MENTAL MODELS IN THE LEARNING AND TEACHING OF MUSIC THEORY CONCEPTS

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Abstract

A retired physicist attempting to master elements of music theory in a short time found the Mental Model of the keyboard layout invaluable in overcoming some of the related learning challenges and this has been followed up in collaboration with a professor of Music Education. Possible cognitive mechanisms for his response are discussed and it is concluded that his engrained learning habits, which emphasise models as found in physics, are potentially of wider applicability. A survey of the use of Mental Models among competent young musicians indicated that although various models are widely used, this is largely subconscious. The practical question of whether exposure of students to the keyboard would assist them in mastering music theory remains unresolved.

Keywords: keyboard, learning music theory, teaching music theory, mental models.

1. INTRODUCTION

Western music students are required to develop an understanding of pitches, intervals, scales and chords[1] as an essential part of their progress up the ladder of music qualifications. A commonly held view is that approximately Theory Grade 5 or 6, of the well-known examining boards in South Africa[2], provides such an essential foundation. The understanding developed in studying towards such a qualification creates a framework for working with notes, intervals and scales that provides, inter alia:

- Familiarity with intervals that enables singers to sight-read
- Recognition of chords, in their various inversions, and common chord sequences that act as recognisable 'chunks'[3] for instrumental players.
- Structure for key signatures by identifying the notes that 'belong to' the scale and will thus occur most commonly in tonal music played in that scale.

For students who begin music theory study at a very early age, much of this happens in parallel with instrumental or voice exercises. This process is well characterised by Elliott (1995), a prominent music education philosopher and advocate of the praxis-based approach to teaching, as 'parenthetical and contextual'.

[1]For readers unfamiliar with music terms, the definitions in Felix (2010) or Blood (2011) may be useful.
[2]University of South Africa (UNISA), Associated Board of the Royal Schools of Music (ABRSM), Trinity Guildhall.
[3]A 'chunk', in the music context, typically refers to a group of notes, as in a chord or in a phrase, that is recognizable and remembered as a single entity, rather than an assemblage of notes. This was noted by Miller (1956) more than half a century ago.

Whereas much of the effort in learning and playing a scale might appear to be focused on finger and hand dexterity, these note structures, with their underlying logic, are typically established by the mind *en passant* and do not present as tedious memorising tasks.

For the first author (RPS), a retired physicist, a different process was necessary in learning music theory. Lacking the necessary patience for protracted memorising exercises (not to mention the expected future life-span), he attempted to master this foundation in a period of about 5 months, largely as an observer in MAM 301[4] at the University of Pretoria, which was arranged by the second author (CvN). He had become accustomed to achieving mastery of a range of specialisations in a lengthy career, but the quantity of material to be absorbed in such a relatively indigestible lump proved daunting initially. This was overcome by the discovery of the layout of the black and white keys on a piano keyboard as a Mental Model. This paper describes the further exploration of this revelation, both theoretically and by exploration of Mental Model usage in competent musicians, which integrates the world views of physicists and musicians into an acknowledged psychological framework. Important practical implications are explored.

2. LEARNING EXPERIENCES OF A MATURE STUDENT

The musical background of the first author, RPS, was entirely in singing; commencing as a 9 year old entrant at the Eisteddfod in Senekal, a small town in the Orange Free State in South Africa; later involving much choral and solo singing at university and in church; and also, for the past 19 years, as a member of a male singing group and regular soloist in annual amateur Gilbert and Sullivan productions. In common with many of his ilk, he had developed a facility in listening to a part played on a piano and using the score as an *aide memoire* in performance or memorising of the piece. To less experienced fakers, this may masquerade as sight-reading!

As with most singers he was accustomed to listening to hear whether his note harmonised[5] with others sung simultaneously, but he had no real sense of chords. Certainly he lacked the ability to identify a chord, nor was he accustomed to identifying changes of pitch as intervals other than the 3rd and the octave. As a tenor, he was accustomed to singing from both the Treble and Bass Clefs and had learned to cope with the ambiguity in note positions on the staff that this involves. Only at the commencement of MAM 301, however, did he learn that C on the first leger line below the Treble Clef corresponds with the one on the first leger line above the Bass Clef and is known as 'Middle C'. In retrospect it is astonishing that, despite having sung from hundreds of scores, he had never encountered the Grand Stave. (That tenors reading from the Treble Clef actually sing an octave lower than altos or sopranos reading the same written notes may excuse this shortcoming.)

[4]This is the 3rd year music theory course for students majoring in Music for their BA (Mus) degrees. The students typically combine Music with another Major, aimed at preparing them for careers other than as professional musicians.

[5]The 4 simultaneously sounding notes in much choral music tend to fall within a single chord, and choristers develop an 'ear' for this 'harmonising'.

Other experiential baggage that burdened the learning process was the counter-intuitive, at least to one trained in mathematics, process used to identify intervals, leading to such puzzles as chord addition that renders the 'equation' “a third plus a third makes a fifth” ($\frac{1}{3}+\frac{1}{3}=\frac{1}{5}$), which is an arithmetic absurdity. This is remarkable because most of the relationships in music are logical and, indeed, readily accessible to those with a mathematical turn of mind (Garland and Kahn, 1995).

Competent pianists, especially those acting as repetiteurs for amateur singers, have a practice of illustrating structural points in a piece by reaching for the keyboard and playing rapid sequences of notes, often useful to a listener, but mesmerising to an observer, such as RPS, who would be attempting to discover the Why as well as the What behind the point. Furthermore, as a 'life-long learner' RPS had become strongly autodidactic in his learning style[6], which proved to be a hindrance because he frequently needed to hear good music theory learning advice several times for it to be adopted in his learning process[7]. Against this background, RPS received an assignment to research and present the Whole Tone Scale to the MAM 301 class, combined with a, by now familiar, injunction to 'use your keyboard'. This advice had not previously taken hold, but now proved to be crucial in the learning process. In attempting to master this scale, he assimilated, for the first time, the fact that all adjacent notes on a keyboard are separated by a semi-tone but, because of the pattern of positions of black notes, the interval between some adjacent white notes is a full tone. Several important consequences arise:

- If one starts on C, and builds a Whole Tone Scale on the keyboard, the significance of the semi-tone gap between the white keys E - F and B - C immediately becomes apparent.
- One can construct only two distinct Whole Tone Scales: {C, D, E, F#, G#, A#, C} and {C#, D#, F, G, A, B, C#}. Transposing up or down yields the same set of notes. (The scale qualifies as the first in Olivier Messiaen's list of Modes of Limited Transposition.)
- The lack of a 'leading note' separated by only a semi-tone from the return to the tonic, or any other semi-tone interval in the scale, makes this possible.
- Because they are all identical, the ordering of the intervals is insignificant.
- The use of the Whole Tone Scale generates a characteristically 'colourless' effect in music.

Suddenly many of these essential features of music fell into place; puzzles swam into focus and huge discomfort was dissipated. RPS had found a Mental Model and was back in a physicist's comfort zone!

[6]Further references to learning 'styles' recur in the text, usually with the same meaning as in this case viz 'the way in which learners perceive and process information.' (Felder et al, 1988)

[7]This is an important point, because many readers might respond with the question 'But didn't the lecturer tell you this?' Answer: 'Almost certainly, but I couldn't 'hear' it!'

At about the same time RPS attended a performance by a ringer of hand bells and was fascinated to note that he had white and black bells whose pitches corresponded with those of white and black keys on a piano, and he laid them out on his performance bench in the familiar pattern of white and black keys on a keyboard. This seemed to confirm the fundamental character of this pattern. This is not the place for a detailed exposition of why the keyboard has this layout but interested readers, especially physicists, are directed to John Powell (2010) for his 'Ugly Harp' model. RPS encountered this only much later but it would have been a boon during the learning exercise just described. Powell's description is much easier to follow than the classic work of the physicist Helmholtz (1875), although the 800pp of the latter make a fascinating read, not least because of his painstaking experimentation using apparatus alien to the experience of present day physicists; carefully tuned resonators for each note, for example.

3. MENTAL MODELS AND A PHYSICS BACKGROUND

The use of Mental Models to describe the invisible or intangible is routine in Physics. A common example is the Bohr model of the atom, which was Physics III material in RPS's student days but is now familiar to his Gr 10 teenage granddaughter. This uses large white and red balls to represent the neutrons and positively charged protons, respectively, in the nucleus, surrounded by very much lighter electrons with negative charges in orbits around them. Add orbits of different diameters and hence different energy levels and you have a model that can be used to discuss most Inorganic and Physical Chemistry, never mind that no serious physicist or chemist 'believes' that the atom 'looks like' that.

A more contemporary model is 'beam-forming', used by astrophysicists to describe the workings of a radio telescope. Such a telescope comprises an array of aerials designed to capture the radiation emitted long ago by distant stars, where the expanding universe has stretched the wavelengths of the initial radiation into the radio part of the electro-magnetic spectrum. Because the most powerful radio telescopes are vast (cf the Square Kilometre Array planned for the Karoo and surrounding countries) and thus not steerable, they are 'aimed' by calculation, taking account of the fact that the radiation from, say, a distant pulsar, will strike each aerial at a slightly different time. Synchronising the signals thus gives the effect of 'aiming'. To most people the notion of aiming a beam, which is familiar as a ray that comes toward one's eye as visible light, is counter-intuitive, but the model makes it intelligible. This use of models to enable understanding of invisible phenomena is sometimes described[8] as 'model-dependent realism'.

It seems obvious to conclude that the identification of a familiar style of thinking – the Mental Model – enabled RPS as a mature learner to 'break through' into the Music Theory paradigm. Is there any corroborative evidence for this in established thinking in the Cognitive Sciences, however?

[8] See Hawking and Mlodinow (2010) for an accessible discourse.

Interactions with mature musicians suggest that they are not especially aware of having any Mental Model, which impression is corroborated by the experience of the second author (CvN). However, interrogation of a very experienced flautist exacted the comment that a key signature at the beginning of a piece 'told him' that his fingers would be operating in a particular pattern as he played (Hinch, 2010). Also, a very experienced pianist responded that it 'helps me to think in the key' (Theron, 2011). Furthermore, the phenomenon of 'chunking' familiar or repetitive patterns of notes in order to simplify sight-reading (Miller, 1956) appears to be common, and the mind-hand link in pianists referred to above appears universal. There was thus limited evidence that Mental Models are used by musicians.

4. THE PHYSICAL/MENTAL COGNITIVE LINK

The models used in Physics are not personal but are developed by an individual or group and accepted by the relevant knowledge fraternity as being useful for sharing insights. Usage to support reasoning remains central, but these models are readily shed or modified by the users as the contributory facts increase in number. What is known about individual use of Mental Models?

Literature on cognitive processes involved in the performance and appreciation of music was surveyed by the authors for evidence supporting the Mental Model hypothesis that sprang naturally to the mind of a physicist. The sources are mainly in the neurosciences and psychological studies of mental modelling and learning, and in the plethora of, often proprietary, psychological models used to assist subjects with an understanding of their own cognitive/psychological make-up and its behavioural consequences. These are now dealt with *seriatim*.

It is common in modern neuroscience to describe music as an 'emergent' phenomenon, i.e. something that arises when many features of heard sound, viz pitch, timbre, tone duration and loudness, are integrated by the brain into a whole called music but which has no existence outside the mind (Levitin, 2008). There is also a great deal published on the modelling of mental processes in different parts of the brain and the neural correlates associated with learning, playing and hearing music are well identified (Levitin, ibid). The physical properties of the sounds that make up music can be observed to be processed in different portions of the brain before integration in the frontal cortex. One model of how this becomes permanent memory is to view the hippocampus as a store for short-term experience that repetitively 'teaches' the networks in the frontal cortex to establish permanent 'memories' that result in knowledge (McClelland, McNaughton and O'Reilly, 1995, as quoted in Spitzer,1999). On the other hand, Gruhn and Rauscher (2008) note that despite all this, such studies have not moved from correlation to causation and little is known about the neural processes that constitute music learning.

It is commonplace that older persons have lost many brain neurons which should reduce their neuroplasticity. However, in their overview of the literature in Neurosciences in Musical Pedagogy, Edwards and Hodges (2007) make no mention of the effect on learning of loss of neuroplasticity in aging. These examples from the neurosciences seem thus to address a different approach to the Mental Model that forms the subject of this article.

The notion that humans create Mental Models of situations and phenomena is often traced to the psychology researcher Craik (1943) but the work of Johnson-Laird and Byrne (1991) on the model theory of reasoning ushered in a new approach. They describe Mental Models as 'psychological representations of real, hypothetical, or imaginary situations.' They can be fairly extensive and 'structured' as in a Mental Model of one's relationship to another person, or of how electricity works, or of the relationship between one's studies, the examinations to be written and a future career. Tellingly, in the context of this study, they may be 'akin to architects' models of buildings, to molecular biologists' models of complex molecules, and to physicists' diagrams of particle interactions' (Johnson-Laird, Girotto and Legrenzi, 1998).

Unlike this latter group, however, some of the models may be generated in an individual mind and may be unique. In the context of this article, one might also argue that this process is well engrained in a mature learner, especially one who has constantly entered into cycles of learning new skills and working in new areas of specialisation. For such a learner, the need to create a Mental Model for him/herself possibly overrides any willingness to adopt established paradigms by accepting and memorising their content.

A possible conceptual model is to suggest that very experienced autodidacts develop a preference for a particular mode of thinking, possibly even a paradigm, and are comfortable only when they can establish a route to understanding that corresponds to their usual, engrained reasoning style. This is confirmed by Merriam, Cafferella and Baumgartner (2007). In reflecting on the structure of knowledge, they quote the work of Anderson in emphasizing the importance of prior knowledge as well as knowledge being accumulated. They identify so-called 'schemas' as follows:

> *Schemas "represent categorical knowledge… what specific things have in common" (Anderson, 2005 p158)... Schemas are not just passive storehouses of experience, however; they are also active processes whose primary function is to facilitate the use of knowledge. We all carry around with us our own individualised set of schemata that reflect both our experience and our worldview. Therefore, as adult learners, each of us comes to a learning situation with a somewhat different configuration of knowledge and how it can be used.*

Perhaps this is the best summing up of RPS's experience?

In modern management practice it is common for various proprietary behavioural models to be used to assist managers to understand the drivers of their inter-personal behaviour, as well as that of their colleagues (Chapman, 2011). Reference to these affirmed RPS's need to discover a specific route to understanding, e.g. his categorisation in the Myers-Briggs Type Indicator system as an INTJ, one of whose characteristics is to derive comfort once a topic is understood and a decision made, fits this conceptual model. Another relevant behavioural model would be Hermann's 4 Quadrant Thinking Style, in which RPS would fit into Quadrant A (Rational Self/Analytical thinking/Theorist) (Hermann, 2007).

These experiences and this review of Mental Models all beg the question 'If the keyboard layout as a Mental Model helped RPS to understand scales, etc., would it assist music students who don't use keyboards, and possibly have no access to them, to master music theory up to Grade 5?' To some, the Tonic Sol-Fa is a learning framework for identification of intervals and is widely used in South Africa, especially by choral singers and within black communities. This is an essentially aural model which may be an adequate substitute for the more visual keyboard. This gave rise to a survey of young musicians, who play keyboard or melodic instruments or sing, to identify their current models.

5. SURVEY OF MENTAL MODELS USED BY YOUNG MUSICIANS

The authors were able to make good use of CvN's professional network to conduct an experiment to identify the extent to which young musicians use Mental Models, consciously or otherwise. A questionnaire was designed and piloted with a small group (6 students in the 2011 MAM 301 class) and the refined version applied to two groups of students involved in musical performance at the University of Pretoria, viz the members of UPSO, the University of Pretoria Symphony Orchestra, and members of the Camerata Choir. The questions are given in Table 1, although not in the questionnaire layout. The respondents were told that the surveyors were investigating aids to working with intervals, chords and scales; they were asked to interpret the questions for themselves.

An acceptable response was achieved: 31/140 for UPSO and 27/70 for the Camerata; a sample of 58. Not all questionnaires were completed fully, although most omissions were in the section on personal data. Other characteristics of the sample are given in Table 2.

5.1 Discussion of sample characteristics

Age: The majority of the respondents who gave their ages (75%) fell in the typical student age group of 18-25, with two school-going and three more mature orchestra members making up the remainder.

Field of Study: Of the 57 respondents who provided this information, only 20 (35%) were Music Students, half of them in the UPSO. The 8 Engineers were all in the UPSO, 5 of them in the Brass section, whereas all the Architects/Quantity Surveyors, and Arts and Medicine students were in the Camerata.

Table 1: Questions asked in Survey: Use of Mental Models in Music Practice
(Underlined questions called for free-form responses)

Personal Data: Name, Age, Contact No, e-mail.
(These were optional, but requested as useful for follow-up).
Music Background: Current field of study, Musical Instruments (inc voice),
Dates commenced and Formal Qualifications achieved with each instrument as well as Music Theory.
Have you had access to a piano during your studies?
Sight-reading Style or Technique:
Did you learn to sight-read via a formal programme or incidental to music studies?
Did you find learning to sight-read easy or difficult? Can you give an illustrative example?
What made learning to sight-read a Pleasure, or a Pain? Can you give an illustrative example?
What helps you work with Intervals, Chords, Scales?

- Keyboard layout
- Musical sounds in your mind
- Mnemonics that you write out to help you remember
- Rhymes
- Other – Please describe briefly

When you read the **key signature** at the commencement of a piece or section, what signals does it send you? How does this influence your playing/singing?
Do you use Tonic Sol Fa

- For sight-singing?
- To hear intervals in your head before playing them?
- Other?

Number of Instruments played: Over a third of the respondents (38%) play 3 or more instruments and 64% play the piano, although not necessarily as their principal competence.

Formal Qualifications: Of the 45 who reported on this, 42 (93%) had achieved Gr 5 Theory or higher and 40 of the 41 who reported on Practical qualifications had achieved a level of Gr 5 or higher. In the UPSO 16 of 28 (48%) had achieved Gr 8 or higher.

It can thus reasonably be assumed that the sample comprised intelligent, thinking individuals with significant musical competence. (That the general level of musical competence was considerably higher than RPS's is also significant.)

Table 2: Sample Characteristics			
Feature	**Total**	**UPSO**	**Camerata**
Number of responses	58	31	27
Number giving contact details	43	20	23
Age			
Not given	13	11	2
<17	2	2	
18-25	37	12	25
26-39	4	4	
>40	3	3	
Musical Experience			
Not Given	6	3	3
<5	5	1	4
5-10	18	8	10
10-15	22	13	9
16-40	9	6	3
Current Field of Study			
Music	14	10	4
Engineering	7	7	
Accounting/Finance/Commerce	9	1	8
Architecture/Quantity Surveying	6		6
Arts	3		3
Medicine	2		2
Education	2	1	1
Law	1	1	
Agriculture	1		1
Science	1		1
Sport	1		1
Visual Communication	1	1	
Veterinary Science	1	1	
Formal Music Qualifications: Theory			
	Total	**UPSO**	**Camerata**
Gr3	1		1
Gr4	2		2
Gr5	16	9	7
Gr6	15	10	5
Gr7	4	4	
Gr8	5	4	1
Teaching Licentiate			
B Degree	2	2	
Formal Music Qualifications: Practical			
Gr3			
Gr4	1		1
Gr5	8	6	2
Gr6	5	2	3
Gr7	10	4	6
Gr8	17	13	4
Teaching Licentiate		1	
B degree		2	

Number of Instruments Played (incl Voice)	Total	UPSO	Camerata
1	19	9	10
2	17	8	9
3	15	8	7
4	7	6	1

Instruments Played (incl voice)	Total	UPSO	Camerata	No in Group
Voice	29	2	27	**Voice 29**
Organ	4	3	1	**Keyboard 37**
Marimba	1		1	
Piano	31	16	15	
Harp	1	1		**Plucked String 12**
Guitar	11	8	3	
Violin	14	12	2	**Bowed String 24**
Viola	2	2		
Cello	6	5	1	
Double Bass	2	2		
Flute	7	7		**Woodwind 19**
Clarinet	3	3		
Saxophone	1	1		
Recorder	4	4		
Oboe	3	3		
Bassoon	1	1		
Trumpet	2	2		**Brass 13**
Trombone	5	5		
French Horn	4	4		
Percussion	2	1	1	

5.2 Analysis of the Responses

The questions were phrased to enable respondents to identify a range of possible Mental Models. Focus was on the possible role of the Keyboard Layout and Sounds created in the musician's Mind, but ample space for free-form comment was provided in the hope that this would stimulate insightful remarks, especially on mental processing of the printed score into a musical performance. This hope was only partially fulfilled, as will appear below.

Aids to identify Notes/Chords/Intervals: The analysis of these responses by sample group is given in Table 3. The dominant aid is clearly the hearing of Sounds in the Mind, registering over half the responses (54%) whereas the Keyboard Layout scored just a third (33%), although 21% of respondents selected both. Mnemonics and Rhymes were mentioned much less frequently, together comprising less than 13% of the total. These preferences were represented in roughly equal proportions in the UPSO and Camerata data.

The Tonic Sol Fa had apparently been useful for sight singing to about 38% of the total sample and within the group who recorded this there were roughly equal numbers in the UPSO and the Camerata, whereas 42% of the Tonic Sol Fa responses related to assistance with hearing intervals.

Table 3: Aids to identify Notes/Chords/Intervals

Responses	TOTAL	UPSO	Camerata
Keyboard Layout	27	14	13
Mnemonics	1		1
Sounds in Mind	44	21	23
Rhymes	9	3	6
Total	**81**	**38**	**43**
Keyboard Layout + Sounds in Mind	17	8	9
Tonic Sol Fa			
Sight Singing	22	10	12
Hearing intervals to play	16	7	9
Total	**38**	**17**	**21**

One would expect there to be a difference in the use of learning/playing aids relating to the type of instrument in which each respondent is most competent, as indicated by the instrument (including voice) which the respondent had studied and played for the longest period. For purposes of this analysis the competence groupings were taken to be:

1. *Piano (or other keyboard instrument):* involving multiple lines of music and simultaneous playing of many notes.
2. *Strings:* where the player has to 'make the note' and usually only one is played at a time.
3. *Blown:* including woodwinds and brass instruments, where the combinations of keys that are pressed for each note differ significantly and only one note is played at a time.
4. *Voice:* where the singer is the instrument and only one line of music is sung.

The results are given in Table 4. The number of Pianists using Keyboard Layout was slightly less than using Sounds in Mind, which may be slightly surprising, but the majority used both. For players of String and Blown instruments the disparity was predictably much greater. Equal numbers of vocalists used these aids, although nearly all who used Keyboard Layout (9/10) also play the piano.

Table 4: Use of learning/playing aids by Principal Competence						
Identification of Notes, Chords and Scales	**Total**	**Piano**	**String**	**Blown**	**Voice**	**Voice(P)* + Piano**
- by number of Respondents	**Number of Respondents**					
No of respondents	55	18	12	12	13	n/a
by Keyboard Layout	33	12	4	7	10	9
by Sounds in Mind	44	15	8	11	10	9
by Keyboard + Sounds in Mind	19	9	3	4	3	4
		*Voice(P) – Voice as Principal Competence				
- by % of Respondents	**Percent of Respondents**					
by Keyboard Layout	60	67	33	58	77	
by Sounds in Mind	80	83	66	92	77	
by Keyboard + Sounds in Mind	36	50	25	33	25	

Table 5: Use of Tonic Sol Fa by Principal Competence						
Use of Tonic Sol Fa	**Total**	**Piano**	**String**	**Blown**	**Voice**	**Voice (P) + Piano**
- by number of Respondents	**Number of Respondents**					
for Sight Singing	21	9	3	4	5	2
for Hearing Intervals	16	6	2	4	4	2
for both Sight Singing and Hearing Intervals	11	4	0	2	3	2
- by % of Respondents	**Percent of Respondents**					
for Sight Singing	38	50	25	33	38	
for Hearing Intervals	29	33	17	33	31	
for both Sight Singing and Hearing Intervals	20	22	0	17	23	

Tonic Sol Fa (see Table 5) was used by almost as many pianists as singers and a good number of Blown instrument players, but not much favoured by string players.

To test whether the Study Discipline of the respondents had any influence on these identification approaches they were analysed and the results are given in Table 6, as numbers and percentages of the respondents in three possibly relevant Study Disciplines viz Engineering, Engineering and related ('left brain') disciplines and Music. The Engineering and Engineering+ groups showed a distinct preference for Sounds in Mind, by contrast with the Music students, among whom there was no difference.

Table 6: Keyboard Layout and Sounds in Mind by Study Discipline						
	Eng		**Eng+***		**Music**	
Number of respondents	7		16		14	
	No	**%**	**No**	**%**	**No**	**%**
Keyboard Layout	3	43	10	71	5	36
Sounds in Mind	6	86	14	100	8	57
Both	2	29	5	36	2	14
Ratio: Keyboard Layout / Sounds in mind		0.5		0.71		0.63

Eng+* : Engineering, Architecture, Quantity Surveying, Medicine, Sciences

One might expect that Engineering students, whether by a narrow or broad definition, would be very likely to share RPS's mindset with regard to the use of Mental Models. This is certainly not borne out by the data; the ratio of respondents favouring Keyboard Layout relative to those preferring Sounds in Mind is consistently much less than 1, regardless of the group, with narrowly defined Engineers who prefer Keyboard Layout being in a significant minority.

The final analysis relates to the free form responses on Mental Models given to all the groups of questions, although the question re the message conveyed by the Key Signature yielded the most explicit responses. In the event 17 such responses were obtained (see Table 7) and these grouped themselves naturally into two categories of Mental Model, viz:

- Responses identifying Finger Positions, which resolved into two sub-categories
    - o Positions for Melodic Instruments (String, Woodwind or Brass) and
    - o Positions on a Keyboard
- Responses relating to Pictures in the Mind were significantly predominant in all cases.

Table 7: References to Models and Mental Images from freeform responses				
	Total	**Piano**	**String**	**Blown**
Finger position/picture (melodic instr)	7	0	5	2
Finger position/picture (keyboard)	4	4	0	0
Mental Pictures	14	6	3	5

5.3 Discussion of Survey Results

Demonstrated differences in brain structure between musicians and non-musicians have been widely attributed to intensive music training (Hyde, 2009, Norton et al, 2005; Schlaug et al, 2005). An important feature of this sample was that the respondents were predominantly much better qualified in Music Theory than RPS and would thus, unlike him, have spent considerable effort in preparation for aural tests, with the relevant skills well developed in their brains. Many, especially in the UPSO, are likely to be efficient sight-readers. This is probably a valid explanation for the predominance of 'Sounds in Mind' as a Mental Model, rather than the more visual/physical 'Keyboard Layout 'which engaged RPS's attention. This is not to deny the importance of the spatial layout of the keys emphasized by Sudnow (1978) in his book 'Ways of the Hand'. Baily (1991) indeed, came to 'regard auditory and spatio-motor modes of musical cognition as of potentially equal importance'. It was not possible to draw any conclusions with regard to respondents who had not been exposed to keyboards, because only one respondent registered this.

When it comes to the learning process, on the other hand, as the respondents can largely be regarded as just setting out on their professional careers, it cannot be assumed that their learning schemas or Mental Models are as engrained as RPS's. Indeed the attempt to associate a preference for Keyboard Layout with students of 'left-brained subjects' tended to contradict any such expectation, with the responses of Music students being more disposed than the Engineering students to Keyboard Layout rather than to Sounds in Mind. In most cases, however, the respondents' exposure to Mental Models in Physics and other branches of study would be much more recent than their musical training.

The analysis of the more limited number of responses describing Mental Models in the respondents' own words also showed half referring to Pictures of Finger Positions in melodic and keyboard instruments while the other half described Mental Pictures – the latter being not more vividly described in most cases. The relatively small number of responses (Table 7) militates against detailed analysis, and the relative scores for Finger Position and Mental Pictures across the spectrum of use of Keyboard, String and Blown instruments cannot be claimed as significant.

Susan Bruckner in her book ‘The Whole Musician’ (2005) identifies three modes of learning: the Visual, Auditory and Kinesthetic. The survey respondents' mental processing seems to reflect these elements, if not necessarily in such carefully distinguished form.

The dominance of engrained learning patterns in a mature (aged) candidate, especially one who has undergone many changes of specialization is consistent with conventional thinking on learning.

6. CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

The study has shed some light on the mental processes by which a mature student could approach the task of learning Music Theory and confirmed that the use of Mental Models, standard practice in Physics, also occurs, although not often recognized, within the field of Music. Grounded in an individual's learning experience, it is also an example of Mode 2 Knowledge Generation. The findings support the notion that specialists in one field can bring to bear their conditioned learning style on a new field, but may need some help to overcome engrained perception conflicts.

The work has also raised a number of possible avenues for future research. Among these is the limited but real reaction that has been elicited to questions regarding Mental Models in learning and performing music. It is likely that more in-depth probing via Focus Groups drawn from the respondents and from non-responding members of the same two populations would present a clearer picture. The study suggests that this will be a worthwhile effort.

Furthermore, the possibility that a more explicitly keyboard-based training programme for students working towards Gr 5 would assist those who are not normally able to access keyboards will need to be assessed using a sample of learners who are generally more keyboard-naive than were the surveyed groups.

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