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## Chapter six

# Conclusion

This dissertation presents results of four experiments which investigated various aspects of the production and perception of lexical tones by beginning and advanced Dutch learners of Mandarin as well as the developmental trajectory in their L2 tone acquisition.

### 6.1 Recapitulation of research questions

In connected speech, tones can be influenced by the preceding and following tones and show coarticulated  $f_0$  realizations which are different from the canonical contours when produced in isolation. Such deviant  $f_0$  shapes of coarticulated tones also make it a great challenge for adult non-tonal L2 learners to achieve native-like tone production. Previous research on tonal coarticulation has mainly focused on the directionality (carryover or anticipatory), the nature (assimilatory or dissimilatory), and the magnitude of contextual effects on tonal production by native speakers. However, no systematic empirical research has been devoted to the underlying mechanisms of tonal coarticulation and the acquisition of coarticulated patterns by L2 learners of Mandarin. Whether fine-grained phonetic details such as tonal coarticulation patterns can be acquired by L2 learners is still not clear. So, Chapter 2 in the current dissertation examined disyllabic tonal coarticulation in native Mandarin speakers as well as beginning and advanced L2 learners in a reading-aloud task under cognitive load, based on two research questions:

- (1) What are the underlying mechanisms of tonal coarticulation for native speakers and L2 learners?
- (2) What is the developmental trajectory in the acquisition of fine-grained phonetic details in tonal coarticulation for L2 learners?

In terms of tone perception, previous studies have demonstrated that non-tonal L2 learners can be trained to improve their ability in tonal identification and discrimination, but how they learn to use pitch information in lexical contrastive way and form new tonal categories is still less understood. Therefore, Chapter 3 in this thesis tested beginning and advanced Dutch learners of Mandarin as well as native Mandarin and native Dutch speakers in an ABX matching-to-sample test, aiming to reveal whether L2 learners can redistribute their attention to segments and tones and develop a more integral processing of these two kinds of information like native Mandarin speakers, as well as the developmental trajectory in these processes during the period of Mandarin acquisition.

Previous findings generally show a good performance of L2 learners of Mandarin in basic identification and discrimination tasks, in which phonetic mode of processing can be employed to focus on phonetic details. However, in cognitively demanding tasks more like real communication situations, listeners are not likely to rely on fine-grained phonetic details and have to use “automatic selective perception routines” (Strange, 2011) to detect phonologically contrastive tonal information. The performance of L2 learners in demanding tasks requiring phonological mode of processing has not been tested before. To our knowledge, another crucial issue in L2 tonal acquisition, learning to use tonal information in lexical access, has also not been systematically investigated. Therefore, Chapter 4 employed a cognitively demanding sequence-recall task and a tonal lexical decision task to answer two additional questions:

- (3) To what extent can advanced Dutch learners of Mandarin achieve a native-like pattern in phonological processing of tonal contrasts?
- (4) Can lexical tones be used properly in lexical activation by Dutch learners of Mandarin?

The developmental trajectory observed in Chapter 4 suggests that for Dutch learners of Mandarin, tonal information can be exploited in lexical access. However, the time course of lexical activation and the relative role of segmental and tonal information in speech recognition in L2 learners remained an interesting issue to explore. Chapter 5 therefore employed an eye-tracking experiment with the Visual World Paradigm to investigate the relative role of segmental and tonal information in lexical activation by native Mandarin speakers and Dutch learners of Mandarin, as well as the developmental trajectory for Dutch learners of Mandarin in using segmental and tonal information in spoken word recognition.

## 6.2 Results of individual chapters

**Chapter 2** examined disyllabic tonal coarticulation in native Mandarin speakers and L2 learners. For native Mandarin speakers, the result suggested that tonal coarticulation is bidirectional. The carryover effect exerted by the offset of the initial tones exhibited an assimilatory nature: this effect was strong and the influence could still be seen at least two-thirds into the vowel. The anticipatory effect exerted by the following tones on the tones in the initial position was dissimilatory in nature and had a smaller magnitude compared to the carryover effect. For T1, T2 and T4, the dissimilatory effect had been found when followed by most pairs of tones with contrastive onsets. It should be noted that, different from Xu’s (1997) finding, the raising effect of the following low onsets was not constrained to the maximum  $f_0$ . The whole contours of T1 and T2 were raised by the following tones with low onsets (T2 and T3) in the current experiment. The underlying coarticulatory mechanism was investigated in the high-cognitive-load condition. The carryover effect was robust and remained intact under high cognitive load, indicating that the carryover effect does not involve advance planning and is likely to be caused by physiological constraints – which is in line with the findings from segmental coarticulation (Whalen, 1990). The anticipatory effect, on the other hand, decreased with high cognitive load, indicating that anticipatory coarticulation involves advance planning. This finding can be potentially accounted for by the model proposed by

Tilsen (2013, 2009), who argued that an inhibitory speech planning mechanism is used for contemporaneously planned articulatory targets to maintain and maximize the contrasts of different phonemes. In the no-cognitive-load condition of the present study, the inhibitory mechanism functioned well and led to a clear dissimilatory anticipatory effect, maximizing the contrast between the adjacent tones. In the high-cognitive-load condition, however, as the inhibitory mechanism was constrained, the dissimilatory anticipatory effect also decreased.

For L2 learners, a clear developmental path was found in both carryover and anticipatory effects. The beginning learners showed a weaker assimilatory carryover effect compared to native speakers, while the performance of advanced learners was more similar to the native patterns, showing substantial carryover effects in T1, T2 and T4. That is, although the carryover effect did not include advance planning and was mainly a result of physiological constraints, its acquisition was still a gradual process.

Different from the carryover effect, the anticipatory coarticulation was strong for Dutch learners of Mandarin. For beginning learners, the dissimilatory anticipatory effect had been found on T1, T2 and T4 in the first syllable. This effect remained robust for T1 and T2 with high cognitive load. The advanced learners showed an anticipatory effect comparable to that of native Mandarin speakers in the normal condition. Different from the native speakers, the anticipatory effect remained robust for all tones under the influence of high cognitive load for advanced learners.

The strong anticipatory effect in L2 tonal coarticulation can be potentially explained with the help of Tilsen's model (Tilsen, 2013). The inhibitory mechanism had been acquired by beginning and advanced learners as an effective way to maintain the contrast and ensure the perceptibility of different tonal categories in connected speech.

**Chapter 3** investigated how beginning and advanced Dutch learners of Mandarin process tonal information. An ABX task was adopted to investigate phonological discrimination of Mandarin tones and segment-tone integration in Dutch learners of Mandarin, with both native Mandarin and Dutch speakers (without tonal learning experience) as control groups. Results showed a developmental path in lexical tone processing. The beginning learners could not process tonal contrast adequately at the phonological level, and they processed segmental and tonal information separately, like native Dutch listeners without Mandarin experience. The advanced learners showed a good phonological discrimination of tonal contrasts. They showed a more native-like pattern in distributing their attention between segmental and tonal information, and they processed the two dimensions in an integrated manner, similar to native Mandarin listeners. This suggests that the acquisition of new tonal categories in L2 involves a redistribution of attention along perceptual dimensions and the development of segment-tone integration.

**Chapter 4** further investigated the phonological processing of all tonal contrasts and the use of tones in lexical access by Dutch learners of Mandarin using a cognitively demanding sequence recall task and a lexical decision task. The results showed a clear developmental path by comparing the performance of two learner groups in the sequence recall task: the advanced learners, with more Mandarin experience, exhibited a significant improvement compared to the beginners, approximating the performance of native Mandarins. The result of the lexical decision task also showed that, compared to beginners, advanced learners performed significantly better in correctly identifying real words and rejecting non-words which were minimally different from real words in tones. The improvement of advanced learners in both

tasks demonstrated that they were shaping new selective perception routines, and their phonological mode of tone processing was in development which is in line with the ASP model (Strange, 2011). However, it should be noted that the RTs were longer for advanced learners than for native Mandarin listeners in all conditions, indicating that their L2 selective processing routines were still in development and were not as automatic as those of native Mandarin listeners.

However, in the sequence recall task, T2 and T3 was the most confusable tone pair for both learner groups. In the lexical decision task, T2 and T3 was mutually confusable for learners and was resistant to improve. Such difficulty may have stemmed from the acoustic similarity between these two tones, in that they have similar pitch contours and there is overlap in their pitch ranges (Moore & Jongman, 1997). Moreover, some asymmetric patterns were found for advanced learners in the lexical decision task. The advanced learners were significantly more accurate in recognizing real words with T1 and rejecting non-words in which T1 was produced as the other three tones than the other way round. That is, the category of T1 had been relatively well established when compared to the other three tones. Contrastively, it was difficult for advanced learners to make a correct response when T4 was produced as T1, T2 or T3, that is, the category of T4 was relatively less well-established when compared to the other three tones in pairs. These results are potentially related to the prosodic features of the learners' native language, since Gandour (1983) showed that compared to tone-language speakers, intonational language speakers are more sensitive to pitch height than to pitch direction.

Taken together, the advanced learners showed a significant improvement in tonal processing at phonological level and using lexical tones in lexical access compared to beginning learners. This improvement in tone acquisition can be attributed to the important role of tones in Mandarin. Different tone pairs were not equally difficult to learners in lexical access, and the source of such differences can be attributed to acoustic similarity between particular tones as well as interference from L1 supra-segmental features.

**Chapter 5** investigates the time course of lexical activation and the relative role of segmental and tonal information in speech recognition by testing native Mandarin speakers, as well as the beginning and advanced learners of Mandarin in an eye-tracking experiment. Using visual word paradigm, the participants heard an auditory word and were asked to identify the corresponding picture from a display of four pictures that consisted of the target (*chuang1* 'window'), a phonological competitor (segmental: *chuang2* 'bed'; cohort: *che1* 'car'; rhyme: *guang1* 'light'; tonal: *ji1* 'chicken'), and two phonologically unrelated distractors. The probability of fixation to the target and competitor was recorded since it may reflect the activation of the corresponding items. In this task, the auditory and visual stimuli were presented concurrently to participants, so when processing the pictures, the participants heard the rhyme part at the mean time. For native speakers, slower eye movements to the target were found in the rhyme condition, accompanied by high proportion of looks to the rhyme competitor, indicating that the rhyme competitor was activated adequately for competition. A lower and delayed peak in proportion of looks to the competitor in the segmental condition compared to the rhyme condition indicated that for native Mandarin speakers, tones play an early constraining role. As the input unfolded, only those candidates matching the input both in segmental and tonal information (i.e., the rhyme competitor) were

activated. Segmental competitors with non-matching tonal information were not activated in the early stage.

Compared to the native Mandarin speakers, both groups of learners generally showed less target activation and increased competitor activation across all conditions. Among conditions, the rhyme competitor was activated most to compete with the target for both learner groups. The segmental competitor also received a high proportion of looks, but activated less and later than the rhyme competitor. This suggested that, similar to native speakers, the non-matching tonal information was used effectively to constrain lexical activation in an early stage by both learner groups. However, more late fixations to the segmental competitor indicated that both learner groups were confronted with great difficulty in discriminating tonal minimal pairs. The cohort and tonal competitors, on the other hand, were not activated enough for lexical competition for both groups of learners.

Furthermore, the advanced learners generally showed a higher proportion of looks to the target and less looks to the competitor in all conditions than the beginning learners, suggesting that the advanced learners could activate the correct targets and suppress the competitors to a greater extent, approaching the performance of native Mandarin speakers.

### 6.3 General conclusion

In sum, with regard to L2 tone production, we found that the fine-grained patterns in carryover and anticipatory tonal coarticulation can be acquired by Dutch learners of Mandarin. Compared to native Mandarin speakers, advanced learners showed a more robust anticipatory effect. This dissimilatory effect was quite probably adopted by them as a strategy to prevent tonal targets from becoming perceptually indistinct. This finding is in line with Tilsen's model (2013): the dissimilatory effect between contemporaneously planned articulatory targets may function as a general mechanism to maintain perceptual differences between sounds.

In terms of tone perception, we found that, first, advanced learners improved significantly compared to beginning learners and approximated the performance of native Mandarin speakers in discriminating tones and redistributing their attention between segments and tones. These results suggest that Dutch learners of Mandarin can learn to distinguish tonal contrasts, which provides general support to the SLM model. That is, the capacities of forming new sound categories remain intact for adult L2 learners. The PAM-L2 model can also be used to account for L2 tonal acquisition. The case of non-native tonal contrasts fits the Uncategorized-uncategorized scenario best, with both sounds in the tonal contrast falling within the learners' L1 phonetic space, but neither fits any single L1 phonological category. The prediction of this scenario is in agreement with our results.

Second, through the cognitively demanding sequence recall task and the lexical decision task, we found that, compared to beginning learners, advanced learners could process tones at the phonological level more accurately and use tonal information in lexical access more effectively. The learners' success in these tasks is generally in line with the suggestions of the ASP model (Strange, 2011): they are developing new selective perception routines attuned to the most reliable information for recognition of different tone categories.



Finally, in the eye-tracking experiment, advanced learners could activate the correct targets and suppress the phonologically similar competitors to a greater extent than beginning learners, exhibiting a developmental trajectory in using segmental and tonal information in spoken word recognition. Advanced learners could use segmental and tonal information in the early stage to constrain lexical activation, which is consistent with the concept of the TRACE model: the speech sounds are perceived in an incremental way. With the unfolding of the signal, segmental and tonal information was used by the learners to activate compatible word candidates and inhibit the incompatible ones.

These findings of this dissertation thus have some implications for language teaching. To make the production more natural and to facilitate the learning of coarticulation patterns, pronunciation of tones should be trained not only in monosyllables, but also in disyllabic words. Furthermore, tests on auditory and phonological processing of tones can be used to assist individual learners in finding out the problematic aspects in their tone learning.

#### 6.4 Future research

Based on the findings of this dissertation, some suggestions can be made for future research.

As shown in past research and in Chapter 2 in the current dissertation, tonal contours can be distorted by the influence of the preceding and following tones, showing coarticulated forms which deviate substantially from the canonical contours. In tone perception, some studies have found that native Mandarin speakers can compensate for tonal variations due to coarticulation to some extent (Xu, 1994). The results of Chapter 2 demonstrated that the fine-grained phonetic details of tonal coarticulation can be acquired gradually by L2 learners in tone production. Whether coarticulated tones in running speech can be correctly perceived by L2 learners and whether they can develop a perceptual compensation mechanism for deviant tonal contours become interesting issues to investigate. Such an investigation can also shed light on the issue of ultimate attainment in tone acquisition.

Chapter 3 showed that the advanced Dutch learners of Mandarin had not only successfully acquired the distinctions between tonal categories, but had also developed a strategy similar to that of native Mandarin listeners in terms of attention distribution and segmental-tonal integration. Previous studies showed that bilinguals integrate both languages in a common phonetic space and that learning an L2 may bring about systematic phonetic changes in L1 production, which indicates that the L1 sound system is not static, but remains dynamic and adaptable (Aneta, 2000; Antoniou, 2012; Chang, 2012). It would be interesting to test whether a tonal L2 learning experience can further shape listeners' L1 perception. Specifically, it would be interesting to examine whether Dutch learners of Mandarin, when listening to Dutch, would attach more perceptual weight to pitch information and whether they would process segmental and pitch in a more integral manner compared to native Dutch speakers without any tone language learning experience.

Chapter 4 found that tones can be used in lexical access by Dutch learners of Mandarin. Interestingly, asymmetric patterns in the perception of tonal minimal pairs were found in advanced learners. The category of T1 was more well-established and T4



was less well-established compared to the other tones. Previous studies have also found asymmetric patterns in mapping phonetic information of a sound contrast to lexical representations in L2 listening, with one sound in the contrast more dominant than the other (Cutler, Weber, & Otake, 2006; Weber & Cutler, 2004). To further understand the asymmetric mapping from phonetic tonal information to lexical representations in L2 listening, the eye-tracking method can be employed to probe the temporal dynamics of L2 word recognition.

Furthermore, since this study only focused on the acquisition of lexical tones by Dutch learners of Mandarin, it would be worthwhile testing tonal processing by L2 learners with L1s different in prosodic structure. Such research can reveal how L2 tonal processing can be modulated by different L1s.