Children's matching of melodies and line graphs

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Children (10-11 years) were asked to match short melodies and line graphs. Evidence was found for significant visual/graphical influences in the matching process (as well as previously established melodic factors). Intramodal tasks were performed better than cross-modal task, and within those categories, visual-first items were performed better than melody-first items. Mathematics ability was a significant main effect, but evidence pointed towards an effect of mathematics experience more than aptitude. Musical ability had only a limited effect.

Introduction

This research was designed to investigate children's matching of melodies with line graphs, with reference to the effects of modality, contour complexity, and musical and mathematical ability.

Morrongiello and Roes (1990) investigated children's ability to match short melodies with line graphs presented concurrently, and considered matching task performance in relation to contour complexity and melodic tonality, along with the age and musical training of the children. Their study showed that musically-trained children performed better at the matching tasks overall than musically-untrained children. However, for those musically trained, performance levels decreased with the use of atonal melodies in contrast to the consistent but lower performance levels of the musically-untrained children. These results indicate the sensitivity of the musical children to Western scale structure, and hence the importance of the melodic stimuli in the matching tasks. However, it is likely that the visual materials are just as important as the auditory materials in the matching process, and their effect should be investigated also.

To determine the extent to which visual stimuli have an influence on the matching process, this experiment tested children's sensitivity to conventional line graphs by comparing their performance using such graphs with their performance using non-conventional graphs. The non-conventional format comprised graphs with the vertical and horizontal axes rotated and reversed, such that up/down changes of pitch were represented by left/right changes of position, and time was represented vertically, from top down rather than horizontally from left to right. After considering the results of Morrongiello and Roes (1990) concerning tonal versus atonal melodies, it seemed reasonable to expect that, similarly, performance with conventional graphs would exceed performance with non-conventional graphs (the visual equivalent of atonal melodies). Also it seemed reasonable to expect that if the nature of the visual materials had a significant influence on task performance then there would be an interaction between contour complexity and visual format, such that increasing contour complexity would lower performance levels more with non-conventional line graphs than with conventional line graphs.

Balch and Muscatelli (1986) also investigated the matching of melodies and their visual representations; in their study, the visual representations were contour markers. They employed four modality conditions (visual to visual, visual to auditory, auditory to visual, auditory to auditory) and five presentation rates (from 10 notes per second to one note every two seconds). When melodies were presented at a rate of two notes per second or slower, significant differences emerged among modality conditions. For both low and high musically trained groups, intramodal visual to visual recognition was best, followed by recognition in both cross-modal conditions (visual to auditory and auditory to visual), and lowest performance occurred with the auditory to auditory condition. These results led Balch and Muscatelli to propose the *contour abstraction hypothesis* to the effect that the abstraction of up-down contour is more efficient from visual patterns than from auditory patterns. It is assumed that up/down contour abstraction takes time. Thus contour recognition should be difficult when presentation rate is extremely fast, regardless of modality condition. However as the presentation rate becomes slower, contour recognition would improve at different rates for different modality conditions producing an interaction between presentation rate and modality condition. The four modality conditions employed by Balch and Muscatelli (1986) were used in this experiment to extend the matching tasks involved in the study of Morrongiello and Roes (1990). The presentation rate selected for this experiment was 2 notes/second, the rate at which Balch and Muscatelli noted performance-level differences between modalities (on slowing the rate from 10 notes/second).

The contour abstraction hypothesis contrasts with the findings of some of the earlier research on the performance of various cross-modal and intramodal tasks. Although the results of research in this area from the 1960s and 1970s were not uniform, the general thrust was that cross-modal tasks are more difficult than intramodal tasks (Freides, 1974), including tasks involving auditory and visual modalities.

With the results of Balch and Muscatelli (1986) and the conclusions from modality studies implying otherwise, it was debatable as to which influences would be apparent with the tasks of this experiment under its particular conditions. If the contour abstraction hypothesis were applicable, then the order of performance would be the same as that observed by Balch and Muscatelli (1986), namely, visual-first tasks better than auditory-first tasks. Otherwise, it might be that intramodal tasks (visual-to-visual and auditory-to-auditory) would be performed better than cross-modal tasks (visual-to-auditory and auditory-to-visual).

With reference to contour complexity, the study by Morrongiello and Roes (1990) found that matching task performance levels generally decreased with higher levels of contour complexity. However the performance of musically-trained nine-year olds did not decline as complexity increased. In this experiment, it was expected that increasing contour complexity would have a detrimental effect on matching task performance overall. However, if musical ability has a positive influence on the perceptual processes in the matching tasks, then the musically-able children should be less influenced by increases in complexity compared to the musically less able children.

Both key studies referred to here (Morrongiello & Roes, 1990 and Balch & Muscatelli, 1986) identified musical training as a significant factor in the matching-task performance. The former study found that musically-trained children performed better than musically-untrained children at the matching tasks overall, as well as at the higher complexity levels. However, for those musically trained, performance levels decreased with the use of atonal melodies in contrast to the consistent but lower performance levels of the musically untrained children. Balch and Muscatelli also found that formal music experience facilitated matching-task performance overall for young adults. However, there was no interaction of music experience with modality condition nor was there an interaction of music experience with presentation rate. This raises questions concerning the role of the modality experience factor in the matching tasks. Work by Vande Voort, Senf and Benton (1972) and Goodnow (1971) suggests that it is not modality *per se* that matters in determining performance levels, but experience in the specific modality. The importance of experience with a particular modality and with specific tasks was highlighted further by Hershkovitz (1993) who found that children's ability at visual estimation was dependent on experience and instruction. If the variable, musical experience, does not affect the preferred modality conditions for the matching tasks, then perhaps musical ability does. Musical ability, as measured in this study, is likely to represent students with music experience in much the same way as those with aptitude but little experience. Hence musical ability includes aptitude and experience, and offers the prospect of confirming and extending the findings of Morrongiello and Roes (1990) and Balch and Muscatelli (1986) that were more obviously on experience/training. Hence musical ability was used as an alternative to music experience as a between-subject variable.

Mathematics training/experience would not have been a usefully discriminating variable to include in the study, because it would not vary greatly for children in any particular year level at school. They all would have studied mathematics for the same number of years, and would have spent similar numbers of hours per week at school engaged in mathematical activity. Hence, an experience-centred measure of mathematics would not be likely to apply cogently to the children in the study, and thus the need arose for a measure which was sensitive to aptitude and experience. Accordingly, it was decided to include mathematics ability as an individual difference variable rather than mathematics experience. The use of musical ability and mathematical meant that the music area and the spatial/mathematics area were treated comparably in this study.

Hence, tests of music ability and mathematical ability were constructed for the purpose of forming two sub-groups of children (high ability and low ability) for each area. The music ability test contained items on pitch and melody recognition and discrimination, and basic music notation. The mathematics ability test contained items on interpreting graphs, pattern recognition and measurement of length.

Method

Participants

Fifty-one children in Year 5 (aged between 10 and 11) from two regular suburban primary schools participated in the study. The sample contained approximately equal numbers of boys and girls; 38% of the children had been learning to play a musical instrument at the school or privately for at least one year. The formal music experiences of the other children had been one class-music lesson per week or less than one year of instrumental lessons plus one class-music lesson per week.

Design

The experiment was a 2 x 4 x 2 within-subject design (2 formats, 4 modality conditions and 2 complexity levels), combined (in separate analyses) with the between-subject variables of music ability and mathematical ability. Two visual formats were employed: conventional and non-conventional. The matching tasks required subjects to match melodies and line graphs in four modality conditions: auditory-to-visual, visual-to-auditory, visual-to-visual, and auditory-to-auditory. Melodies and line graphs were produced at two levels of complexity: low complexity with one contour change, and high complexity with three contour changes. The order of presentation of the experimental conditions was counterbalanced to distribute order effects (Burns, 1994).

Materials

The auditory materials were short tonal melodies, with nine notes of equal duration, played at a rate of 2 notes per second. They were generated on a Yamaha PSR7 keyboard using the familiar piano sound, taped by direct line on a Sony cassette recorder and subsequently played back to the children on a portable cassette player.

The visual materials of the matching task test were line graphs, each consisting of nine points joined by a single line. The line graphs (each measuring 16cm x 10cm) were printed black on white paper. The conventional line graphs were designed to be read from left to right, with up-down pitch movement being represented by vertical movement on the graph. In contrast, the non-conventional graphs were designed to be read from top to bottom, with corresponding up-down contour of melody represented by lateral movement on the graph: low on the right and high on the left. The materials were assembled into order in a spiral bound booklet for easy display and viewing. Half of the pairs of stimuli were matching pairs and half were not matching pairs. The pairs which did not match differed in terms of overall contour shape or the locations within the melody at which contour reversals occurred (start, middle, end).

The mathematics ability test consisted of 25 multiple-choice items on three mathematical topics: interpreting graphs, pattern recognition, and measurement of length. All items of the mathematics test were completed in a class situation. The written questions were also read to the class so that any children with reading difficulties would not be disadvantaged. The music ability test was a composite written and aural test of 25 items, some of which were multiple choice response items, and the others, short answer. Approximately half of the items in the test were completed in a class situation and the remainder were presented on an individual basis. The written items were also read to the class, as with the mathematics test, for the same reason.

Procedure

All children underwent the tests in mathematics ability and music ability initially and then completed all matching tasks. For the *melody-to-visual* modality condition, a melody was played on the cassette player to the child, and then a line graph was shown for approximately four to five seconds (long enough for the child to indicate that he/she had noted its features, and for a duration comparable to the length of time required to hear the nine-note melody). The question was asked, "Is this graph the same as the melody you have just heard, or is it different?" In the *visual-to-melody* modality condition, a line graph was shown to the child for four to five seconds. Then a nine-note melody was played. The child was asked, "Was that melody the same as the graph on the page before, or different?" In the *visual-to-visual* modality condition, a line graph was shown to the child, then the page was turned to reveal another line graph. The child was asked if the two graphs were the same or different. In the *melody-to-melody* condition, two melodies were played consecutively and the child was asked if the two melodies were the same or different.

Results and discussion

The proportion of correct matching responses was determined on the basis of the number of correctly identified matches (hits) plus the number of correctly identified mismatches (correct rejections), the latter being included to reduce the undesirable effects of false alarms, and also to conform to the basis used in the study by Balch and Muscatelli (1986); i.e. p(correct) = (no. hits + no. correct rejections) / (no. matches + no. mismatches).

Mean proportions correct were calculated for levels of matching task performance in each experimental condition for the whole sample and for each ability group: high/low mathematics ability and high/low music ability. Ability groups were determined on the basis of median splits on the aggregate test scores.

There were four major issues investigated in this experiment -
(i) the extent of visual/graphical influences in the melody-visual matching process; (ii) the claim that contour abstraction is more successful from visual materials than from auditory materials; (iii) the effect of ability factors on the order of task-performance levels of the various modality conditions; and (iv) the effect of ability factors on the perceptual processes involved in the matching process. Results relating to these major issues are now presented in turn.

The extent of visual/graphical influences in the matching process

Evidence was found for significant visual/graphical influences in the matching process. Manipulation of the visual materials in terms of conventional and non-conventional format produced different levels of performance, significantly with visual-to-melody and melody-to-visual tasks. There were significant main effects for format, $F(1, 49) = 8.74$, $p < .01$, $MSE = 0.067$, (conventional better than non-conventional), complexity, $F(1, 49) = 22.61$, $p = .0001$, $MSE = 0.039$, (low better than high), and modality, $F(2, 98) = 92.33$, $p = .0001$, $MSE = 0.072$, (visual-to-visual better than visual-to-melody, in turn, better than melody-to-visual; melody-to-melody was approximately equal to visual-to-melody in the four-modality condition model, Table 2). However, the significant format x complexity interaction, $F(1, 49) = 20.56$, $p = .0001$, $MSE = 0.04$, qualified the first two main effects such that increasing the complexity level reduced performance of tasks involving conventional line graphs more than performance of tasks involving non-conventional line graphs, performance on which was relatively weak. Clearly, the matching process is influenced not only by melodic/auditory factors (as assumed implicitly by Morrongiello & Roes, 1990) but also by visual/graphical factors.

The claim that contour abstraction is more successful from visual materials than from auditory materials

The superiority of visual-first items as proposed by Balch and Muscatelli (1986) was not supported. Instead, it was found that performance was determined by two considerations - (i) intramodal tasks were performed better than cross-modal tasks, consistent with much of the modality literature (Freides, 1974), and (ii) within each of the modality-condition categories, intramodal and cross-modal, visual-first items were superior to auditory-first items.

The observed effects of modality and format lead to the development of a set of theoretical principles for the auditory/visual matching process, which proposed that matching entailed a comparison of two specific components, (i) an abstraction of the first-presented stimulus and (ii) the second stimulus. Abstractions of visual contour differ from abstractions of auditory contour in that visual coding differs from auditory coding. The contour information abstracted preserves modality information as well as the up/down sequence information. In the case of intramodal matching, as the two stimuli are of the same modality, the second stimulus is compared with an abstraction of the first stimulus. In the case of cross-modal tasks, before a comparison can be made, a conversion (or recoding) step is required to allow for the matching of 'like' modalities. For example, in a visual-to-melody task, the contour first is abstracted from the line graph. Then for a comparison to be made with the melody, either the contour is abstracted from the melody and then converted (recoded) to its visual equivalent for matching, or the visually abstracted contour is converted (recoded) to an auditory equivalent for comparison with the melody as it is played. It seems reasonable that this step in the process would vary from child to child, depending on his/her ability and experience. This extra complication in the process reduces the likelihood of a successful match being made - hence the lower performance levels of cross-modal tasks.

The effect of ability factors on the order of task-performance levels of the various modality conditions

Ability factors had little effect on performance under the modality conditions. Although musical ability, music experience and mathematical ability had significant effects on performance levels of tasks in certain modality conditions, these effects were not as great as the effects of modality, format, and complexity.

The effect of ability factors on the perceptual processes involved in the matching tasks

Mathematics ability had a significant positive effect on performance levels overall, $F(1, 49) = 4.34$, $p < .05$, $MSE = .097$, but investigation of the results of the two visual formats separately revealed that the effect of mathematics ability was significant for the tasks involving conventional line graphs, $F(1, 49) = 5.31$, $p < .05$, $MSE = .077$, but not for tasks involving non-conventional line graphs, $F(1, 49) = 1.53$, $p > .05$, $MSE = .093$. In other words, the advantage that the high mathematics ability group had over their low ability counterparts with tasks involving conventional line graphs disappeared when non-conventional line graphs were involved. This result suggests that the superior performance of the high mathematics ability group can be attributed to some extent to that group's greater familiarity and with the conventional line-graph format, and hence is evidence of an experience effect, rather than an effect of natural aptitude. Given the overlap between mathematics ability and mathematics experience, it is likely that a test of mathematical ability is also a measure, to some degree, of mathematics experience. Hence the positive effect of mathematics ability on performance levels found in this experiment is evidence of the contribution experience makes to the ability measure.

In contrast to the effect of mathematics ability, music ability had no significant effect on performance overall, $F(1, 49) = 2.24$, $p > .05$, $MSE = .124$, on performance with tasks involving conventional format, $F(1, 49) = 3.68$, $p > .05$, $MSE = .079$, nor on performance with tasks involving non-conventional format, $F(1, 49) = 4.44$, $p > .05$, $MSE = .095$. However, music ability did have a significant main effect in one particular condition, namely, high-complexity, visual-to-melody items involving conventional format in which high-ability children performed at a higher level than their low-ability counterparts, $F(1, 49) = 7.15$, $p = .01$, $MSE = .130$. This instance of a positive music-ability effect is the only one that corresponds with the results of Morrongiello and Roes (1990) who demonstrated that musical training was a significant positive factor in matching performance levels. The discrepancies with the other conditions (e.g. low and high complexity melody-to-visual tasks) may be explained by differences in mode of presentation and the nature of the tasks. This experiment used consecutive presentation of auditory and visual materials, whereas Morrongiello and Roes used concurrent presentation. The consecutive mode of presentation requires an element of short-term memory which may have caused greater difficulty for many of the children in some conditions of the present study, both musical and non-musical. Morrongiello and Roes noted that many of their musically-trained children actually watched the line graph intently as the melody was played, and some nodded their heads up and down in phase with the contour movement. This strategy is possible for concurrent presentation, but not for consecutive presentation, and indicates that these particular children were making a point-to-point comparison of melody and line graph. It is also consistent with an effect of music experience rather than natural aptitude, and therefore suggests that music experience is an important component of the ability measure.

Moreover, the nature of the tasks differed with respect to the visual materials used and the response required of the children. In this experiment, a new pair of stimuli was presented to the children for each item and they were asked to indicate whether the stimuli matched or not, whereas Morrongiello and Roes (1990) had just three standard visual stimuli from which the children could select one which they thought matched the melody heard. On one hand, the presence of the three graphs in the Morrongiello and Roes procedure may have simplified the tasks because the children could be sure that one of the graphs did match the melody. However, on the other hand, it may have complicated the tasks if the first graph observed did not seem to match the melody, because a child would have had to shift visual focus to a second graph while the melody was still playing, and possibly to a third. The children least likely to be distracted by this complication would be the musically-trained children, those who were experienced in associating a melody with a visual representation of it.

Conclusion

This study demonstrated that children's ability to match melodies with line graphs is determined not only by auditory factors (as found by Morrongiello & Roes, 1990) but also by visual factors. Just as matching-task performance is affected by a change in musical scale structure (from tonal to atonal), so too is it affected by a change of visual format (from conventional to non-conventional). The contrast of the results of this study (in which the visual materials were line grapsh) with those of Balch and Muscatelli (1986) (in which the visual materials were contour markers) also suggests that performance levels are influenced by the nature of the visual materials. This effect could be further investigated by the use another visual representation, one which is particularly relevant to the study of melodies, namely conventional music notation. Future research could investigate the matching process with the use of both conventional music notation and a non-conventional notation.

The study also showed that the effect of modality on matching-task performance is not as clear-cut as claimed by Balch and Muscatelli (1986). The claim of the superiority of visual-first items did not hold true for the materials used with Year 5 school children. In this study, visual-first was a second consideration after intramodal versus cross-modal considerations. Would it be so for matching tasks involving music notation too?

The effect of musical ability on the perceptual processes involved in the matching tasks was less marked than that exhibited in the studies by Morrongiello and Roes (1990) and Balch and Muscatelli (1986). However, in the light of the demonstrated effect of mathematics ability in the present study, it seems feasible that in the future research alluded to in the above paragraph (matching melodies with music notation) an effect of music ability might be shown rather than mathematical ability.

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