High Durational Variability of Consonant Geminates and Their Surrounding Vowels in Stuttering Japanese Speakers' Fluent Speech

Haute variabilité dans la durée de consonnes géminées et des voyelles avoisinantes dans la production verbale de bègues japonais

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KEY WORDS
JAPANESE CONSONANT GEMINATE
VOWEL DURATION
INSTABILITY OF Q DURATION

Abstract

This study compared the oral reading performances of stuttering and nonstuttering Japanese speakers with respect to (a) durations of V1, V2, and Q (geminate consonant) in the (C)V1QCV2 sequence in words, (b) V1/V2, Q/3S, Q/V1, and Q/V2 durational ratios, and (c) variability coefficients for V1, V2, and Q durations, and for V1/V2, Q/3S, Q/V1, and Q/V2 durational ratios. Results showed that the means of the duration of V2 and Q, and those of the variability coefficient for V1/V2, Q/3S, Q/V1, and Q/V2 durational ratios were significantly greater for the stuttering group than for the nonstuttering group. These findings are interpreted as reflecting covert markers of stuttering events (e.g., blocking) caused through asynchronous interactions between V1, Q, and V2 in the stuttering individuals' aberrant timing system.

Abrégé

Cette recherche a comparé les performances à l'oral de lecteurs japonais bègues et non-bègues pour ce qui est (a) de la durée de V1, V2 et Q (consonnes géminées) dans les séquences de mots (C) V1QCV2, (b) de V1/V2, Q/3S, Q/V1, et Q/V2 et (c) du rapport de durée pour V1, V2 et Q, et des coefficients de variabilité pour V1/V2, Q/3S, Q/V1 et Q/V2. Les résultats ont démontré que les moyennes de durée de V2 et Q et que les moyennes du coefficient de variabilité pour les rapports de durée V1/V2, Q/3S, Q/V1 et Q/V2 étaient considérablement plus longues pour le groupe bègue que pour le groupe non-bègue. Ces résultats semblent montrer qu'il existe des marqueurs du bégaiement (i.e. blocage) associés aux interactions asynchrones entre V1, Q et V2 dans le système d'analyse temporelle des individus bègues. Ce système serait atypique chez ces individus.

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Introduction

Japanese, a mora-timed language in which the rhythm of a mora (roughly a syllable) is the basic unit of organization in speech production, exhibits complex and subtle rhythm patterns although the isochrony of mora-timing is a key principle (e.g., Vance, 2008; Warner & Arai, 2001). The first geminate consonant represented as Q and its adjacent vowels provide one such example. Take *sakka* "a writer" and *saka* "a slope," for example. The first word consists of three moras (CV.C.CV, i.e., /sa.Q.ka/) including Q, and the second word two moras (CV.CV, i.e., /sa.ka/) with no Q. Q "represents a generic moraic oral obstruent with no specific place of articulation" (Labrune, 2012, p. 135), and tends, in the face of the principle of isochrony, to be slightly shorter than the first mora /sa/ and the third mora /ka/. Furthermore, many studies demonstrated that vowels preceding geminate consonants (V1) tend to be longer, and vowels following them (V2) shorter, as compared to the case of singletons (Han, 1992, 1994; Campbell, 1999; Hirata; 2007; Hirata & Whiton, 2005; Idemaru & Guion, 2008; cf. Pickett, Blumstein, & Burton, 1999). For example, Idemaru and Guion (2008) compared two-mora words (CV1.CV2) such as *Seto* (the name of a city) and three-mora words (CV1.C.CV2) such as *setto* (a loan word meaning "set"), and found that the mean of V1 duration was 75 msec before geminates and 59 msec before singletons, whereas the mean of V2 duration was 63 msec after geminates and 76 msec after singletons. This indicates that the mean V1/V2 ratio is 1.19 for words with geminate consonants and 0.74 for words with singletons, with the ratio of the former to the latter being as large as 1.6.

The finding that a vowel preceding a geminate lengthens while a vowel following a geminate shortens may be viewed as a unique rhythm pattern in Japanese. Maddieson (1985) states, "A shorter vowel before geminate than before singleton consonants is known to occur at least in Kannada, Tamil, Telugu, Hausa, Italian, Icelandic, Norwegian, Finnish, Hungarian, Arabic, Shilha, Amharic, Galla, Dogri, Bengali, Sinhalese, and Rembarrnga" (p. 208). Maddieson (1985) viewed this pattern as a universal property of natural language.

With this background in mind, one may wonder if the timing of geminate consonants and their adjacent vowels are difficult for Japanese speakers, especially persons who stutter, to acquire. However, we were not able to locate a single study on this issue. Shimamori and Ito (2006), employing a nonword reading task, found that Japanese children who stutter yielded more stuttering events for nonwords beginning with simple CV syllables than those beginning with heavy syllables such as CVQ and CVV. However, we point out the following possibility. That is, it could be difficult to determine whether words with Q, conventionally called a "choked sound" in Japanese, are stuttered or not. It would be difficult, for example, to determine a longer Q with the mean plus two standard deviations (SD) in duration to be a stuttering case. But if a Q is abnormally longer or shorter in duration even though it may go unnoticed, that could be taken as a covert marker of a stuttering event. Shimamori and Ito did not consider this possibility.

This study focuses on adults who stutter instead of children who stutter because we were not able to recruit many children who stutter. This study is exploratory in nature, and addresses the following three questions: Do stuttering adults differ from nonstuttering adults with respect to (a) absolute durations of V1, V2, and Q, (b) V1/V2, Q/3S (where 3S indicates three segments, V1, V2, and Q, combined), Q/V1, and Q/V2 durational ratios, and (c) variability coefficients (i.e., SD/Mean) for V1, V2, and Q durations, and for V1/V2, Q/3S, Q/V1, and QV2 durational ratios? The last question was motivated by Jancke (1994) and Homma (2011). These researchers found that the variability of voice onset time (VOT) was greater in persons who stutter than in persons who do not stutter. The question thus involves the findings of Jancke (1994) and Homma (2011) applied to the above variables.

Method

The data examined in this study were part of those that were collected for different purposes in the first author's PhD study (Homma, 2011). The number of participants was smaller than that of Homma (2011) because persons with mild stuttering were not included in this study. Those with mild stuttering were excluded to enhance the observability of subtle markers of stuttering, if any, such as abnormally longer or shorter durations of V1, V2, and Q.

Participants

Participants were all native Japanese speakers, 11 stuttering people (eight male and three female) and 11 nonstuttering people (eight male and three female) of comparable age (M = 27.3 and 27.6 years, SD = 5.2 and 5.0, respectively). All persons who stuttered had no deficits other than stuttering, and none had participated in stuttering treatment. The severity of stuttering was measured on the basis of participants' oral reading performances as follows. The test text used in this study consisted of 131 Japanese "phrases" (see below), and the number of stuttered phrases were counted and divided by

131 for each person who stuttered. The mean stuttering rate was 0.19 (SD = 0.13), ranging from 0.06 to 0.42. The persons who stuttered were classified into two subgroups: 7 people in the moderate (0.06 to 0.17) group and 4 people in the severe (0.21 to 0.42) group. The cutoff points 0.18-.20 are more or less a subjective measure, but they can be taken as conventional (cf. O'Brian, Packman, Onslow, & O'Brian, 2004).

After undertaking an interview, stuttering and nonstuttering persons all signed informed consent documents to participate in this study, and were paid for their participation.

Procedure

The passage used in an oral reading task was taken from a Japanese language textbook for fifth graders. The passage consisted of 22 sentences which had 13 phrases containing the sequence (C)V1QCV2 (see Appendix 1). Each participant was given two oral reading tasks. In one, the participant read the passage out loud in front of a one-stranger audience (the experimenter) in a quiet room. This was called a high-anxiety condition. The experimenter recorded the participant's oral reading with a Roland recorder (R-09) with a sampling rate of 44.1 kHz and 16-bit resolution. In the other task, the participant read the same passage out loud alone with no other person in the same room, recoding his/her reading by him/herself. This was called a low-anxiety condition. This study reports performance in the high-anxiety condition. The data for the low-anxiety condition are to be measured, and reported, if informative, in further research.

Measurements

The total number of target tokens was 858 (13 phrases×3 segments×22 speakers). Each speech token was measured using Praat (Version, 5.1.29) with a sampling rate of 44.1 kHz and 16-bit resolution. 783 of the 858 tokens (91%) were measured, and the remaining 75 (44 for the stutterers and 31 for the nonstutterers) were discarded because of the difficulty of measurement with some words stuttered or slurred, and other vowels devoiced. The segments analyzed were (a) the vowel preceding the Q, i.e., V1, (b) the Q, and (c) the vowel following the Q, i.e., V2, in the sequence (C)V1QCV2 in each target phrase. Where the segment preceding V1 was a vowel instead of a consonant, the duration of the vowel and V1 was measured and divided by two, and that duration was used as the duration of V1. Similarly, where the segment following V2 was a vowel, the duration of the two vowels combined was measured and divided by two, and that duration was taken as the duration of V2. The general procedure for measurements was essentially the same as those employed by previous researchers such as Han (1994) and Idemaru and Guion (2008).

Results

It is first noted that the absolute duration of speech segments is affected by speaking rate. Speaking rate was thus estimated on the basis of the duration of moras in the first half of the text. The linguistic unit measured was the Japanese "phrase," which is defined as a unit composed of a content word and one or more bound morphemes, if any. For example, a noun and a case particle, e.g., *shinshi-ga* (*shinshi* meaning "gentleman," and *-ga* being a subject marker), comprise a phrase; likewise, a verb and a past tense marker, e.g., *ka-tte* (*ka* meaning "to buy" and *-tte* being a past tense marker) constitute another phrase. The duration of each phrase was measured and divided by the number of moras; thus, the duration of *shinshi-ga*, for example, was divided by four and that of *katte* was divided by three. There were 71 phrases, and thus 71 mora durations were obtained for each participant. The mean mora duration was 119 msec (SD = 11) for the stuttering group and 113 msec (SD = 12) for the nonstuttering group, the difference being non-significant, $t(20) = 1.29$, $p > .20$. It is thus assumed that speaking rate was comparable between the groups.

The results are divided into two parts: results from participant analysis and those from item analysis. The first part is reported in detail and the second briefly.

Results from Participant Analysis

The first question of this study involves group differences for mean durations of V1, V2, and Q. Results are presented in Table 1.

The group difference was not significant for V1, $t(14) = 1.39$, $p > .20$, but the mean V2 and Q durations were significantly longer for the stuttering group than for the nonstuttering group, $t(20) = 2.42$, $p < .05$, and $t(20) = 2.78$, $p < .05$, respectively. Thus the conclusion drawn from Table 1 is that the stuttering groups' timing of Q and V2 is deviant from a normal pattern, both segments becoming longer than expected.

Regarding the second question, mean V1/V2, Q/3S, Q/V1, and Q/V2 durational ratios (SDs), and group differences are shown in Table 2.

The means were not significantly different between the groups for V1/V2, $t(12) = 0.50$, for Q/3S, $t(20) = 1.53$, $p > .15$, and for Q/V2, $t(20) = 1.38$, $p > .18$. The difference in Q/V1 approached significance, $t(15) = 1.88$, $p = .08$, which indicates

Table 1. Mean Durations in msec (SD) of V1, Q, and V2 for the Stuttering and Nonstuttering Groups and Group Differences

	Stuttering	Nonstuttering	Difference
V1	80 (15)	73 (7)	7
Q	139 (31)	111 (16)	28*
V2	72 (17)	60 (6)	12*

*p < .05.

Table 2. Mean V1/V2, Q/3S, Q/V1, and Q/V2 Duration Ratios (SD)

	Stuttering	Nonstuttering	Difference
V1/V2	1.25 (0.22)	1.28 (0.08)	0.03
Q/3S	0.48 (0.03)	0.46 (0.03)	0.02
Q/V1	1.87 (0.47)	1.57 (0.23)	0.30†
Q/V2	2.21 (0.34)	2.01 (0.33)	0.20

†.05 < p < .10.

that because the mean Q durations did not differ between the groups (Table 1), the mean V1 duration tended to be relatively longer in stuttering than nonstuttering individuals.

As for the third question concerning variability coefficients (SD/M), Table 3 shows that the stuttering group consistently differed from the nonstuttering group.

All of the variable coefficients for durational ratios were significantly higher in the stuttering group than in the nonstuttering group: $t(18) = 4.49$, $p < .001$ for V1/V2; $t(20) = 2.92$, $p < .01$ for Q/3S, $t(19) = 2.86$, $p = .01$ for Q/V1; and $t(19) = 2.54$, $p < .02$ for Q/V2. These results are taken as reflections of stuttering persons' instability in timing V1, Q, and V2 durations within words.

Results from Item Analysis

Differences between groups were examined for each segment. Results are presented in Appendices 1 and 2, which basically correspond to Tables 1 and 2. Variability coefficients could not be computed for each segment, and no appendix is presented which corresponds to Table 3. Results from item analysis show similar patterns to those from participant analysis. As shown in Appendices 1 and 2, group differences are observed only for a relatively small number of items. While the question as to where such differences come from is intriguing, no further discussion is made because the sample size is small.

Discussion

The questions addressed in this study were whether persons who stutter differ from persons who do not stutter with respect to (a) absolute durations of V1, V2, and Q, (b) V1/V2, Q/3S, Q/V1, and Q/V2 durational ratios, and (c) variability for V1, V2, and Q durations, and for V1/V2, Q/3S, Q/V1, and Q/V2 durational ratios. Results showed that the groups did not significantly differ with respect to (a) the duration of V1, (b) the durational ratios of V1/V2, Q/3S, Q/V1, and Q/V2, and (c) variability for V1, V2, and Q durations. However, the groups did differ with respect to (a) the

Table 3. Mean Variability Coefficients (SD) for V1, Q, and V2 Durations, and for V1/V2, Q/3S, Q/V1, and Q/V2 Duration Ratios

	Stuttering	Nonstuttering	Difference
V1	0.20 (0.06)	0.19 (0.05)	0.01
Q	0.33 (0.07)	0.28 (0.08)	0.05
V2	0.38 (0.11)	0.32 (0.09)	0.06
V1/V2	0.37 (0.07)	0.25 (0.05)	0.12**
Q/3S	0.18 (0.03)	0.14 (0.03)	0.04**
Q/V1	0.43 (0.09)	0.33 (0.07)	0.10**
Q/V2	0.42 (0.11)	0.31 (0.09)	0.11

*p < .05, **p < .01.

durations of V2 and Q, and (c) variability for V1/V2, Q/3S, Q/V1, and Q/V2 durational ratios, i.e., the means of these latter parameters were all significantly greater for the stuttering group than for the nonstuttering group. Persons who stutter, even when producing fluent speech, exhibit an aberrant timing relationship of V1, Q, and V2 in the (C)V1QCV2 sequence in words. For example, while a stuttering person's duration ratio of V1/V2 is taken as being within the normal range (e.g., Han, 1994; Campbell, 1999; Idemaru & Guion, 2008), his/her ratio, albeit difficult to perceive, substantially fluctuates. We discuss a few implications about the longer duration of Q and V2, and the more variability or instability in durational ratios of V1/V2, Q/3S, Q/V1, and Q/V2 below.

Longer Duration of Q and V2

In regard with the longer duration of Q, one interpretation is to view a longer Q as a mild type of blocking. If we characterize a Q longer than 230 msec as stutter-like, or blocking-like (considering that the mean duration of moras was 119 msec for the stuttering group and 113 msec for the nonstuttering group), eight persons who produced one or more stutter-like Qs (73%) were in the stuttering group, whereas only one such person (9%) was in the nonstuttering group. It is notable that the two longest Qs, 418 msec and 370 msec, which were not taken as stutterings because they were not perceived as unnatural, were produced by one stuttering person with moderate stuttering (Stutterer 3) and one stuttering person with severe stuttering (Stutterer 4). These longer Qs may not be uncommon in laboratory and everyday situations, and go without notice. As mentioned in the introduction, Shimamori and Ito (2006) reported that Japanese children who stutter yielded more stuttering events for nonwords with lower syllable onset complexity (CV) than those with higher onset complexity (e.g., CVQ and CVV), but this finding must be interpreted with caution.

Regarding the longer duration of V2, it would be natural to hypothesize that a longer Q triggers a longer V2. This hypothesis is consistent with the finding that the correlation between Q and V2 durations was significant for the stuttering group, $r(9) = .75$, $p < .01$ but not for the nonstuttering group, $r(9) = .47$, $p > .10$. It is noted, however, that only one person who stutters showed a significant correlation between them, $r(8) = .90$, $p < .01$). The reason for the non-significant correlations for most persons who stutter may be that most of them unconsciously attempted to shorten the longer-Q-following mora in order to compensate for the longer Q and keep the length of the phrase constant.

Variability of Q and its Adjacent Vowels

This issue brings out an obvious implication: The relationship among stuttering, variability in the speech motor, and related systems (e.g., Homma, 2011; Jancke, 1994; Olander, Smith, & Zelaznik, 2010; Onslow, van Doorn, & Newman, 1992; Ward, 1997). Going one step further, the present findings may be interpreted as providing a causal implication, i.e., the instability or variability in speech, if substantial, could lead to blocking and/or prolongations of speech sounds such that some abnormally longer segments may be regarded as prolongations. Specifically, intra-subjects' variability seems much greater among stuttering individuals than the mean variability coefficients in Table 3 may suggest. For example, for Stutterer 3, whose variability coefficient for Q was the greatest 0.48 in the group, exhibited as long as 418 msec for Q of *ippiki* "one (and a quantifier)" and as short as 53 msec for Q of *sakki* "a short time ago." The 418 msec duration may be taken as an intra-word pause or blocking, and the 53 msec duration as an absence of Q. For Stutterer 4, whose variability coefficient was the third greatest 0.37, took 370 msec for Q of *natte* "became" while he did not produce shorter Qs. As stated above, one was a person with moderate stuttering and the other with severe stuttering. And somewhat unexpectedly, there was no significant correlation between degree of severity of stuttering and variability for Q duration, $r(9) = 0.19$, n.s., and thus this finding remains to be an issue for further research.

More difficult to interpret is the significantly greater variability of V1/V2, Q/3S, Q/V1, and Q/V2 duration ratios for the stuttering group. In spite of the non-significant effects of group on variability for V1, Q, and V2 durations, the significant effects on variability of ratios such as V1/V2 may appear to be inconsistent with the above-mentioned causal relation between variability and stuttering. It is argued, however, that more variability in these parameters involving Q intermittently causes a longer Q duration through asynchronous interactions between V1, Q, and V2 in the aberrant timing system of stuttering persons. Thus, the variability observed here can be taken as a cause of potentially long Q duration which may intermittently surface as blocking or a prolongation.

The greater variability of V1/V2, Q/3S, Q/V1, and Q/V2 duration ratios in the stuttering group may involve an asynchronous interaction between V1, Q, and V2 durations. One aspect of the asynchronous interaction may be that V1, V2, and Q durations are relatively more independent of one another in the stuttering group than in the nonstuttering group. To verify this asynchronous interaction hypothesis, the mean of the correlation between V1 and V2 durations was first compared between the groups. If this hypothesis is tenable, the correlation would be lower in the stuttering group than in the nonstuttering group. Likewise, the same would be the case for V1 and Q durations and Q and V2 durations. Results are shown in Table 4.

The results are by and large consistent with the hypothesis. The mean differences in the correlations between V1 and V2, and between V1 and Q were significantly lower in the stuttering group than in the nonstuttering group, $t(20) = 2.37$, $p < .05$, and $t(20) = 3.56$, $p < .01$, respectively. The mean difference in the Q and V2 correlation means was not significantly different between the groups, $t(20) = 1.27$, $p > .10$, but the pattern is in the expected direction. Thus, aside from Q and V2 pairs, it is concluded that the stuttering individuals are likely to produce V1, Q, and V2 in a more independent or asynchronous manner in the Q-involving context than are the nonstuttering individuals, which may underlie intermittent longer Q duration.

Finally, we asked two questions concerning the generality of the major findings in this study. First, do the findings in Tables 1 to 4 extend to moras in general? As reported in the Results section, the mean duration of moras computed on the basis of the Japanese phrase was 119 msec for the stutterer group and 113 msec for the nonstutterer group, and the difference was not significant. Given the above question, mean variability coefficients were computed and compared between the groups, and the difference was found non-significant, 0.19 (SD = 0.03) and 0.18 (SD = 0.03), $t(20) = 1.03$, $p > .30$. This means that the stuttering persons' variability of mora durations at the phrase level does not deviate from the normal pattern. But

Table 4. Mean Correlations (SD) Between V1 and V2, V1 and Q, and Q and V2 Durations

	Stuttering	Nonstuttering	Difference
V1 and V2	0.08 (0.39)	0.49 (0.41)	0.40*
V1 and Q	-.15 (0.21)	0.25 (0.36)	0.40**
Q and V2	0.32 (0.34)	0.47 (0.20)	0.20

*p < .05, **p < .01.

the variability of the mora durations within and/or across phrases might have been erased by averaging the mora durations in each phrase. Thus, the question of whether the variability of mora durations at the mora level is also normal (cf. Warner & Arai, 2001) or not in stuttering individuals remains unanswered.

Second and more generally, the asynchronous timing reported in this study may be subsumed in a more general motor deficit involving the variability of rhythmic motor timing suggested by Olander et al. (2010). If it is, it would be possible to identify stutterers with a motor deficit among the participants in the present study.

Acknowledgements

The authors are grateful to Joe Lauer, Peter Skaer, Christine Turgeon, and an anonymous reviewer of this journal for commenting on an earlier version of this paper.

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Received date: September 26, 2012

Accepted date: October 1, 2013

Appendix 1

Mean Durations (in msec) of V1, Q, and V2 Q for the Stuttering (S) and Nonstuttering (NS) Groups and Group Differences (D)

	V1			Q			V2		
Word	S	NS	D	S	NS	D	S	NS	D
kakkoo	74	73	1	153	126	27	60	57	3
teppoo	67	69	0	181	138	43*	67	50	17
ippiki	79	69	10	149	121	28	53	50	3
natta	80	79	1	109	91	18*	66	57	9
katte	67	67	0	154	103	51**	75	46	29
komatta	81	7	38	88	110	-22	48	53	-5
docchie	87	77	10	126	99	27	69	64	5
natte	93	72	11	119	79	40	60	46	14
sakki	88	73	15	94	91	3	46†	55†	-11
yokoppara	72	57	15	109	96	13	71	57	14*
rippana[1]	65	68	-3	155	120	35*	75	67	8
atte	93	92	1	165	155	10	105	99	6
rippana[2]	75	81	-6	132	121	11	80	78	2
Mean	79	73	5	133	112	22	67	60	7
SD	10	8	7	29	21	19	15	14	10

Note. kakkoo: appearance (and a object case marker); teppo: a gun; ippiki: one (and a quantifier); natta: became; katte: once; komatta: in trouble; docchie: in which direction; natte: became; sakki: a short while ago; yokoppara: the side; rippana: splendid; atte: existed; rippana: splendid. *p < .05, **p < .01. †Only one token could be measured due to devoicing in the stuttering group, and only five, in the nonstuttering group.

Appendix 2

Mean V1/V2, Q/V1, and Q/V2 Duration Ratios

	V1/V2			Q/V1			Q/V2		
Word	S	N	D	S	N	D	S	N	D
kakko	1.27	1.31	-.04	2.28	1.78	.50	2.73	2.27	.46
teppo	1.12	1.41	-.29*	2.72	2.05	.67**	2.94	2.85	.09
ippiki	1.50	1.43	.07	2.03	1.90	.13	3.14	2.47	.67
natta	1.30	1.44	-.14	1.42	1.18	.24	1.70	1.67	.03
katte	1.16	1.51	-.35	2.49	1.62	.87*	2.50	2.40	.10
komatta	1.57	1.35	.22	0.95	1.62	-.67	1.68	2.08	-.40
docchie	1.43	1.29	.14	1.45	1.34	.11	1.97	1.65	.32
natte	1.77	1.53	.22	1.49	1.11	.38	2.16	1.76	.40
sakki	1.47†	1.41	.06	1.05	1.26	-.21	2.14†	1.97	.17
yokoppara	1.01	0.81	.20	1.58	1.73	-.15	1.64	1.50	.14
rippana	0.89	1.07	-.18	2.57	1.77	.80**	2.24	1.90	.34
atte	0.97	0.96	.01	1.76	1.72	.04	1.64	1.68	-.04
rippana	0.95	1.10	-.15	1.76	1.51	.25	1.65	1.61	.04
Mean	1.26	1.28	-.02	1.81	1.58	.23	2.16	1.99	.18
SD	0.27	0.22	.19	0.29	0.52	.43	0.52	0.41	.27

*$p < .05$, **$p < .01$.

†Only one token could be measured due to devoicing in the stuttering group.