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Incidental Learning of Modal Features of North Indian Music

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ABSTRACT

Musical knowledge is largely implicit; it is acquired without awareness of its complex rules, through interaction with a large number of samples during musical enculturation. Whereas several studies explored implicit learning of features of Western music, very little work has been done with respect to non-Western music, and synthetic rather than ecologically valid stimuli have been predominantly used. The present study investigated implicit learning of modal melodic features in traditional North Indian music in a realistic and ecologically valid way. It employed a cross-grammar design, using melodic materials from two ragas that use the same scale, Toṛī and Multānī. Participants were trained on the ālāp section of either rāga and tested on novel excerpts from joṛ sections of both ragas featuring 5 distinct melodic features and using binary familiarity and 6-point confidence judgments. Three of the five features were melodically distinctive of either rāga, whereas two were only distinctive based on other than mere pitch sequence features (for instance, emphasis). Findings indicated that Western participants in both groups incidentally learned to recognise some, but not all, of the five features above chance level, and that the melodically distinctive features were better recognised than the non-distinctive ones. Confidence ratings suggest that participants' performance was consistently correlated with confidence, indicating that they became aware of whether they were right in their responses, i.e. they possessed explicit judgment knowledge. Altogether participants began to incidentally acquire familiarity with a musical style from beyond their cultural background during only a very short exposure.

I. INTRODUCTION

The cognition of music of a particular style is grounded on a large amount of knowledge about the particular features of the musical style and culture. Western participants deploy detailed musical knowledge and competence even if they have had very little or no formal musical training (Bigand, 2003; Bigand & Poulin-Charronat, 2006). Knowledge of musical structure is acquired through attention and interaction with music, listening, performing, dancing during development and enculturation or later familiarisation (Deliège & Sloboda, 1996). There is ample evidence for knowledge of (Western tonal) music that is acquired during development (Trehub, 2006). Such musical knowledge is largely *implicit*: it is represented without explicit awareness of underlying complex structure or rules governing the musical style, and it is acquired incidentally, by interaction without explicit searching for rules. In this respect it resembles implicit linguistic syntactic knowledge (Williams, 2009).

The term "implicit learning" was coined by Reber (1967) and refers to the ability to acquire knowledge rapidly about a particular domain without intending to (by mere exposure or interaction; "incidental learning"), and frequently without awareness of the knowledge acquired ("implicit knowledge"; see, e.g., Reber, 1993; Perruchet, 2008; Williams, 2009; Dienes, 2011, for reviews). Implicit learning is a general cognitive process involved in skill acquisition, decision making, language acquisition and production (e.g. Reber, 1993; Cleeremans et al., 1998). Similarly implicit learning constitutes a root process for music cognition across cultures (Frances, 1958/1988; Krumhansl, 1990; Tillmann, 2005; Stevens & Byron, 2009; Rohrmeier & Rebuschat, accepted). Although the importance of implicit learning for cross-cultural music cognition has been conceptualised theoretically, more experimental work is required to explore and underpin its fundamental role.

Implicit musical knowledge and implicit learning are closely related to processes of statistical learning that are assumed fundamental to music perception (Huron, 2006), for instance with respect to pitch profiles, statistical knowledge of pitch or chord transitions, relations between keys, chords and pitches (e.g. Krumhansl, 1990). From a methodological perspective, it has been argued that research on implicit learning and statistical learning examine the same phenomenon with different methodologies (Perruchet & Pacton, 2006). While implicit learning research is largely concerned with the types of structures that may be learned (e.g. chunks, abstract patterns, nonlocal dependencies; see Pothos, 2007), statistical learning research is concerned with the role of event frequencies, forward or inverse transition probabilities and their role for segmentation, (musical) „word" learning, etc. (e.g. Saffran et al., 1999; Huron, 2006). Implicit/statistical knowledge is fundamental for processes of music prediction and expectancy formation (Rohrmeier & Koelsch, 2012; Pearce, 2005), style recognition, performance and production. Through the formation of expectancies and subsequent patterns of fulfilled, unfulfilled, delayed, anticipated continuations it plays an important role for the establishment of some of the emotional reactions to music (Meyer, 1956; Huron, 2006; Koelsch, 2011).

A. Background

Implicit learning of music has been explored in a series of studies that mostly use synthetic stimuli. Several studies explored learning of melody under artificial grammar learning or statistical learning paradigms. In the context of segmentation, Saffran et al. (1999) showed that adults and infants were able to learn boundaries between short tone „words" from a continuous monophonic stream. Tillmann & McAdams (2004) showed learning of short timbre triplets using a similar paradigm. Schön et al. (2008) showed that statistical learning of tone words was enhanced when sung, particularly when statistical information between syllable words and tone words matched. ERP experiments with similar methodologies found evidence for statistical learning that could not be measured behaviourally (Clement & Schön, 2010) and a learning advantage of musicians over nonmusicians (Clement & Schön, 2011). Omigie & Steward (2011) found statistical learning to be robust even in participants with amusia.

Another set of studies explored implicit learning of melodic structure governed by an artificial finite-state grammar (Chomsky, 1956). Loui et al. employed an artificial non-Western scale to explore statistical learning of melodies of the complexity of a small finite-state grammar (Loui & Wessel, 2008; Loui et al., 2010). They found learning of the novel tone profiles as well as knowledge of the melodies. Implicit learning of short finite-state melodies had an effect on priming of target tones (Tillmann & Poulin-Charronat, 2010). Rohrmeier et al (2011) constructed a finite-state grammar to create larger melodies of up to 32 notes and found implicit learning that could not only be accounted for with statistical knowledge of small fragments (chunks) as well as evidence for a strong online learning effect (cf. Rohrmeier, 2009). In a follow-up study, Rohrmeier & Cross (2010) showed that implicit learning was reduced when the artificial grammar systematically violated Narmour‘s (simplified) melodic principles (Narmour, 1990; Schellenberg, 1997) melodic principles.

A central question in the implicit learning literature concerns the types of structure that may be acquired implicitly (cf. Perruchet, 2008; Pothos, 2007; Williams, 2009). Learning of small fragments (chunks) has been found in numerous studies. Similarly, learning of tone statistics from listening has been shown as a stable finding (Krumhansl & Keil, 1982; Castellano et al., 1984; Krumhansl, 1990; Loui et al., 2010). A series of studies examined learning of melodic structures of the type A1B1C1D1 A2B2C2D2, in which A1 and A2, etc, are corresponding elements (cross-serial dependencies). Dienes & Longuet-Higgins (2004) found learning of dodecaphonic melodies of this structure (inversion or inverse-retrograde) only by selected experts. Kuhn & Dienes (2005, 2006) examined the learning of similar diatonic melodies further, though their results remain debated (cf. Desmet et al., 2009; Dienes & Kuhn, forthcoming). Creel et al. (2004) extended the statistical learning paradigm (above) by exploring whether interleaved tone words of the type AxByCz could acquired, but only found learning when the two tone words were perceptually separated by auditory streaming.

Apart from the study of melodic structure, implicit and statistical learning has been found in other musical parameters. Learning of harmony sequences has been examined using artificial finite-state grammars to structure chord sequences (Jonaitis & Saffran, 2009; Bly et al., 2009). Based on theoretical results that harmony is governed by a more complex context-free grammar (Lerdahl & Jackendoff, 1983; Rohrmeier, 2007, 2011), Rohrmeier & Cross (2009) employed an artificial octatonic context-free grammar and found evidence that participants acquired more than mere knowledge of chunks. A few studies have extended the implicit learning paradigm to other musical parameters, notably, artificial timbre sequences (e.g. Bigand et al., 1998; Tillmann & McAdams, 2004), and rhythmical patterns (e.g. Shin & Ivry, 2002; Salidis, 2001; Tillmann et al., 2011).

Most of the studies reported employ artificial synthetic stimuli and are concerned with the types of structure that could be acquired by participants or not. All studies, however, share the underlying hypothesis that the learning found using artificial structures extends to ecologically valid learning. The purpose of the present study is to provide a case study for implicit learning of realistic non-Western music in order to underpin and examine this link. Further, it has been argued that implicit learning constitutes a fundamental cognitive process which is generally relevant for music cognition in all cultures (Stevens & Byron, 2009); however, there has been very little research exploring implicit learning in cross-cultural contexts or using non-Western materials.

While the importance of cross-cultural research and focus on non-Western music for music cognition has long been recognised (e.g. Carterette & Kendall, 1999; Stevens, 2004, in press; Cross, in press), many ethnomusicology researchers, with exceptions (e.g. Stobart & Cross, 2000), have been wary of the empirical methods accompanying cognitive music psychology. Recent interest in cross-cultural research methodologies, however, makes a step towards integration (this is reflected in the recent discussion of this issue in *Ethnomusicology* (Lawson, 2012; Becker, 2012; Harwood, 2012; Zbikowski, 2012). This joint paper results from exactly such a convergence of interests. Our study links with a body of studies that address such comparative cross-cultural cognitive questions: Ayari & McAdams (2003) compared segmentation of a performance of Arab modal music (maqam) by European or Arabic listeners and found that both groups applied salient surface features (e.g. register changes or pauses). The latter group, however, also chose segmentations based on small modal changes which the European listeners seemed not to notice. Other studies examined melodic expectation with a reference to Narmour’s rules (1990) that were presumed to be universal (e.g. Schellenberg, 1996; Krumhansl et al., 2000; Eerola, 2004). With respect to musical learning and the acquisition of pitch profiles following the fundamental concept of tonal hierarchies (Krumhansl, 1990), several pieces of research have been carried out with respect to Indian music (Castellano et al. 1984), Balinese music (Kessler, Hansen & Shepard, 1984), and Korean music (Nam, 1998).

Indian classical music figures comparatively large in the literature of cross-cultural music cognition. One thinks for example of the work of Vaughn (1992) and others on Jairazbhoy’s “circle of ṭhāṭs” theory (Jairazbhoy 1971: 46–64), or Krumhansl’s on tonal hierarchies (1990: 253–70). These studies focus on very basic elements of music – i.e. pitches and scales – and rely on synthetic materials as experimental stimuli rather than “real” musical performance. The work of Kippen on tabla grammar stands out for involving the performers in analysing performance material (e.g. Kippen 1992 etc.); that of Clayton on vocal *khayāl* performance analyses actual performances and looks at audiences as well as performers (Clayton 2007).

II. MOTIVATION

The aim of the present work was to apply the cross-cultural cognitive framework of implicit learning to the case of modal melodic features in traditional North Indian music. In this context we refer to modal structure as the combination of specific scale structure with characteristic melodic patterns (Powers, 2001). The study uses real recorded performances in order to explore the acquisition of an unfamiliar, yet realistic and ecologically valid musical system from real performances. It therefore focuses not on Indian musicians or enculturated audiences but particularly on Western subjects who are not familiar with Indian music, including both musicians trained in Western music and non-musicians. Our aim was to extend the previous work by Castellano et al (1984) on learning tonal hierarchies of North Indian music, by employing established implicit learning paradigms (Cleeremans et al., 1998) in order to explore learning of prototypical melodic features. Accordingly, we selected two ragas which featured 7 identical pitches as their scale degrees (see below), but differed with respect to the sequence and emphasis of pitches in melody. This would enable us to explore the extent to which specific unfamiliar non-Western stylistic melodic constructions are acquired, which goes beyond investigating the statistical learning of pitch profiles (Krumhansl, 1990).

To perform an experiment with a real performance of Indian music provides several challenges for the analysis (regarding pitch features and intonation, see below). Despite these difficulties, we decided to perform this experiment in order to examine *implicit learning of a real performance* as a whole and to reserve fine-grained computational or statistical analysis or modelling of the involved features for subsequent research addressing these methodological points separately. For the same reasons this study does not subscribe to the aforementioned debate exploring the boundaries of the type of complexity that may be acquired.

III. NORTH INDIAN CLASSICAL MUSIC

Several factors make North Indian classical music an appropriate case study for implicit learning research - not only with respect to perception but also performance. Unlike Western classical music, it makes only limited use of written notation; students learn mainly through reproducing sample materials played or sung by the teacher, often with little or no verbal explanation, until they have been internalised. The grammatical rules of melody are thus inferred, consciously or unconsciously, from the materials learned. The music is typically performed by a soloist, with percussion and drone accompaniment, and the soloist is expected not only to play from memory but also to improvise spontaneously (though this may be rehearsed to some degree). Such improvisation is constrained by the rāga, a modal concept operating between the levels of scale and tune (Powers, 2001); the chosen rāga will determine not only the scale to be used (based on a semitonal division of the octave), but also typical phrases, allowable pitch-sequences, a hierarchy of strong and weak notes, and other features. The voice, and melody instruments such as the sitār, embellish melodic pitches with oscillations and pitch-glides; nevertheless pitch awareness is acute, and out-of-tune (*besur*) playing is sharply criticised. Listeners show varying degrees of connoisseurship, but it is assumed that they recognise at least the most popular rāgas, whether through conscious learning or repeated exposure. Performance typically begins with a free-tempo introduction (*ālāp*) in which the melodic features of the rāga are systematically exposed; on the sitār, this is followed by a second introduction (*joṛ*) in which the same features are introduced in a different rhythmic style. We have exploited this structure in our experimental design, and hypothesise that part of its function is to encourage implicit learning of key features of the rāga by listeners, regardless of their previous exposure to it.

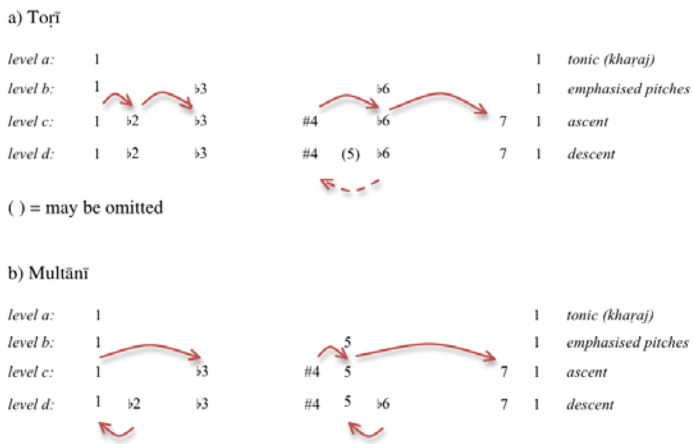

Figure 1. The tonal hierarchy of the rāgas Toṛī and Multānī.

A. The ragas Toṛī and Multānī

Our study is based on exploring implicit learning of the two different ragas Toṛī and Multānī. Both ragas feature the same seven scale degrees, but differ with respect to how these scale degrees are employed in melodic composition and improvisation. The structure of Toṛī is described by Powers (1970), the structure of Multānī by Sanyal and Widdess (2004: 180-208). Examples of both rāgas are given by Bor (1999: 120–3).

The tonal hierarchy of these two rāgas can be expressed as follows (Fig. 1; in analogy to the representation by Lerdahl, 2001). In each rāga, all 7 scale-degrees can be used in descent (level d), but some are omitted in ascent (level c). Of those that remain, the tonic (*kharaj*) and one or two other degrees are recognized as having structural significance (*vādī* and *samvād*ī in theoretical terminology) (level b). The tonic (represented as pitch-class C in Fig. 2) is sustained in the drone throughout (level a), and is regarded as the concluding pitch. Taking all these factors into account, it can be seen that in Toṛī, b6 has greater significance than 5, while in Multānī, the reverse is the case. While 4 and 7 are of similar importance in both rāgas, b2 is more prominent in Toṛī than in Multānī. b3 is prominent in both rāgas, but in Toṛī it functions additionally as a segment boundary, as does b6 (Powers 1970).

Some of the melodic movements characteristic of these rāgas can be mapped onto their pitch hierarchy (Fig. 1). Thus in Toṛī, because *b*2 is included in the ascending line (level c), it is included in stepwise movement from 1 to *b*3, whereas in Multānī, one must move by leap from 1 directly to *b*3, since b2 occurs only in descent. Similarly, in descent one may repeat the step *b*3 *b*2 in Toṛī, but never in Multānī; in the latter, *b*2 and *b*6 are treated as very weak transient notes occurring only as descending leading-notes to 1 and 5 respectively. The relative positions of 5 and b6 in the pitch hierarchy determine that in Toṛī, one moves from #4 to b6 and vice versa, omitting 5 except occasionally in descent, whereas in Multānī one moves by semitone steps from #4 to 5 and from *b*6 to 5. Correspondingly one ascends from b6 to 7 in Toṛī, but from 5 to 7 in Multānī.

A performer might express the above information in non-verbal mode by playing characteristic phrases that embody the features we have described (cf Bor 1999: 120 and 122). Of particular importance are phrases that uniquely identify the rāga concerned (*pakad, rāg ang*); such phrases may be used near the beginning of a performance instead of verbally announcing the rāga. In Toṛī, the pitch-sequence 1 *b*2 *b*3 *b*2 1, often approached from below: b6 7 1 *b*2 *b*3 *b*2 1, is considered to identify this rāga (Powers 1970). In Multānī, the equivalent identifying feature would be the sequence *b3* (*b*2) 1, approached either from below: 7 1 *b*3 (*b*2) 1, or above: #4 *b*3 (*b*2) 1, where the (*b*2) is very lightly played, and only included in descent (Sanyal and Widdess 2004: 180–1).

IV. METHOD

A. Participants

Sixty-five western adults participated in either group A (Toṛī) or B (Multānī). Five participants were excluded because they had previous knowledge of North Indian music and one participant because she or he did not fill out the forms and did the experiment in a serious way. The remaining participants were grouped by their musical experience. Participants who had received 6 or more years of instrumental lessons were assigned to the "musician" group, others to the "nonmusician" group. Group A (Toṛī) had 18 musicians and 10 nonmusicians (mean age 24.4 years). Group B (Multānī) featured 21 musicians and 10 nonmusicians (mean age 23.2 years). All participants were from a Western cultural background with no knowledge and little or no experience of Indian music. Musician participants all played their instrument(s) actively, had an average of 12.5 years of music lessons and practised/performed 8.3h per week on average. Nonmusician participants were playing music, if at all, not regularly at the time of the experiment (0.6 h per week); in the past, they had practised an instrument for 0.8 years on average or had stopped practising (if they had played) for 9 years on average.

B. Materials

1) Ragas and recording. The experiment employed melodic materials from two ragas that use the same scale, Toṛī and Multānī. Two performances were recorded for the purpose by a professional sitarist, Dharambir Singh Dadhyalla, one in each rāga. An additional short performance of the rāga Jaijaivantī, which has a markedly different scale from Toṛī and Multānī, was recorded to be used for the familiarisation period of the experiment. For each rāga the performer played two sections, ālāp and joṛ; he was asked to play each section for 5 minutes, in order to minimise any difference in overall tempo (which tends to reflect the length of the performance: the performer may start more slowly if there is more time available, and vice versa). We chose the rāgas Toṛī and Multānī for the following reasons: They are both very well-known rāgas, such that any trained Indian classical musician would be able to play them. They are both heptatonic and employ the same basic scale (*ṭhāṭ*). This scale is markedly different from the Western major or minor modes, so listeners are less likely to be influenced by chance resemblances to familiar music (cf. Rohrmeier & Cross, 2010). They have distinctively different tonal hierarchies and pitch sequences: that is, different strong and weak notes, and different ascending and descending lines. Thus if listeners show awareness of the differences between these rāgas, they must be responding to differences in melodic features, since in all other respects the rāgas are alike.

2) Melodic features. We selected five different features (see Fig. 2 at the end of the document) to explore patterns that can be learned by participants (similar to the methodologies by Shanks, Johnstone & Staggs, 1997; Rohrmeier, Rebuschat & Cross., 2011). According to the core melodic characteristics of each rāga outlined above, we employed three prototypical melodic features (1-3) where the sequence of pitches and the relative degrees of pitch emphasis clearly distinguish the two rāgas. Feature 1 (fifth treatment) corresponded to the difference regarding the area around 5 (from 3 below to 6 above). Feature 2 (tonic establishment) corresponded to the area around 1, 2 and 3, with extensions to 6 or 7 below and 4 above. Feature 3 (tonic ascend) corresponded to the ascending line from 4 to 1. We also sought two features that would be ambiguous regarding pitch sequence: features where we could expect subjects to have difficulty distinguishing one rāga from the other based on pitch sequence only. In point of fact, hardly any possible phrase in either rāga is truly ambiguous. In the features we chose, the sequence of pitches is the same in both rāgas, but the different tonal hierarchies impose different patterns of emphasis, as illustrated above (Figure 1). Nonetheless we hypothesised that these features with identical pitch sequences would be learned less well compared with the first 3 features. Feature 4 & 5 employed the descending lines from 1 to 5 (upper descend) and 4 to 1 (lower descend) respectively.

3) Training and testing materials. The entire ālāp section of the one or the other recording was taken as training material for each group. Short snippets (of 2-4 seconds) from the joṛ sections of both recordings were selected as testing materials for both groups. This insured that participants would not just have learned the exact example as played in the learning phase (mere memorisation), but that they had to recognise a different form or instance of the same melodic feature. Eight instances for each feature type were chosen from each rāga. In total 40 testing stimuli were selected for each rāga.

C. Procedure

The experiment followed established implicit learning methodologies (Cleeremans et al., 1998) and applied a cross-grammar design (e.g. similar to Jonaitis & Saffran, 2009) using melodic materials from both ragas above. It consisted of a learning phase and a testing phase. Before the learning phase participants had a brief introduction to the difference between ālāp and joṛ sections of North Indian music performances (without using these terms): they heard extracts from an ālāp and joṛ, by the same performer, in rāga Jaijaivantī. The learning phase was not announced as such. Participants were exposed two times to the training ālāp under incidental learning conditions using a phrase-segmentation task in order to force them to pay close attention to the music. They were instructed to indicate by pressing the space bar whenever they heard a musical phrase end. Participants of group A were exposed to the Toṛī ālāp recording, while participants of group B were exposed to the Multānī ālāp. Participants were also not informed that they would be tested afterwards. The testing phase was identical for both groups and presented all 80 stimuli from both ragas in randomised order. Our main hypothesis was that participants would exhibit learning through different endorsement patterns depending on the ragas they were exposed to. Following common implicit learning procedures (Cleeremans et al., 1998; Williams, 2009), participants responded to each stimulus with forced-choice familiarity ratings (familiar vs. unfamiliar) and subsequent binary confidence judgments. The confidence judgments used a 6-step scale (from 1=complete guess, 2=slight intuition, to 6=completely sure). Participants were instructed to press 1 only when the answer was a complete guess (they could have equally tossed a coin). The instructions emphasised that the task was not easy and that participants should follow their intuition.

V. RESULTS

A. Modal features

An ANOVA with group (trained with Toṛī or Multānī) and musical training as between subject variables and test rāga (tested with Toṛī or Multānī) and feature type as within-subject variables (composed of the different 5 feature types) found no significant effect of group (p = .61) and a significant effect of musical training, F(1, 55)=6.49, MSE=.083, p=.014, and a highly significant interaction of test rāga and group, F(1, 55)=11.13, MSE=.45, p=.002. This underpins that there were no significant differences in overall endorsements between the two groups, and that musical training had an effect on participants' endorsement patterns (i.e. they tended to endorse items more frequently than nonmusicians). The strong interaction supports the main hypothesis of the experiment, that training with either rāga affects the responses to either Toṛī or Multānī stimuli in the test: i.e. overall participants tended to endorse excerpts from the rāga they were exposed more frequently than the ones from the other rāga.

There was a highly significant within-subjects effect of feature type, F(4, 55)=32.74, MSE=.84, p<.0005, but no interactions with musical training or group (all p>0.2). This suggests that there were overall response differences between the different stimulus types, which we will analyse in detail below. Except for the strong interaction of test rāga and group, there was no significant effect of test rāga and no interaction of test rāga with musical training (p>0.05). This suggests that neither rāga yielded significantly different performance patterns independently of the training. There was a marginally significant interaction between test rāga, group and musical training, F(55, 1)= 3.62, MSE=.15, p=.062. This indicates that the musician group were marginally better in distinguishing both ragas than the nonmusician group (compare Fig. 3).

Further there was a significant within-subjects interaction between feature type and test rāga, F(4,55)=3.51, MSE=.082, p=.008, but no other significant interactions between feature type, test rāga and other variables (all p>.15). This indicates that the 5 feature types had different response patterns between the two ragas, and that this was independent of musical background or group.

Specific contrasts compared differences between feature type and group responses (compare Fig. 4). An overall contrast comparing feature type 1-3 ("unambiguous") with type 4-5 ("ambiguous") between both groups was highly significant, F(1,57)=14.94, MSE=1.05, p<0.0005. This suggests that there was a systematic response difference between the melodically different features 1-3 and the more subtle differences reflected in type 4 and 5. Another set of specific contrasts compared differences between each feature type and group. These group differences were significant for feature 1, F(1, 57)=4.49, MSE=.21, p=.039, feature 2, F(1,57)=14.81, MSE=.88, p>.0005, while features 4 and 5 reached only marginal significance, F(1,57)=3.43, MSE=.22, p=.069 and F(1,57)=3.79, MSE=.18, p=.057, respectively. The contrast for feature 3 was not significant (p>.13).

The stimuli were controlled by one expert participant in Indian music in order to control for the adequacy of the stimuli and their distinctness between both ragas. He performed near ceiling distinguishing both ragas.

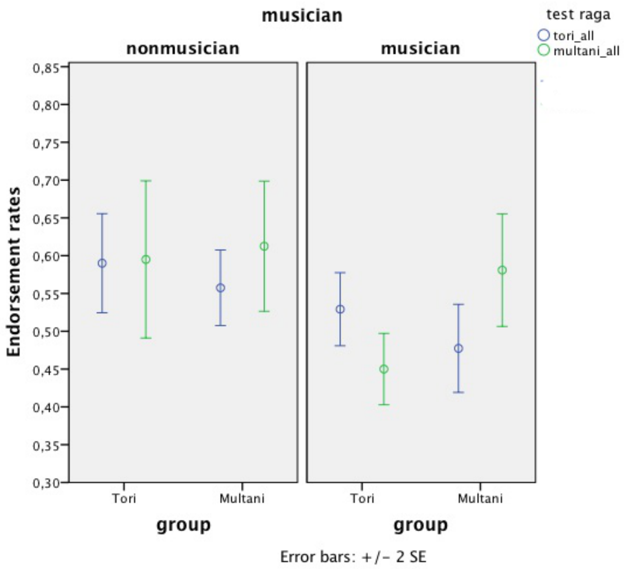

Figure 3. Overall endorsements of musician and nonmusician participants in both groups.

B. Awareness

We employed the method by Dienes & Longuet-Higgins (2004) to assess participants' awareness of their acquired knowledge. They discuss two criteria for assessing a relationship between confidence and performance in order to assess awareness. According to the guessing criterion (Dienes & Berry, 1997), above chance performance when participants report to be guessing indicates that they possess some implicit knowledge. Secondly, the zero-correlation criterion assumes knowledge to be implicit if performance and confidence are unrelated. Both criteria are examined by computing the regression of performance against confidence for each participant separately and analysing mean intercept (at the guessing level; confidence=complete guess) and mean slope.

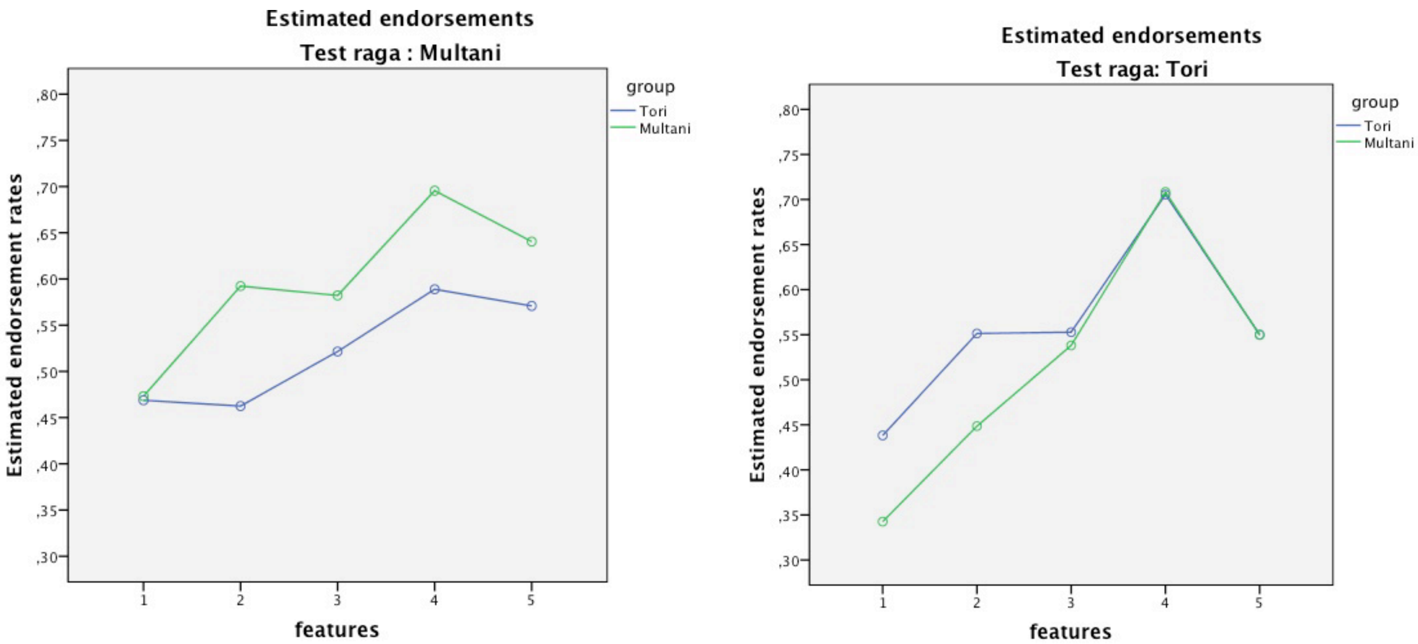

Figure 4. Endorsements for the five features for the test raga Tori (left) and the test raga Multani (right).

For musician participants of the Toṛī and Multānī groups, intercepts (47.1% and 46.1% respectively) were not significantly different from chance (both p>.3), while the slopes (0.023 and 0.034 respectively) were significantly above 0 (t(18)=1.24, p=0.23 and p=.015; t(20)=2.67). For nonmusician participants of the Toṛī and Multānī groups, intercepts (42.0% and 46.1% respectively) were not significantly different from chance (both p>.16), while the slopes (0.069 and 0.037 respectively) were marginally significantly different from 0 in the first case (t(9)=1.94, p=.084) and significant in the second case (t(20)=2.67, p=.015).

This indicates that for musician participants performance was correlated with confidence, suggesting that they knew when they were right. Nonmusicians' responses were only correlated with performance for the case of Multānī, but marginally for the case of Toṛī , suggesting that nonmusicians of the Multānī group could judge when they were right, while those in the Toṛī group could not do so equally well. Overall this suggests that participants learned incidentally but became largely aware of their knowledge according to both criteria. Following the distinctions by Dienes & Scott (2005), it may be argued that participants possessed conscious *judgment knowledge*: i.e. they knew that they were right. It is less likely that they had explicit *structural knowledge* of the specific melodic features of the rāga.

VI. DISCUSSION

The findings suggest that participants became sensitive to some features of the modal structure and provide strong evidence for *incidental learning*: depending on the rāga they listened to during exposure, they endorsed excerpts that came from this rāga more frequently than those from the other rāga (see fig. 3). The learning is incidental because it happened unintentionally (i.e. without explicit testing, search for rules, examining, etc.) when participants paid attention to the rāga they were exposed to; we cannot claim it to be entirely implicit because participants acquired explicit judgment knowledge; however, as argued below, it is unlikely that participants had explicit structural knowledge. In this respect, the results have several implications: First, they provide a prime example of rapid familiarisation to a specific musical system. While there has mostly been evidence for such an effect based on small and limited artificial systems (as discussed above), these findings link these abstract effects with an ecologically valid musical case of a real performance. They further underpin that familiarisation through incidental learning can be remarkably rapid - in this case participants perform above chance after only 10 minutes of exposure, and one may hypothesise that participants' performance may increase after even longer times of exposure. From this perspective, the findings are in accordance with theories that assume that musical familiarisation and enculturation (in adulthood or development) are to a large part based on incidental learning.

Second, the rapid learning found in this study supports that particular knowledge of a piece may be picked up during its performance (this is consistent with strong online learning found by Rohrmeier et al., 2011; or, Tillmann & McAdams, 2004; as well as computer models, Rohrmeier, 2009). In this case, the exposition of the melodic features during the ālāp section may indeed be sufficiently rich to make possible not only recognition of the features, but also elicitation of some emotional effects resulting from predictive knowledge (Huron, 2006; Rohrmeier & Koelsch, 2012), as well as appreciation of the elaboration and variation of these features in the joṛ section.

The results with respect to the five different features entail a number of insights with respect to both ragas. It is remarkable that feature 2 was learnt best - since in each case it is recognized by musicians as a distinctive, identifying feature of the rāga (see above). The weaker, but still significant learning of the neutral features 4 and 5 underpins that participants are sensitive to and acquire expressive and emphatic features - a factor additional to mere learning of pitch statistics and pitch transitions. It is important to remark here that feature 2 contains feature 5 in part or entirely. Hence, the better performance for feature 2 suggests that participants picked up some additional structure on top of the difference of emphasis of b2, to recognise the differences between both ragas.

It may be objected that these rāgas are distinguished by differences in the microtonal intonation of certain pitches, and that listeners may therefore be responding to these differences rather than to differences of melodic grammar. Thus the scale-degrees *b*2 and *b*3 in Toṛī are sometimes said to be microtonally lower than in other rāgas such as Multānī (e.g. Bor, 1999:120, Jairazbhoy, 1971:167 f.). Measurements of the tuning of the sympathetic strings of the sitār, which are sounded in sequence at the beginning of each ālāp, indicated that the performer did tune the sympathetic strings for *b*2 and *b*3 microtonally lower in Toṛī than in Multānī, by about 9 and 13 cents respectively. In the performance, tunings for *b*3 similarly average about 12 cents lower in Toṛī than in Multānī, but tunings for *b*2 average around the same pitch for both rāgas; and there is considerable variation in the pitch of both scale-degrees in both rāgas.

Microtonal intonation is a problematic issue in Indian music because the consistency with which it occurs and its significance has been exaggerated by some writers (notably Daniélou, 1954; refuted by Jairazbhoy and Stone, 1963). It is more helpful to consider microtonal pitch-nuance as closely bound to pitch-sequence: in general, pitches tend to be tuned higher in ascending than in descending contexts (Levy, 1982). In Toṛī, *b*2 and *b*3 in the identifying phrase 1*b*2 *b*3 *b*2 1 may be pitched slightly lower than usual—without becoming "out of tune" (*besur*)—because the motif starts from and returns to 1. Given this variability, it seems unlikely that microtonal differences of pitch could have been the only or main factor in determining participants' responses. Rather microtonal intonation may possibly combine with pitch sequence and melodic emphasis as a joint pitch representation shaping participants' learning and perception. It may have contributed to the high performance for feature 2 (tonic establishment) while other features containing these pitches were not comparably efficiently learned.

Statistical or implicit learning experiments commonly analyse patterns of frequencies and transition probabilities in order to assess hypotheses about learned representations. Because our experiment features a real performance, Western standards of pitch categorisation and identity do not transfer easily to this case; differences in intonation and integral parts of modal features such as slides (e.g. in features 1-3) cannot be straightforwardly adopted into common pitch profiles or transition matrices and thus standard statistical or chunk analyses require substantial additional research work with respect to their well-defined characterisation based on features of the signal and the implementation of specific reliable computational analysis methods.

Accordingly, unlike some other studies in the implicit and statistical learning literature, this experiment was not intended to employ complex structural features (like nonlocal dependencies) in order to explore the limits of what could be learned implicitly (such as chunks, nonlocal dependencies, repetition structure). The five feature types constitute prototypical pitch sequences with some, but constrained flexibility in pitch order/sequence and some greater rhythmic variability. There are solid findings that transition probabilities (or bigrams) as well as larger melodic chunks are acquired (e.g. Perruchet & Pacteau, 1990; Saffran et al., 1999; Rohrmeier et al., 2011; Loui et al., 2010). Similarly computational models like IDyOM underpin the cognitive plausibility of rapid chunk learning and the integration of different melodic features (such as scale degree, rhythm, metre, etc.; Conklin & Witten, 1995; Pearce, 2005; Pearce & Wiggins, 2006). In the context of our study, the inference and mental representation of the modal scale, scale degree and slide categorisation, pitch emphasis and tuning, and short pitch fragments constitute the necessary prerequisites that make learning of these modal structures possible. A detailed computational analysis based on specifically tailored audio transcription and sophisticated categorisation methods is left for future research.

The evidence we have found for recognition of variant instances of melodic features is highly significant because it relates to the communication process between player and listener. Listening to a rāga ideally requires the ability to recognise melodic features in constantly changing instances, i.e. using a form of generalisation with likely implicit structural knowledge about pitch sequences, transitions and emphasis beyond mere exemplar memorisation. Such generalisation presumably contributes to the generation of expectation, an important aspect of the listener's experience in Indian as in Western classical music (Huron 2006).The present findings link with the continuous build-up of patterns and expectancies within ongoing continuous mechanisms of auditory prediction (cf. Rohrmeier & Koelsch, 2012). In relation to the strong links between expectancy and triggered emotions (Meyer, 1956; Huron, 2006) another next step is to explore whether such rapid learning of non-Western melodies already changes melodic priming (cf. Tillmann & Poulin-Charronat, 2010) or even elicits emotional responses.

The results with respect to awareness suggest that participants were to a large extent aware of their learning. This entails that we found evidence for incidental, statistical learning, yet, not implicit learning per se. This does, however, not imply that participants dispose of explicit knowledge - this would be highly unlikely after only 10 minutes of exposure and only partial knowledge of the differences of the feature types. It rather reiterates the distinction made by Dienes & Scott (2005) between structural knowledge and judgment knowledge: one may be aware of one's knowledge without necessarily being aware of the concrete and correct content (or rule) of the knowledge. A native speaker of English may, for instance, be explicitly certain about his judgment that a given English sentence is syntactically wrong (such as "*there is a difference between both ragas*"), yet may not be able to explicitly state the precise rule behind the intuition. Analogously, participants in the present study learned very efficiently, which may have led to them becoming aware of the correctness of their responses (judgment knowledge), yet likely not of the modal melodic rules (structural knowledge).

VII. CONCLUSION

Our study found incidental learning of ecologically valid modal music, and links previous results based on artificial, constructed systems obtained in implicit or statistical learning studies with the case of real musical performance and cross-cultural research. Both musician and nonmusician participants learned the modal structure very efficiently after relatively brief exposure; this further suggests that assumptions about statistical or incidental learning during performances and related emotional effects (cf. Huron, 2006) may be realistically assumed even in unfamiliar music. Our research sheds light on learning processes that are directly linked to fundamental cognitive mechanisms of musical acquisition, enculturation and also development. It is further relevant for stylistic learning with respect to performance or connoisseurship. We found that participants picked up expressive and emphatic features beyond mere pitch sequence structure to distinguish between the ragas. In this study, we have employed real music and a listening experience to provide an appropriate ecologically valid small case study for musical enculturation. In these ways, our study aligns with a growing front of cross-cultural studies which examine fundamental cognitive aspects beyond Western music and bridge methodological gaps between ethnomusicological and music cognition research.

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Figure 2. Description of the five different melodic features used in the experiment.

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