COARTICULATION AND GESTURE: AN ANALYSIS OF MELODIC MOVEMENT IN SOUTH INDIAN RAGA PERFORMANCE

Lara Pearson

Introduction

Karṇāṭaka saṅgīta, referred to here as Karnatak music,[1] is a genre of art and devotional music which developed in the royal courts and temples of southern India over a period of many centuries and that still enjoys popularity in India today.[2] The style comprises both compositional and improvisational elements, with the two overlapping, as compositions may be modified by the performer, and improvisations draw on characteristic phrases handed down from teacher to student. This article will focus on the element known as *rāga ālāpana*, a form of improvisation without meter. A short section of such improvisation will be analysed here from a novel perspective employing the concept of coarticulation, a phenomenon more commonly discussed in the field of phonetics where it is defined as the variation that a speech sound undergoes due to the influence of neighboring sounds (Hardcastle and Hewlett 1999, p. i). Following from this definition, the aim of the present study is to account for variations in the performance of Karnatak musical units known as *svaras* (scale degrees of a rāga) and *gamakas* (ornaments) through the phenomenon of coarticulation, looking at the influence of context on the realisation of musical units. This analysis focuses more on coarticulation in the music itself, than in the movements that create it; however, as the two are closely related, some discussion of the physical motion of sound-producing gestures is included here. Through this analysis the article seeks to provide an account of small-scale melodic movement in the Karnatak style, drawing more from musical practice than music theory, and focusing on the dynamic processes that form the style rather than categorisation of discrete elements.

My inquiry finds an apt analogy in Kühnert and Nolan's (1999) insight regarding the presence of coarticulation in handwriting. They note that the tail of a 'y' is drawn differently depending on its context: remaining open when written at the end of a word, and closed with a loop if followed by another letter (1999, p. 9). I suggest that just as handwriting can be conceptualised as the trace of human movement on paper, so can music be thought of as the trace of human movement through sound. In this study I ask whether *svaras*, the basic conceptual units of Karnatak music, vary in the way they are rendered during performance due to the influence of their immediate context, in the same way that handwritten letters vary in execution according to the letters that precede and follow them.

In Karnatak music, *svaras* (scale degrees of a rāga) and *gamakas* (ornaments) are the smallest melodic units commonly referred to by performers. *Svaras* are not equivalent to musical 'notes', because while *svaras* as they exist in theory refer to a single pitch position, in practice they are frequently expressed through melodic fluctuations known as *gamakas*. The term *gamaka* is usually translated as ornament, however in Karnatak music *gamakas* cannot be considered mere embellishments, as they convey fundamental information regarding the rāga and its associated *bhāva* (mood or feeling). In performance, *gamakas* can be heard as wide and narrow pitch oscillations, fleeting leaps, turns around a central pitch, and slides with various types of emphasis. Attempts to categorise and systematise *gamakas* have been numerous in the history of Indian musicology; examples can be found in ancient treatises such as the thirteenth century *Saṅgīta-ratnākara* (see Shringy and Sharma 2007) which describes fifteen types of *gamakas*, the early 17th century R*āga-vibhoda*, which cites the existence of twenty categories (Powers and Widdess 2001, p. 190), as well as in more recent accounts (for example, Powers 1959 and Kassebaum 1987). Categories presented by Powers based on existing typologies found in music treatises include deflections (oscillations such as kaṁpita), slides (jāru), and fingered stresses (janta) (1959, p. 147).

Such categorisations may indeed be useful when seeking to refer to some of the melodic

fluctuations found in the style. However, notwithstanding his own creation of a *gamaka* typology, the Karnatak musician and musicologist T. Viswanathan noted that the multitude of subtle variations seen in the performance of *gamakas* tend to defy systematic classification (1977, p. 32). As a professional Karnatak musician of the highest calibre, Viswanathan was well positioned to know whether *gamaka* typologies were adequate to fully account for the range of fluctuations found in performance, and so his reservations here should be pondered. While *gamaka* typologies are taught in theory classes at music colleges, such terms are rarely used in practical vocal and instrumental lessons; music tuition in South India proceeds largely through demonstration and imitation with verbal explanation and use of notation kept to a minimum.[3] I would suggest that the relative absence of *gamaka* typologies in practical music lessons points to their limitations as descriptors for small-scale melodic movement in Karnatak music from a performer's perspective, which in a style that includes a high proportion of improvised content should be considered a perspective of great significance.[4] Therefore, in line with Viswanathan's reservations I avoid conceptualising *gamakas* through typologies, and instead treat them as a multiplicity of melodic fluctuations that serve a number of functions, which include expressing the mood of the rāga and creating links between one *svara* and the next.[5] Rather than provide a typology of *gamaka*, one of my aims here is to demonstrate how coarticulation plays a role in determining the forms taken by *gamakas* in performance.

While there has been no previous analysis of *svaras* and *gamakas* using such an approach, various authors have pointed towards the significance of context in determining the performance of *gamakas*. Swift (1990) states that the countours of *gamakas* 'vary from one context to another, depending on the preceding and succeeding *svara*(s)' (p. 72). Here he draws on a quote from Rangaramanujar Ayyangar (1972) who explains the role played by *gamakas* in forming relationships between *svaras*.

The moment a Gamaka clothes the Swarasthana [position of a rāga's scale degree], the

latter is quickened into life. For the Gamaka builds up a relationship with neighbouring members of the family to the right and to the left. (Rangaramanujar Ayyangar 1972, p. 148)

The significance of context on the form taken by *gamakas* used to perform *svaras* is also emphasised by the Karnatak musician and musicologist N. Ramanathan who refers to the 'contextual determination of the shape of a svara' (2004, p. 14). Considering such statements, coarticulation, which deals with variation in the realisation of units depending on their context, appears to be a suitable concept for the analysis of *svaras* and *gamakas* as they appear in musical practice. Just as coarticulation in phonetics is the analysis of phonemes as they are spoken, this will be an analysis of *svaras* as they are realised by *gamakas* in performance.

Background

(i)   Coarticulation

In the field of phonetics, research into coarticulation was prompted by the observation that a phonological segment is not realised identically in all contexts, but rather varies due to the influence of neighbouring sounds (Kühnert and Nolan 1999, p. 7). For example, the articulation of a phoneme may be influenced by the vowel that follows it:

The English phoneme /k/, for instance, will be articulated further forward on the palate before a front vowel ([kiː] 'key') and further back before a back vowel ([kɔː] 'caw'); and will have a lip position influenced by the following vowel (in particular, with some rounding before the rounded vowel in [kɔː] 'caw'). (Kühnert and Nolan 1999, p. 7)

While coarticulation is an important area of study in phonetics, where it has a long research history (see Farnetani and Recasens, 2010 for an overview), studies of coarticulation in human movement are relatively uncommon. For coarticulation to exist, there must first be discrete,

4

conceptually invariant units that subsequently show variation in performance (Kühnert and

Nolan, 1999, p. 7). In phonetics this unit is the phonological segment, but most examples of

human movement are not comprised of conceptually discrete elements. However, phenomena

such as sign language and music do consist of such units, making the study of coarticulation

possible in these cases. For example, in their study on fingerspelling in American Sign Language,

Jerde et al. (2003, 2006) define coarticulation as the influence of surrounding movements on the

posture of individual units within sequences (2006 p. 82), and find that hand postures spelling a

letter contain significant information regarding preceding and following letters (p. 83).

Meanwhile, other sign language based studies have focused on detecting and modeling

coarticulation in this context (for example, Yang and Sarkar 2006; Segouat 2009).

     A relatively small number of studies have explored coarticulation in musicians' sound-

producing gestures. Engel et al. find evidence of anticipatory modifications in pianists' hand

movements (1997, p. 198) while Wiesendanger et al. (2006, pp. 114-115) note anticipatory

mechanisms at work in violin fingering. In addition, an examination of muscle activity during

piano performances by Winges et al. finds evidence of neuromuscular coarticulation within hand

movement sequences (2013, p. 230).

     While these music-based studies observe coarticulation in sound-producing movements,

Godøy (2011) has explored the perceptual results of such physical coarticulation in addition to

examining the processes involved in its production (Godøy et al. 2010). His definition of

coarticulation as 'the fusion of otherwise distinct events, meaning both action events and sound

events, into larger and holistically perceived chunks' (Godøy et al. 2009, p. 1) contrasts with

definitions employed in phonetics, which, as we have seen, more usually refer to variations in the

performance of a unit dependent on context. However, both approaches refer to the same

phenomenon, one from a production perspective, and the other focusing more on perception.

Following from this approach, Godøy (2011) coins the term 'contextual smearing' to describe the

blurring of borders between 'atom events' such as individual notes, resulting from physical

coarticulation. Such contextual smearing may lead larger chunks to be perceived as fused units, referred to by Godøy as 'gestural-sonic objects' (2011, pp. 73 and 68).

Further to his discussion of coarticulation in music, Godøy suggests that such gestural-sonic objects should be regarded as 'primordial' to 'atom events' such as individual tones (2011, p. 71). This proposal leads to a discussion of whether gestural-sonic objects are formed from sequences of discrete units subject to coarticulation, or whether instead gestural-sonic objects should be considered as basic musical units that have over the course of time been split into atom events such as individual notes (2011, p. 72). In Karnatak music, *svaras* as they exist in practice, expressed through *gamakas* and connected in sequences known as *sañcāras* (characteristic phrases), could be described as gestural-sonic objects, while *svaras* as they exist in theory, without ornament and divorced from characteristic phrases, could be viewed as atom events. Interviews with Karnatak musicians conducted during the course of my research indicate they consider all three concepts, *svara, gamaka*, and *sañcāra*, to be essential for successful performance and teaching of the style. Therefore, the present study refrains from claiming either an atomistic or gestural approach to be more significant than the other, and instead aims to explore the relationship between the two in theory and in practice.

(ii)   *Svara*, *gamaka*, and *sañcāra* – interrelated concepts
The primary melodic idea in Karnatak music is rāga, the performance of which aims to create a particular *bhāva* (mood or feeling). This is achieved through the expressive rendition of *sañcāras* (characteristic phrases) formed from *svaras* (scale degrees) at particular *svarasthānas* (pitch positions) with the assistance of *gamakas* (ornaments). There are 12 *svarasthānas* in an octave, although as we shall see, the pitches touched during a performance are not confined to a division of the octave into 12 equally spaced semitones. *Gamakas* are often described as adding colour to *svaras*, and if the appropriate *gamakas* are not used when performing a *svara* sequence, the mood of the rāga will not be properly expressed (see Viswanathan 1977, Powers and Widdess 2001, and

6

Pesch 2009).

Svaras are sung and often referred to using the *sargam* syllables *sa*, *ri*, *ga*, *ma*, *pa*, *dha*, and *ni*, similar to the *solfège* system in Western music. In addition the *svaras* have full names, *ṣaḍja*, *ṛṣabha*, *gāndhāra*, and so on, which I have avoided using here for the sake of simplicity. While *svara* names and *sargam* syllables are used to refer to a rāga's scale degrees and theoretical pitch positions, *svaras* can, however, only be performed in combination with the *gamakas* that convention dictates should be played on each *svara* in a given rāga. Viswanathan clarifies this point:

> Theoretically, one can define a svara simply as a scale degree (sa = tonic, pa = fifth, ni = seventh, etc.) or interval (ga flat, ma sharp, da natural), but in practice a svara is properly defined only when taking into consideration the gamaka(s) traditionally associated with it. (Viswanathan 1977, p. 31).

While in theory *svaras* and *gamakas* are separate concepts, in practice, *svaras* are inextricable from the *gamakas* with which they are played. Therefore, as my analysis is of performance practice rather than music theory, it will be necessary to examine the two in tandem. Consequently, this article will be an exploration of coarticulation that occurs between *svaras* as they are performed through *gamakas*. Although it is *svaras* that are subject to coarticulation with those that precede or follow, this coarticulation is realised through the *gamakas* with which *svaras* are played.

(iii)   The expression of *svaras* through *gamakas*: apparent conflicts between theory and practice

It is important to note that in Karnatak music, certain wide oscillating *gamakas* do not rest on the pitch theoretically indicated by the *svara*, but instead imply the pitch through an oscillation either

side of it. For example, in rāga Toḍi, the third degree of the scale, *ga*, is often played as an oscillation between the pitch below and pitch above that which is indicated by the *svara's* name. To illustrate further, if the tonic, *sa*, is placed on A, the theoretical pitch position of *ga* is C♮. However, in rāga Toḍi, *ga* is commonly performed as an oscillation between B♮ and D, without dwelling on C♮ at any point (see Fig. 3). An additional confusing factor is that B♮ does not even appear in the theoretical scale of Toḍi when *sa* is placed on A; however, it is prominent in the *gamaka* used to play *ga* in this rāga.[6] Although these aspects of rāga performance may seem perplexing to those unfamiliar with Karnatak music, they are common in the style, and something that students learn to accept early in their studies. Oscillations implying a pitch without actually resting on it exist in many important Karnatak rāgas including Śaṅkarābharaṇam, and Bhairavi, and the emphasis of pitches that lie outside of the theoretical scale also occurs in rāgas such as Asāvēri and Madhymavāthi (Krishnaswamy 2004). This feature of Karnatak music is referred to by the musicologist N. Ramanathan when he notes that 'In practice, quite often a svara might originate from or/and involve touches of svarasthāna-s that are not associated with the rāga at all (2004, p. 13).

Such variance between Karnatak music theory and practice is largely due to the tendency for theory to be created as a post-hoc abstraction of existing musical practices. For example, the precursor of the *meḷakartā* system of rāga scales that is used today was proposed in the 17th century in the treatise *Caturdaṇḍī-prakāśikā*, authored by Veṅkaṭamakhin (see Powers and Widdess 2001, p. 177). However, the rāgas it attempted to categorise existed long before that time (Pesch 2009, p. 174), and, in fact, many rāgas, both ancient and modern, fail to fit in any one of the scalar divisions employed today.[7] Although the categorisation of rāgas by scale was an interesting intellectual effort, and is perhaps useful for ease of reference, the more ancient rāgas tend not to be primarily scalar in nature, but instead are better defined by characteristic phrases known as *sañcāras* or *prayogas,* as well as through the combined sonic-gestural quality of certain

8

gamakas typical of the rāga.[8]

The conflicts between theory and practice in Karnatak music were highlighted in a series of debates that took place at the Music Academy of Madras from 1930 to 1952 during the organisation's yearly conferences. These meetings aimed to systematise the style, with the goals of reducing variance in performance and resolving conflicts between theory and practice (Allen 2008). Frequent disagreements occurred between members of the Experts Committee as they attempted to reconcile music practice with theoretical structures such as the *meḷakartā* system (2008, pp. 108-118). Although on paper, the conflicts were resolved, in practice disjuncture still remains.

(iv) *Svara* **and** *gamaka* **as they are conceived in practice**

Considering that in the performance of certain *svaras*, the theoretical pitch degree is not touched directly but implied, there is a sense in which the *svara* name acts a placeholder for a musical gesture that expresses the *svara* as it should appear in that rāga. As Morris (2011) explains, conceptually it is incorrect to characterise *gamakas* as ornaments embellishing a particular pitch; instead a more accurate approach is to consider that there are a number of possible ways to perform a *svara* in a given rāga (2011, p. 16). His analysis of two recordings in rāgas Kalyāṇi and Bhairavi demonstrates the latter approach, transcribing and listing the brief melodic motifs used to realise each *svara*. For example, in the recording of a composition in rāga Kalyāṇi, Morris finds between four and eleven different motifs used to perform each *svara* (2011, pp. 20-21). I would suggest that the analytical approach used by Morris here supports the significance of the merged *svara-gamaka* unit for the analysis of Karnatak music. Therefore, I will, for the sake of brevity, occasionally use the term *svara-gamaka* unit when referring to a brief melodic motif, which is in effect the *gamaka* used to play a *svara* in a particular context.

It should be noted that within such *svara-gamaka* units, the pitches touched in addition to or instead of the named *svara* pitch, including those that lie outside of the theoretical rāga scale,

9

are not random or subject to the whim of the performer. A degree of precision in pitch, rhythm, and emphasis is required in order that the performance of the *svara* should conform to unwritten conventions. My Karnatak violin teacher, based in Tamil Nadu, clearly considers that there is a right and wrong way to play the *gamakas* on each *svara* in a rāga, as he takes great pains to correct my rendition when I make errors in intonation or emphasis. Indeed, if the *gamaka* on a *svara* is not performed correctly, a different rāga may be implied or the rāga *bhāva* (mood of the rāga) may be lost.[9] However, pitch analysis studies of Karnatak music recordings have found that the pitches touched during *gamakas* do vary to some extent across performers and performances (see Subramanian, M. 2002, 2007; Krishnaswamy 2003). So there remains the somewhat confusing scenario in which musicians believe precision in the performance of *gamakas* to be important, while in practice there exists a degree of pitch variation. It may be that precision in pitch is important only to an extent, with the style displaying a certain degree of tolerance towards variation, particularly in fast passages or for lightly touched pitches. Alternatively, it is possible that certain points of *svara-gamaka* units require precision, while others may be treated more loosely. Pitch is only one element in the correct rendition of *svara-gamaka* units, with rhythm and emphasis also being critical. As we shall see later in the present study, there are cases in which the overall gestural quality of a *svara-gamaka* unit seems to hold equal significance to the pitches touched during its performance. Further research is required on such issues; however, this lies outside the scope of the present study.

The performance and analytical method

The video analysed here was recorded in Srirangam, Tamil Nadu in September 2011 and shows the violinist T.K.V. Ramanujacharlu, a senior performer and top graded artist at All India Radio, performing *ālāpana* in rāga Toḍi. The recital took place in the musician's home, and was made specifically for the purpose of this research in order to afford optimum conditions for video and sound recording. As a respected professional performer, T.K.V. Ramanujacharlu's rendition here

10

can be seen as typical of the Karnatak style, which although allowing subtle variations between performers is bound by a complex system of conventions.

Between 2007 and 2011 I spent several long periods learning Karnatak violin in South India, the last three years of which were as a student of the violinist in the recording analysed here. The hundreds of hours spent observing and learning from my teacher form the foundation of this article. Between 2012 and 2014 I conducted several fieldwork trips, videoing lessons given by a range of musicians across South India, and interviewing both teachers and students on subjects such as the relationship between music theory and practice. This accumulated experience has proved invaluable for the insights provided into Karnatak music practice and transmission.

Fig. 1. A single frame from the video image analysed in this study. Karnatak violin is played with the scroll held against the violinist's foot. During oscillations the fingers are held together in a bunch, and move together as one unit.

The analysis that follows is formed from a joint examination of melodic and physical movement in the particular performance. The kinetic data used in this study is the tracked position of the violinist's left hand as it moves up and down the fingerboard, derived through video tracking.[10] Video was recorded at 23.98 frames per second, and framed to show a close-up of the violinist's

left hand on the fingerboard (see Fig. 1). In Karnatak music the violinist sits on the floor with the scroll of the violin held against his or her foot. The other end of the violin rests either just above or below the performer's collarbone, and is sometimes gripped by the chin for increased stability. The manner in which the violin is held means that the camera, when placed directly in front of the performer, is presented a clear and relatively stable view of the violinist's left hand motion in two dimensions.

Once the video recordings had been made, Adobe After Effects motion graphics software was used to track the position of the first finger of the violinist's left hand. Karnatak violin technique differs from the Western classical style in that for much of the time the fingers of the left hand are held tightly together; my teacher once used the analogy of a flower bud to convey the correct finger posture. This hand position is used particularly when performing the oscillations that are characteristic of the Karnatak style. When an oscillation is executed, the entire hand usually moves back and forth as one unit. Therefore, by tracking the position of the first finger the resulting data can be used to create visual representations of the left hand's motion trajectory during oscillations.

The opening thirty-nine seconds the violinist's performance was parsed into phrases of between two and five seconds. Choices for phrase divisions were based on both sonic and kinetic parameters; the recording was split at points where there was either a sonic gap, or lack of hand movement for more than one second. A single phrase in which there were no such breaks for over five seconds was divided into two sub-phrases, cut at the point where the hand was motionless for the longest period within that time. This parsing process resulted in the creation of seven phrases for analysis.

The audio files for these phrases were imported into Praat sound analysis software (Boersma and Weenink 2012), in which graphs plotting pitch against time were produced. Composite figures were then created, with transcriptions into both Indian *sargam* and Western staff notation. The transcriptions and pitch contour graphs, together with descriptions of the

violinist's hand movements and figures showing the tracked hand positions, are presented and discussed in the following analysis of coarticulation in small-scale melodic movement.

Notes on the transcriptions and figures

The *sargam* notation provided here was written in collaboration with the performer, while I created the staff notation alone through repeated listening to the recording. The aim of the transcription into staff notation was to present a detailed picture of the perceptually salient points in the *gamakas* that were used to perform the *svaras* in each phrase. Observing the relationship between the pitch contour graphs and transcription into Western staff notation, it can be seen that where the graph shows a continuous oscillation or slide, I have transcribed those pitches that lie at the outer edges of the melodic movement. This is because when listening to the recording these are the most perceptually salient events. Although the sliding or smearing that occurs between pitches can be heard in the recording, the pitch events at the outer edges of the oscillations and leaps are more prominent than the 'glissandi' in between. The outer edges of the oscillations are also the salient points for instrumentalists, as their fingers should land at these pitch points, to within a certain degree of tolerance, for the rendition to be considered acceptable.

I have avoided using accidental symbols or arrows in the staff transcription to indicate intervals slightly larger or smaller than a semitone, as this would result in a confusing profusion of such marks. Instead, the subtle details of pitch can be viewed in the pitch contour graph. In addition it will be seen that I have not added lines to indicate slides between pitches touched at the extremes of oscillations, as the abundance of such marks would make the transcription rather unclear. Instead, the reader should note that all oscillations seen in the transcriptions are joined by a sonic sliding or smearing effect, as the violinist performs such oscillations using a combination of sliding and rocking motions in the left hand.

Regarding the transposition, in Karnatak music, *sa* (the tonic) is placed at whichever pitch the soloist finds most comfortable. For female vocalists *sa* is usually placed between G

(196Hz) and A (220Hz), and for male vocalists it is typically set between B (124Hz) and C sharp (139Hz). When accompanying a vocalist, the violinist tunes their violin to accommodate the soloist's preferred pitch, but played one octave higher. Violin solos, however, are usually performed with *sa* at D sharp or E (311 or 330 Hz), and in the performance analysed here, *sa* is placed at D sharp. The transcriptions that appear in this analysis have been transposed to place *sa* at A, to bring Western and Karnatak violin fingerings into alignment.[11] This should make it easier for Western violinists to relate the transcriptions to their own fingering patterns.

The graphs showing left hand movement (for example, Fig. 6) illustrate the position of the first finger of the violinist's left hand, with each data point representing one frame of the video from which the finger's position was tracked. The position of the first finger provides a good reference for the overall movement of the hand, due to the previously noted tendency for the hand to move up and down the string as a unit in Karnatak violin technique. However, in addition to this motion, there is often a rocking movement articulated at the wrist, during which time the second, third, and fourth fingers may also touch the string or even reach out to sound a much higher pitch. Therefore, the hand motion graph does not map directly on to pitch, as it does not take into account the movement of the other fingers. It simply shows the first finger position, and reflects the motion of the hand as a whole.

The shaded areas of the hand motion figures give an approximate indication of the *svara* being played at each point of the movement. These are separated by white spaces to aid legibility. Spaces longer than one frame indicate silence. However, these graphic elements are for guidance only, as the very phenomenon explored in this article, coarticulation between *svaras*, makes it difficult to state precisely where one *svara* ends and another begins.

Rāga Toḍi

Here I will build a picture of rāga Toḍi as it exists in theory and in practice, before moving on to the analysis of the rāga *ālāpana* performance. A transcription of the theoretical pitch positions of

14

the *svaras* in rāga Toḍi is given in Fig. 2. However, an ascending and descending phrase in Toḍi would never be performed with plain notes as shown here. All *svaras* in this rāga, with the exception of *sa* and *pa*, should be performed with appropriate *gamakas*, although *ma* is frequently performed as a plain note. Fig. 3 presents a transcription of *gamakas* that may be used to perform the *svaras* of Toḍi, based on a demonstration given by T.K.V. Ramanujacharlu. This outline is typical of what a teacher might play to a beginner student when introducing them to the rāga. As can be seen in this transcription, the majority of *svaras* in Toḍi are performed using *gamakas*, constituting small units of melodic movement on and between *svaras*. As we shall see in the analysis that follows, the way a *svara* is played varies greatly depending on its context, and it is these variations that I will be examining for evidence of coarticulation.
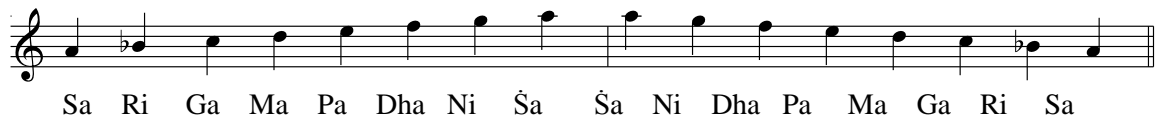
Fig.2. The theoretical pitch positions in the *ārohaṇa* and *avarohaṇa* (ascending and descending scale progression) of rāga Toḍi transcribed into staff notation with the *svara* names indicated using *sargam* syllables below.
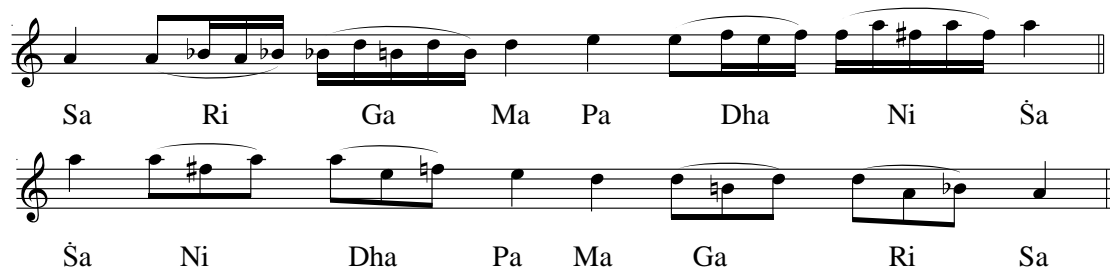

Fig. 3. A basic rendition of the *ārohaṇa* and *avarohaṇa* (ascending and descending scale progression) *in* rāga Toḍi showing the clusters of pitches that form the *gamakas* on each *svara*. This transcription has been made from a demonstration given by T.K.V. Ramanujacharlu during an interview recorded in Srirangam in September 2011.

The transcriptions in Figs. 2 and 3 provide only an approximation of the actual pitches touched in Toḍi, as intervals less than a semitone are conventionally played in this rāga. While contemporary

15

books of Karnatak music theory usually cite the existence of 22 *śrutis* (pitches) in an octave (for example Chelladurai 2005, p. 267), in practice the pitches played in many rāgas do not correspond to this or any other existing theoretical subdivision (Komaragiri 2013, Subramanian, M. 2002; see also Rao and van der Meer 2010 for a discussion of pitch in Hindustani music). Several examples of intervals smaller than a semitone can be seen in the pitch contour graphs accompanying the analysis that follows. For example, the highest point of the oscillation forming *ri* is often placed less than a semitone up from *sa* (see Fig. 5).

Looking at Fig. 3 it can be seen that the pitches transcribed, which lie at the outer edges of the oscillating *gamakas*, include two that are foreign to the rāga scale in Fig. 2: B♮ and F♯. These two pitches, although not present in the rāga scale, are standardised across performers and performances as being the correct lower pitch in the rendition of oscillations used to express *ga* and *ni* respectively; all the teachers observed during my research have imparted Toḍi in this way. This information is rarely given in books of music theory, and even in music lessons certain teachers may prefer not to explicitly name these foreign pitch positions. However, through repeated demonstration and correction teachers ensure that their students understand that the oscillating *gamakas* for *ga* and *ni* should employ these pitches. As we shall see in the analysis that follows, B♮ and F♯ appear frequently when these two *svaras* are performed. However, in addition to these two frequently occurring foreign pitches, we shall see several others that are not standardised across performers and performances in the same way. The presence of such divergent pitches, I would suggest, is likely due to a certain degree of tolerance in the style towards variance in pitches touched at the outer extremes of *gamakas* that are particularly rapid, or otherwise indistinct.

Analysis

The opening section of rāga *ālāpana* performed by T.K.V. Ramanujacharlu has been transcribed

16

in full in Fig. 4. The analysis that follows will treat each of the seven phrases within this opening section individually, examining context dependent variation in the performance of *svaras*.

Fig. 4. The opening thirty-nine seconds of Toḍi *rāga ālāpana*, performed by T.K.V. Ramanujacharlu in Srirangam, Tamil Nadu in September 2011. The transcription into staff notation is a representation of the prominent pitches touched during the *gamakas* that express the *svaras* comprising each phrase. The *svaras* are indicated as *sargam* syllables below the staff notation.

(a) Phrase One
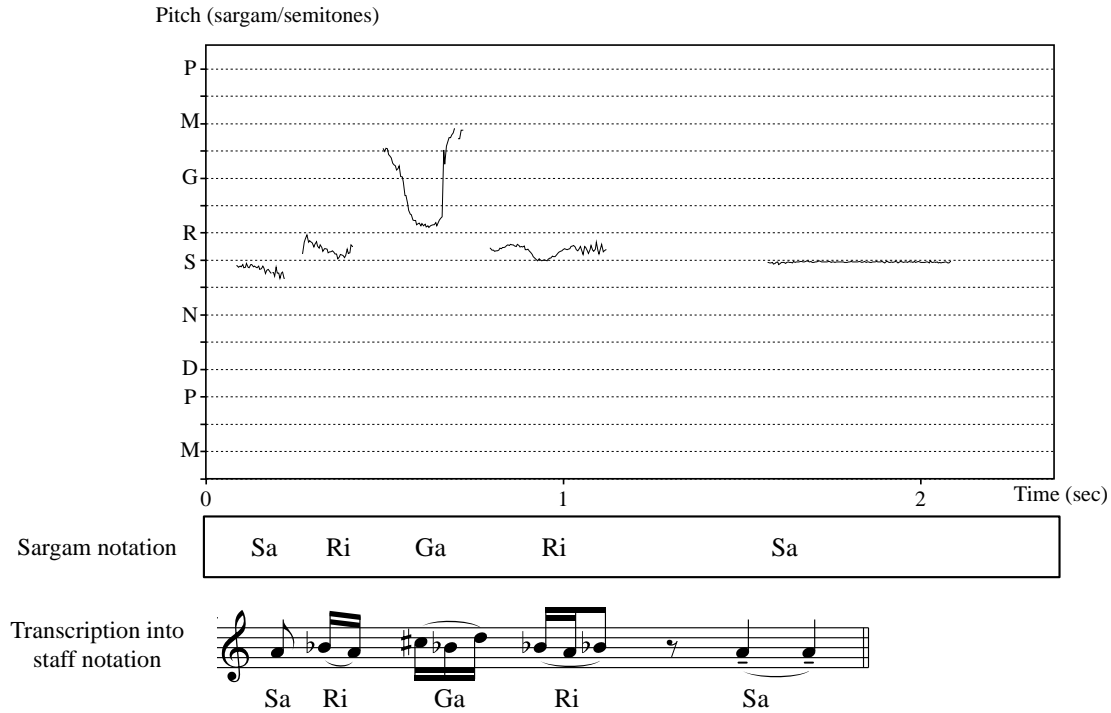
Fig. 5. Toḍi *rāga ālāpana*. Phrase 1. A composite figure showing pitch contour graph, *sargam* notation, and transcription into staff notation for the phrase *sa-ri-ga-ri-sa*.

The opening section (Fig. 5) comprises five *svaras*, forming a characteristic phrase that is often used to open *ālāpana* in this rāga. *Sa* is played without *gamaka*, as is usually the case in Karnatak music. The other three *svaras*, *ri-ga-ri*, are performed with *gamakas* appropriate to the rāga. The pitch contour graph in Fig. 5 concurs with the *sargam* notation, showing five separate sonic events, each played with a separate stroke of the bow. In addition, this graph shows the glissandi that occur between pitches, created by the violinist through a combination of sliding and rocking motions in the left hand.
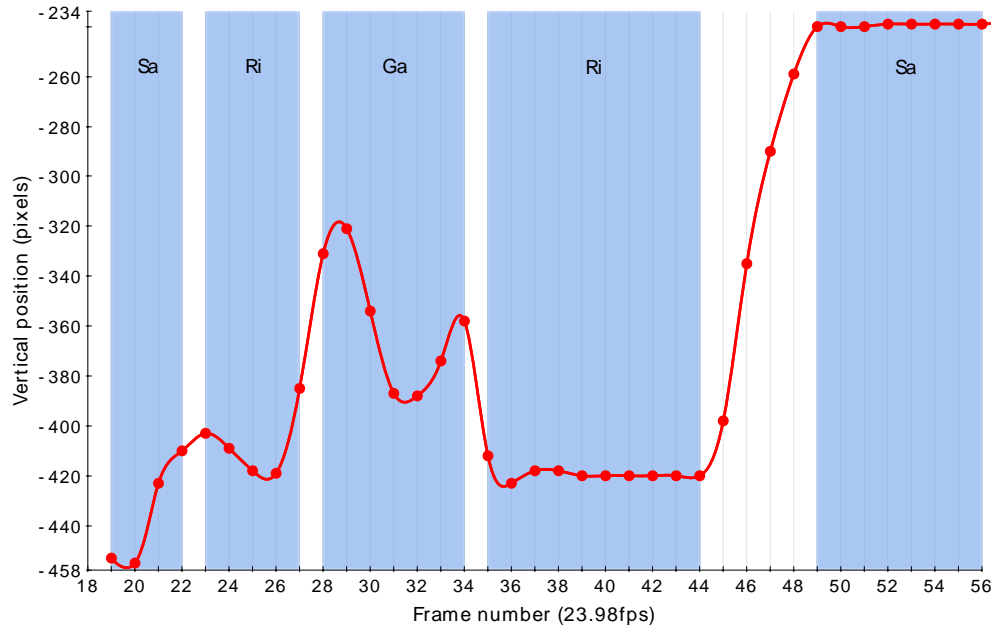
18

Fig. 6. The tracked vertical position of the first finger as the entire left hand oscillates back and forth to create the *svaras sa-ri-ga-ri-sa*, in phrase 1. The final *sa* is at a high vertical position due to being played with the first finger on the third string. The shaded areas provide a guide to the *svaras* being played at each stage of the motion.

A visualisation of the sound-producing gestures can be seen in Fig. 6, in which the tracked vertical position of the violinist's first finger is given. Inspection of this figure reveals that the finger approaches the first *ri* from above, playing the *svara* with a motion trajectory that travels down the string towards the violin nut.[12] This downward force acts as impetus for the oscillation that follows, taking the hand back and forth three times, ending with a narrow oscillation between B♭ and A to create the last *ri*. While the sequence *ri-ga-ri* sounds as though it might be created from three separate hand movements, the position data in Fig. 6 shows instead that the left hand motion for the sequence *ri-ga-ri* is one continuous oscillation; the sound is broken by the bow changes while the left hand continues to move. As we shall see in the course of this analysis, the subsuming of several *svaras* within one oscillating melodic and physical movement is common in the Karnatak style, leading to the creation of coarticulatory effects as the performance of each *svara* in the phrase tends to be influenced by the performance of those that precede and follow it.

19

Although the theoretical pitch position for *ga* in rāga Toḍi is C♮, this pitch is not held at any

point in the phrase. Instead it is implied through the oscillation that touches C♯, B♭, and D at its

outer extremes. This is only one of several ways that *ga* may traditionally be performed in Toḍi,

and so the question arises, why is this particular combination of pitches used here? Further

phrases in the performance will be analysed before an attempt is made to answer this question.
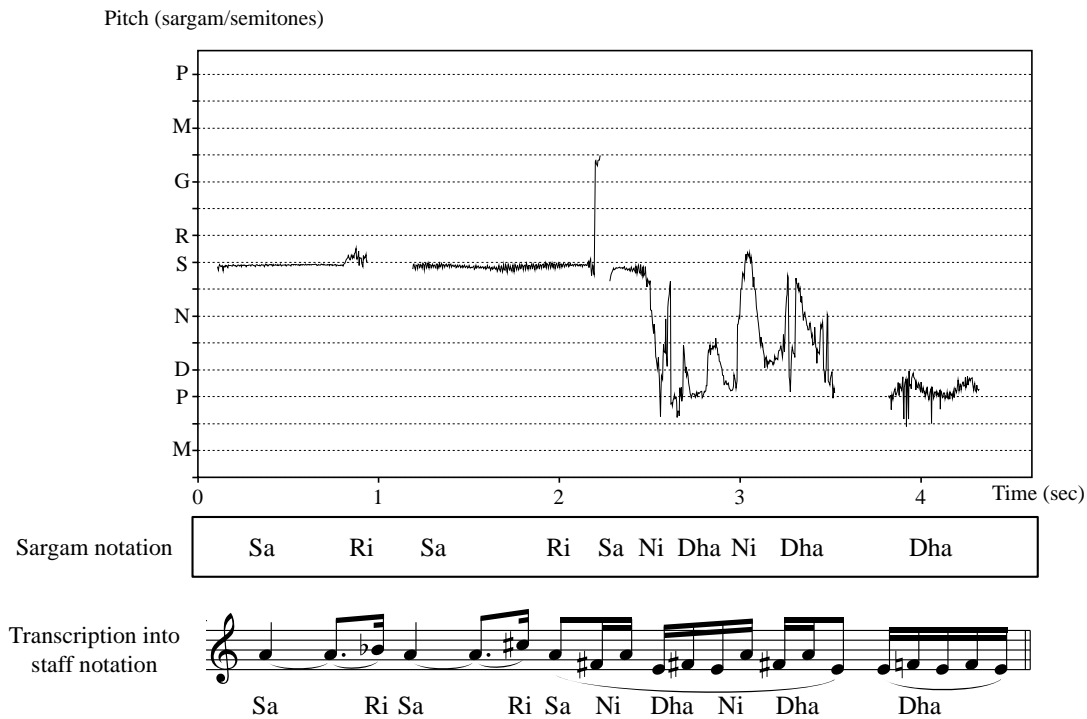

(b) Phrase Two

Fig. 7. Toḍi *rāga ālāpana*. Phrase 2. A composite figure showing pitch contour graph, *sargam* notation, and transcription into staff notation.

The opening of phrase two, *sa-ri-sa-ri*, is played on the third string of the violin, with each *ri*

created by a light flick of the finger up onto a higher pitch. The pitch contour graph (Fig. 7)

shows that the second *ri* is played at a higher pitch than the first: C♯ instead of B♭. However, the

svara is still named *ri* (Interview with T.K.V. Ramanujacharlu, July 2012). In fact, the actual

pitch is touched so fleetingly it can hardly be heard, but it leaves a sonic impression that is

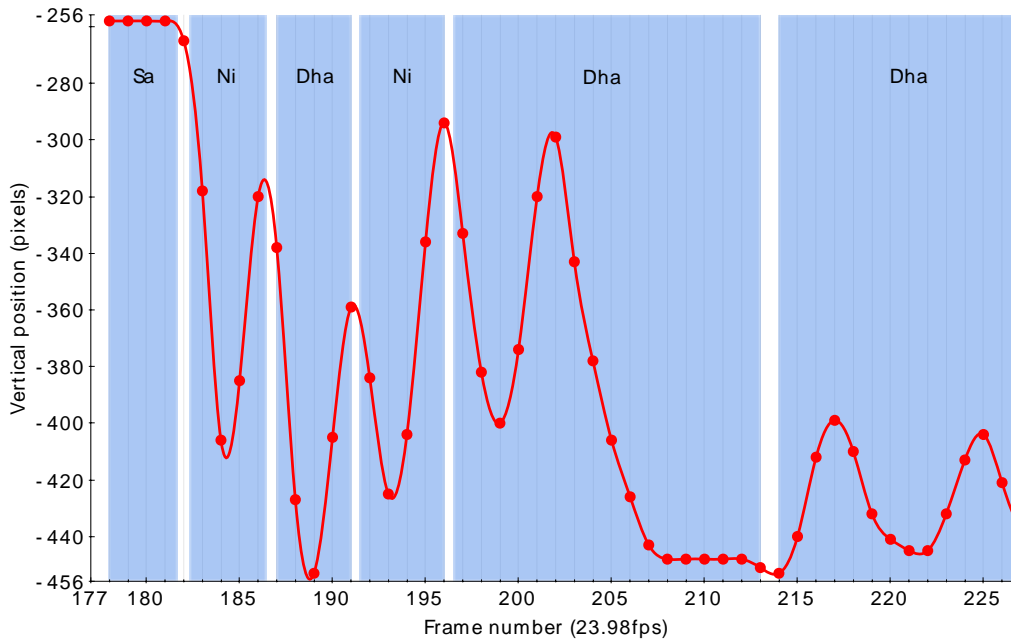considered desirable by some performers in this particular context.[13]

Fig. 8. The tracked vertical position of the first finger as the entire left hand oscillates back and forth to create the *svaras sa-ni-dha-ni-dha-dha* in phrase 2. The shaded areas provide a guide to the *svaras* being played at each stage of the motion.

The second part of phrase two, *sa-ni-dha-ni-dha*, is played with one continuous motion of the left hand (see Fig. 8). This movement consists of four and a half oscillations, each one describing a *svara* in the sequence *ni-dha-ni-dha,* with one and a half oscillations used for the final *dha*. It will be noted that the last two renditions of *dha* in phrase two differ (see Fig. 9). The first is played as a movement starting from the A that formed the end of *ni*, oscillating back and forth touching F♯-A-E, while the *dha* that follows consists of an oscillation between E and F♮. This is a good example of the way in which different musical contexts influence the performance of the same *svara*. The *gamaka* used to play the first *dha* allows the oscillation initiated in the *svaras* before it to continue. There are other ways of performing *dha* in Toḍi, but the one chosen here creates flow through the extension of a musical and physical motion initiated in the previous *svaras*. In this case, the influence of the preceding oscillation on the performance of *dha* can be viewed as an

21

example of coarticulation, wherein the performance of a unit is influenced by that which precedes or follows it. *Dha* here is subsumed under the musical and physical motion that precedes it.

Fig. 9. Variation in the performance of *dha* at the end of phrase 2.

The last *dha* in phrase two differs substantially from the one that precedes it (see Fig. 9), consisting of an oscillation between E and F♮. This is the form of *dha* often used in Toḍi when the *svara* is played alone or ascends from *pa* as in the demonstration in Fig. 3. Musical conventions relating to context mean that it may not be performed in the same way as the previous *dha* (F♯-A-E), as that motif, would only used to perform the *svara* during descending phrases subsumed under an oscillatory movement. In this way the performance of each *dha* here is influenced greatly by its immediate context.
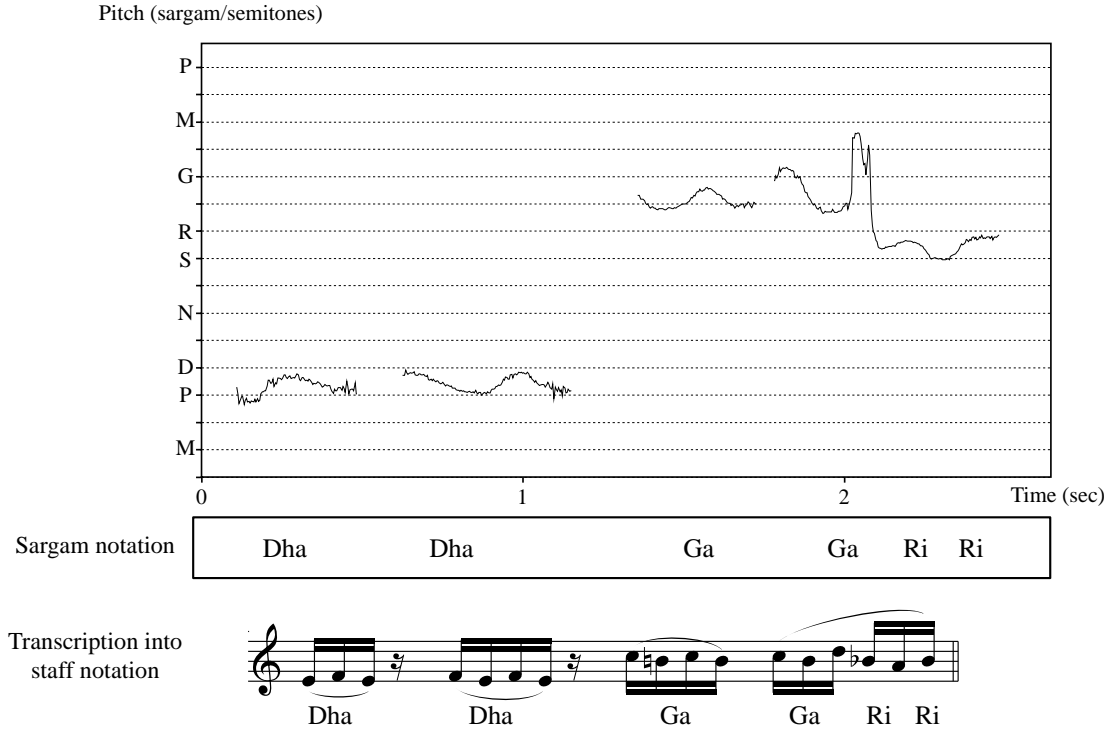
(c) Phrase Three

Fig. 10. Toḍi *rāga ālāpana*. Phrase 3. A composite figure showing pitch contour graph, *sargam* notation, and transcription into staff notation.

Inspection of Figs. 10 and 11 reveals that phrase three consists of two sub-gestures: the opening *svaras*, *dha-dha*, are played with one continuous oscillation of the left hand, while the following *ga-ga-ri-ri* is formed from a second oscillatory motion played on the next string. In the opening gesture, the two *svaras*, *dha-dha*, are the same but the pitch patterning of each differs: E-F♮-E in the first *dha* and F♮-E-F♮-E in the second. The hand motion used to perform the second *dha* flows smoothly from the movement employed for the previous *svara*, creating a continuous oscillation. I would suggest the pitch patterning of the second *dha* is determined by the tendency of the Karnatak style to subsume proximal *svaras* within continuous oscillations. Employing this interpretation, the second *dha* starts on F so that the oscillation used to perform the previous *dha* may continue. This, therefore, can be seen as an example of coarticulation between *svaras*, as the movement of the first *dha*, both musical and physical, carries over into the motion of the second.
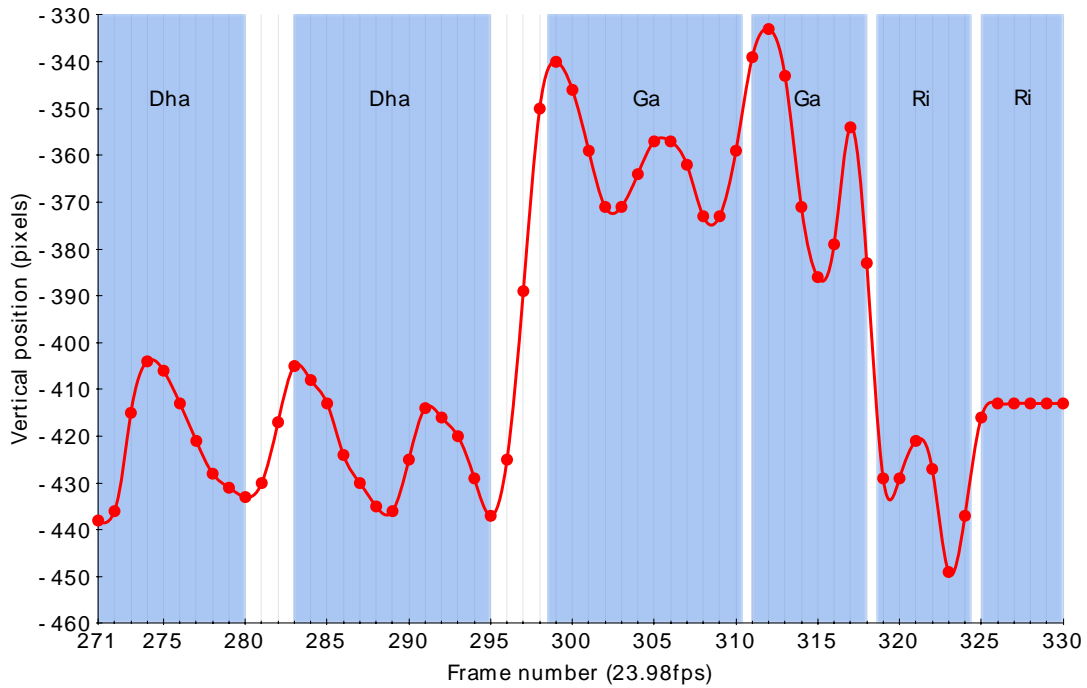
23

Fig. 11. The tracked vertical position of the first finger as the entire left hand oscillates back and forth to create the *svaras dha-dha-ga-ga-ri-ri* in phrase 3. The shaded areas provide a guide to the *svaras* being played at each stage of the motion.

In the second part of phrase three, the first *ga* gently oscillates between C and B♮, before widening out to form the second *ga*, performed as C-B♮-D. Finally the hand moves down sharply to create the final *ri-ri* (see Figs. 10 and 11). Here once again there are two *svaras* with the same name, but performed differently due to their context. *Ga* performed as part of an ascending phrase is normally formed from an oscillation: either between B♮ and D, or occasionally if the phrase is rapid or indistinct between B♭and D, or even B♮ and D♯. However, *ga* when played alone, or before a descending phrase is more likely to be performed as an oscillation between C and B♮. So, once again, the performance of this *svara* is very much dependent on its immediate context.

(d) Phrase Four

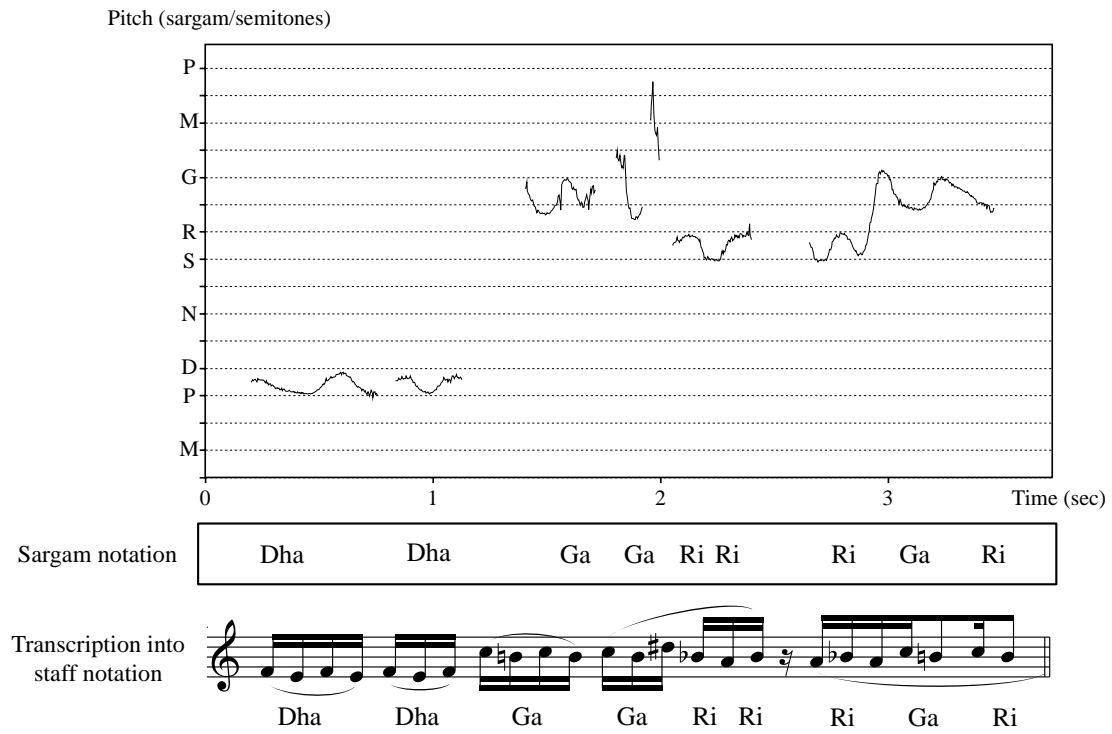Pitch (sargam/semitones)

Sargam notation

Dha   Dha   Ga   Ga   Ri Ri   Ri   Ga   Ri

Transcription into
staff notation

Dha   Dha   Ga   Ga   Ri   Ri   Ri   Ga   Ri

Fig. 12.   Toḍi *rāga ālāpana*. Phrase 4. A composite figure showing pitch contour graph, *sargam* notation, and transcription into staff notation.

The opening of phrase four (Fig. 12) is a repetition of the *svaras* played in the previous phrase. However, their realisation differs subtly, as the first *dha* starts on F♮ rather than E. Although the pitch patterning of *dha-dha* is different in the two phrases, the musical logic of two *svaras* subsumed under one oscillating gesture remains the same (Fig. 13).
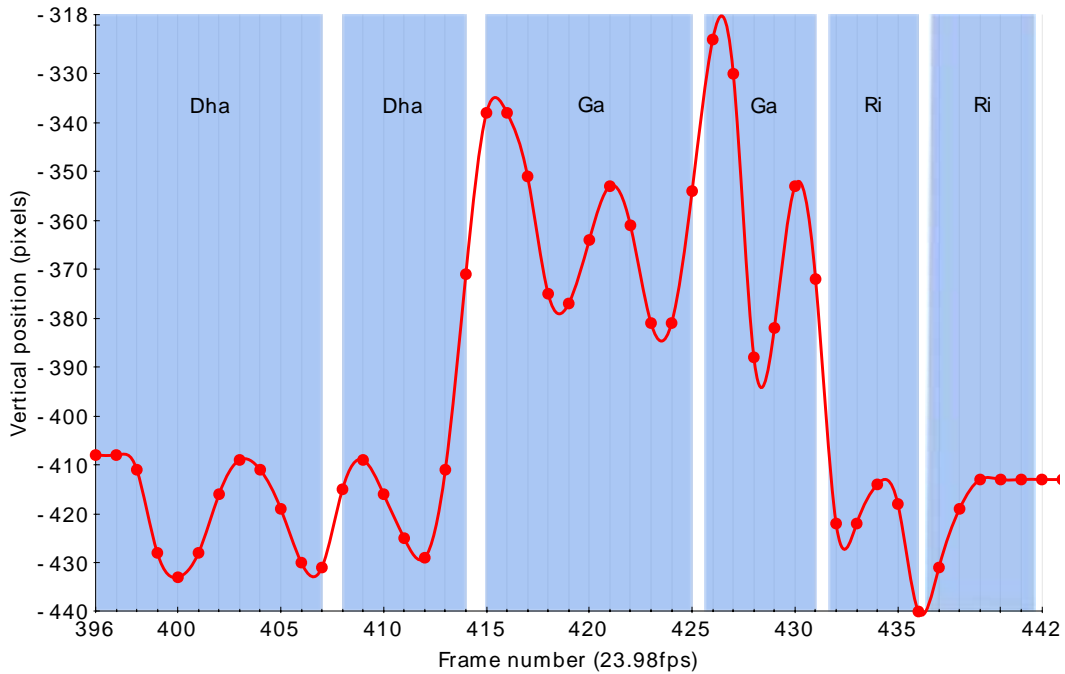
Fig. 13. The tracked vertical position of the first finger as the entire left hand oscillates back and forth to create the *svaras dha-dha-ga-ga-ri-ri* in the first part of phrase 4. The shaded areas provide a guide to the *svaras* being played at each stage of the motion.

The final *ri* in this phrase is notable in that it falls only to around B♮ rather down to B♭, the pitch theoretically indicated by *ri* in Toḍi. In fact, this only works here because the violinist takes the pressure off of the bow as the left hand slides down the string, leading to a type of fade-out effect that implies that the hand may still be continuing downwards. If, conversely, the violinist were to emphasise B♮ here it would be unacceptable. In this case we can see the importance of musical emphasis in forming the characteristic phrases of Toḍi. While the pitches touched are significant to an extent, the gestural qualities of the phrases are often of equal importance in conveying the mood of the rāga.
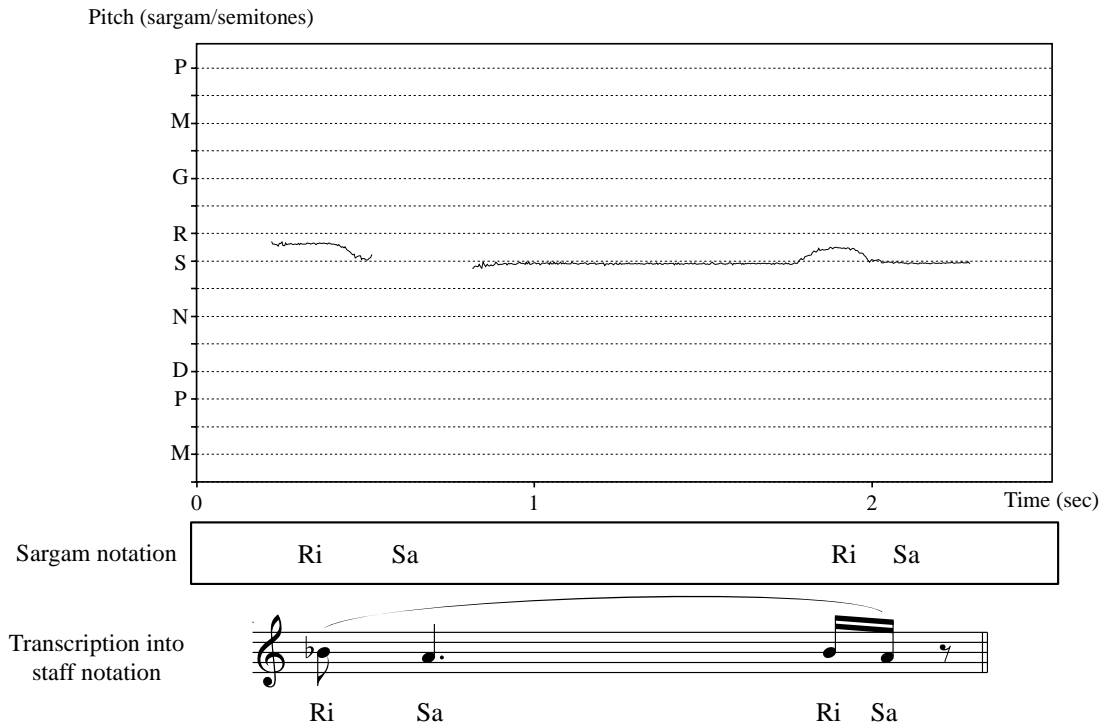
(e) Phrase Five

Fig. 14. Toḍi *rāga ālāpana*. Phrase 5. A composite figure showing pitch contour graph, *sargam* notation, and transcription into staff notation.

The slow oscillation between *ri* and *sa* in phrase five (Fig. 14) acts as a prelude to the phrase that follows.

(f) Phrase Six

Phrase six (Fig. 15) consists of three gestures. The first conveys *sa-ri-sa* through a subtle touch of the first finger onto B ♭ for *ri* before sliding down to the violin nut, leaving *sa* played as an open string. In the second gesture an oscillation emerges from *ri*, continuing back and forth one and a half times to form the *svara* sequence *ri-ga-ma*, then plunges back down to B♮ holding for a moment before continuing the oscillation down to a subtle *ri*. In this sub-phrase, the *svaras* are subsumed under a single oscillatory movement, and the *gamaka* used to perform each *svara* starts from the end point of the previous *gamaka*. In this way, as Rangaramanujar Ayyangar described,

27

the *gamakas* build relationships between the *svaras* (1972, p. 148). It is this tendency to build

relationships between *svaras* by linking them that leads to their coarticulation. The central section

of phrase 6, *ri-ga-ma-ga-ri* (Fig. 16), can be considered a 'gestural-sonic object' (Godøy 2011) in

which the borders between *svaras* have, through the *gamakas* used to perform them, become
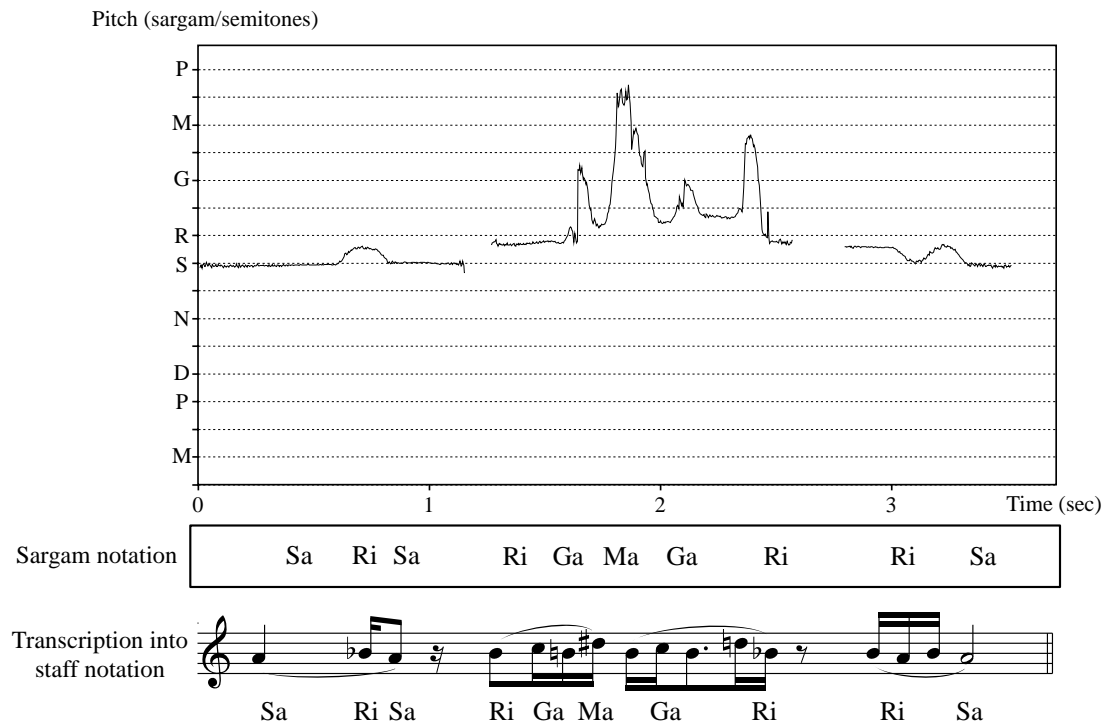
blurred.

Fig. 15.   Toḍi *rāga ālāpana*. Phrase 6. A composite figure showing pitch contour graph, *sargam* notation,
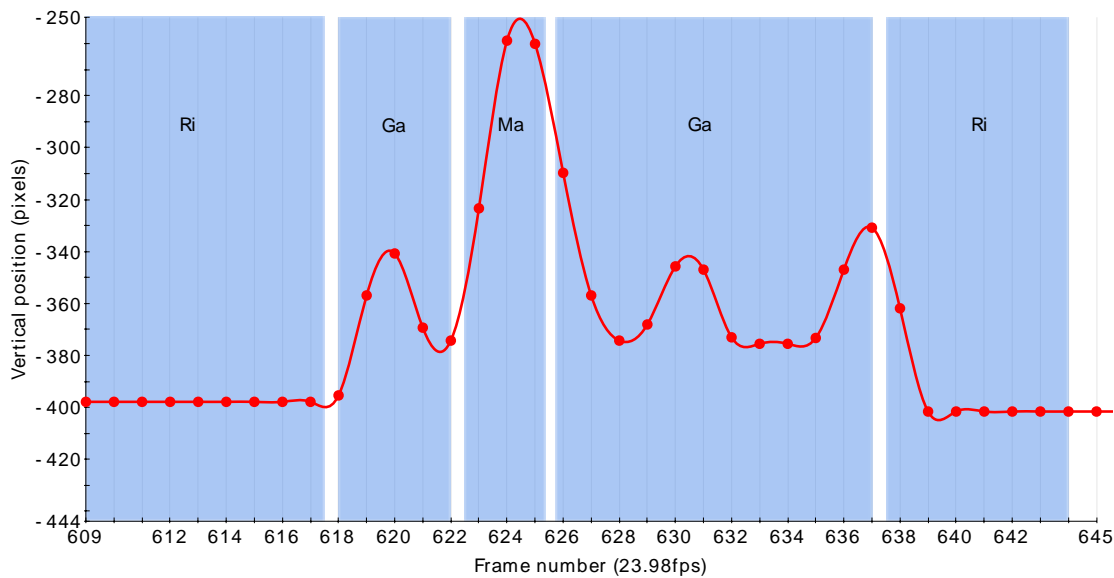and transcription into staff notation.

Fig. 16. The tracked vertical position of the first finger as the entire left hand oscillates back and forth to create the *svaras ri-ga-ma-ga-ri* in phrase 6.
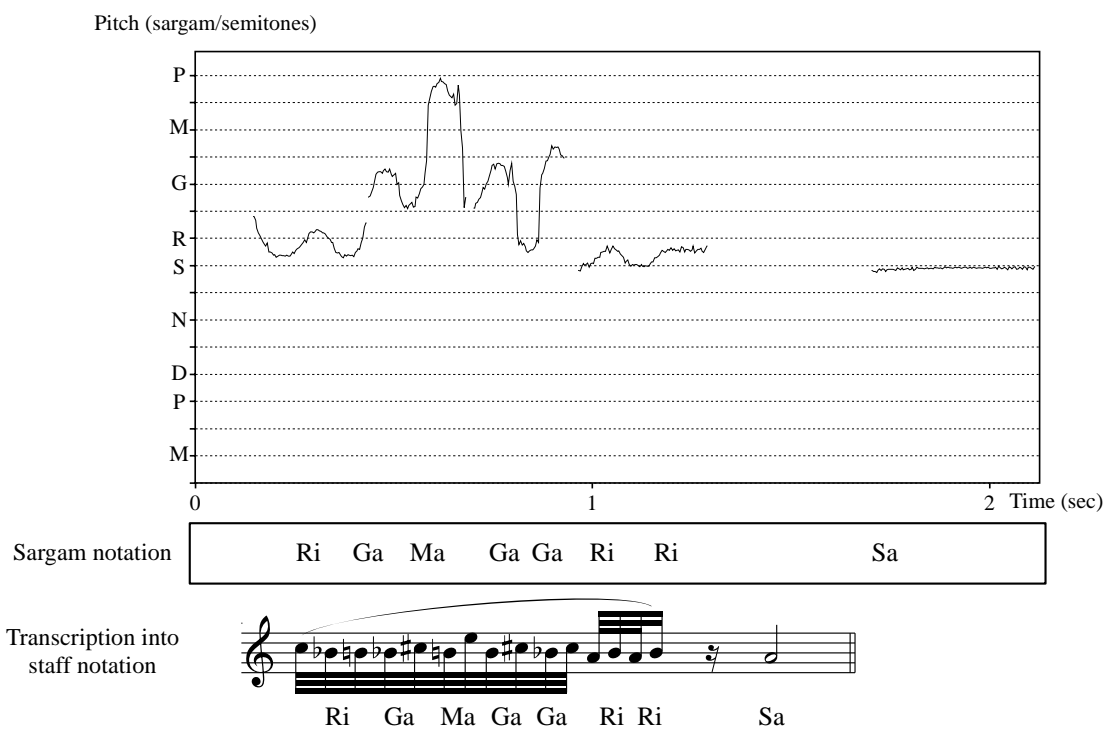
(g) Phrase Seven

Fig. 17. Toḍi *rāga ālāpana*. Phrase 7. A composite figure showing pitch contour graph, *sargam* notation, and transcription into staff notation.

29

The final phrase (Fig. 17) is formed from a single extremely rapid oscillatory movement of the left hand that describes the *svaras ri-ga-ma-ga-ga-ri-ri*, followed by *sa* on the open string. From the transcription and pitch contour graph in Fig. 17 it can be seen that several of the pitches touched do not appear among the theoretical pitch positions of *todi rāga*. While the use of B♮ to perform *ga* is standardised in this rāga, as discussed earlier in this article, C♯ is not. The sharp *ga* seen here may, therefore, result from a degree of tolerance in the style towards variance in pitch during rapid or indistinct *gamakas*.

The graph of the tracked first finger (Fig. 18) shows that the oscillating hand movement used to create this phrase. Every *svara* in the phrase shows evidence of coarticulation with the one that precedes it, as each *gamaka* starts from the point at which the previous one ends in order that the oscillation may continue throughout. Here, once again, the borders between individual *svaras* are difficult to define due to the coarticulation between them, and the *svaras* are, therefore, subject to 'contextual smearing' through the *gamakas* used to perform them (Godøy 2011).
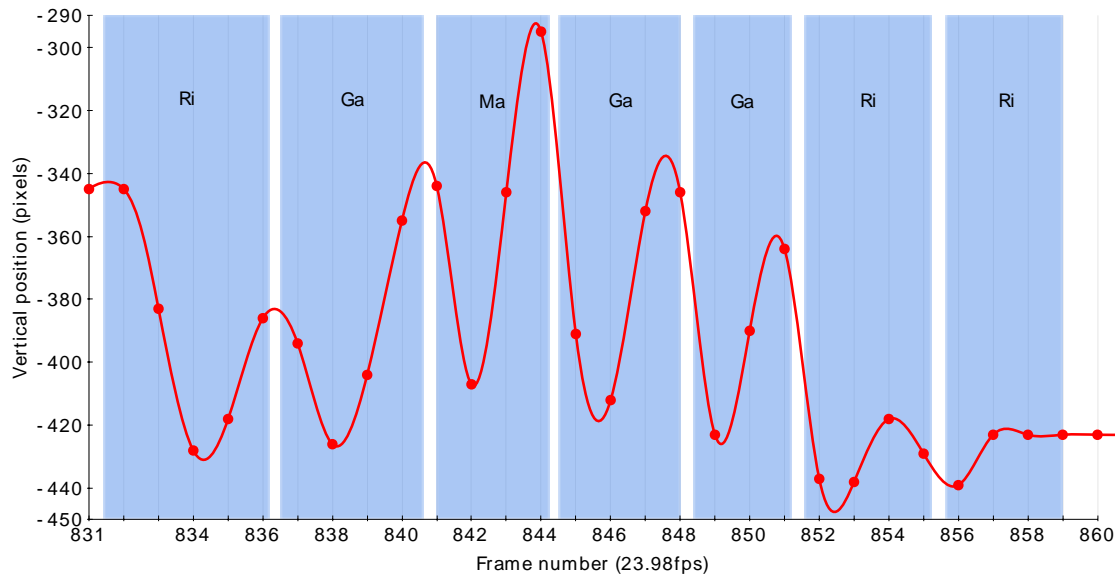

Fig. 18. The tracked vertical position of the first finger as the entire left hand oscillates back and forth to create the *svaras ri-ga-ma-ga-ga-ri-ri* in phrase 7.

30

Discussion of Variation in the Performance of *Ga*

So far in this analysis, the way that a *svara* is performed has been shown to vary depending on its context. Several of these variations have been identified as exhibiting characteristics of coarticulation, for example when the *gamaka* used to perform a *svara* starts from the end point of the one that precedes it, or when a *gamaka* continues an oscillatory movement initiated in the preceding sequence. In the following discussion I will explore a single *svara* in more detail, looking at its various manifestations in the phrases examined.

There are ten performances of *ga* in the first thirty-nine seconds of this *rāga ālāpana*. The *gamakas* used to perform each of these is distinct in some respect, if not in pitch then in emphasis. Three of the variations have been highlighted in Fig. 19, together with a fourth version transcribed from a separate demonstration of the rāga scale by the same performer.[14] Looking at the range of variations, there appear to be two broadly defined schemas available for performing *ga* in Toḍi.[15] One is a wide oscillation as seen in phrase 1 (C♯-B♭-D) and also the rāga scale demonstration (B♭-D-B♮-D-B♮); the other is a narrow oscillation between C and B♮, which can be seen in phrases 3, 4, and 6. Within these two schemas for *ga* there exist a multitude of potential subtle variations in pitch, patterning and emphasis. The remainder of this discussion will consider the factors that determine the form of *ga* in each of the four phrases shown in Fig. 19.

In the case of the rāga scale demonstration (Fig. 19, fourth example) *ga* is preceded by *ri* and followed by *ma*, and is played as B♭-D-B♮-D-B♮. Keeping in mind that one of the functions of *gamakas* is to create a fluid movement from one *svara* to the next (Interview with T.K.V. Ramanujacharlu, Srirangam, Tamil Nadu, 16th June 2012), this performance of *ga* can be interpreted as starting from B♭ because it is the pitch at which the previous *svara* ends. In addition, the oscillation that follows takes the player neatly back up to the D required to play *ma*. This example can therefore be seen as an example of coarticulation in two directions. If instead,

ga was played here as C-B♮-C-B♮ it would fail to join smoothly with either the preceding or following *svara*: it would not make the *svaras* flow, as *gamakas* should (*ibid*.).

Fig. 19. Varieties of *ga* performed in the opening section of Toḍi *rāga ālāpana*, and the rāga scale demonstration by the same performer.

Although both the *ga* in phrase six and the one that occurs in the rāga scale demonstration appear between the *svaras ri* and *ma*, the wider phrase differs, as does the speed at which it is played (see Fig. 19). These factors affect the realisation of the *svara*, and in phrase six *ga* is performed as C-B♮ rather than B♭-D-B♮-D-B♮. However, in both cases the same kinetic rationale is followed, with *ga* being performed using an oscillation that links *ri* to *ma*. In the case of the *ga* in phrase six only a single oscillation is used, as the phrase is faster and therefore allows less time for elaboration.

In phrase one (see Fig. 19), the performance of *ga* does not, from the transcription alone, seem to show any evidence of coarticulation with the *svaras* preceding or following it: the

gamaka used to perform *ri* ends on A, and the one used to play *ga* starts on C♯. However, from the kinetic analysis in Fig. 6 we can see that this entire phrase, while sounding like three separate sonic events, is performed using one continuous left hand movement. The performance of *ga* as C♯-B ♭-D allows this oscillatory movement to continue through the sequence. Here it is primarily the hand movement that shows evidence of coarticulation; the separate bow articulations used to play the phrase prevent the continuous hand movement from resulting in an uninterrupted sonic oscillation. However, the pitches touched are a direct result of the hand movement that subsumes the phrase, and so coarticulation can be said to occur between *svaras*.

Conclusions, wider significance, and applications

Coarticulation has been observed in this example of *rāga ālāpana* in the contextual influences exerted on the performance of *svaras*. Much of the coarticulation examined here is created through the oscillatory motions, both musical and physical, that are characteristic of the Karnatak style. As sequences of *svaras* are subsumed under single oscillatory gestures, each *svara* coarticulates with the next through the *gamaka* with which it is performed.

The remainder of this article will consist of a discussion of atomistic and gestural perspectives in Karnatak music performance, and the way that coarticulation manifests in each. Finally, the article will conclude with an exploration of the wider implications of coarticulation for musicological research, and the various potential applications of the concept.

(i)   Coarticulation in atomistic and gestural conceptions of Karnatak music: the performer's perspective

The contrast between atomistic and gestural perspectives has been a frequent point of discussion in this article: atomistic in this context being a *svara* based approach, while a gestural perspective functions holistically, focusing on phrases and sub-phrases often performed using one continuous movement. I will argue here that musicians use both of these perspectives during their training,

and within performances. In addition, I will discuss how coarticulation manifests in each of the two perspectives.

As we have seen, Indian music theory tends to emphasise the atomistic, *svara* based perspective, perhaps because it is more tangible and easier to notate. However, Viswanathan states that musicians largely conceive of *rāga ālāpana* through characteristic phrases (1977, p. 38), a view that is supported by musicians' statements made during interviews conducted in the course of my research. As we have seen in this analysis, coarticulation is built into the structure of such phrases.

Notwithstanding the significance of characteristic phrases in Karnatak music, patterning of *svaras* with little reference to such phrases does occur both during the learning process and in performance. In fact, a *svara* based perspective is often adopted by musicians. *Svarajnāna* (awareness or knowledge of *svaras*) is considered an essential element of Karnatak musicianship, and at any moment the performer should be able to say exactly which *svaras* are being sung within a phrase. The early stages of the learning process place great emphasis on singing *svaras* using their *sargam* nomenclature (Kassebaum 1987, p. 47). Beginners, both instrumentalists and vocalists, practice elaborate vocal exercises in which patterns of *svaras* performed as plain notes or sometimes with a few *gamakas* are subject to exhaustive permutations. This training must be completed before students move on to learn simple compositions, the stage at which *gamakas* are typically introduced. Therefore, having been taught exercises with *svaras* largely performed as plain notes, they must then learn how to connect the *svaras* through *gamakas*. As a result, the concept and practice of linking *svaras* through *gamakas* is ingrained in performers from an early point in their musical training.

Later, as students learn compositions and *ālāpana* by imitating phrases played or sung by their teacher, *svara* awareness still plays an important role. In the course of my fieldwork I regularly observed that when a student fails to correctly imitate a phrase, the teacher would then repeat it, this time singing the *svara's sargam* nomenclature rather than the lyrics or other

34

syllables. This pedagogic technique frequently resulted in the student singing the phrase without difficulty on their next attempt. In such cases, awareness of which *svaras* are being sung appears to trigger memories of how they should be performed in that particular context. Therefore, it seems possible that students, to some extent, retain conceptual models of how each *svara* should be rendered in a particular context in a given *rāga*, without any direct reference to characteristic phrases.

In addition to providing an important pedagogical and phonemic foundation throughout the style, a *svara* based perspective is also prominent in musical forms such as *svara kalpana,* where the performer improvises *svara* patterns which are sung using their *sargam* syllables. In this form, characteristic phrases, or *sañcāras*, play a lesser role and the manipulation of *svara* patterns dominates.[16]

Given such evidence, I would suggest that although characteristic phrases may be the dominant conceptual mode for Karnatak musicians, a *svara*-based perspective is also present: deliberately formed during the learning process and remaining active in professional performers. When this *svara*-based mode dominates, there is also the stylistic imperative to link *svaras* using *gamakas*. In later stages of the learning process, linking occurs without planning or effort; however, earlier on the student may be conscious of the need to create such connections. Although Karnatak performers do not directly refer to the concept of coarticulation using this or any equivalent term, they are very much aware of the need to link *svaras* using *gamakas* (personal interview with Balu Raghuraman, London, 24 July 2012), and it is this linking that leads to coarticulation.

(ii)   Coarticulation and musicology: implications and applications

From a music analysis perspective, I would characterise the status of coarticulation in musical contexts as similar in many respects to that which it holds in phonetics. Words are not usually learnt by arranging phonetic units and then coarticulating them, rather people learn the vocal

35

gestures to produce words in which coarticulation is already present. However, in phonetics, coarticulation is still considered a useful tool for understanding how a language works and why phonemes take a particular form in a given context. In addition, the concept plays an essential role in modeling language, and also in developing automatic speech recognition (Cohen et al. 1993, Hwang et al. 1989). In the same way, being aware that individual *svaras* in Karnatak music are subsumed under larger gestural units and are, therefore, subject to coarticulation should help musicologists understand how this particular musical language works, providing insight into why a *svara* is played in a particular way in a given context.

An awareness of coarticulatory processes in Karnatak music also allows us to better understand the relationship between *svara*, *gamaka* and *sañcāra* as they exist in practice; for example, it helps to explain why *gamakas* appear in such a variety of forms. While it is certainly reasonable to define *gamakas* as belonging to types such as *kaṁpita* (oscillation), *jāru* (slide) and *janta* (finger stresses) (Powers 1959, p. 147), this is not sufficient information for us to understand how such *gamakas* should be performed. However, what can help us in this endeavor is to know that there is a stylistic tendency to form links between two or more *svaras* and to subsume individual *svaras* under single oscillating gestures. In this way the dynamic processes underlying the style become clearer.

I would suggest that coarticulatory theory provides an appropriate way of modeling Karnatak music as it exists in practice, and could potentially assist in the prediction of how a particular *svara* should be played if its immediate context is given. Coarticulation may also be a useful concept for application in the field of music information retrieval (MIR), both in Indian and other musical contexts, in a similar way to that which it is used in speech recognition.[17] Finally, coarticulation is likely to occur in other musical styles, particularly those that are highly ornamented or melismatic, and so these may also be suitable for analysis or modeling with respect to the phenomenon.

NOTES

1. While many scholarly texts refer to this genre as Karnatak music, in India and elsewhere it is often transliterated as Carnatic. Karnatic and Karnatik can also be seen found.

2. See Powers and Katz (2001) for details on the history of Indian music. Early Indian treatises focusing solely on Indian music include the 13th century *Saṅgīta-ratnākara* and the R*āga-vibhoda*, written in the early 17th century. Distinctions between South and North Indian music are made in references from the 16th century onwards (Qureshi 2001, p. 152). The Karnatak style flourished in the royal courts of South India from the 17-19th centuries, but as these courts suffered loss in power and wealth during the 19th century, a gradual shift in patronage took place (Subramanian 2006, 2008). The primary patrons of Karnatak musicians today are local cultural organisations known as *sabhās* and government run institutions such as All India Radio (Viswanathan and Allen 2003, pp. 86-88).

3. This is based on observations made in the course of my training in Karnatak violin and mridangam with top-level professional musicians over a period of four years in Srirangam and Tiruchirappalli, Tamil Nadu, supplemented by fieldwork in which I videoed lessons given by a range of teachers across South India from 2012-2014.

4. Improvisatory forms within the style include *rāga ālāpana*, *svara kalpana*, and *niraval*. These require that the performer should improvise within the rules of the rāga, drawing on characteristic phrases passed down orally and learnt through gradual assimilation rather than systematic rote learning. The performance of compositions, which in Karnatak music are often long and elaborate, also typically involves a degree of improvisation as musicians create variations on phrases that have been passed down to them by their teachers.

5. *Gamakas* function to express the mood (*bhāva*) of the rāga through the creation of subtle melodic movement on and between *svaras* (see Viswanathan, 1977 and also Swift, 1990). In

addition, from a practitioner's perspective it is clear that *gamakas* are used to link one *svara* to the next through oscillations and slides (personal interview with the violinist Balu Raghuraman, London, 24 July 2012).

6. Krishnaswamy (2004) acknowledges the presence of this 'foreign' pitch in the *gamakas* used to play *ga* in Toḍi. In the following quote he refers to the pitches touched as 'R2+' using his own variant of *sargam* notation devised to assist in the analysis of what he refers to as 'melodic atoms' (2004). The term R2+ here refers to a combination of tones including a sharpened *ri*: 'There are also ragams which use entities anchored on swarasthanams that are not part of the ragam. For example, in Thodi, R2+ appears as a particular form of G2 sometimes' (2004, p. 2). Further details on Toḍi as it exists in theory and practice are given in later sections of the present article (see Figs. 2-4).

7. The difficulty in fitting some of the more ancient rāgas (and even those that are not so ancient) into the *meḷakartā* scheme is aptly illustrated by the heated discussions that took place during the Experts Committee meetings at the Madras Music Academy conferences between 1930-1952 when attempting to decide into which *meḷakartā* certain rāgas should be placed (see Allen 2008 for an examination of these debates). In many cases, consensus could not be reached, due to what Allen (2008) describes as 'the difficulty of trying to reduce ragas to a scalar framework', and, in order to move forward, decisions were sometimes forced by the committee's president (2008, pp. 116-118).

8. In an article for the Madras Music Academy's journal titled 'The Melakartā – a critique', K.V. Ramachandran argued that the *meḷakartā* system was partially responsible for deforming comprehension of certain rāgas. He explained that rāgas should be defined not only by *svara* scales but also through their 'characteristic figures and exclusive phrases' as well as 'movements of various kinds': referring to *sañcāras* and *gamakas* respectively (1938, p. 31). Powers (1959) also emphasises the importance of 'rāga-phrases', describing the South

Indian rāga system as 'a musical system which has, incidentally, very little to do with the scale-system' (1959, p. 87).

9. Kassebaum (1999) observes that in certain cases, it can be the *gamaka* used to play a *svara* that distinguishes one rāga from another: 'When two rāga s have the same scale pitches, the integrally associated ornamentation of certain tones serves to differentiate between the two' (1999, p. 93).

10. Video recording was used in this case, as although motion-capture recordings would have provided hand position data in three-dimensions, the technology is still rather intrusive, requiring multiple cameras and the placing of markers on the performer's body. Motion-capture was therefore unsuitable for research in which the bulk of the recording took place in musicians' homes in locations spread across South India. In the recordings made for this study, the video camera lens was positioned parallel to the plane of the violinist's left hand motion along the fingerboard to ensure that video tracking would capture kinetic data pertinent to this study.

11. In Karnatak violin the second string is tuned to Sa, which means that by transposing the performance to A, the fingering is brought into alignment with that of the Western violin.

12. The downward hand movement referred to here is away from the bridge and towards the violin nut. This is also a movement towards the ground, as the violin is held almost vertically with the scroll resting on the performer's heal.

13. Similar motifs in which *sa* is broken by a lightly touched high-pitched *ri* can also be found in *ālāpanas* in Toḍi rāga performed by the renowned violinist M.S. Gopalakrishnan.

14. It should be noted that the rāga scale demonstration is a special context, existing somewhere between theory and practice. The entire phrase as seen here would not appear in a performance of Toḍi *rāga ālāpana*: phrases more characteristic of the rāga would be used instead. However, it does represent the teacher's authorised version of the *gamakas* used to perform the *svaras* in an ascending and descending context.

15. See Widdess 2013 for a discussion of schemas in the context of North Indian music.

16. Although it may be argued that many *svara* patterns in this context become 'characteristic' through repetition, there is still great latitude in *svara kalpana* for the creation of innovative *svara* combinations.

17. Although Godøy and Jensenius (2009) have discussed coarticulation in an article on body movement in music information retrieval, there is to date no published MIR research applying the concept of coarticulation to Indian music contexts.

REFERENCES

Allen, Matthew Harp, 2008: 'Standardize, Classicize, and Nationalize: The Scientific Work of the Music Academy of Madras, 1930-52', in I.V. Peterson and D. Soneji (eds), *Performing Pasts: Reinventing the Arts in Modern South India*, (New Delhi: Oxford University Press), pp. 90-129.

Boersma, Paul, and Weenink, David, 2012: Praat: Doing Phonetics by Computer [Computer program]. Version 5.3.11, retrieved 27 March 2012 from http://www.praat.org/.

Chelladurai, P.T., 2005: *The Splendour of South Indian Music* (Dindigul, Tamil Nadu: Vaigarai Publishers).

Cohen, Michael M and Massaro, Dominic W, 1993: 'Modeling Coarticulation in Synthetic Visual Speech', *Models and Techniques in Computer Animation*, Springer), pp. 139-56.

Engel, Kevin C., Flanders, Martha and Soechting, John F., 1997: 'Anticipatory and Sequential Motor Control in Piano Playing', *Experimental Brain Research*, 113/ii, pp. 189-99.

Farnetani, Edda and Recasens, Daniel, 2010: 'Coarticulation and Connected Speech Processes', in William J Hardcastle, John Laver and Fiona E Gibbon (eds), *The Handbook of Phonetic Sciences*, (Oxford:Wiley-Blackwell), pp. 316-52.

Godøy, Rolf Inge and Jensenius, Alexander Refsum 2009. 'Body Movement in Music

Information Retrieval', in *10th International Society for Music Information Retrieval Conference (ISMIR 2009)*.

Godøy, Rolf Inge, Jensenius, Alexander Refsum and Nymoen, Kristian, 2009: 'Chunking by Coarticulation in Music-Related Gestures', paper presented at The *8th International Gesture Workshop, Bielefeld, 25-27 February 2009.*.

Godøy, Rolf Inge, Jensenius, Alexander Refsum and Nymoen, Kristian, 2010: 'Chunking in Music by Coarticulation', *Acta Acustica United with Acustica*, 96/iv, pp. 690-700.

Godøy, Rolf Inge, 2011: 'Coarticulated Gestural-Sonic Objects in Music', in Anthony Gritten and Elaine King (eds), *New Perspectives on Music and Gesture*, (Farnham: Ashgate), pp. 67-82.

Hardcastle, William J and Hewlett, Nigel, 1999: *Coarticulation: Theory, Data and Techniques* (New York: Cambridge University Press).

Hwang, Mei-Yuh, Hon, Hsiao-Wuen and Lee, Kai-Fu 1989. 'Modeling between-Word Coarticulation in Continuous Speech Recognition', in *First European Conference on Speech Communication and Technology*.

Jerde, Thomas E., Soechting, John F. and Flanders, Martha, 2003: 'Coarticulation in Fluent Fingerspelling', *Journal of Neuroscience*, 23/6, pp. 2383-93.

Jerde, Thomas E., Santello, Marco, Flanders, Martha and Soechting, John F., 2006: 'Hand Movements and Musical Performance', in Eckart Altenmuller, Mario Wiesendanger and Jürg Kesselring (eds), *Music, Motor Control and the Brain*, (Oxford: Oxford University Press), pp. 79-90.

Kassebaum, Gayathri Rajapur, 1987: 'Improvisation in Alapana Performance: A Comparative View of Raga Shankarabharana', *Yearbook for Traditional Music*, 19, pp. 45-64.

Kassebaum, Gayathri Rajapur, 1999: 'Karnatak Raga', in Alison Arnold (ed), *The Garland Encyclopedia of World Music: South Asia: The Indian Subcontinent*, (New York: Routledge), p. 89.

Komaragiri, Madhu Mohan, 2013: *Pitch Analysis in South Indian Music: With a Critical*

> *Examination of the Theory of 22 Śruti-S* (New Delhi: Munshiram Manoharlal Publishers).

Krishnaswamy, Arvindh 2003. 'Application of Pitch Tracking to South Indian Classical Music', in

> *IEEE International Conference on Acoustics, Speech, and Signal Processing - ICASSP*

> *'03*, pp. V-557-60 vol. 5.

Krishnaswamy, Arvindh 2004. 'Melodic Atoms for Transcribing Carnatic Music', presented at

> *ISMIR*. Retrieved January 20, 2015 from https://ccrma.stanford.edu/~arvindh/cmt/

Kühnert, Barbara and Nolan, Francis, 1999: 'The Origin of Coarticulation', in William J

> Hardcastle and Nigel Hewlett (eds), *Coarticulation: Theory, Data and Techniques*, (New

> York: Cambridge University Press), pp. 7-30.

Pesch, Ludwig, 2009: *The Oxford Illustrated Companion to South Indian Classical Music* (New

> Delhi: Oxford University Press).

Powers, Harold S. 1959. 'The Background of the South Indian Raga-System', PhD, Princeton

> University.

Powers, Harold S. and Katz, Jonathan, 2001: 'Ii: Classical Music', in Stanley Sadie (ed), *The New

> Grove Dictionary of Music and Musicians. 2nd Ed.*, (London: Macmillan).

Powers, Harold S. and Widdess, Richard, 2001: 'India III: Theory and Practice of Classical

> Music', in Stanley Sadie (ed), *The New Grove Dictionary of Music and Musicians. 2nd*

> *Ed.*, (London: Macmillan).

Qureshi, Regula, 2001: 'India I: Art Music: Northern and Southern Styles', in Stanley Sadie (ed),

> *The New Grove Dictionary of Music and Musicians. 2nd Ed.*, (London: Macmillan).

Ramachandran, K.V., 1938: 'The Melakartā – a Critique', *Journal of the Music Academy, Madras*,

> 9/1-4.

Ramanathan, N. 2004. 'Sargam and Musical Conception in Karnataka System', in *Sargam as a*

> *musical material*, (Prabha Atrre Foundation, Pu. La. Deshpande Maharashtra Kala

> Academy, Mumbai).

Rangaramanuja Ayyangar, R, 1972: *History of South Indian (Carnatic) Music, from Vedic Times to the Present* (Madras: The author).

Rao, Suvarnalata and van der Meer, Wim, 2010: 'The Construction, Reconstruction, and Deconstruction of Shruti', in Joep Bor (ed), *Hindustani Music - Thirteenth to Twentieth Centuries*, (New Delhi: Codarts and Manohar), pp. 673-96.

Segouat, Jérémie, 2009: 'A Study of Sign Language Coarticulation', *ACM SIGACCESS Accessibility and Computing*, 93, pp. 31-8.

Shringy, Ravindra Kumar and Sharma, Prem Lata, 2007: *Sangitaratnakara of Sarngadeva* (New Delhi: Munshiram Manoharlal Publishers).

Subramanian, Lakshmi, 2006: *From the Tanjore Court to the Madras Music Academy: A Social History of Music in South India* (New Delhi: Oxford University Press).

Subramanian, Lakshmi, 2008: 'Embracing the Canonical: Identity, Tradition, and Modernity in Karnatak Music', in I.V. Peterson and D. Soneji (eds), *Performing Pasts: Reinventing the Arts in Modern South India*, (New Delhi: Oxford University Press), pp. 43-70.

Subramanian, M, 2002: 'Analysis of Gamakams of Carnatic Music Using the Computer', *Sangeet Natak*, 37/i, pp. 26-47.

Subramanian, M, 2007: 'Carnatic Ragam Thodi–Pitch Analysis of Notes and Gamakams', *Journal of the Sangeet Natak Akademi*, 41/1, pp. 3-28.

Swift, Gordon N, 1990: 'South Indian" Gamaka" and the Violin', *Asian Music*, 21/ii, pp. 71-89.

Viswanathan, Tanjore, 1977: 'The Analysis of Rāga Ālāpana in South Indian Music', *Asian Music*, 9/1, pp. 13-71.

Viswanathan, Tanjore and Allen, Matthew Harp, 2003: *Music in South India: Experiencing Music, Expressing Culture* (New York: Oxford University Press).

Widdess, Richard, 2013: 'Schemas and Improvisation in Indian Music', in Ruth Kempson, Christine Howes and Martin Orwin (eds), *Language, Music and Interaction*, (London: College Publications), pp. 197-209.

Wiesendanger, Mario, Baader, Andreas and Kazennikov, Oleg, 2006: 'Fingering and Bowing in Violinists: A Motor Control Approach', in Eckart Altenmüller, Mario Wiesendanger and Jürg Kesselring (eds), *Music, Motor Control and the Brain*, (Oxford: Oxford University Press), pp. 109-23.

Winges, Sara A, Furuya, Shinichi, Faber, Nathaniel J and Flanders, Martha, 2013: 'Patterns of Muscle Activity for Digital Coarticulation', *Journal of neurophysiology*, 110/1, pp. 230-42.

Yang, Ruiduo and Sarkar, Sudeep 2006. 'Detecting Coarticulation in Sign Language Using Conditional Random Fields', in *Pattern Recognition, 2006. ICPR 2006. 18th International Conference on*, pp. 108-12.

ABSTRACT

This article presents an analysis of small-scale melodic movement in South Indian rāga performance, employing the concept of coarticulation, defined here as the tendency for the performance of a unit to be influenced by that which precedes or follows it. Coarticulation has been much studied in phonetics, and also explored to some extent in sign language and the kinematics of musical instrument performance. Here, I seek to account for variation in the performance of Karnatak musical units known as *svaras* (scale degrees of a rāga) and *gamakas* (ornaments) through the phenomenon of coarticulation, thus providing an analysis of small-scale melodic movement that focuses on the dynamic processes that form the style rather than categorisation of discrete elements.

   The material investigated is a video recording of *ālāpana* (improvisation) in rāga Toḍi performed by the Karnatak violinist T.K.V. Ramanujacharlu in Tamil Nadu, South India. A section of the recording is transcribed into staff notation and

visualised through pitch contour graphs created in Praat sound analysis software. The hand movements required to produce the musical phrases are described from observation of the video alongside figures showing motion-tracking data. Interviews with musicians, participant observation, and the author's experience as a student of Karnatak violin provide the foundation for interpretation of the material.

Results show that coarticulation can be seen between *svaras* through the oscillatory *gamakas* with which they are performed. Atomistic and gestural conceptions of South Indian music are discussed, following which suggestions are made for the implications of this research in modeling the Karnatak style, and potential applications in musical information retrieval.