MUSIC, LEARNING, AND BEHAVIOR:
A CASE FOR MENTAL STRETCHING

by

MARTIN F. GARDINER, PH.D.

(Editor's Preface: In this article, two spheres of interest are presented in counterpoint: (a) on the left side, Martin Gardiner introduces an expanding framework for research on the effect of music on learning and discusses his concept of "mental stretching" and (b) on the right side, data displays review the range of evidence Dr. Gardiner and his associates have produced in Pawtucket, Minneapolis, and Boston to support his evolving framework.)

INTRODUCTION

If I tell you that two groups of students are found to progress at different rates in learning reading or math in an elementary school, you might suspect that this was due to a difference in curriculum, or teachers. Or perhaps the groups were in different schools, private or public, urban or suburban. But how likely would you think it that the significant difference in progress could be attributed to a very small change in music instruction, for example involving only one extra hour per week?

For several years, my colleagues and I have been collecting data to measure the impact music lessons can have on the ways children learn. Our research shows that a concept which I term *mental stretching* (Gardiner, 1997, 1998; Gardiner and Olson, 1999, 2000) can help to explain how, why, and when such interactions between music training and learning can take place.

What I am calling *mental stretching* focuses attention on the role of representation and change in representation in learning. I will outline our still developing theory and touch briefly on its relationship to some other current work on arts in education.

Research supports five different ways in which an art form such as music can have value to education:

- Values specific to music
- Music instruction as a support for other topics of learning
- Effects of music on attitudes and mental skills broadly useful to learning
- Effects of music instruction on specific subcomponents of mental skill useful to subcomponents of learning
- Music as an aid to social/emotional and personal development.

The first two items are familiar and represent the major focus for music teaching in many schools. Research adds the three additional items to the list. I will focus on these. For illustration I have selected five studies (as presented in the data displays on the right hand side of the two-page layout). Other related work is ongoing at other sites in Rhode Island, Vermont and Massachusetts.

MARTIN GARDINER IS A RESEARCHER AT BROWN UNIVERSITY'S CENTER FOR THE STUDY OF HUMAN DEVELOPMENT, A FACULTY MEMBER AT NEW ENGLAND CONSERVATORY, AND A SENIOR RESEARCH ASSOCIATE OF THE CONSERVATORY'S RESEARCH CENTER FOR *LEARNING THROUGH MUSIC* WHO ASSESSES THE IMPACT OF MUSICAL TRAINING ON ACADEMIC PERFORMANCE AND SOCIAL/EMOTIONAL DEVELOPMENT IN ELEMENTARY SCHOOL CHILDREN AND ADOLESCENTS.

Half of the classrooms in two elementary school first grades were assigned by the schools to receive the standard arts curriculum for the district approximately one hour per week, while the other two classrooms in each first grade received intead two hours weekly of the test arts program. The test arts program used its arts time differently than the standard program, placing greater emphasis on development of musical skill (60 minutes each week as compared to 55 minutes every other week, and special emphasis on musical skill development through use of a Kodály music training method). Otherwise, the curriculum of all classes was identical. Academic progress of the students was assessed by standardized Metropolitan Achievement Tests (MAT) given in every grade each spring.

Though starting significantly behind the controls, by the end of first grade the test arts students had caught up to their control peers in reading (Figure 1a), and were now actually significantly ahead of them in math (Figures 1a & b). This lead in math was maintained in second grade (Figure 1c).

(Gardiner et al., 1996; Gardiner, 1997; 1998b)

Achievement Test Performance: Standard Arts vs. Test Arts
In the Two Schools
At Or Above the National Average

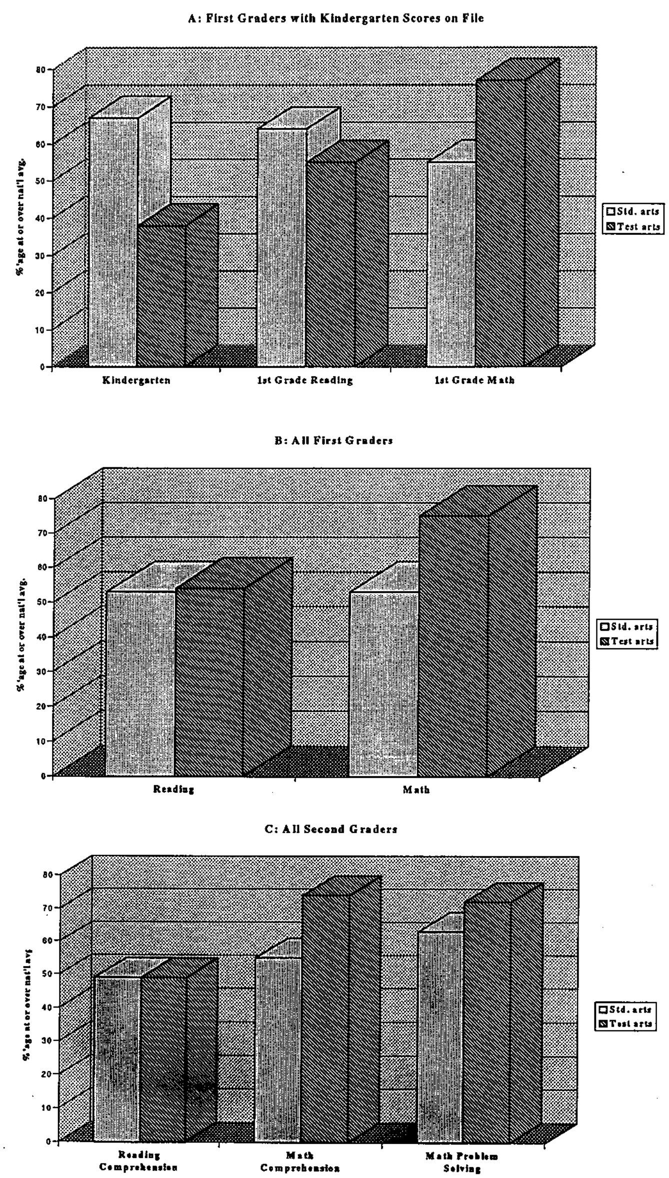


FIGURE 1

MENTAL STRETCHING AND LEARNING

The general idea of mental stretching has to do with changes in the representation and organization of a particular aspect of thinking that improves the way we think about distinctive kinds of information or specific kinds of mental tasks (Gardiner 1997, 1998). For example, as children begin to learn math, some ways of thinking about numbers will prove less useful than others if the child is to progress in math thinking most easily. A critical part of the best representation, according to work by Piaget and more recently, Case (Piaget and Szeminska, 1941; Case and Okamoto, 1996) leads ultimately to the creation of a special type of representation for numbers called the number line. A first step in this direction is to represent and use ordering: That "2" lies between "1" and "3", "2" is greater than "1" and "3" greater than "2." Learning how to think about numbers in this way seems to be critical to understanding how best to do addition and subtraction, and still more essentially, how to relate these operations to problems.

I suggest that parts of math and music may require similar, mutually supportive representations. The ability to sing a melody properly, for example, very likely needs development of mental operations somewhat like those of math. Thus, the development of musical thinking concerning a "pitch line" that keeps track of pitch levels in relation to the sequence and hierarchies of the musical scale can require a kind of "mental stretching" that can support understanding and ability in both math and music.

Why might this be? I propose that our brains can take advantage of *analogous thinking* in both areas — i.e. that learning how to think in terms of a "line" in math can help the child to figure out how to do something similar for musical pitch, or *visa versa*. Thus, similar processing in different areas of application (here math and melody singing) can be related by the way the brain handles mental tasks within these areas. The idea of mental stretching suggests that realizing such similarities can help the brain apply what is learned in one area of application to the other.

WHAT I AM CALLING "MENTAL STRETCHING" FOCUSES ATTENTION ON THE ROLE OF REPRESENTATION AND CHANGE IN REPRESENTATION IN LEARNING.

The initial evidence for this example of mental stretching (Gardiner *et al.*, 1996- see figures 1-6) was based on evidence of impact of music training on math learning, but there is nothing in the theory to preclude influence in the opposite direction as well (Gardiner, 1998a). Dialogue within the brain may help to ratchet up capability in both areas of application.

There is evidence also for cross fertilizations such as this between music and other areas of learning not only within elementary students but also older students, (Gardiner, 1998a) and not only for math but also for some of the mental skills involved in reading (Gardiner and Olson, 2000) (Figure 6).

The treatment of thinking here incorporates both the notion of specialized thinking and expertise that is specific to different areas of application *within* domains (e.g. Fodor, 1982; Gardner, 1983; Simon and Simon, 1978; Anderson, 1983), and the possibility of developing and exploiting similarities for processing *across* domains. Thus, it is in line with recent notions that the brain lies somewhere between full modularity and fully general problem solving design (Cecci, 1989; Sternberg, 1989).

The treatment of math learning that follows, though developed independently, is similar in many respects to the work of Robbie Case (Case, 1992, 1996). Case's theory, presented from a developmental perspective, for which she provides a large body of supporting evidence, emphasizes the importance of what she terms the mental number line in the development of capability for math. She also has data that reveals the less adequate understanding of students who fail to develop a full representation of the number line. I emphasize that even when developmentally ready, a student can be "caught" in an inappropriate type of representation. My treatment of theory does not specifically depend on the semantic network format she uses to develop her theory.

Case's development of "central conceptual structure" also considers the interactions between learning within different domains of processing. Her treatment emphasizes the joining of concepts through the *unification of the components of representation*, whereas my treatment places greater emphasis on interrelated *changes in specific representations* that possibly leads to unification.

The types of representation discussed here concern the way thinking is organized, for example, representation that reflects the change from more procedural to more cognitive thinking. Given the distinction between changes in learning that result in a minor reorganization of thinking around a central focus, as compared to more "revolutionary" changes that involve major reorganization of processing (Carey, 1988), it is upon these more revolutionary changes that the present discussion will focus.

MENTAL STRETCHING AND TRANSFER

Interactions between music training and other learning may appear to involve what is called in the psychological literature *transfer*. Such terminology should be used with care.

The concept of transfer most typically involves moving a skill from the domain where it was learned to a different or broader domain — for example, taking a skill for driving learned in the parking lot to the highway. Another example of transfer could perhaps involve a student who develops the capacity for attentiveness through music, and then transfers this capacity to math. Or one can reformulate

Test arts students, though starting first grade, are significantly behind the controls in classroom behaviors related to learning, as assessed through Lickert Scale Questionnaires given to classroom teachers (Figure 2), caught up by the end of the year.

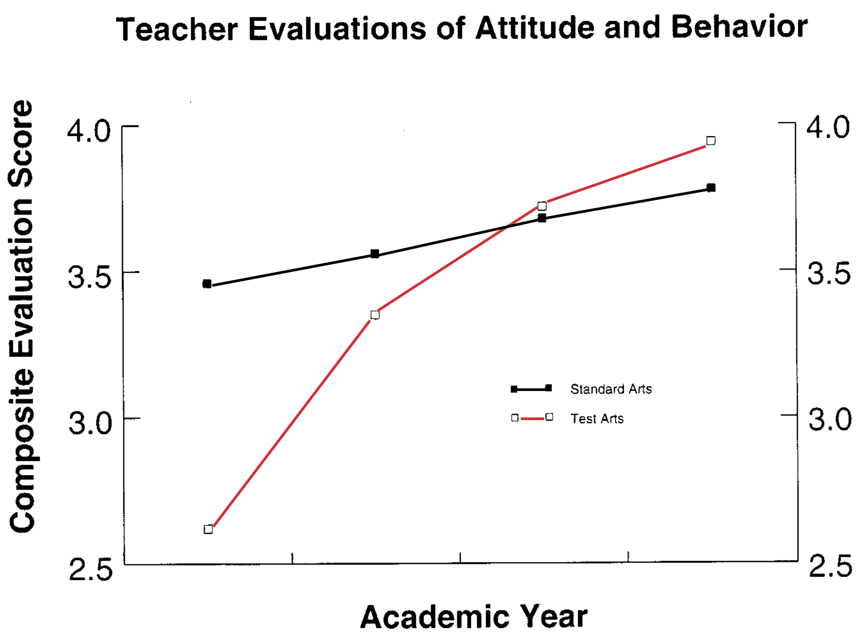


FIGURE II

The test arts gains in reading (Figure 1) were found to parallel improvements in classroom attitudes and behaviors as assessed by Lickert scale questionnaires given to classroom teachers (Figure 2).

Teachers reported that they felt the arts training could be contributing in a useful way to the improved classroom behaviors that were in turn associated with improved reading.

The improvement in math (Figures 1 & 3) went well beyond what could be accounted for by the changes in classroom behaviors.

(Gardiner et al., 1996; Gardiner, 1997; 1998b)

I SUGGEST THAT MATH AND MUSIC MAY REQUIRE SIMILAR, MUTUALLY SUPPORTIVE REPRESENTATIONS. THE ABILITY TO SING A MELODY PROPERLY, FOR EXAMPLE, VERY LIKELY NEEDS DEVELOPMENT OF MENTAL OPERATIONS SOMEWHAT LIKE THOSE OF MATH. THUS, THE DEVELOPMENT OF MUSICAL THINKING CONCERNING A "PITCH LINE" THAT KEEPS TRACK OF PITCH LEVELS IN RELATION TO THE SEQUENCE AND HIERARCHIES OF THE MUSICAL SCALE CAN REQUIRE A KIND OF "MENTAL STRETCHING" THAT CAN SUPPORT UNDERSTANDING AND ABILITY IN BOTH MATH AND MUSIC.

what I have said about the connection between pitch learning and math as involving transfer of some skill, or perhaps aspect of skill, from music to math.

However, I want to suggest three potential difficulties or limitations with this type of terminology. One is in deciding what it is that is transferred. Even the driving skills that can be learned in the parking lot may be similar but cannot be entirely identical to those needed on the open highway. Likewise, such a thing as "attentiveness" is quite vague. As we look more carefully at how an "attentive" person might behave in the two situations of music and math class it may well become harder to decide if the same thing is going on.

A second problem has to do with deciding how to frame consideration of the possible dynamics of learning. If, as I suggest, there can be dialogue, perhaps even in both directions, between areas of interconnected learning, the fine structure of what is transferred may well change dynamically during learning.

The third problem is assuming how skills and information may be stored in the brain. The notion of transfer can imply that something lives with one area of application and then moves to another. But there are many other ways that skills might be organized in the brain. If, for example, two areas of skill change by changing their relationships to other areas of the brain, is this still transfer?

For reasons such as this I prefer to use the somewhat different conceptualizations presented here and consider them in relation to questions of transfer rather than trying to fully replace them with notions of transfer.

CHANGING REPRESENTATIONS IN MATH AND MUSIC

Every computer programmer quickly learns something about programming that is of increasing interest to cognitive scientists: the way in which we can use, i.e. think about, information is influenced by the way we represent it. By mental stretching I mean the process by which one can change to a new way of representing and thus thinking about information that, in turn, is beneficial to the person's understanding of the skill or subject matter. In the example I focus on, I will be referring to a particular kind of benefit of mental stretching, but I am stating this definition in more general terms because different kinds of benefits are also possible. We all speak metaphorically about the value of changing and improving how one "looks at" something. What I am discussing below is exactly the kind of change in organization of thinking to which this metaphor refers.

THE PROBLEM OF REPRESENTATION OF NUMBER IN EARLY STAGES OF MATH LEARNING

The main point of what follows is to show that there is more than one way for a child to represent numbers as he or she begins to learn math, and that one representation can be more useful than another for facilitating the emergence of mathematical thinking.

One of the most difficult and yet most important problems for a child beginning to learn mathematics is to learn how to represent and think about numbers as numbers. In what follows I wish to suggest that it may be especially difficult for the child if she begins to think of numbers in the same way as she thinks about words. A child at this time has already been talking for quite a while and is wrestling with learning to read. Thus, word thinking is definitely on her mind when learning about numbers.

What does the name "John" mean? The child no doubt knows that it represents something very specific, for example, "That person over there." What does the word "boy" mean? The child knows something about this type of meaning, perhaps that this represents a general characteristic common to "John" and "Harry." The child can no doubt then understand the statement "John is a boy" as meaning that John has the characteristic common to John and Harry. Perhaps, still more importantly, she learned what a "boy" is by statements such as "John and Harry are both boys." By now

Figure 3 demonstrates that the greater impact on math compared to reading (Figure 1) was found in first grade whether students were weaker than average, average, or above average in standardized testing leaving Kindergarten.

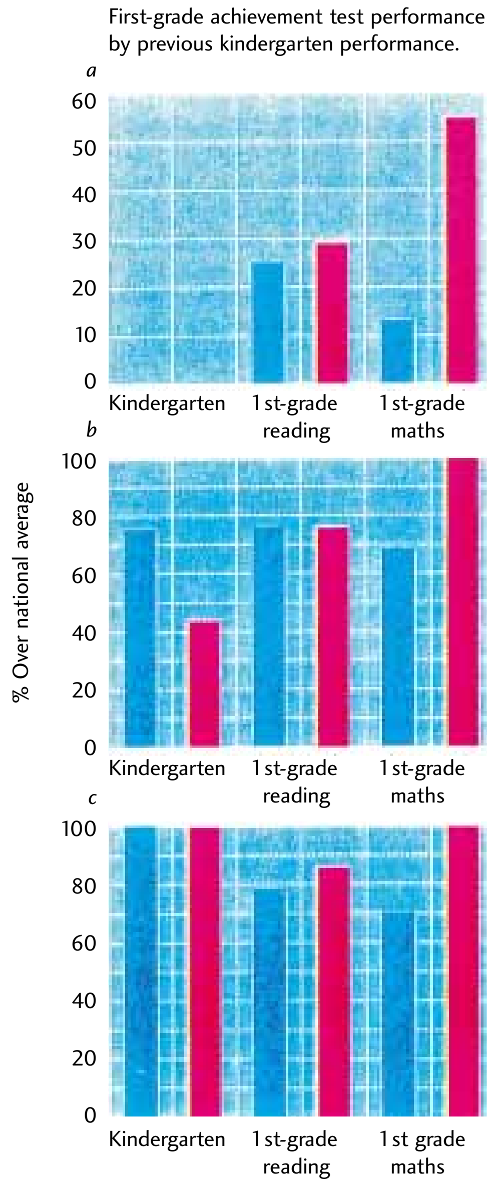


FIGURE III

(Gardiner et al., 1996; Gardiner, 1997; 1998b)

the child is probably quite advanced in working out ways to represent and think about such facts. A critical part of the thinking about words has to do with going from the truth of statements such as "John and Harry are both boys" to representing this information so that it can be used more richly. It is more critical to begin to take truth statements such as these as "facts" and learn how to store (i.e., remember) and then use these facts.

Consider now that this verbal ("v") child is confronted with the beginning of math, which is to learn to count. But to properly understand this operation as the first step to the development of the idea of number will require a completely different way of thinking about, and representing this information, compared to verbal language. The numbers "1," "2," "3,"...sound like words, but they must not be thought of in the same way as verbal words. But unfortunately it is possible to make a start at thinking of them as if they were words: The child may think "1" is the name for something, that "2" on the blackboard is the name for that different looking squiggle; that she is supposed to memorize "1, 2, 3, 4, 5,..." She may say, "Yes, I can do that. I can point to the right squiggle each time I say or read its word. I have to remember the right order of the words. Look, I can even memorize the list going backwards."

Suppose this "v" child who has learned counting in a verbal way moves on to what are often called number facts and elementary arithmetic. Number facts may sound like verbal facts, and the "v" child may try to represent and think about them in the same way, but they aren't really the same. A number fact could be a statement like "1 and 1 is 2." The "v" child may think, "Not sure what that means, but I suppose I'll understand some day. Anyway, I'll memorize '1 plus 1 equals 2.' Well that is confusing. I suppose that means that "and" and "plus" mean the same thing, and that "is" and "equals" means the same thing. Well, I guess I better change what I thought "and" meant. And then, '2 plus 1 is 3.' Gosh, so much to remember."

There are a lot of "facts" about numbers and the operations of mathematics that a the "v" child can learn by rote by thinking of numbers as if they were just new words that have to be learned. With a good memory a child can then answer questions such as "What does 1 plus 1 give?" Note that the "v" child can do this even without really understanding what the symbol "1" means as a number rather than just as a name. Even addition and subtraction tables can be learned by rote. But the more facts there are to learn, the harder and harder it will be to keep them straight, and the more and more confusing it can become as long as the representation is close to that used for verbal language.

To understand "numberness" involves developing a new way of thinking about numbers compared to words. This new way can also begin to be developed through counting. The easiest problem in counting is to be given a sequence of things, and then learn to assign the proper "name" to the position in the sequence, e.g. "moving from left to right, 1, 2, 3, ..." So far, the "v" child could go already. But what of more complicated counting problems such as "How many toys are in that box?" Well, if she realizes that she needs to take the toys out and put them in a row, the "v" child can learn to do this too. Working from a picture, however, is different. The child must begin to realize the usefulness of a strategy for going through the items sequentially, through the group of items in such a way that each item is only "counted" once, changing the name for the count in an orderly way from item to item:(1, 2, 3,...) and continuing until all the items to be counted have been counted. Within the context of the counting operation "1" is no longer an arbitrary name or merely a symbol, but has begun to take on a very specific meaning: *As the name for the first count within a counting sequence*. The next count is called "2", the next "3" etc. "2" no longer is just a name associated arbitrarily with the second position in a counting sequence, but *means* the second position in the counting sequence. The number meaning of "2" is inherently tied to this counting operation and its place within it. Thus "2" is the name for a step in counting, not a thing. If and when the "verbal" ("v") child realizes this, she is on the way to becoming a "math" ("m") child, i.e. is beginning to develop more productive representations that will assist her with math.

There is much more to learn. Consider, for example, the difficult "cardinality" property of numbers. To begin to understand cardinality, a child must realize that she is free to go through the items to be counted in any order she wishes, but that the number "2" will be always assigned to the 2nd count whatever the order. The next kind of problem may be something like "How many balls and how many triangles are in this picture?" The child must learn to add a new operation, grouping, and then carry out two separate counts to answer this question. Case, (1996) shows that joining concepts like "more" and "less," "higher" and "lower" is again critical to the development of a mental number line. "More" becomes one direction in a counting sequence, while "less" is the other direction; "higher" is associated with the "more" direction, and "lower" with the "less" direction.

Now consider mathematical operations such as addition. We have already seen that the child who is using rote memory of "facts" can go quite far initially. For the counting "m" child, addition can be conceptually quite different. "2 plus 2 gives 4" means numerically to go through a count to 2, then go 2 more up to 4. This now requires two counting operations, one to keep track of "where you are," another, linked to it, to keep track of change. One implementation might be to count up to 2, then "turn on" the second counter starting it at 0 and at each step linking a further step in the first counter to a step in the second. Addition then becomes a matter of creating a second counter and working out how to interrelate its operations to that of the first.

Subtraction would be quite similar, except that in the detail, the "change" counter perhaps moving in the opposite direction from the "where we are" counter. Thus, subtraction would involve moving in the opposite direction to addition, down instead of up the count.

Note that the pure memorizing method for doing arithmetic requires more and more facts to be learned, producing ever

The boost in math compared to reading was again seen in test arts students at the end of second grade (Figure 1). Since some students changed assignment to test arts or control before second grade, it was possible to compare academic progress against number of years in the program. The math boost was found to increase significantly with number of years in the program (Figure 4).

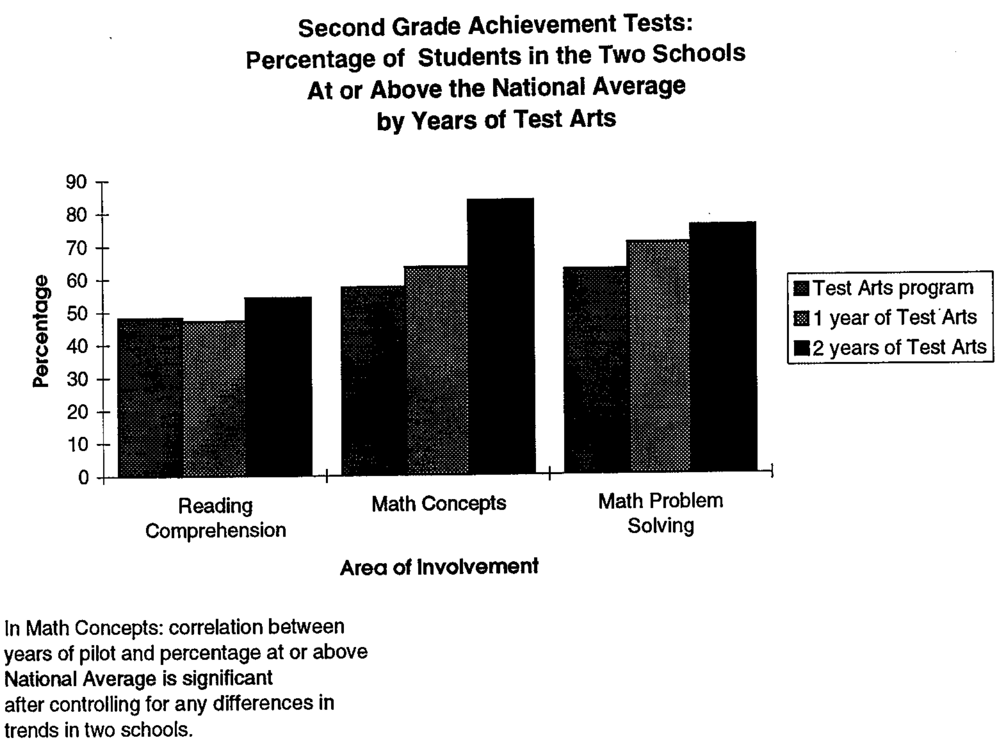


FIGURE IV

Progress in total reading could be accounted for by improvement in classroom behaviors that teachers attributed at least partly to the music training. Still greater improvements in math compared to reading implied a further and more focal influence on learning math.

(Gardiner et al., 1996; Gardiner, 1997; 1998b)

ONCE A CHILD LEARNS HOW TO MOVE UP AND DOWN THE MUSICAL SCALE FROM PITCH TO PITCH, THEY HAVE A NEW...WAY TO ORGANIZE THE GESTURES CALLED UPON FOR DEALING WITH PITCH...THIS RELATIONAL, MORE SYSTEMATIC KNOWLEDGE OF PITCH IS REPRESENTED THROUGH SYLLABLES (DO-RE-MI) OR NUMBERS WHICH STAND FOR THE DEGREES OF A MUSICAL SCALE.

longer lists of facts to be run through. The representations associated with counting and incorporating the operations of counting once set up does not change its efficiency as the size and number of different problems increase.

The next step for the "m" child is to begin to find a way to represent number as position within a count in a useful way which no longer requires going through the count each time, but abstracts salient features from the count. Piaget has suggested and presented evidence that the first important step here is to capture the ordering inherent in the meaning of numbers, 1 less than 2, less than 3, etc. and the organization of operations on the ordering, i.e. moving up and down the ordering. This, in turn, can begin to lead to the representation through topology, first a number line, developing into richer kinds of number representation spaces, for example, representing step sizes between the integers as equal intervals, and thinking of fractions in terms of movement along subspaces and overlapping spaces on the number line.

DEVELOPING REPRESENTATION OF MUSICAL PITCH

The student learning how to sing on pitch and use pitch within melodies faces in some ways a similar problem to the "verbal" student learning about numbers. The complex muscular movements required to sing a particular pitch to the words of a song can be learned note by note or by general melodic contour, and both processes are usually initiated without taking into account the arrangement of tones into a tonal system. As a child learns a particular song, often it is represented simply as a sequence of gestures (Davidson, 1985; Davidson & Scripp, 1986) that are unregulated by a musical scale. Many songs could be represented in such a way, and yet in a way this is very inefficient and unreliable. Each new song must be learned as a new sequence of gestures that do not have any particular relation to another song.

The development of new representations of organization of pitch similar to that we have discussed for number would again seem to be very useful. Once a child learns how to move up and down the musical scale from pitch to pitch, they have a new and much more generalizable and self-regulated way to organize the gestures called upon for dealing with pitch during singing. In elementary school programs that offer comprehensive, long-term music instruction, this relational, more systematic knowledge of pitch is represented through syllables (do-re-mi) or numbers which stand for the degrees of a musical scale. The relationship of musical pitch to number is powerful once incorporated into the mathematical and musical thinking. Moving up and down numbers in operations like addition and subtraction is like moving up and down scales in creating melodies out of pitch (Bamberger, 1991). If this pitch line representation captures some useful *similarity* in the way the brain can think about pitch and number, this does not imply that at any point the representations of pitch and number are completely *identical* or that they will develop further in identical ways. Unlike numbers (integers), for example, Western Music employs scales containing not whole but half steps at some positions, and this structural feature of the scales is critically important musically.

How can a teacher develop such representation? In Kodály training, as an example, teaching of pitch starts with two-note scales and relative "do," expands progressively to scales with more notes, typically spending much time with the pentatonic. Each level is represented by a different hand signal presented to the student spatially in such a way that "higher" and "lower" scale positions are taught through "higher" and "lower" positioning of the hand signals in space. Written musical notation, again, is introduced with an initially simplified notation that develops into conventional western notation, which represents pitch position and upward and downward pitch movement through analog graphical representation. All such features of the method seem well adapted to emphasize the value of a "pitch line" mental representation.

The interactions between math and pitch learning shown in research in the Greater Boston area (Johnson School in Nahant and the Conservatory Lab Charter School in Boston) provide further evidence in support of significant positive correlations between music and academic achievement. This research allows us to study how the implementation of programs such as New England Conservatory's Learning Through Music curriculum can help build many types of "mental stretching" connections between music, math, and other learning.

CROSS-FERTILIZATION OF MUSIC AND MATH AS ANALOGOUS THINKING

We have just seen two examples from quite different areas of thinking where there can be important similarities of useful thinking. If analogy depends on the detection of similarity (in many but not all

Again studying the impact of a Kodály music training similar to that of the Pawtucket study, this time without the further visual arts training of the Pawtucket study. The test group received an extra 30 minutes each week and had both the music and classroom teacher present in the classroom during that time.

Based both on the Pawtucket results and on the concept of mental stretching, we hypothesized that we would see greater academic progress and greater changes in classroom behavior in students who received the more extended music (treatment) training.

We also hypothesized that

- progress in reading would be more closely tied to changes in classroom behavior than would progress in math
- progress in math would be more specifically associated with progress in musical skills

Figure 5 summarizes data from the first two years of this study.

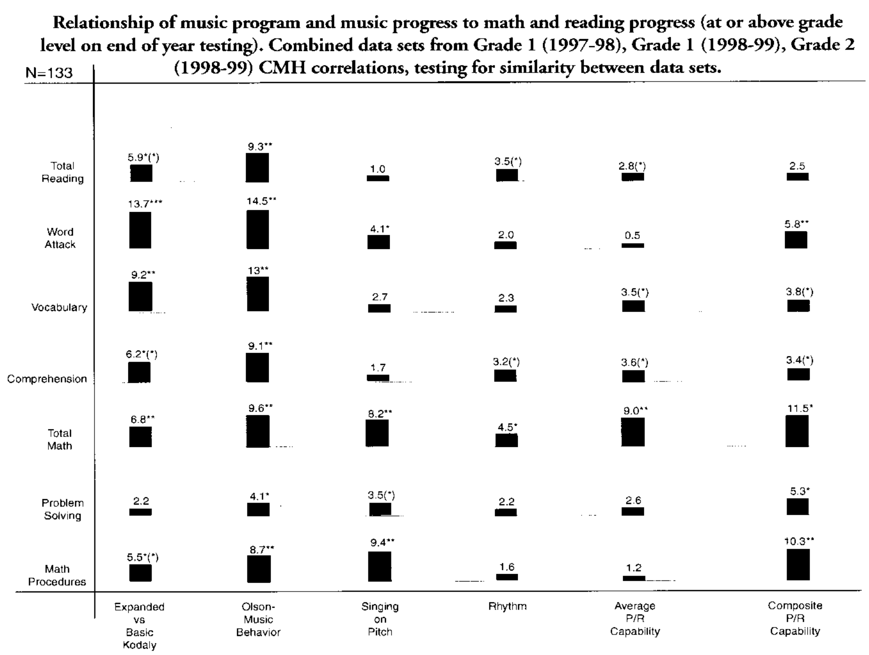


FIGURE V

Supporting and extending the earlier findings from the Pawtucket study, Figure 5 shows that students in the expanded training music program made greater progress than the students receiving just the basic music training, not only in total math and reading — but in sub-areas of math and reading that were tested, as assessed by the same standardized instrument, Metropolitan Achievement Test (MAT), used in the Pawtucket study (see also Figure 6).

(Gardiner, 1997; Gardiner and Olson, 1999; 2000a, b)

ways) between things, what we are seeing here can be thought of as an example of useful analogous thinking — i.e., the possibility that thinking within different domains is similar (though not completely identical) in important ways that can be useful to both.

The evidence suggests that when useful analogies within thinking exist, the development of thinking through learning in one area of application (such as pitch learning) can help to catalyze or in some other way cross-fertilize analogous thinking in the other area of application (such as math learning).

Why may it be useful to recognize and exploit such opportunities for analogous thinking within different areas of learning? There are several possible answers. There is, of course, the advantage of efficiency: Why should the brain develop a new way of thinking for each area of application if it is possible to reuse some of what it has already developed in another area? But our example suggests an opposite type of answer as well: discovering analogous thinking can perhaps help a learner to move beyond, or not be trapped by, less effective ways of thinking about some problem area. It may be especially interesting to continue to explore the possibility that these areas of analogous thinking signal deep similarities in the way the brain is prepared, through its design, to support the most powerful thinking in these different areas of application. To exploit such analogous thinking may then be an especially important example of what I am calling mental stretching: cross-fertilization that can move thinking in two different areas in ways that are mutually beneficial.

We have been discussing evidence that mental stretching in music learning can help to promote mental stretching that is useful to math. Another study (Gardiner, 1998c) in 8th graders in Vermont found evidence for dialogue within learning in both directions: baseline math progress helped to account for progress in a midi-based music composition program, and progress in music composition in turn helped to account for further progress in math between baseline and later testing. I suspect that dialogue such as this may be especially advantageous during learning; the brain continues to develop and exploit opportunities for analogous thinking when it works on similar types of problems at the same time.

The Minneapolis project (Figures 5 and 6) and data from New England Conservatory's Learning Through Music programs suggest evidence of other cross-connections between music and other learning that again suggest cross-fertilizations of the kind we have been discussing. For example, progress in pitch correlates not only to progress in math, as we have discussed, but also to progress in word attack skills. Similarly, initial studies are showing evidence that progress in rhythm correlates to progress in total math, but also, more weakly to different aspects of reading compared to progress in pitch, specifically to total reading, and reading comprehension. Progress in classroom behaviors are also related to academic progress, especially closely to progress in reading (Figures 2 and 5). Statistical analysis shows that these different influences are sufficiently distinct from each other that they cannot be reduced to the same connective paths, but their influences can combine.

MUSIC TRAINING AND CHANGES IN BEHAVIOR

If mental stretching involves a new way to approach the role of mutually reinforcing representations among music, math and reading, as I am proposing, then it may be useful also to rethink the changes in classroom behaviors within this same framework. Is it possible that changes of representation and analogous thinking may also exist between music learning processes and social/emotional development?

In addition to positive correlations between music and academic achievement in the Minneapolis study, for example, behaviors were found to change in association with the music training (see Figure 6). These changes were detected from data reflecting measures of a) *Class Participation*, b) *Direction Following*, c) *Cooperation with the Teacher*, and d) *Cooperation with Peers*, all variables that may reflect changes in social/emotional development in the classroom setting. Changes in personal behaviors also occurred and include improvement in a) *Self Motivation*, b) *Self Esteem*, c) *Responsibility*, and d) *Initiative* directly involve changes in the way students think of themselves, as they are observed by classroom teachers.

THE EVIDENCE SUGGESTS THAT WHEN USEFUL ANALOGIES WITHIN THINKING EXIST, THE DEVELOPMENT OF THINKING THROUGH LEARNING IN ONE AREA OF APPLICATION (SUCH AS PITCH LEARNING) CAN HELP TO CATALYZE OR IN SOME OTHER WAY CROSS-FERTILIZE ANALOGOUS THINKING IN THE OTHER AREA OF APPLICATION (SUCH AS MATH LEARNING).

INTERPLAY WITHIN MENTAL STRETCHING

The Minneapolis project (Figures 5 and 6) shows evidence of many quite complex interactions between music training and other learning. We have evidence of interplay among mental stretching connections.

These data, for example, do not support the conclusion that improvements in self-

Teachers rated the children during the year on eight aspects of classroom behavior that included Class Participation, Direction Following, Cooperation with the Teacher, Cooperation with Peers, Self Motivation, Self-Esteem, Responsibility, and Initiative.

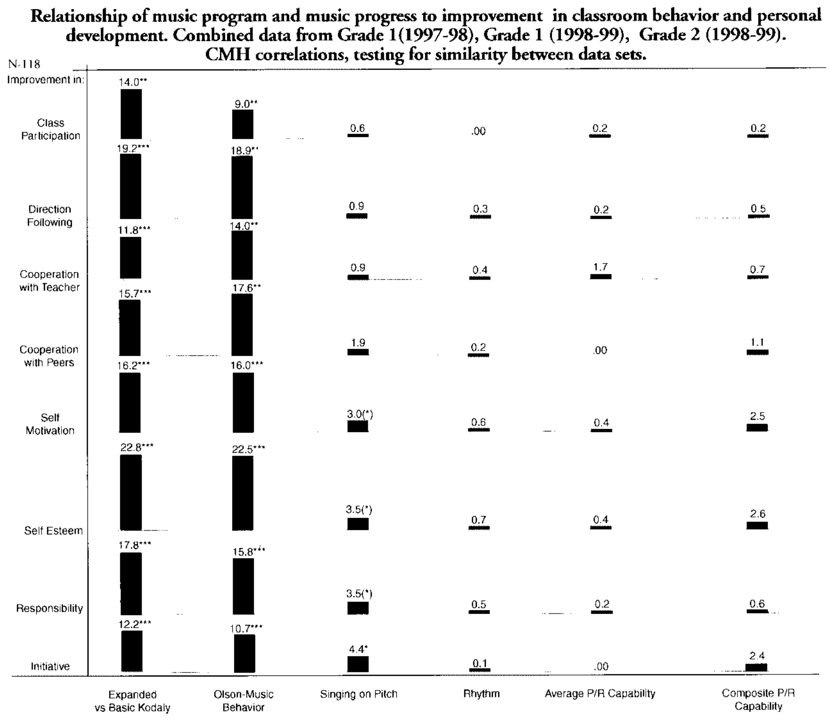


FIGURE VI

The first column of Figure 6 shows that the students who received the enhanced training showed very significantly greater improvements in classroom behaviors when compared to their peers who received only the basic musical training.

Further, statistical analysis showed, as hypothesized, that progress in total reading was could be 'accounted for' statistically by progress in four of the measures of classroom behavior: 1) Class Participation, 2) Self-Motivation, 3) Self-Esteem and 4) Responsibility, and to a lesser extent a fifth measure, 5) Initiative.

As hypothesized, the statistical analysis showed that Progress in Total Math could not be explained in this same way, but could be explained by relationship to development of specific skills in music (Figure 5) predicted by the theory of mental stretching.

The Minneapolis study provides further and more detailed evidence for the same three types of interactions between music training and broader academic progress already seen in the Pawtucket study.

(Gardiner, 1997; Gardiner and Olson, 1999; 2000a, b)

esteem (Figure 6) in and of itself can help a student learn to sing on pitch, but do, however, suggest that a student with lower self-esteem can have a harder time in learning to sing on pitch than one with higher self-esteem, and that learning to sing on pitch can improve self-esteem. The direct connection of singing on pitch to math learning, which we can now relate to mental stretching, is seen in these data to be associated with higher self-esteem — and is likely to develop more easily in students with higher self-esteem.

Self-esteem may be very much influenced by other aspects of the music training as well as other aspects of academic progress. All this, if complex, somehow still seems very much in line with typical experiences in the classroom. A child can grow in confidence with success in learning, and this confidence can help the child to learn more effectively, quite possibly increasing courage to engage other areas of learning with new interest and confidence. Lack of progress can lead to discouragement and have an opposite effect on learning. Our data suggest then, that interactions between self-esteem and academic or musical success can be important but do not, in and of themselves, account for the other types of cross-fertilization we have been discussing.

DURATION OF EFFECT

As Kandel has shown (Kandel, 2000) even a relatively simple nervous system such as that of the sea snail Aplysia distinguishes between short term and longer term learning. Aplysia have specific mechanisms that react quickly through temporary changes in nervous function to noxious stimuli but prevent long lasting changes in nervous system unless noxious stimulation is maintained for a long time. Other organisms, including humans, also make frequent reactions to changes in their world, and make longer term changes in their behavior less frequently.

The mental stretching effects detected in school settings discussed in this article so far suggest longer rather than short-term changes in function. The duration of the effects under study here is an important aspect of our research and can influence the design of school programs in various ways. Other factors may also be involved in the case of mental stretching with regard to music and social-emotional development. Such things as the stability of personality structures, capabilities for understanding languages, and of neurotic psychiatric disturbances imply that the human nervous system has mechanisms for structuring patterns of thinking that can persist for very long periods of time. Some long term effects have been detected with respect to musical training. Recent studies of pianists, for example, show examples of motor representations persist as long as playing is maintained, but then begin to die away unless playing is continued. What can we expect the effect of long-term musical training in public to be in relation to long-term cognitive, physical, or social-emotional development?

For example, if students who received the enhanced music curriculum showed significantly greater improvements in classroom behaviors, to what extent might these results have long-term effect on these children's lives as adults? Analysis of a longitudinal database begun in Providence, RI almost 40 years ago now provides an alluring example of how music may influence social-emotional development in youth. This study reveals (see Figures 7a and 7b) that the probability of having been arrested at least once by age 18 drops significantly in inverse proportion to degree of positive attitudes about music, and development of musical skill. These data suggest that the mental stretching associated with music study and the development of skill can have a long-term impact on concepts and skills related to social-emotional development (Gardiner and Buka, 2000).

IMPLICATIONS FOR MENTAL STRETCHING AND EDUCATION

The general role of mental stretching in relationships of music to learning and development:

The discussion of mental stretching began with consideration of interactions between music and learning within the areas of its effects on general attitudes and general skills for learning and as an aid in the development of useful new specific thinking skills. I have suggested that both the narrower and broader impacts and dialogues within the brain between music training and other learning that I and my colleagues are studying have to do with changes in the way one learns to think, or, metaphorically, look at information.

Mental stretching, as now defined more broadly here, can be involved in the other ways music can interact with learning. With regard to values specific to music, for example, we have already examined the development of thinking that may be needed to support development of capability to sing on pitch.

Even applications of music as an aid to learning within other subjects or social development can involve mental stretching, and such influence should be taken into account in planning. A child who learns addition tables through rhythmic songs can perhaps have musical skills, and particularly rhythmic skills strengthened, but if the rhythms are very much the same from song to song, the rhythmic representational learning may be quite narrow. And, as we have discussed, the rote learning of arithmetic supported here can lead to ways of representing arithmetic operations which may ultimately hold back the student unless they are successfully supplemented by other teaching that helps build representation moving more towards the number line. Hearing and building understanding of music from a particular time or place whose history is being studied may affect the way a student thinks about the people of that time, and thus may influence the way he or she understands the history. Performing and improvising music may affect the way young children look at rule structures, cooperative learning, and empathy of others. These examples can all involve mental stretching and involve changing representations from that on which we normally focus on in traditional schools.

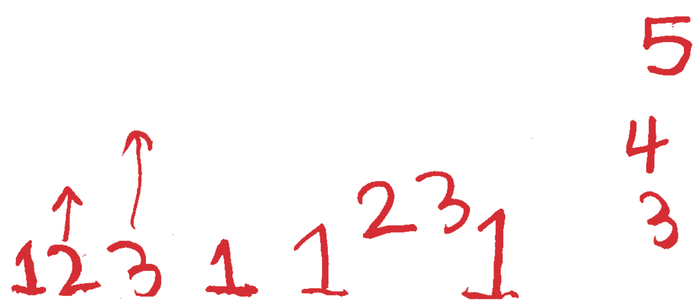
Stretching vs. being stretched

My colleague Don Walter has alerted me to the fact that the metaphor of mental stretching can leave ambiguous the matter of agency: Is the mind or brain being stretched

At the Conservatory Laboratory Charter School in Boston we have begun this year to carefully follow and study statistical relationships between musical, academic, cognitive, and social progress and development in children in grades K-2. The Learning Through Music program plays a central role in the curriculum.

A detailed battery of Learning Through Music examinations enable us to investigate musical skills and concepts that are typically considered on a more global basis. For example, knowledge of a song is measured not simply by being able to repeat it after it has been learned, but to repeat it with and without the words, while clapping the underlying beats, or while pointing to the pitches of the melody. In one such examination, the Kindergarten students were tested on their ability to name a tune by examining pitches coded by numbers representing the notes of a diatonic scale. For example, 3 2 1 2 3 3 3 had to be recognized as *Mary Had a Little Lamb*.

As an example of our research, kindergarten students' performance on this task was found to correlate significantly with scores on total math progress as assessed by standardized Stanford 9 testing (.50, $p < .05$) administered at roughly the same time, but did not correlate significantly with the score on any of the other areas of standardized testing, which included total reading, word attack skills, word reading, and language use.



In this exercise, children are given a number series and asked to represent them in relation to the way they sing Frère Jacques. *Children at the Conservatory Lab Charter School learn quickly that numbers may be used to represent many things, not just quantity. In music, numbers can represent sequence, duration, or scaled pitch, or structural parts of the song (Davidson and Scripp, 1988).*

THESE DATA DO NOT SUPPORT THE CONCLUSION THAT SELF-ESTEEM IN AND OF ITSELF CAN HELP A STUDENT LEARN TO SING ON PITCH, BUT DO, HOWEVER, SUGGEST THAT A STUDENT WITH LOWER SELF-ESTEEM CAN HAVE A HARDER TIME IN LEARNING TO SING ON PITCH THAN ONE WITH HIGHER SELF-ESTEEM, AND THAT LEARNING TO SING ON PITCH CAN IMPROVE SELF-ESTEEM.

Math, music proportion, and measurement come together as audible diagrams in the clapping patterns of these young Nahant schoolchildren.

by experience? Though this is not the place to discuss this further, I have a different sense of agency: a mind, a brain that, from the beginning, continues to work actively to try to represent the world and information about it and can change its way of thinking about the world as it learns. This thinking thus perhaps lies within the area of "constructivist" modeling. At this level of detail this issue may not matter, but it could be more important as we begin to test models of learning in relation to representation within a brain that comes already with a great deal of structure in place.

The contribution of music to learning.

The results we report support the possibility that the cross-connections between musical training and other aspects of learning developed here are useful to the educational and broader development of these students. The size of the statistical effects we discuss here are of an order which indicates that they are statistically significant; they are unlikely to be due to chance alone, and therefore can assist, but certainly in no way fully account for, the role of music in "non-musical" learning.

It would seem quite implausible, in fact impossible, that a child could learn how to do math problems or how to read from music training alone. But the data continue to suggest that the right kind of music training can support some of the cognitive development on which math and reading progress depend, helping also with the development of social or personal skills. Since children seem to enjoy learning how to make music, cross connections from music training within the curriculum such as we are studying appear to have potentially great practical value. Students who become more proficient in, and more acquainted with, the art of music, opens new entry points into learning beyond the discipline of music alone. Indeed, it is possible that the understanding of cross-connections and general messages about learning in music reported here may also help to illuminate the nature of music and its enormous appeal and importance to a vast segment of our society.

Implications and cautions for program design.

The impact of arts training on math learning which have been documented so far are very specific: they have to do with the nature of the specific arts training used, the type of academic skills students were learning, and the possibility that there was enough overlap in the kind of mentation and changes of representation needed to ensure that learning in one area could help support learning in the other. The degree to which interactions between music and math learning can be expected with a different type of music training, or different types of arts training such as painting, drama, or dance would depend, according to the theory proposed here, on the specific nature of arts skills being developed. The possibility of impact of music across the curriculum depends on the exact nature of mental skills, representations, and analogous thinking developed in each area, and the degree to which they overlapped.

From the viewpoint of this theory, we can anticipate that interrelationships between arts training and other areas of learning

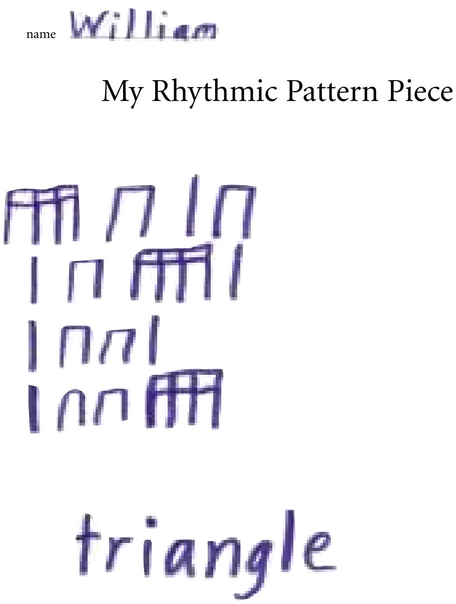
While, in the kindergarten students, the tasks of imitating clapped rhythm patterns and clapping rhythms from written notation correlated significantly to math progress, one particular musical task correlated with a range of academic measures.

In this task a child had to listen to rhythmic patterns, then represent them symbolically in writing. This task requires that children coordinate and integrate many different kinds of thinking to achieve high performance.

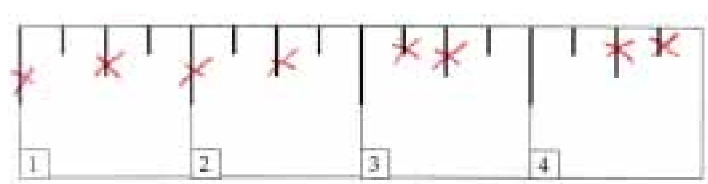
Performance on this task was found to correlate not only with progress in all areas of progress testing including total math, total reading, word attack skills, word reading and language use (p <.01).

The breadth of connections to academic progress of this task supports our expectation that many different mental skills are needed for this task. The broad academic progress of those who did well on this task supports this.

Each year, as additional grades are added, we will continue to follow the progress of the children as they continue into the upper grades, while adding new students to the study as well.



In the "My Rhythm Pattern Piece" start with manipulatives to represent rhythmic figures, convert them into original compositions in more conventional musical notation, and then perform them using the one, two, three and four syllable mnemonics (cha, taki, gamela, tiritiri) to perform the patterns.



Elementary age students at the Conservatory Lab Charter School create their own rhythms on "Rhythm," teach their rhythms to a partner, and then answer questions such as "How did you know if your partner did the rhythm the way you composed it? How are rhythm rulers like other rulers? How are rhythm rulers different from other rulers?"

IT WOULD SEEM QUITE IMPLAUSIBLE, IN FACT IMPOSSIBLE, THAT A CHILD COULD LEARN HOW TO DO MATH PROBLEMS OR HOW TO READ FROM MUSIC TRAINING ALONE. BUT THE DATA CONTINUE TO SUGGEST THAT THE RIGHT KIND OF MUSIC TRAINING CAN SUPPORT SOME OF THE COGNITIVE DEVELOPMENT ON WHICH MATH AND READING PROGRESS DEPEND, HELPING ALSO WITH THE DEVELOPMENT OF SOCIAL OR PERSONAL SKILLS.


JEFF THIEBAUTH

Members of the Young Achievers Science and Mathematics School's Percussion Ensemble led by John Belcher, featured in the Boston Music Education Collaborative's "Best Practices in Action MusicFest" at New England Conservatory.

can change at different stages of learning. Recent data (Harland *et al.*, 1998), though open to other interpretations, supports the possibility that, in upper grades, there can be strong interactions between music training and not only math but also verbal language skills, while drama training interacts with language, but not with math. Such a result is plausible when the types of specific training involved is kept in mind. It is plausible to think of interrelationships of "mental stretching skills" in upper grade music training to skills needed in both upper grade math and verbal language, and interrelationship between drama and verbal language skills, but perhaps not so strongly between drama and math skills.

The current interest in using arts programs to help build more general creativity in students seems well founded: arts programs clearly can be designed to require, and present opportunities to be creative with regard to art productions, and it seems plausible from what is already known that through mental stretching and other paths capabilities for applying creative skill to topics outside of the arts may well develop as a result. Here again, however, there does not seem reason to expect magic bullets. Research into mechanisms, good design, good teaching will still be needed (Weinberger, 2000).

The current data just reviewed supports a variety of opportunities for music programs to contribute significantly to education. Such opportunities should continue to be studied and developed. They do not mean that simply having arts programs within a total program will in itself guarantee benefits. To properly exploit arts training potentialities is as likely to depend on good design based on what is already known, good teaching, and continued research, and development of understanding of the factors involved and related theory, as is true of any other area of education.

Arts skill.

An important feature of the arts experience impact research just reviewed is to focus on the impact of arts training where students are expected to develop not only *appreciation of* but also *skill with* an art. As noted (Gardiner, 1998a), what is critical in our theory, and so far supported by our data, is that not just appreciation, but specific musical skills are developed in the expanded music programs. And it appears from the data, which we continue to collect from the Learning Through Music program research at New England Conservatory, that specific musical skills do correlate with specific aspects of academic achievement, findings which suggest that mental stretching relies on evolved and generative representations that accompany the development of musical skill and understanding.

Within an art form such as music, development of skill with, and development of appreciation for, the art and its artistic process are not independent, but are highly interdependent. We would not expect to learn much about math until we

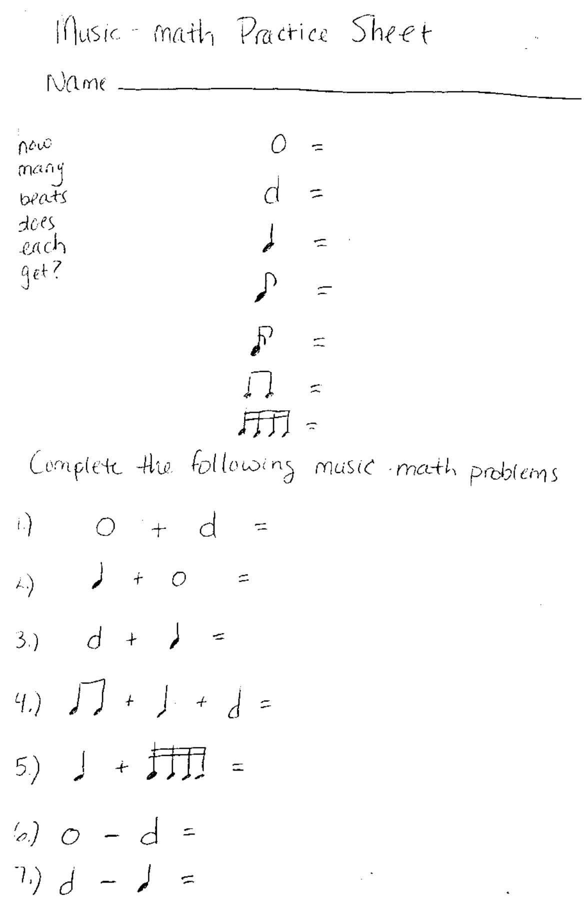
Through the *Learning Through Music* program, music is also being connected to other learning in a great variety of projects in addition to the music program that is part of the school's curriculum.

Data from the first year of work within the school reveals that in the school, as a whole, performance in Math and Reading and Science were all significantly correlated with total progress in music capability (as measured by teacher ratings).

In the upper grades, where it was possible to compare with previous year's testing, music progress was significantly correlated with improvement in Reading Comprehension, Language Mechanics, Math Problem Solving, and Analysis.

The second year of work at the school has now been completed, and the data from this second year will be analyzed this summer.

To summarize, then, the Learning Through Music program at NEC is providing further evidence in support of the observations in Pawtucket and Minneapolis.



The Music-Math Practice Sheet used at the Johnson Elementary School in Nahant by New England Conservatory faculty Rhoda Bernard suggests how musical representations of rhythmic duration can take the form of mathematical computations. Student reflections on this activity suggest that fourth grade students find this kind of change of representation refreshing and useful in their math classes.

start to do math, or reading. Why should the arts be so very different? From my experience as a teacher I have seen that especially children value being able to learn to *do*. They can be very poor observers unless they can begin to sense that this is something they can begin to do themselves; then suddenly you have their full attention.

This is not to say that students must focus on skill at the expense of appreciation or enjoyment of the art. It is the enjoyment and appreciation of the art that in our experience strongly amplifies the motivation in the student to strive to build skill. They want to be able to do what they admire, and will strive to do so.

At the present time, even in education programs where children are exposed quite extensively to the arts and learn about the arts, very frequently only a small number are expected to develop more than rudimentary skill with the art. In my view, this lack of emphasis on the development of skill can severely attenuate the fullest impact that arts training can have on learning, both within the art form and more generally as well.

JEFF THIEBAUTH

Teachers at the Conservatory Lab Charter School in Boston report that music activities appear to generate more inclusion in classroom settings compared with their experiences in teaching in other public schools. Social and personal changes in classroom data (Figures 2 and 6) further reinforce these teacher observations. The Brown data suggests that these shorter term effects may have longer term implications as well.

Brain research of the last twenty years has developed an enormous amount of evidence suggesting that activity in the brain at work is very different from the brain at idle, and that what goes on in the brain changes very substantially as what we are doing increases and changes. The value of doing to learning, not just observing, may perhaps have partly to do with the special qualities of brain involvement.

The important recent work of Gordon Shaw and Francis Rauscher (e.g. Rauscher *et al.*, 1993; Rauscher *et al.*, 1997) provides further evidence of the impact of arts training on broader learning when training of skill is included. In their data, simply listening to music appears to produce only brief impact in humans.

Training of skill at arts is still thought of by many as specialized learning that should be provided only to those with special gifts or who can afford private instruction. But there are methods of pedagogy, for example the Kodály music program that formed the treatment in the test groups in Pawtucket and other schools, which make it possible to develop significant arts skill within the time constraints of typical current education programs. The Kodály method was specifically developed as a pedagogy to be provided for every student as a part of their standard education beginning already at Kindergarten age. The curriculum being developed at the Conservatory Lab Charter School, a comprehensive, interdisciplinary Learning Through Music program gives an opportunity to test my hypotheses and provide a model for explicitly supporting "mental stretching" in public school education.

Further exploration of teaching involving the arts in education is evolving at the same time musicians are considering wider, more inclusive objectives for musical training in public school education. Along with other issues of integration, strong attention should be paid to making certain that students develop *not only* appreciation but also *skill* in the arts as the arts are integrated across the curriculum. Not just a small number, but *all* students can very likely reach a quite reasonable level of skill that is much higher than current expectations in most schools. The research, as I have reviewed, suggests that various forms of musical instruction may stimulate mental stretching across the borders of academic subjects and the arts in a number of different and productive ways. These findings may well require changes in the way teachers are prepared for careers involving the arts in education, as well as in the ways arts education is thought of in the schools, but this is a challenge that seems worth meeting. ¶

Compared to their peers who received only the basic musical curriculum, the students in the Minneapolis study who received the enhanced curriculum showed very significantly greater improvements in classroom behaviors on all the measures teachers reported (Figure 6). These measures involve both social and personal development. Furthermore, a specific measure of engagement and behavior during the music activity, the Olson Index, correlates highly significantly with these improvements as well. To what extent might these correlations have long-lasting effect?

Dr. Steven Buka of Harvard School of Public Health and Dr. Lewis Lipsitt of Brown University have been developing a longitudinal database based on a study begun in Providence, RI almost 40 years ago. Data on the subjects now extends from prenatal records to age 35. It includes rich information about social, psychological, and cognitive outcomes that can be compared with testing up to age seven. These data are now being analyzed in detail. Self reports from 522 individuals through a questionnaire reveal their current interest in music, extent, type, and timing of previous music training. This provides an opportunity to test and study many hypotheses that concern the long-term consequences of music training and experience, while adjusting for confounding factors, such as socioeconomic status.

Figures 7a and b show that the probability of having been arrested at least once by age 18 drops with increased interest and in music and drops still further as individual or group musical skill levels increase. These data then support the possibility of longer duration effects similar to those detected in shorter scale with the Minneapolis data.

The Brown Longitudinal Study provides a means of testing the idea of mental stretching for evidence of long term cognitive, social, or emotional effects of music training.. We have observed evidence of long-term social-emotional effects of interest in music and music training which we continue to analyze.

(Gardiner and Buka, 2000; Gardiner and Olson, 1999; 2000)

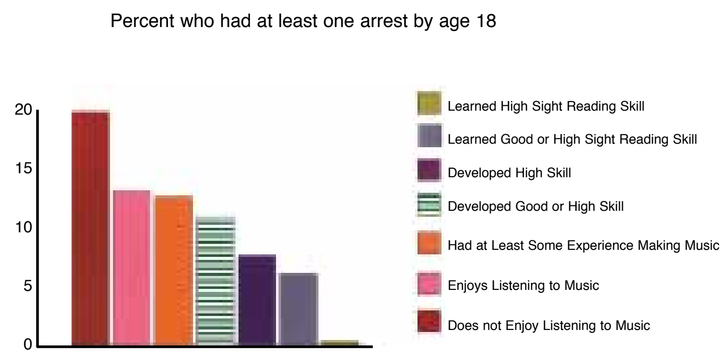


FIGURE VIIa

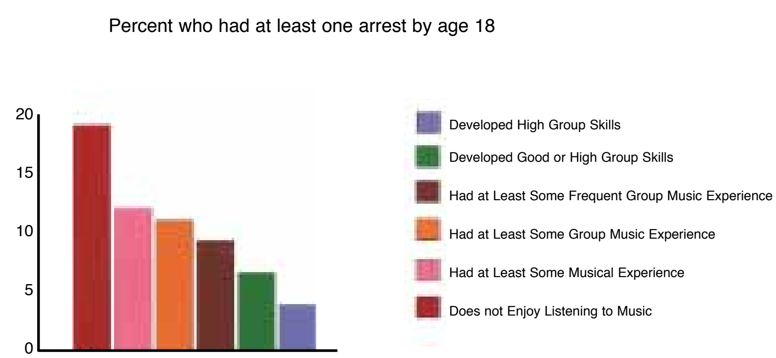


FIGURE VIIb

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