CHILDREN'S PERCEPTION OF MATHEMATICAL & MUSICAL PATTERNS

STEVEN NISBET
Griffith University

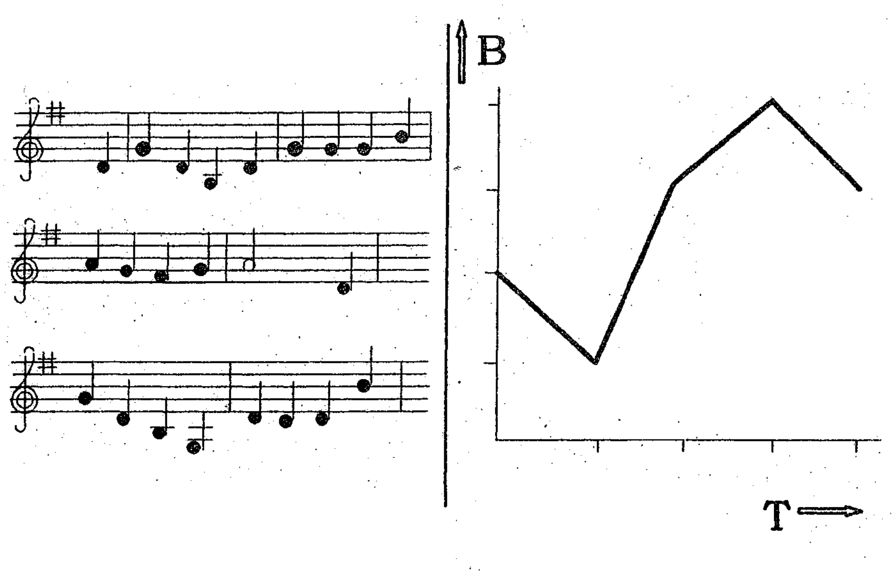
This paper focuses on the function of contour in the association of melodic and visual patterns, and investigates the role played by ability in mathematics and music in children's performance at matching melodies and music notation, and at matching melodies and graphs. Initially, tests in mathematics and music were administered to 101 children in Year 5. Factor analysis confirmed specific sub-scales in the tests and revealed a positive and significant correlation between results in the two tests. However this correlation was no greater than the correlations between other school subjects and mathematics and music. The melody matching tasks (four modality conditions altogether) revealed that format (conventional/non-conventional) was a significant main effect for graphs but not for music notation. Modality condition and level of contour complexity were main effects for both types of matching (melodies _ music notation and melodies _ graphs). Success at matching melodies and both types of visual contours was related to ability in music more than ability in mathematics.

Links between mathematics & music have been well documented for centuries. The Greek mathematician and philosopher, Pythagoras established that the pitch of musical notes was related to lengths of vibrating strings and organ pipes, and that simple mathematical ratios existed between resonating lengths for notes which harmonised. Since that time the study of acoustics and the production of musical sounds in instruments has progressed to the stage where the field is highly scientific, and mathematical modelling is very sophisticated. Not only are there people who study the mathematics and science of music, but also there exists anecdotal and research evidence indicating that there are those who are gifted in both mathematics and music. Browne (1987) has reported that the composition of some university orchestras is biased towards students majoring in science, engineering and mathematics fields (in contrast to arts and humanities). Among the top university orchestras in the USA is that of the Massachusetts Institute of Technology where some 80% of the members are students in these fields.

Educational research data on the "spin-off" effect of developmental music education programs, such as the program developed by the Hungarian composer and teacher Zoltan Kodaly, have shown that participating primary school children improve in academic areas of mathematics (number, geometry and problem solving), reading comprehension and spelling, and general learning ability (Bridges, 1979; Herbert, 1973; Gregory, 1988). Why does this happen, and what links are there, if any, between children's understanding and skill in the two subjects? This research project investigates these questions. Further, the project has been prompted by a perceived relationship between a musician's interpretation of music notation and a mathematicians interpretation of graphs. Both interpretation processes involve abstraction of visual contour from their particular conventional frameworks. The former then requires a translation to knowledge of musical sounds, while the latter requires a translation to knowledge of the mathematical context. For instance in Figure 1, (i) What does the tune sound like? and (ii) What does the graph tell us?

LITERATURE ON PERCEPTION OF MUSICAL AND VISUAL PATTERNS

The relationship between melodic and visual contour as perceived by children was studied by Morrongiello and Roes (1990). Five-year old and nine-year old children were asked to match visual contours to given nine-note melodies, and a number of significant factors emerged. Performance levels increased with age, but decreased with higher levels of contour complexity. Tonality (tonal versus atonal) was significant for nine-year olds but not for five-year olds, and musical training ensured better performance at the matching tasks.



: Samples of music notation and mathematical graphing.

The fundamental role of contour in melody recognition and melody discrimination has been well established. Dowling (1978) showed that the up-down contour of melodies plays the major role in recognition of musical stimuli. If the melodic contours are changed, subjects are able to recognise the melodies as being different (Bartlett & Dowling, 1980). Dyson & Watkins (1984) proved that contour changes were more easily identified if they occurred at contour reversal points. In a study of children's perception of melodies, Pick et al (1988) found that subjects were able to discern similarity between melodies that had the same contour but had changes in intervals between notes within the melodies. Cross-modal & intramodal matching of melodic & visual contours has been investigated by Balch & Muscatelli (1986). Key factors emerging from the study were rate of presentation, modality, and musical experience. For both low and high music experience groups, intramodal visual → visual recognition was best, followed by recognition in both cross-modal conditions (visual → auditory and auditory → visual) and last was the auditory →auditory condition. This result and the interaction between presentation rate and modality gives rise to the contour abstraction hypothesis which maintains that up-down contour abstraction for visual presentation is more efficient than for auditory presentation.

PURPOSE OF THE STUDY

The purpose of the study was to investigate children's performance at matching melodies with music notation and mathematical graphs in relation to their abilities in mathematics and music. The role of musical and mathematical training was to be further investigated by contrasting performance with conventional materials with performance with non-conventional materials. It was hypothesised that children with more ability in music would be more competent with the conventional notation, and that the use of non-conventional notation would reduce performance levels. Similarly, it was hypothesised that non-conventional graphs would reduce the performance levels of mathematically able children. The influence of contour complexity was to be studied by having materials of two levels of complexity, high and low. The study was designed to test the contour abstraction hypothesis by analysing differences in performance between the various modality conditions -melody → visual, visual → melody, visual → visual and melody → melody.

METHOD

Subjects: One hundred and one children in Year 5 (aged between 10 and 11) at two regular suburban state schools were used as subjects. All children underwent the set of tests in mathematics ability and music ability, but were split into two groups (50 and 51) for the two separate sets of matching tasks (melodies with music notation, and melodies with graphs).

Materials: The mathematics ability test was a written test which consisted of 25 multiple-choice items on three topics which reflected elements common to both disciplines, namely, number patterns, measurement of length and interpreting graphs. Thesc topics are regarded also as essential components of a contemporary primary school mathematics program according to Australian Education Council (1990) and the National Council of Teachers of Mathematics (1989). The items were adapted from items included in standardised tests produced by the Australian Council for Educational Research (1974). All items of the mathematics test were completed in a class situation. Questions were also read out aloud to the children so that any with reading difficulties were not disadvantaged in this way. The music ability test was a composite written and aural test of 25 items based on items from the musicianship syllabus and practical aural tests produced by the Australian Music Examinations Board (1991). Some items were multiple choice response, the others short answer. Approximately half of the items in the test were completed in a class situation and the remainder were done on an individual basis. Items were read out aloud also, as with the mathematics test. Information was also collected about the children's music experience (instrumental and choral), and their levels of performance in other school subjects (language arts, social studies and science).

The matching task tests each consisted of 42 items requiring subjects to match (i) a 9-note melody with music notation or graph (auditory→visual), (ii) music notation or graph with a 9-note melody (visual→auditory), (iii) music notation or graph with music notation or graph (visual→visual), and (iv) melody with melody (auditory→auditory). Melodies were of low complexity (1 contour change) or high complexity (3 contour changes) and were played on a Sony portable audio cassette player placed adjacent to the subject. The melodies had been recorded directly from a Yamaha PSR7 keyboard using the familiar piano sound on the keyboard. Visual materials (samples of single line music notation or line graphs) were printed black on white paper, and were placed on the desk in front of the subject. Music notation in the matching task test was presented in conventional format (standard crotchets on a horizontal five-line staff, read from left to right), and also in non-conventional format (triangle shapes on a four-line vertical staff, read from top to bottom). Conventional graphs consisted of connected lines segments (none points) with up-down contour changes read from left to right. Graphs of the non-conventional variety however were to be read from top to bottom, with corresponding up-down contour of melody represented by left-right movement (low on the left and high on the right).

The experiment was a 2 x 3 x 2 factorial design (2 formats x 3 modality conditions x 2 complexity levels). The inclusion of items of the fourth modality condition (auditory→auditory) allowed comparison across all four conditions, giving a supplementary framework for analysis of results, namely 4 modality conditions x 2 complexity levels).

Design: 2 formats x 2 complexities x 3 modalities

Format	Complexity	Modality		
		Mel-Vis	Vis-Mel	Vis-Vis
Conv.	Low	Cell 1	Cell 3	Cell 5
	High	Cell 2	Cell 4	Cell 6
Non-conv.	Low	Cell 7	Cell 9	Cell 11
	High	Cell 8	Cell 10	Cell 12

Design: 2 complexities x 4 modalities

Format	Complexity	Modality			
		Mel-Vis	Vis-Mel	Vis-Vis	Mel-Mel
Conv.	Low	Cell 1	Cell 3	Cell 5	Cell 13
	High	Cell 2	Cell 4	Cell 6	Cell 14

In the matching task tests, the following procedure was carried out with each child. For the melody→visual modality condition, a 9-note melody was played on a cassette player to the child, and then a 9-note sample of music notation (or a 9-point connected line graph) was shown. The question was asked, "Is this music (or graph) the same as the melody you have just heard, or is it different?" In the visual→melody modality condition, a 9-note sample of music notation (or a graph) was shown to the child for approximately 5 seconds (long enough for the child to indicate that he/she had noted its features), and, after the page was turned, a 9-note melody was played. The child was asked, "Was that melody the same as the music (or graph) on the page before, or different?" In the visual→visual modality condition, a 9-note sample of music notation (or graph) was shown to the child, then the page was turned to reveal another sample of notation (or graph). The child was asked if the two samples of music notation (or the two graphs) were the same or different. In the melody→melody condition, two 9-note melodies were played consecutively and the child was asked if the two melodies were the same or different. At the end of the session the child was asked what strategy he/she used to remember the melodic and visual contours, and determined if they matched or not.

RESULTS

Ability Tests: Factor analysis of the mathematics ability test confirmed the three original test sections as subscales: interpretation of graphs, measurement of length, and number patterns. However, the music test revealed three subscales musical performance, notation skills, and aural skills. These scales are process & skill related rather than topic related. There was a significant and positive correlation between mathematics and music scores ($r = 0.42$, $p = 0.001$), but this no more significant than the correlations between mathematics and music with other school subjects. See r values below.

	Music	Mathematics
Language	0.44	0.51
Social Studies	0.46	0.44
Science	0.45	0.51

Matching Tasks - Melodies and music notation: Analysis of the results revealed that format was not a significant main effect, indicating that overall there was no difference in performance between items in conventional and non-conventional format. However there were two significant main effects: modality and complexity. Children were more successful at intramodal tasks than cross-modal tasks: the order of success being (from high to low) visual→visual > visual→melody > melody→visual and melody→melody = visual→visual. Performance dropped significantly as complexity increased from low to high. An interaction between modality and complexity indicated that cross-modal task performance drops more as complexity increases than for intramodal task performance. There was a significant interaction between format, modality & complexity revealing that task performance depended significantly on the status of each of the three variables. There were some combinations which produced performance no better than chance level, for example conventional format, high complexity, melody→visual modality.

Music ability was a significant factor with performance at conventional format items and for melody→visual items. Further, there was a significant interaction between format, modality and modality. Music experience was a significant factor for low complexity items, and for test aggregate scores. Mathematics ability appeared to play little part in matching task performance.

Matching Tasks - Melodies and graphs: Contrary to the results for melodies and music notation, format was a significant main effect for matching melodies and graphs. Modality also was a significant main effect with intramodal tasks showing higher levels of performance than cross-modal tasks: the order of success being (from high to low) visual→visual > melody→melody > visual→melody > melody→visual. Complexity was another significant main effect, and it also had different effects in each of the modality conditions, as well as in each format, as indicated by significant interactions.

Mathematics ability was a significant factor in the performance of melody→visual items, but not for any other class of matching tasks (even though mathematical graphs were used as one of the matching halves). However musical ability was a significant factor for conventional items and for high complexity items. Further, music experience was a significant factor for conventional items, low complexity items, high complexity items, and for melody→visual items. Music experience also interacted significantly with format x complexity, modality x complexity, and with the test aggregate score. The importance of music ability was reinforced by the significance of aural scale scores for non-conventional items, low complexity items, the interaction of format x complexity, and for test aggregate scores.

Children's descriptions of strategy: The children generally agreed about how they remembered the melodic and visual contours, and determined whether they were the same or different. With the melody → visual items, they said that they could remember the up/down shape of the melody and the actual notes of the tune, along with the first and last notes. Some musical children could see the shape of the tune in their minds from hearing the melody. With the visual → melody items, again they could remember the shape (for example, "like a W"), kept a mental picture, and checked the melody note by note. Some musical children could hear the tune in head, just by looking at the visual contour. With the visual → visual items they again could remember the overall shape, in particular the beginning and the end, and could keep a mental picture of the contour. With the melody → melody items, they said that they could keep the tune in their minds, however the presentation of the second melody often wiped the memory of the first melody. Many children reported that the task was very difficult when there were "too many ups and downs".

Most children noted that the non-conventional format of music notation was harder to read than the conventional format because "it was opposite to normal way", but noted that the non-conventional graphs were no more difficult that the conventional graphs. Results showed that music notation format had more influence in the high music group than the low group. In the melodies and graphs test, results showed similar levels of performance for visual→visual tasks, but with cross-modal tasks, performance deteriorated with the introduction of non-conventional graph format.

DISCUSSION

The results have confirmed that musical ability is a significant factor in matching task performance for melodies and visual contours and that experience with conventional music notation is one reason for the tasks with music notation. The fact that mathematics ability is not a significant factor for graphs, may be due to the fact that children spend equivalent amounts of time doing mathematics but not for music, in which some children may learn two instruments and sing in the school choir but some just play the recorder for 15 minutes per week. The situation where music ability is a significant factor in both tests, especially with melody→visual items, points to musical children's superior accuracy at perceiving melodies and abstracting contour features. The importance of modality condition has been highlighted by the results, which show that children are more adept at intramodal tasks than cross-modal tasks, and that the contour abstraction hypothesis holds (but only for cross-modal tasks). An explanation for why visual→visual tasks were performed more accurately than melody→melody tasks with graphs and not music notation could be that music notation is more information dense than the comparable graph. One feature of the melodies and visual contours used in this study is the type of presentation, namely simultaneous versus sequential presentation. Melodies are by nature heard sequentially whereas music notation and graphs are presented as a whole. Hence, further research should investigate children's abstraction of contour from melodic and visual materials in relation to their simultaneous and sequential processing skills.

REFERENCES

Australian Council for Educational Research (1974). **ACER Mathematics Tests (AM Series).** Hawthorn, Victoria: Australian Council for Educational Research .

Australian Education Council (1990). **National statement on mathematics for Australian schools.** Melbourne: Curriculum Corporation for AEC.

Australian Music Examinations Board (1991). **Manual of syllabuses.**

Balch, W. & Muscatelli, D. (1986). The interaction of modality condition and presentation rate in short-term contour recognition. **Perception & Psychophysics.** 40 (5), 351-358.

Bartlett, & Dowling (1980). Recognition of transposed melodies: A key distance effect in developmental perspective. **Journal of Experimental Psychology: Human Perception & Performance**, 6, 501-515.

Bridges, D. (1979). **Outcomes of a developmental music program.** Paper presented to the Fourth International Kodaly Symposium, Sydney, 1979.

Browne, M. (1987). **The intimate links between music and the lab. in Why music is basic.** Queensland Department of Education.

Dowling, W.J. (1978). Scale & contour: Two components of a theory of memory for melodies. **Psychological Review**, 85, 341-354.

Dyson, M. & Watkins, A. (1984). A figural approach to the role of melodic contour in melody recognition. **Perception & Psychophysics.** 35 (5), 477-488.

Gregory, A.S. (1988). **The effects of a musical instructional technique on a mathematical achievement of third grade students.** Doctoral Dissertation, University of Alabama.

Herbert, G. (1973). Cited in Bridges, D. (1979) **Outcomes of a developmental music program.** Paper presented to the Fourth International Kodaly Symposium, Sydney, 1979.

Morrongiello, B. & Roes, C. (1990). Developmental changes in children's perception of musical sequences: Effects of musical training. **Developmental Psychology**, 26 (5), 814-820.

National Council of Teachers of Mathematics (1989). **Curriculum & evaluation standards for school mathematics.** Reston, Virginia: NCTM.

Pick, A., Palmer, C., Hennessy, B., (1988) **Journal of Experimental Child Psychology**, Vol.45, pp.28-51.