NON-NATIVE SPEECH SOUND PRODUCTION CHANGES EVEN WITH PASSIVE LISTENING TRAINING

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Abstract

The difficulty of non-native speech sound acquisition depends on several factors in addition to the central role of the mother tongue sound system. Age of exposure, amount of exposure as well as the type of training provided have been shown to have an effect on learning outcomes. In addition, theories of speech perception suggest that perception and production may either be strongly dependent upon each other as to the degree that perception triggers motoric patterns as well, or that activation of the auditory system is enough for perception so that the production system remains inactivated. In order to study whether mere exposure to auditory stimulation would result in production changes, we selected two groups of Finnish learners in a two-day listen-and-repeat training protocol. Both groups were auditively exposed to a non-native speech sound contrast embedded in a semi-synthetically produced pseudo-word context /ty:ti/ - /tʉ:ti/. While the passive listening group merely listened to the stimulus pairs without any motoric actions, the production group actively produced the stimulus words according to the provided model. We performed acoustic analyses and extracted the values of the two lowest resonance frequencies, formant 1 (F1) and formant 2 (F2) from the productions. The results indicated no statistically significant differences between the groups, neither in the formant values nor in their standard deviations. However, as a function of training, both groups showed clear changes in the standard deviation values thus indicating changes in production performances. This suggests that both training protocols have an effect on production learning, and more importantly, that the motoric commands seem to alter on the basis of mere auditory stimulation. This further suggests that the motoric system is activated even in perceptual tasks.

Keywords: non-native speech sound production, training, auditory exposure, motor commands

1. Introduction

The role of the mother tongue speech sound system has been shown to have a decisive role in how second language learners perceive and produce non-native phonemes and their allophones. According to the formulations of the traditional Contrastive Analysis Hypothesis (Weinreich 1953; Lado 1957), a difference between the native language and the target language system leads inevitably into learning problems. Later models of second language acquisition have further elaborated this idea in order to obtain a more comprehensive description of the learning setting, which seldom seems this straightforward. One of the most popular postulations, Speech Learning Model (SLM, Flege 1987), argues that the relation between the native and the non-native speech sounds can be described in terms of three distinct types: Firstly, the speech sounds can be considered to be *Identical*, which naturally leads into no learning obstacles, since the native phonemes and allophones can be used in the new language as well. Secondly, an intermediate degree of difficulty is linked with speech sounds of the type *New*, which means that the target language contains an item alien to the maternal language and thus it is easily distinguishable perceptually, but a completely new production command is required. The third type is labelled *Similar*, and this type of a relation is considered to be the most problematic one, since the foreign element is confused with a native one, which prevents the learner from even perceiving the difference. However, the model can be criticised for not being precise, since it fails to distinguish e.g. distributional differences between sound (Wiik 1965), or the fact that the difference between New and Similar may be blurred, when looking at vowel categories. Be that as it may, the main point seems valid: minute differences between the native and the non-native language appear to result in the most problematic learning settings. This phenomenon is confirmed by another model of second language acquisition, namely the Perceptual Assimilation Model (PAM, Best and Strange 1992), which describes learning problems from the point of view of four assimilation configurations. It shares the idea of SLM that identical settings cause no problems by suggesting that if two phonemes are distinguished from each other in the same way in the two languages in contact, no problems arise. Also, a completely new pair of phonemes is linked with intermediate difficulties in a similar manner as the *New* sound categories in SLM. However, PAM divides the most problematic contrast into two subtypes, where the most difficult problems persist, when two target categories are assimilated equally into one native category, while less difficulty arises when the assimilation is unequal, and the other non-native phoneme is perceived to be a better exemplar of the native category. This is clearly a more precise classification and it is also fundamentally different from SLM in being gestural by nature. However, in both models, as well as in the traditional theories, the main point remains more or less the same: problems arise from differences.

In studying second language speech sound acquisition, understanding speech perception theories is essential. It is possible to divide theories and models of speech perception into two quite distinct groups based on the target of the perception (e.g. Hawkins 1998). The main distinction can be made between auditory and motor oriented theories: In the former, the auditory signal is the object of perception and the acoustic signal with its distinctive features includes all the necessary information for decoding the message (Jacobson et al. 1952; Kuhl et al. 1992; Remez 1994). In the latter, the acoustic signal is merely the carrier of the more important information, namely the motoric gestures, or their motor commands that originally produced the signal (Liberman and Mattingly 1985; Mattingly and Liberman 1988; Browman and Goldstein 1992). Irrespective of whether the object of perception is considered to be directly linked with the signal or whether the relation is rather an indirect one, the implication seems to be that in the auditory theories speech perception is mainly handled by the auditory system, while the activation of the motoric system is required in motor theories. This distinction has evident implications to the manner in which learners of a non-native language process the incoming foreign input and thus alter their production patterns: if the connection between the perceptual and motoric systems is not as direct as assumed by the auditory theories, then production learning should require the training of production patterns. However, if the acoustic signal is closely processed in relation to the production system, i.e. with motoric commands, then a mere exposure to acoustics could trigger motoric reorganisation as well. This is one of the most fundamental questions in speech learning research.

Earlier studies of non-native speech acquisition have shown that, in addition to the role of the mother tongue, several factors may affect the manner in which new speech items are learned. Research focus has been mainly on the age of exposure and it has been argued based on plasticity that earlier is better (Flege et al. 1999). However, adult learners have been shown to develop native-like productions when the amount of input has been extensive (Peltola M. S. et al. 2014) and the lack of constant use of the mother tongue seems to facilitate learning more than mere long exposure (Flege et al. 1997). Targeted training protocols of various designs have also been utilised to pinpoint the main factors in learning to perceive and to produce foreign speech sounds. Tamminen et al. (2015) showed that new perceptual memory traces evolve very quickly with a basic listen-and-repeat training even to speech sound contrasts modelled to be of maximal difficulty. In addition, the same type of training resulted in production changes in both young learners (Taimi et al. 2014a) and linguistically active elderly (Jähi et al. 2015) learners, but neural plastic effects were observed only in child learners (Taimi et al. 2014b). Interestingly, a two-day training protocol used in these studies seems to function, but a one-day training set did not result in major learning effects (Peltola K. U. et al. 2017). However, learners appear to benefit greatly from verbal instructions, since production changes occurred instantly when tutoring was provided (Saloranta et al. 2015) and misleading visual cues were of such prominence compared to auditory stimulation that the visual channel hindered auditory learning altogether (Peltola K. U. et al. 2015).

Based on earlier studies in non-native speech sound learning, it thus seems that the precise method of training may have a decisive role in learning outcomes. When combined with ideas originating from theories of speech perception, the question arises, whether mere auditory exposure is enough to trigger production changes. If so, it would imply that the motor commands are automatically activated, and thus altered, as a result of listening to speech. In contrast, should the results show that production changes require the active use of the motor system, it would suggest that the auditory perceptual system is isolated from motor processing. In order to study this, we conducted two different kinds of trainings on native speakers of Finnish using auditory stimuli that non-native speech sound learning models predict to be of high difficulty to learn. The difference between the trainings was on whether the subjects were allowed to practise productions or whether they were merely instructed to listen to the stimuli. The goal of the study was to investigate whether production learning requires explicit motoric training, or whether new articulation patterns may arise even without motoric practising.

2. Materials and methods

2.1. Subjects

Altogether 18 native speakers of Finnish subjects participated in the experiment. All subjects were voluntary and received no compensation for participation. None of the subjects studied any languages at the university level (neither majoring nor minoring). The participants were divided without prior screening into two separate groups on the basis of the task that they were to perform: Eight subjects were selected into the “Passive listeners” group (mean age 26 years, range 18-32, 3 female) and ten subjects belonged to the “Listen and repeat” group (mean age 24.6 years, range 18-32, 5 female). Consequently, the groups were balanced in relation to the age and gender factor, implying that any differences between the groups would result from task differences.

2.2. Stimuli

We selected a pair of two-syllable non-words as stimuli, and the main focus was on the long vowel of the first syllable. The stimuli are called semi-synthetic after the semi-synthetic speech generation (SSG) method (Alku et al., 1999) that was used in the production of the syllables. The criteria for stimulus selection were based on two main factors: First, the stimuli were to contain an element that would in principle be very difficult for Finnish learners so that the training would be needed due to the contrast effect, i.e. the new item contrasted against a familiar one. Second, the stimuli needed to be both controllable, yet natural sounding so that the subjects would be able to focus their attention completely to the contrast without being distracted by unnaturalness of the sounds. To meet the former criterion, we selected a non-word pair, where the non-target /ty:ti/ contained the native close rounded vowel /y/ (F1 269 Hz, F2 1866 Hz). The target word was /tʉ:ti/, which contained the non-native close rounded central vowel /ʉ/ (F1 338 H, F2 1258 Hz). The stimuli appeared in turns in order to pinpoint the difference. The latter criterion was fulfilled by using stimuli produced with the SSG method, where the synthesis is built on a glottal pulse excitation estimated from a natural speaker. This ensures both the naturalness and the controllability of the stimuli (Alku et al. 1999, and for a more thorough description, see Taimi et al. 2014a). The overall duration of the stimuli was 624 ms and the stimuli were presented to the subjects with an inter-stimulus interval (ISI) of 3 seconds.

2.3. Procedure and analyses

The experiment procedure consisted of a strict two-day protocol, where we ensured that everything was performed in exactly the same manner in both groups, except for the task description. On the first day prior to testing, all subjects filled in a questionnaire about linguistic background and current health. The experiment started with a recording block, which then functioned as the baseline measurement. After that, we provided the subjects with a training session, then the second recording and finally another training block. The second day started with a training session followed by the third recording and continued with yet another training and ended with the final fourth recording. As a result, the subjects performed four training sessions and four recordings, the most critical ones being the baseline and the final registration. In the recording sessions, the stimuli appeared 10 times in turns, and in the trainings they were repeated 30 times both. The difference between the group-specific task was such that the “Listen and repeat” group were instructed to repeat in turns the target and the non-target stimuli according to the model provided, while the “Passive listeners” were only instructed to listen to the stimuli.

The recorded target and non-target words were acoustically analysed using Praat (Boersma & Weenink 1996). We extracted the fundamental frequency (F0) value as well as the three lowest formants (F1, F2, F3) from the signal, but only the first and second formant were statistically analysed. In addition, we calculated the standard deviation value for the F1 and F2 of each produced vowel. Altogether, we thus obtained data from 18 subjects (2 Groups) x 120 vowel repetitions x 2 formants/standard deviation values for the analysis. These data were then separately subjected to a Group x Session x Vowel x Measure Repeated Measures Analysis of Variance (ANOVA) using IBM SPSS Statistics (version 22) and further tests when required and appropriate. The aim was two-fold: firstly we needed to see, whether any significant changes occurred between sessions, and secondly, whether the Groups performed differently in any of tested times.

3. Results

The overall omnibus ANOVA of the actual formant values F1 and F2 did not show any statistically significant changes as a function of training. More interestingly, there were no differences between the two Groups. This can also be observed in the formant values shown in Table 1 below. When we performed the identical ANOVA on the standard deviation values, several significant changes were discovered as a result of training. Firstly, we found the significant main effect of Session ($F(1,16) = 5.610$, $p = 0.031$) and a significant Session x Word x Measure interaction between the baseline and the final recording. In addition, the main effect of Session was valid also between the baseline and the third recording ($F(1,16) = 5.280$, $p = 0.035$). These findings indicated that training had an effect on the standard deviation values already by the third recording and that the changes were not identical in both words and measured values. In order to find out whether the target and the non-target word were treated differently by the subjects, we analysed the data from the two types of stimuli separately. The analysis of the standard deviation values for the non-target word /ty:ti/ showed no statistically significant changes, thus indicating that the native vowel remained stable; this can also be seen in Table 2 below in the overall low values of deviations. However, the analysis of the target word /tʉ:ti/ revealed several interesting changes: We discovered the main effect of Session between the baseline and the final recording ($F(1,16) = 6.506$, $p = 0.021$) as well as a Session x Measure interaction ($F(1,16) = 5.216$, $p = 0.036$). Further analysis indicated that F1 deviations reduced already by the second recording (F(1,16)

= 4.790, p = 0.044) and this change was still valid in the final Session (F (1,16) = 6.373, p = 0.023). In addition, the F2 deviation analysis showed that these values also diminished by the final Session (F(1,16) = 5.876, p = 0.028). Interestingly, no statistically significant differences were found between the two Groups. Taken together these statistical results indicate that the non-target target word was successfully selected for the study so that it represented accurately the native model and consequently no changes occurred. However, the standard deviations of both formants diminished as a function of training either by the second, third or the final recording. Most importantly, both Groups behaved in an identical manner, the observed changes were valid both when articulation was trained and when no production exercises took place.

Table 1. Average Hz values for F1 and F2 in the four recording sessions.

Session	Passive listeners /ʉ/	Listen and repeat /ʉ/	Passive listeners /y/	Listen and repeat /y/
1. F1	374	406	362	390
1. F2	1362	1486	1770	1845
2. F1	382	409	369	387
2. F2	1267	1467	1780	1861
3. F1	382	413	366	385
3. F2	1273	1422	1764	1849
4. F1	386	412	374	397
4. F2	1291	1424	1779	1856

Table 2. Average standard deviation values for F1 and F2 in the four recording sessions.

Session	Passive listeners /ʉ/	Listen and repeat /ʉ/	Passive listeners /y/	Listen and repeat /y/
1. F1	21	22	17	17
1. F2	160	195	55	53
2. F1	19	16	12	17
2. F2	100	125	55	58
3. F1	23	15	14	14
3. F2	102	127	52	44
4. F1	17	17	13	20
4. F2	93	119	57	51

4. Discussion

The aim of this study was to find out whether non-native articulation patterns may be acquired with mere acoustic exposure, or whether motor commands need to be trained explicitly. In order to study this, we conducted two types of trainings on two groups. The listen-and-repeat group was instructed to imitate according to the provided model, while the passive listener group only listened to the presented stimuli. Both groups consisted of native speakers of Finnish, to whom the target vowel /ʉ/ was theoretically extremely difficult to learn.

The results of the experiments are quite clear. A distinction can be made into three lines of indications regarding, firstly, the role of the mother tongue in speech production, secondly, the learnability of difficult speech sounds by means of a listen and repeat training, and thirdly and most interestingly, the interaction between the auditory and motor system. The role of the mother tongue can be seen in the fact that the standard deviations of only the target, i.e. the non-native, vowel diminished with training, while the native vowel remained unchanged. This clearly shows that the native production patterns are so fixed that a repetitive, non-varied stimulation could not affect even the consistency of familiar production. This is in accordance with expectations, since the native system with its production patterns is deeply rooted and from early infancy children become both perceptually and in terms of production committed to the ambient language (Kuhl et al. 1992). It may be argued that the subjects immediately labelled the vowel as a representative of the native category, and thus forward ignored the stimulation. This mechanism of instant labelling would then be linked with neural processing where native within category stimuli do not result in pre-attentively elicited responses signalling the activation of memory traces (Näätänen et al. 1997; Peltola M. S. et al. 2003; Peltola M. S. et al. 2005).

The learnability implications are more complex: The finding that no significant changes occurred in Finnish native speakers in the formant values as a function of training shows that the task was demanding, as was hypothesised. On the other hand, the standard deviations for the target vowel did reduce, which indicates that the productions became more stable. Taken together, this shows that the stimulus to be learned may clearly be labelled as belonging to the type *Similar* according to SLM (Flege et al. 1987). According to PAM, the trained contrast is such where two vowels are assimilated into one native category unequally, /y/ being a good representative and /ʉ/ a poor representative (Best and Strange 1992). The former concentrates on the target vowels while the latter emphasises the significance of the contrast, which is non-existent in the native language. However, in any case the mere addition of a new sound is not enough for learning, but the whole sound system needs to be updated instead. In this context the fact that the native vowels did not change may signal that at least in the level of the system, the training had little effect. In contrast, from SLM point of view, the finding that the target sound production patters started to change, clearly indicates that learning occurs. Thus, the theoretical background may have a decisive role in interpreting the results. On the whole, our interpretation is that, if something changes, then training has had an effect. In this case then, training led into production learning, even though the target was both perceptually and in terms of production extremely difficult to acquire.

The most crucial finding was evidently that the groups did not differ in their production patterns and both groups showed identical changes as a function of training. This would suggest that when new speech items are learned, the auditory stimulation automatically activates the motor cortex and that mere acoustic exposure leads into learning of motoric patters. This has several connection to various speech perception, production and acquisition theories. In speech perception theories, the major division into auditory and motor is now of interest. Several studies have recently shown that the motor areas are in fact activated during speech perception (Pulvermuller et al. 2006), which has been interpreted as giving evidence in favour of the Motor theory (Liberman and Mattingly 1985). However, it is often ignored that in the Motor theory, the idea is that the motoric system is the first and main factor in perception, since the acoustic signal is merely the carrier of the most significant information. Thus the object of perception is primarily gestural. However, evidence in favour of this merely indicates that the motor system is activated in addition to the auditory area, which is actually not what the original proponents of the Motor theory suggested. In that way it is of less importance to argue that these findings support the formulations of the Motor theory proper, but instead it should be noted that the motoric patterns seem to be clearly connected with the acoustic processing. The Template theory (Perkell et al. 1997) suggests that production is governed by motoric commands which develop during childhood but which are constantly upgraded and sustained according to input. This then suggests that the native patterns prevailed when necessary (i.e. with the non-targets) while the templates started to change in accordance with the input deviating from the norm (i.e. with the target). This further strengthens the argument in favour of the strong connection between perception and articulation. From the point of view of language acquisition, this suggests that adult learners benefit from auditory exposure to non-native speech items. This is valid not only for perception, which needs to be able to dissolve the input in a new way, but also for production patterns which begin to update in accordance to the stimulation. Pedagogically, this carries the implication that listening to non-native speech is beneficial also for production learning. Thus the role of authentic exposure is of high significance in tutored language learning settings, since the authentic acoustic signals contain hints that can be used for learning to produce speech sounds in a new manner.

Altogether, our results show that a very simple listen-and-repeat training changes vowel production in adult learners even when the target speech sound is extremely difficult. More importantly, the results indicate that learners acquire non-native production patterns with mere acoustic input. This has significant implications to theories of speech perception as well as pedagogical practices.

5. References

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