Chapter 6: Collateral damage of vocal changes?

When you chop wood, chips fly Nikolai Yezhov (Joseph Stalin NKVD officer, justifying executions of innocents)

6.1 Rationale

In the previous chapter we saw how hierarchical learning might explain the evidence supporting transition from coarse to fine units of vocal change. We suggested that as the acoustic structure becomes more consolidated, the size of segments should decrease (higher granularity). Another possible advantage to decreasing of the segment size is decreasing co-articulation-like adverse effects during learning. As mentioned in Chapter 4 (Discussion) might arise when the learning of one part of a continuous action adversely affect the structure of a neighboring part. Here we present a few cases where such interactions across different parts of the syllable seem to take place during learning. The results presented here are preliminary and conclusions should be considered as hypotheses for further studies.

In order to test how vocal changes of one part of a syllable may affect other parts we developed some new methods for tracking vocal changes across development, which might be useful for future studies and are hence presented in details.

6.2 Methods

6.2.1 Tracking vocal changes by local realignment

In order to track the vocal changes in the syllable across development we have to align syllables, and then locally realign the intra-syllabic events so as to be able to observe how changes in one song elements might affect neighboring elements (Fig. 6.1). As in previous chapters we focus on Wiener entropy as the principal feature. Figure 6.1 is composed of aligned segments of a syllable, where color represents Wiener entropy levels. The shape of Wiener entropy values over the syllable changes across development (from Day 50 to Day 76), starting from three coarse peaks and two minima, into a much more complex shape. On the left the syllables are aligned by the first millisecond (real time). On the right side syllables are locally realigned using our method. Note that on the right side of Fig. 6.1 the x-axis is not time anymore. Instead the x-axis represents the warped time. This representation enables us to align each event of the syllable with the corresponding event in the previous syllable. Figure 6.2 demonstrates the method.

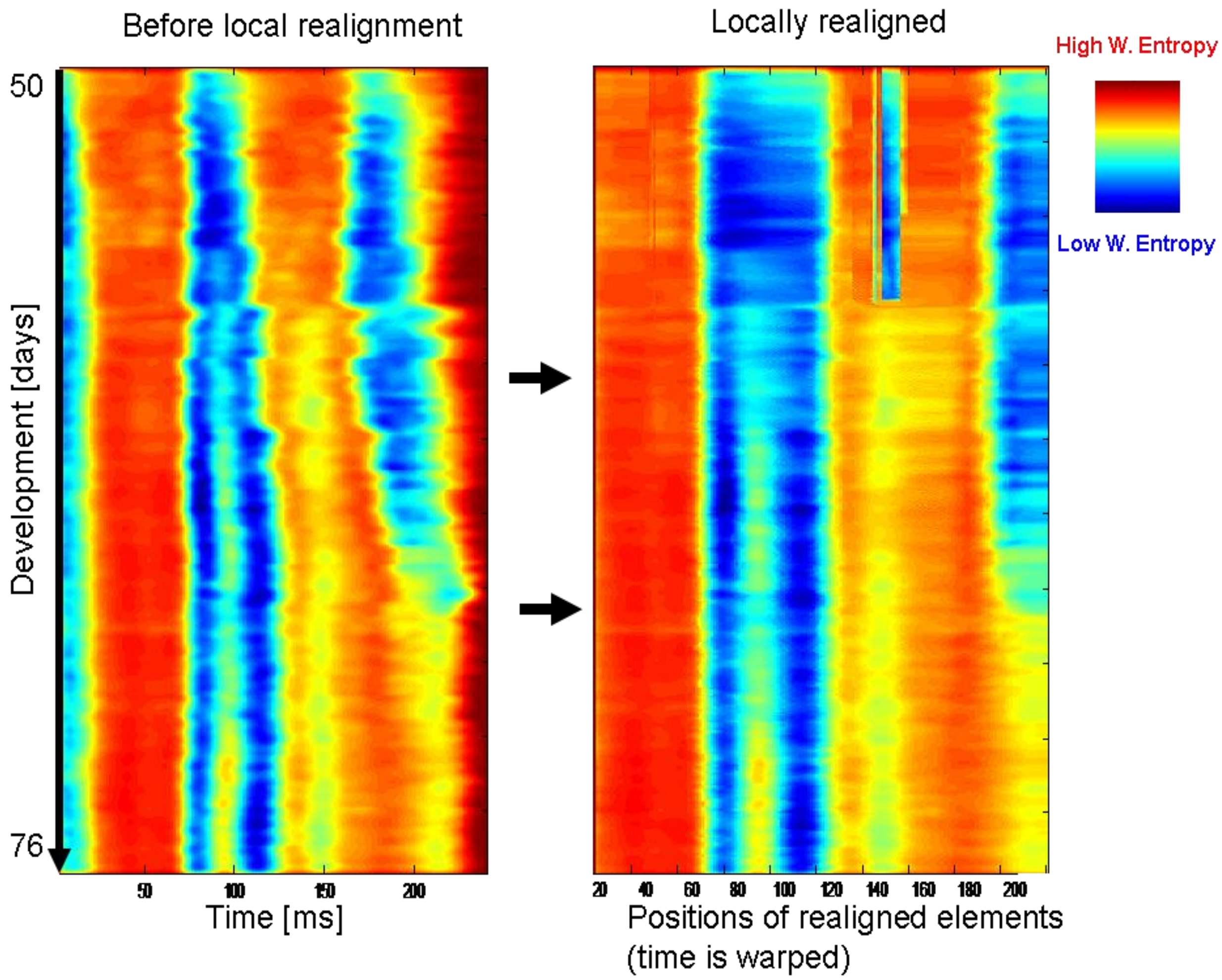

Figure 6.1 Results of local realignment. Wiener entropy is the feature used. The method aligns the syllables locally so that each event of the syllable is aligned with the corresponding event in a previous rendition of the syllables. See text.

We compute the maximum cross-correlation between two consecutive (in developmental time) segments of a syllable as the basis for realignment. However, not the entire syllables are cross-correlated but rather shorter segments (typically 30 ms long frames). The algorithm then "tracks" (according to best cross-correlation) each frame from the last day of development (in this case Day 76) to the first day of development. This is demonstrated in Figure 6.2.

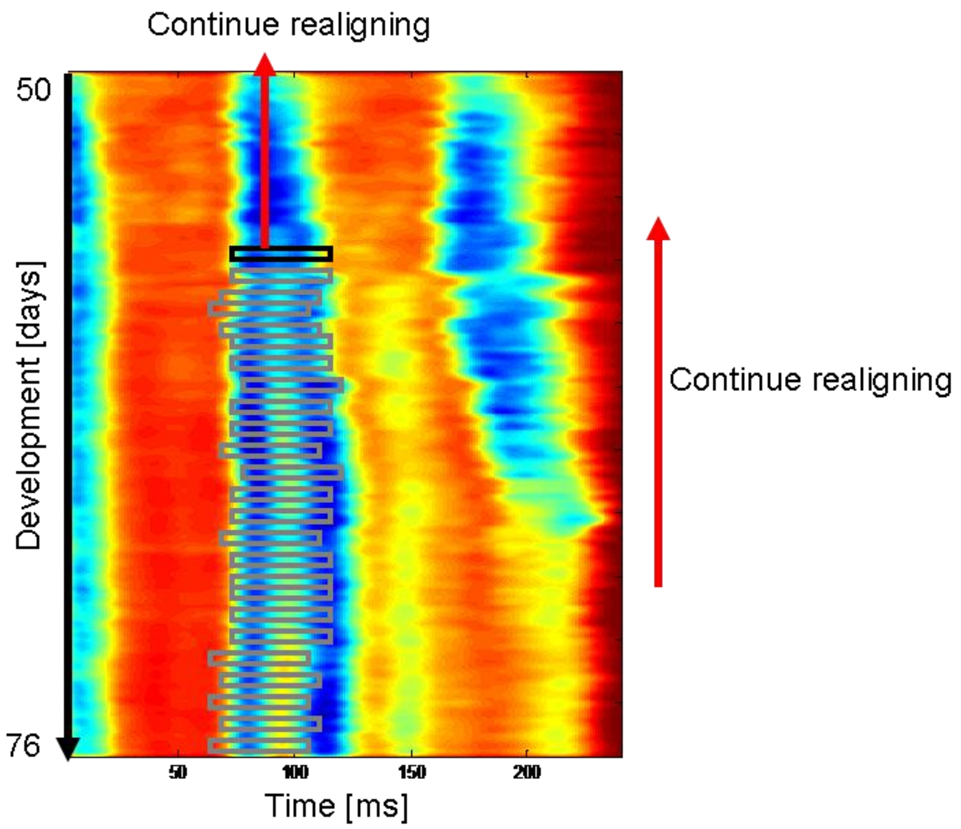

Figure 6.2 Algorithm for local realignment using best cross-correlation. Each frame (gray) is cross-correlated with the previous frame (in developmental time). The maximum cross-correlation is then used to realign the frames. Once the tracking algorithm reaches the beginning of development (Day 50 here) the entire process is repeated but the first frame (at Day 76) is moved for one millisecond in song time (x-axis). The final product of the algorithm is the realigned raster plot in Fig. 6.1 (right side).

The algorithm continues to locally realign frames from the end of development (Day 76) to the beginning of development. Once that point is reached the process repeats, but this time the first frame (at Day 76) is chosen one millisecond later in song time (the x-axis). The final product of the algorithm is the realigned raster plot shown in Fig. 6.1 (right side). Note in the realigned raster Figure 6.1 an artifact caused by the algorithm (right side, starting at Day 50 at about 130 on the x-axis). Such artifacts will be covered in the following figures.

6.2.2 Determining significant vocal changes in the syllable

We used locally realigned raster plots as the one shown in Figure 6.1 in order to measure the developmental vocal changes. For each realigned element (x-axis) we computed the amount of change over a period of one day, for every day of the development. Only the statistically significant changes were accounted for.

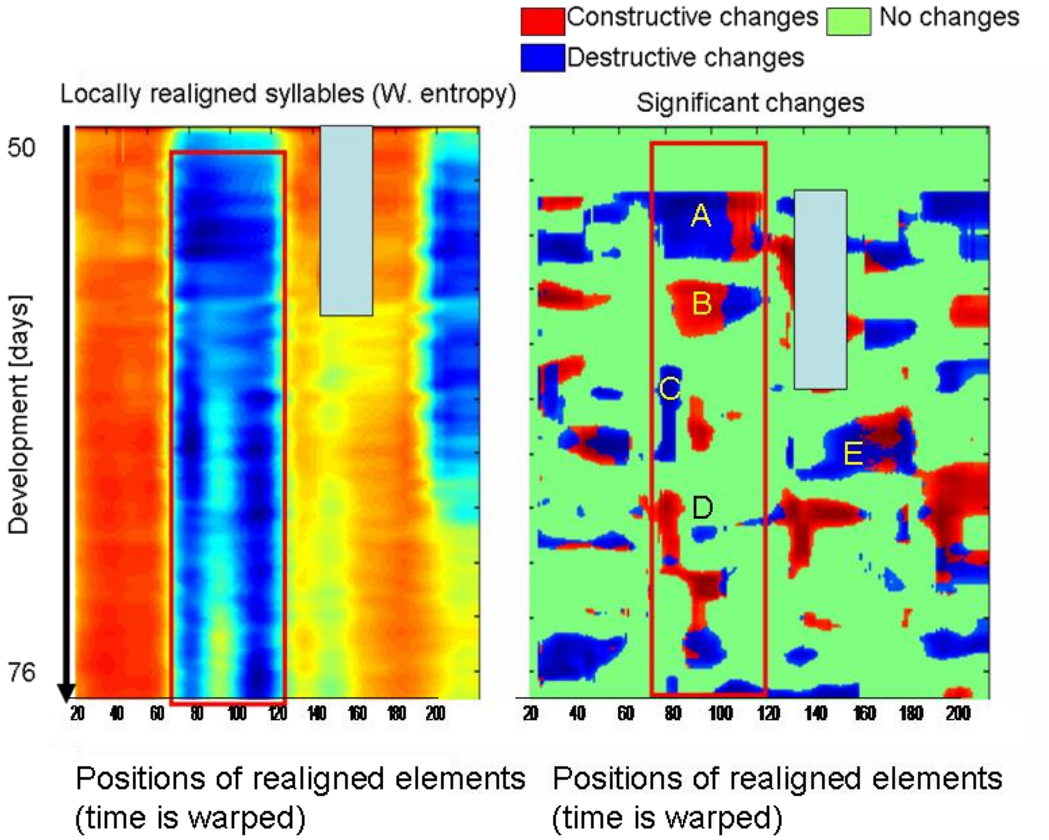

Figure 6.3 Constructive and destructive vocal changes. See text.

6.3 Results and Discussion

Figure 6.3 shows the realigned raster as produced by the local realignment algorithm described in the Methods (left side). The right side of Fig. 6.3 shows statistically significant vocal changes of realigned elements (all events in the syllable) as they occurred each day (one day was the frame in which changes were measured). Red colored changes represent "constructive" changes – where the syllabic structure becomes more similar to the song model that the bird is imitating. Blue areas in Fig. 6.3 (right raster) are significant vocal changes in the direction away from the song model ("destructive changes"). The green background of the raster represents the areas where no significant vocal changes happen (during each day).

Note in Fig. 6.3 that the changes are broad at first (at the beginning of development) but become narrower over developmental time. This is particularly noticeable in the area inside the red frame in the raster.

Compare the area in the red frame in the right raster in Fig. 6.2 to the same frame in the left raster plot. Notice in the left raster that a new event in the Wiener entropy was created. At first the framed area in the left raster is blue (low Wiener entropy) but later in development a peak of Wiener entropy appears. Now note in the right raster the broad vocal change that happens in this developmental period (labeled "A"). Most of this change is destructive (blue) but there is a short part of the change that is constructive (red part). Immediately after this (the next day) another broad change appears (labeled "B") but now most of the change is constructive (red). In fact the change B seems to compliment the previous change A (and is also narrower). The change B happens when the peak in Wiener entropy appears (see left raster).

We speculate that early in development the bird makes broader changes as the segmentation is broad (see Chapter 5, hierarchical learning). As a result only a part of the change is constructive, while its periphery (neighborhood) is destructive. This seems to be the case for change B in Fig. 6.3. As the bird was creating the Wiener entropy peak he also increased the Wiener entropy around the peak. This “collateral damage” shows up as a destructive change in Fig, 6.3 (the change labeled “B”).

There are other possible causes of destructive vocal changes. One such cause could be the attempt to segregate to neighboring parts of the syllable in order to control their development separately (the attempt to segment the action). The change labeled “C” in Fig. 6.3 could suggest such attempt. In such a case it may be preferable to first separate two parts of a syllable by “moving” them in opposite directions and only after the separation (when independent control of both parts becomes possible) change them in the right direction. This may be happening at label “D” in Fig. 6.3 where a narrow corrective change (red, constructive change) is happening.

The third possible cause of destructive changes may be neglect of some parts of the syllable when other parts are changing. This hypothesis suggests the existence of “motor attention”. It could be that some parts of the action that require a large portion of a limited resource of motor attention will cause other parts to slightly deteriorate. This could be particularly relevant when difficult parts of continuous actions are learned. The vocal change labeled “E” could be and example of such deterioration.

So far the data supporting these hypotheses are still anecdotal (observed in two out of eight birds studied). It would be interesting to perform an experiment in which young birds that can presumably only perform broad vocal changes would be reinforced to add a short time-scale element to their syllables as in Tumer and Brainard experiment with older birds (Tumer and Brainard, 2007). We could predict that early in development the birds will make broad changes with significant “collateral damage” in the periphery of the newly added element (such as label “A” in Fig. 6.3).