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Zharkova, N, *et al* (2012) Lingual Coarticulation in Preadolescents and Adults: An Ultrasound Study
ESRC End of Award Report, RES-000-22-4075. Swindon: ESRC

# ESRC End of Award Report

**For awards ending on or after 1 November 2009**

This End of Award Report should be completed and submitted using the **grant reference** as the email subject, to **reportsofficer@esrc.ac.uk** on or before the due date.

The final instalment of the grant will not be paid until an End of Award Report is completed in full and accepted by ESRC.

Grant holders whose End of Award Report is overdue or incomplete will not be eligible for further ESRC funding until the Report is accepted. We reserve the right to recover a sum of the expenditure incurred on the grant if the End of Award Report is overdue. (Please see Section 5 of the ESRC Research Funding Guide for details.)

Please refer to the Guidance notes when completing this End of Award Report.

| | | | |
|---|---|---|---|
| **Grant Reference** | RES-000-22-4075 | | |
| **Grant Title** | Lingual coarticulation in preadolescents and adults: an ultrasound study | | |
| **Grant Start Date** | 01 October 2010 | **Total Amount Expended:** | **£ 100,843** |
| **Grant End Date** | 30 September 2011 | | |
| **Grant holding Institution** | Queen Margaret University | | |
| **Grant Holder** | Dr Natalia Zharkova | | |
| **Grant Holder's Contact Details** | **Address** | **Email** | |
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| | | **+44 131 4740000** | |

| **Co-Investigators (as per project application):** | **Institution** |
|---|---|
| Dr Robin Lickley | Queen Margaret University |
| Dr Nigel Hewlett | Queen Margaret University |
| | |

## 1. Non-technical summary

Please provide below a project summary written in non-technical language. The summary may be used by us to publicise your work and should explain the aims and findings of the project. *[Max 250 words]*

When people combine sounds to make words, there is overlap in the tongue movements involved in articulating individual sounds, referred to as lingual coarticulation. For example, in adult speech, tongue positions at mid-consonant, in the words "she" and "shah", differ because of the influence of the following vowel. The research team's earlier work showed that young children differed from adults in the extent of vowel-on-consonant coarticulation. In this project, for the first time, a quantitative analysis of the dynamics of tongue movements was performed. The project used high-speed ultrasound to measure lingual coarticulation in the syllables "she", "shah", "sea" and 'Sah', comparing preadolescent children and adults, fifteen speakers in each age group.

In both age groups and both consonants, the tongue position at mid-consonant was affected by the identity of the following vowel. There was no significant effect of age on the size of the vowel-related difference in tongue posture, nor on within-speaker variability in tongue placement. Age-related differences were observed in the onset of coarticulation. While in the adults, the vowel effect was present throughout the consonant for both consonants, in preadolescents the effect was apparent later into the first half of the consonant. The results of the study suggest a near-adult-like achievement in the development of lingual control by preadolescents, with respect to the coarticulation of fricative-vowel sequences. However age-related differences in timing may indicate that preadolescents have still to gain the extent of forward planning in speech production which is possible for a typical adult.

## 2. Project overview

### a) Objectives

Please state the aims and objectives of your project as outlined in your proposal to the us. *[Max 200 words]*

The aims of the project were to provide articulatory and acoustic data on the maturation of lingual coarticulatory patterns from preadolescent to adult speech. In particular we investigated how cross-segment differences in coarticulation develop in preadolescents. A quantitative analysis of dynamic information on tongue movements was carried out for the first time.

The objectives of the study were as follows:
1. To record a database of synchronised ultrasound and acoustic data of preadolescent and adult speech, including consonant-vowel syllables in a carrier phrase.
2. To determine whether any differences between consonants in vowel-on-consonant coarticulation increase with age.

Research question: Does a cross-consonant difference in susceptibility to coarticulation increase in the interval between preadolescence and adulthood?
3. To determine how within-speaker variability in coarticulation changes from preadolescence to adulthood.
Research question: Is within-speaker variability in coarticulation greater in preadolescents than in adults?
4. To determine how the temporal dynamics of coarticulation change with age.
Research question: Does a cross-consonant difference in vowel-on-consonant coarticulation onset increase in the interval between preadolescence and adulthood?

All the objectives have been met. For the details on Objective 1, please see section *3a* of this report; for Objectives 2 – 4, see section *2d* of the report.

**b) Project Changes**

Please describe any changes made to the original aims and objectives, and confirm that these were agreed with us. Please also detail any changes to the grant holder's institutional affiliation, project staffing or funding. *[Max 200 words]*

There have been no changes to the original aims and objectives, nor to the grant holder's institutional affiliation, project staffing or funding.

**c) Methodology**

Please describe the methodology that you employed in the project. Please also note any ethical issues that arose during the course of the work, the effects of this and any action taken. *[Max 500 words]*

The project used synchronised high speed (100 Hz) ultrasound tongue video and acoustic data. The participants were 15 preadolescents and 15 adults, all native speakers of Standard Scottish English with no known speech disorders. The mean age for the preadolescents was 11;2 ([years;months]); the range was between 10;0 and 12;4. The mean age of the adults was 37 years; the range was between 18 and 58 years. The stimuli were consonant-vowel (CV) syllables /si/, /sa/, /ʃi/, /ʃa/, in the carrier phrase "It's a … Pam", with six repetitions of each sentence. Tongue curve comparison and normalisation for vocal tract size were made using the methods developed in our previous work. The methods were applied for the first time to comparing sets of tongue curves throughout the consonant.

In each token, cubic splines were fitted to the tongue surface contour at every ultrasound frame between the consonant onset and offset. For each token, x-y values for the tongue curve data from nine Normalised Time Points (NTPs), equally spaced throughout the consonant, were used for analysis. The total number of these tongue surface contours was

6480 (9 tongue contours x 4 CV types x 6 repetitions x 30 participants). For each speaker, consonant and NTP, nearest neighbour distances from each consonant curve in one vowel context to each consonant curve in the other vowel context, called Across-Set (AS) distances, were calculated (36 per speaker per consonant). Distances from each consonant curve from one vowel context to each of the other consonant curves from the same vowel context, called Within-Set (WS) distances, were also computed (15 per speaker per consonant). Linear mixed models were run in SPSS, with Speaker as a random effect.

Significance testing for presence of a coarticulatory effect on the consonant from the contrasting vowels was carried out, separately for each consonant, age group and NTP (with a Bonferroni adjustment for 36 tests). A coarticulatory effect was deemed to be present if AS distances were significantly greater than each set of WS distances. AS and WS distances were then normalised for vocal tract length. First, tongue length values were measured for every speaker. Then the values for each speaker were represented as a proportion of the tongue length value for the speaker with the longest imaged tongue surface, and all distances for each speaker were divided by the proportionate tongue length values.

In the event that a coarticulatory effect at mid-consonant was present in both age groups, AS distances were compared across consonants within age group, and normalised AS distances were compared across age groups, for each consonant. Additionally, a single model including both Age Group and Consonant as fixed effects was run on absolute AS distances. In order to compare variability across age groups, normalised WS distances at mid-consonant were compared within consonant. For each consonant and age group, the NTP was established where the coarticulatory effect was first present.

Ethical approval was secured prior to the commencement of the study, following standard procedures at Queen Margaret University.

**d) Project Findings**

Please summarise the findings of the project, referring where appropriate to outputs recorded on the ESRC website. Any future research plans should also be identified. *[Max 500 words]*

**Differences between consonants in vowel-on-consonant coarticulation**

Linear mixed models results showed that both groups of speakers had a significant coarticulatory effect at mid-/s/ and mid-/ʃ/ (see Table 1).

| | /s/ | | /ʃ/ | |
|---|---|---|---|---|
| NTP | Adults | Preadolescents | Adults | Preadolescents |
| 1 | $F = 150.00$ * | $F = 14.31$ | $F = 119.90$ * | $F = 2.93$ |
| 2 | $F = 203.49$ * | $F = 27.14$ * | $F = 146.57$ * | $F = 5.32$ |
| 3 | $F = 242.04$ * | $F = 48.26$ * | $F = 253.22$ * | $F = 9.98$ |
| 4 | $F = 329.50$ * | $F = 96.59$ * | $F = 273.81$ * | $F = 18.53$ * |
| 5 (mid-consonant) | $F = 432.98$ * | $F = 217.27$ * | $F = 404.07$ * | $F = 41.12$ * |

Table 1. *F* values from linear mixed models testing for the presence of a coarticulatory effect at the first five NTPs (in all subsequent NTPs, not included in the table, the coarticulatory effect was present in both groups of speakers and both consonants). An asterisk next to an *F* value means that a coarticulatory effect was present after the Bonferroni adjustment for 36 tests.

AS distances at mid-consonant are presented in Figure 1. Absolute AS distances were significantly greater for /s/ than for /ʃ/ in both groups of speakers, at $p < 0.001$ (adults: $F(1,1064)=72.64$; preadolescents: $F(1,1064)=247.06$). The effect of Age Group on normalised AS distances was not significant for either consonant. The model including both Age Group and Consonant as fixed factors produced a significant interaction of the two factors ($F(1,2128)=40.54$, $p < 0.001$), suggesting that in the preadolescents the difference between /s/ and /ʃ/ was greater than in the adults. We conclude that the cross-consonant difference in susceptibility to coarticulation does not increase in the interval between preadolescence and adulthood.

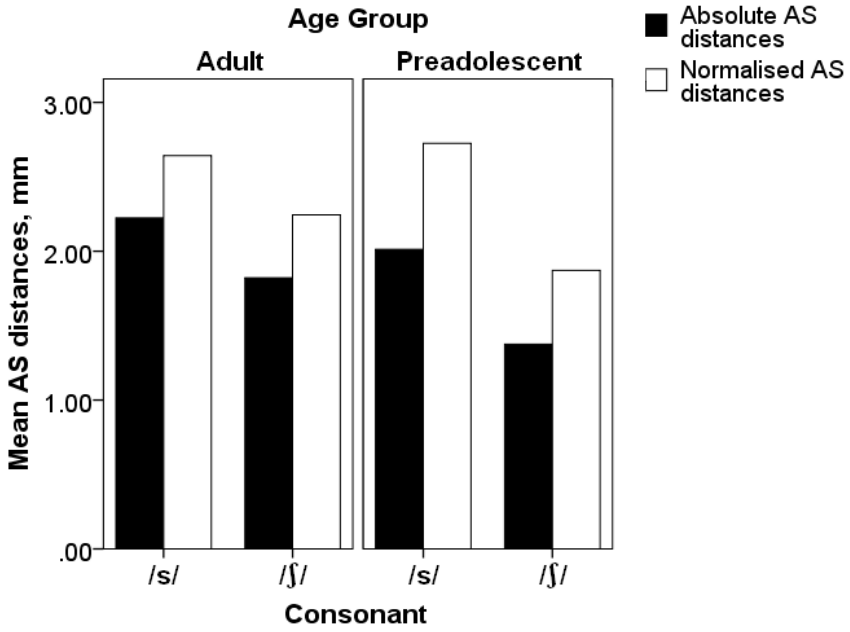


Figure 1. Mean group AS distances at mid-consonant.

**Within-speaker variability in coarticulation**

At mid-/s/, normalised WS distance values were 1.21 mm for adults and 1.52 mm for preadolescents; at mid-/ʃ/, they were 1.12 mm for adults and 1.43 mm for preadolescents. For /s/, the effect of Age Group was not significant; for /ʃ/, there was a significant effect of Age Group ($F(1,28)=5.43$; $p=0.027$), but it failed to reach significance after the Bonferroni adjustment. We conclude that there was no significant age-related difference in within-speaker variability.

**Temporal dynamics of coarticulation**

As shown in Table 1, in the adults, the criteria for the presence of a coarticulatory effect

were satisfied already at the consonant onset, for both consonants. In the preadolescents, the criteria for /s/ were satisfied from NTP 2 onwards, and for /ʃ/, from NTP 4 onwards. Thus, we can conclude that cross-consonant difference in vowel-on-consonant coarticulation onset decreases with age.

Future research plans
Preadolescent-adult differences in amount and speed of tongue movement over time are being analysed. Also, a method of quantifying lingual articulation developed during this project (Zharkova 2011), which does not require head-to-transducer stabilisation, is being applied to the data from this and previous ESRC-funded projects to Dr Zharkova, to evaluate its potential applications to disordered speech.

**e) Contributions to wider ESRC initiatives (eg Research Programmes or Networks)**

If your project was part of a wider ESRC initiative, please describe your contributions to the initiative's objectives and activities and note any effect on your project resulting from participation. *[Max. 200 words]*

The project was not part of a wider ESRC initiative.

## 3. Early and anticipated impacts

**a) Summary of Impacts to date**

Please summarise any impacts of the project to date, referring where appropriate to associated outputs recorded on the Research Outcomes System (ROS). This should include both scientific impacts (relevant to the academic community) and economic and societal impacts (relevant to broader society). The impact can be relevant to any organisation, community or individual. *[Max. 400 words]*

The following article submitted and accepted during the project has appeared online:

Zharkova, N. (2011). Using ultrasound to quantify tongue shape and movement characteristics. *The Cleft Palate–Craniofacial Journal* In-Press. DOI: http://dx.doi.org/10.1597/11-196.

Presentations during the project:

Zharkova, N., Hewlett, N., Lickley, R. & Hardcastle, W. Lingual coarticulation dynamics in preadolescents: an ultrasound study. Poster at the International Child Phonology Conference, York, UK, 16-18 June 2011.

Zharkova, N. Tongue dynamics and speech motor control in preadolescents. Oral paper at the Phonetics/Phonology Workshop 2010-2011, The University of Edinburgh, 26 May 2011.

Zharkova, N. How do preadolescents talk? Evidence from tongue movements. Oral paper at

the Speech and Communication Research Seminar 2010-2011, Queen Margaret University (QMU), Edinburgh, 9 February 2011.

Zharkova, N. The opposition of /i/ and /u/ in Scottish English children: acoustic and articulatory evidence. Poster at the Workshop on Sound Change, Barcelona, Spain, 21-22 October 2010. The workshop was originally selected in the grant proposal for its relevance to the project.

A webpage dedicated to the project has been created and maintained: http://www.qmu.ac.uk/casl/ultra/preadolescentSpeechMotorControl.htm.

At the end of the grant, a Research Information Day was organised at QMU for the project participants, academics and the wider public (23 September 2011). Over 20 people attended, around a half of the attendees were children. The results of the project were presented, the use of ultrasound for tongue imaging was demonstrated, and implications of studying typical articulation for helping people with speech disorders were discussed. Applications of ultrasound in foreign language teaching were explored. Feedback was very positive, encouraging organisation of similar events in future research projects.

The database collected during the project has been stored in the QMU eData repository ("High speed ultrasound/acoustic database of lingual articulation in preadolescents and adults", http://edata.qmu.ac.uk/14). Synchronised audio and tongue video data, with the ultrasound video frame rate of 100 Hz, are in two different formats, in order to facilitate wider access. One format is AVI video, and the other format is read only by the Articulate Assistant Advanced software, which was used to record the data. The data are available for download on request, and can be used for research, teaching and demonstrations.

Since the start of the grant, an article was published in *Motor Control*, and another accepted to the *Journal of the International Phonetic Association* (both arise from our previous study, RES-000-22-2833); for details, see http://www.qmu.ac.uk/casl/staff/nzharkova/Default.htm. Our new articles are building on these two papers.

**b) Anticipated/Potential Future Impacts**

Please outline any anticipated or potential impacts (scientific or economic and societal) that you believe your project might have in future. *[Max. 200 words]*

Article to be submitted in December 2011:
Zharkova, N., Hewlett, N., Hardcastle, W.J. & Lickley, R. Spatial and temporal lingual coarticulation and motor control in preadolescents. *Journal of Speech, Language, and Hearing Research*.

Abstracts submitted:
- Zharkova, N. Vowel-on-fricative dynamic lingual coarticulation in preadolescents and adults. British Association of Academic Phoneticians Colloquium, Leeds, 26-28 March 2012.
- Zharkova, N. Tongue shape measures based on ultrasound data. *14th International Clinical*

*Phonetics and Linguistics Association Conference*, University College Cork, Ireland, 27-30 June 2012.

The methods of analysing tongue shape and dynamics developed in our previous work and in this project will be used in future grants. An application has been submitted to the ESRC (Principal Investigator Dr Robin Lickley, Co-Investigators Dr Natalia Zharkova and Dr Nigel Hewlett; "Speech motor control in children who stutter and in typically developing children: an ultrasound study of tongue movements"). Another grant application is in preparation, for a project on tongue movement characteristics in children with and without cleft palate, which will use ultrasound to quantify abnormal tongue function in order to inform the linguistic theory.

Photographs obtained during the Research Information Day will be used for further dissemination of the project results to non-academic audiences.

You will be asked to complete an ESRC Impact Report 12 months after the end date of your award. The Impact Report will ask for details of any impacts that have arisen since the completion of the End of Award Report.

## 4. Declarations

Please ensure that sections A, B and C below are completed and signed by the appropriate individuals. The End of Award Report will not be accepted unless all sections are signed. Please note hard copies are **not** required; electronic signatures are accepted and should be used.

### A: To be completed by Grant Holder

Please read the following statements. Tick **one** statement under ii) and iii), then sign with an electronic signature at the end of the section (this should be an image of your actual signature).

**i) The Project**

| | |
|---|---|
| This Report is an accurate overview of the project, its findings and impacts. All co-investigators named in the proposal to ESRC or appointed subsequently have seen and approved the Report. | **X** |

**ii) Submissions to the Research Outcomes System (ROS)**

| | |
|---|---|
| Output and impact information has been submitted to the Research Outcomes System. Details of any future outputs and impacts will be submitted as soon as they become available. | **X** |
| **or** | |
| This grant has not yet produced any outputs or impacts. Details of any future outputs and impacts will be submitted to the Research Outcomes System as soon as they become available. | ☐ |

**iii) Submission of Datasets**

| | |
|---|---|
| Datasets arising from this grant have been offered for deposit with the Economic and Social Data Service. | **X** |
| **or** | |
| Datasets that were anticipated in the grant proposal have not been produced and the Economic and Social Data Service has been notified. | ☐ |
| **or** | |
| No datasets were proposed or produced from this grant. | ☐ |