bell-Berti, F., Raphael L.J. (Eds.), *Producing Speech: Contemporary Issues*. For Katherine Safford Harris. New York: AIP Press.

Calamai, S., Bertinetto, P.M. (2006). Per uno studio articolatorio dei legamenti palatale, labio-velare e labio-palatale dell'italiano. In Giordani, V., Bruseghini, V. & Cosi, P. (Eds.), *Atti del III Convegno Nazionale*, Trento, 29-30 novembre - 1 dicembre 2006. Torriana (RN): EDK Editore, 43-56.

Chitoran, I., Nevins, A. (2008). Introduction. In *Lingua*, 118, 1900-1905.

Ciaurelli, L. (2015). Gesti consonantici e vocalici nell'articolazione dei glide /j/ e /w/ dell'italiano in posizioni sillabiche diverse. Tesi di Laurea Magistrale in Linguistica, Università degli Studi di Roma "La Sapienza", Roma.

Fowler, C.A. (2015). The segment in Articulatory Phonology. In Raimy, E., Cairns, C.E. (Eds.), *The segment in phonetics and phonology*. Oxford: Blackwell, 25-43.

Gick, B. (2003). Articulatory correlates of ambisillabicity in English glides and liquids. In Local, J., Ogden, R. & Temple, R. (Eds.), *Phonetic interpretation. Papers in Laboratory Phonology VI*. Cambridge (UK): Cambridge University Press, 222-236.

Henriques, R.N., van Lieshout, P.H.H.M. (2013). A comparison of methods for decoupling tongue and lower lip from jaw movements in 3D articulography. In *Journal of Speech, Language and Hearing Research*, 56, 1503-1516.

Hsieh, F.Y., Goldstein, L. (2015). Temporal organization of off-glides in American English. In *Proceedings of International Congress of Phonetic Sciences (ICPhS 2015)*, Glasgow, UK, 2015.

Jarvis, B.G. (2008). DirectRT. Version 2008.1.0.13 [Computer Software]. New York, NY: Empirisoft Corporation.

Ladefoged, P., Maddieson, I. (1996). *The Sounds of the World's Languages*. Oxford, UK: Blackwell Publishers.

Maddieson, I. (2008). Glides and gemination. In *Lingua*, 118, 1926-1936

Maddieson, I., Emmorey, K. (1985). Relationship between semivowels and vowels: Cross-Linguistics investigations of acoustic difference and coarticulation. In *Phonetica*, 42, 163-174.

Marotta, G. (1988). The Italian dipthongs and the autosegmental framework. In Bertinetto, P.M., Loporcaro, M. (Eds.), *CertamenPhonologicum, I°*. Torino: Rosenberg & Sellier, 389-420.

Nespor, M. (1993). *Fonologia*. Bologna: Il Mulino.

Nevins, A., Chitoran, I. (2008). Phonological representations and the variable patterning of glides. In *Lingua*, 118, 1979-1997.

Salza, P.L. (1991). La problematica della segmentazione del segnale vocale. In Magno Caldognetto, E., Ferrero, F. (Eds.), *Trattamento del segnale vocale ed elaborazione statistica dei dati. Atti delle I Giornate di Studio del GFS*, Padova, 3-6 novembre 1990, 23-48.

Salza, P.L., Marotta, G. & Ricca, D. (1987). Duration and formant frequencies of Italian bivocal sequences. In *Proceedings of the Eleventh international congress of phonetic sciences (ICPhS)*, 1-7 August 1987, Tallinn, Estonia. Tallinn: Academy of Sciences of the Estonian SSR, 6 voll., vol. 3, 113-116.

Schmid, S. (1999). *Fonetica e Fonologia dell'Italiano*. Torino: Paravia.

Sproat, R., Fujimura, O. (1993). Allophonic variation in English /l/ and its implications for phonetic implementation. In *Journal of Phonetics*, 21, 291-311.

Stone, M., Lundberg, A. (1996). Three-dimensional tongue surface shapes of English consonants and vowels. In *Journal of the Acoustical Society of America*, 99(6), 3728-3737.

Telmon, T. (1997). Varietà regionali. In Sobrero, A.A. (Ed.), *Introduzione all'italiano contemporaneo*, vol. II. *La variazione e gli usi*. Bari: Laterza, 93-149.

Tisato, G., Cosi, P., Drioli, C. & Tesser, F. (2005). InterFace: New Tool for Building Emotive/Expressive Talking Heads. In *Proceedings of INTERSPEECH 2005*, Lisbon, Portugal, 2005, 781-784. http://www2.pd.istc.cnr.it/INTERFACE.

van Lieshout, P.H.H.M., Merrick, G. & Goldstein, L. (2008). An articulatory phonology perspective on rhotic articulation problems: A descriptive case study. In *Asia Pacific Journal of Speech, Language, and Hearing*, 11(4), 283-303.

Zmarich, C., van Lieshout, P., Namasivayam, A., Limanni, A., Galatà, V. & Tisato, G. (2011). Consonantal and vocalic gestures in the articulation of Italian glide /w/ at different syllable positions. In Gili Fivela, B., Stella, A., Garrapa, L. & Grimaldi, M. (Eds.), *Contesto comunicativo e variabilità nella produzione e percezione della lingua, Atti del 7° Convegno Nazionale dell'Associazione Italiana Scienze della Voce*, Lecce, 26-28 gennaio 2011. Roma: Bulzoni editore, 9-24.