MUSIC RESEARCH IN BEHAVIOR AND BRAIN:

PAST, PRESENT, AND FUTURE

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Introduction

Several years ago, in the literature on music and the brain, it seemed that there were many people interested in music that never talked to each other. People such as music educators, neuroscientists, child development specialists, music therapists, and medical researchers were disconnected from each other. To begin bridging these gaps in communication, the Music and Science Information Computer Archive (MuSICA) created a computer archive. We have a database that anyone can search. It now has over 43,000 citations and abstracts. We also publish a review of music research three times a year called "MuSICA Research Notes" that is on the Web (http://www.musica.uci.edu). We thought it would be helpful to place citations in a single, accessible database, so everyone would be able to go to one source. This is a resource that may not exist for some of the other arts.

The Past

To better understand the current research on music and behavior, it is important to clarify one issue from past research identified as the Mozart Effect. A few months ago, *Music Research Notes* published an article that attempted to place the Mozart Effect in perspective. The Mozart Effect has been very misunderstood by the public. Dr. Gordon

Shaw at UCI and Fran Rauscher, who was then at UCI and is now at the University of Wisconsin, Oshkosh, conducted the research that evolved from Dr. Shaw's theories about the brain. College students, not pre-schoolers, listened to a Mozart sonata for two pianos; then they were tested on a spatial-temporal task. These tasks can be compared to the skills involved in mentally solving a jigsaw puzzle by rotating the pieces. A person must change spatial relationships over a period of time and hold that information. The most popular spatial test now is the paper folding and cutting test. Cutouts are made in a piece of paper that has been folded several times. The task is to predict how the paper will look when it is unfolded. The original findings were very striking. Spatial-temporal test scores (a sub-test of an IQ test) increased significantly. This made a big splash in the media. The authors were very careful to point out that the duration of the effect was brief, lasting about ten minutes.

Approximately 17 follow-up studies have been published. There is considerable dispute about whether or not the Mozart Effect is genuine. Somebody has reported that the music of Yanni has the same effect, and someone else reported that a Schubert sonata is effective. The Mozart Effect involves a brief, passive effort and has a very transient effect. The field does not yet understand this brief effect. But if a person listens to something briefly, the popular belief is that he or she will receive a long-term benefit on his or her life. This is "cognitive bargain hunting." It is a triumph of hope over reason.

Some people think that they will solve their children's problems by having them listen to classical music for ten minutes, which is unfortunate. The media bears some responsibility for this. There are other effects of music that do not have "effect" names. They involve learning to listen to music in a careful manner, under guidance, and also learning to play music for a period of time. The Mozart Effect might have theoretical significance, but it is not of practical significance in the classroom.

Other issues that need more clarification for current research are the transfer effects of music on education. Transfer effects involve learning one task that influences learning a second task. A person does better on task two than he or she would otherwise. The tasks are not the atoms of behavior, but they tap common underlying processes. If one task uses the same process as used in another task, then a person is actually practicing both tasks as he or she improves on the common underlying processes. Transfer can come about when a person uses common mental modules.

Transfer is much easier to understand for motor behavior than it is for cognitive processes. For example, people who know how to roller-skate do very well at ice-skating. These kinds of transfer effects involve balance. Thinking about transfer effects for cognition is a bit more difficult, and is at an earlier stage of knowledge. For example, some years ago it was found that learning to listen to music increased reading scores in first graders. Subsequently it was found that when first graders listened to music, they achieved better pitch and phonemic awareness. The authors hypothesized that the transfer effects influence learning to read, which involves sounding out the words. If one has better attention to, and understanding of, phonemic transformations or transitions, one is more likely to be better at sounding out the words. This argument is not a closed case, but it is an illustration on how a transfer effect is likely to occur within music.

These are only two studies, but there are many other objective studies in this area that have statistically significant controls. For example, there are also several reports that show music making increases various measures of creativity. The mechanisms are not completely understood. Some people treat this as "magic," even though transfer effects are not new in psychology. There is still a need for more research in this area.

The Present

Currently we are gaining more understanding about the biological roots of music and some of the effects of music on the brain. Children and infants love music. Infants can actually hear music during the third trimester. After birth, they can remember for a short period of time what they have heard. These findings, and others, suggest that music is biological, not just a by-product of culture. Even though music is in every culture, this fact may not convince someone that music is biological. Music could still be a cultural phenomenon. But if it were not universal, then one would suspect that it is not biological in nature. So music at least passes that test. Another finding is that children make music spontaneously. Children have been observed systematically, and they actually react to music at very early ages. They play musical games, make up musical rhymes, and compose music. It is difficult to find a child who does not react to music. Six-year olds actually invent their own musical notation to record on paper the songs that they have made.

Infants also have a lot of musical competency. For example, within the first few months or even weeks of life, their pitch discrimination is as good as an adult's discrimination. This ability allows them to discriminate between two different frequencies. They have the acuity and could be able to do more processing. They can do rhythm discrimination, and they note slight differences in rhythmic changes. They can group a sound stream into perceptual groups, which is essential to make sense of music. And they have the ability to follow contour, that is, the pattern of high and low notes in a song. So even if a person sings off key but retains contour, an infant would recognize it as the same. An infant can not do transposition, which probably develops at four years or older.

A couple years ago, a study from Harvard found that infants distinguish between consonance and dissonance as represented, for example, by an interval of a fifth versus an interval of a second, which is highly dissonant. We have continually underestimated the complete competencies of infants.

To understand how music is learned, it is important to have a grasp of the neurophysiology of sound. The auditory cortex is located in the brain's temporal lobe. Sound enters the ear as complex pressure waves. These waves are sorted out in the cochlea, which essentially sends many pure tone signals into the brain. The tone signals finally reach the brain's auditory cortex, which is the region most involved in what we would consider music. There is no single cell in the brain that listens to everything. Different cells are tuned to one or another frequency across the frequency span. The more a cell discharges to a sound, the more tuned it is to the eliciting frequency. If one plots these discharges as a function of frequency, one would get a tuning curve. A cell responds best to one frequency and not as well to others.

We learn about music like we learn about language. The question we addressed is whether or not those tuning curves are fixed, or whether learning changes them. One can ask this question by doing a simple associative learning experiment. An example is the association between the spoken name of an object and the object itself. The word "dog" can point to a real dog, or "Rover" can point to the actual dog Rover. In the laboratory, we give a tone that we can follow by food. The tone becomes a signal for food. Since the brain is a curiosity machine and tries to make sense out of the causal fabric of the external world, the animal quickly learns that the tone has importance, and that it signals an important event. In a typical experiment, we determine the tuning curve of a cell before and after the subject learns to associate a particular tone with reinforcement. The result is that the cell actually changes its tuning—it becomes tuned to the frequency of the signal tone.

This, and related experiments, reveal that the way our brains are tuned, to even respond to simple tones, is not fixed but is learned. If one knows what happens in the ear, one does not know what happens in the auditory cortex. The learning does not take place in the ear. It does not take place in the lower part of the brain, but it does take place in the highest levels of the auditory system. So as we learn about music and other sounds, our brains get re-tuned to emphasize what is most important to us.

This has some major implications. Suppose we use the metaphor of the brain as a keyboard. And let us suppose that we learned that C was very important. One could expect that the brain would change so that more cells would be tuned to C. C gets an increased representation, or it gathers more neurons to it as a magnet attracts iron particles. As the brain gains one thing, one assumption is that it loses another. That is one possibility, but it is not the only one. The other possibility is that there is plenty of room to learn about C and everything else. The brain's processing capacity can increase, and it can increase by making more connections between nerve cells, synapses, and so forth. It now appears possible that more neurons can be generated.

"Your brain, use it or lose it." This may be an oversimplification of things, but it is also a pretty good rule. Brain cells do need to be exercised. If they are not active or do not discharge, then synapses can actually get weaker. The bad news is that brains are dying, probably from early adulthood. Stress helps kill brain cells. But there is some preliminary evidence that new learning actually may prolong the life of cells that were "scheduled" to die. We need to look to the future for the exciting prospects.

When one is involved in playing music, a lot of things are going on in the brain. The perceptual systems involved are sight for reading a score, sounds for hearing, touch, and so forth. The decoding or symbolic interpretation of a score engages related systems. One includes planning both fine and gross movements, which requires a great deal of coordination. The execution of the movements of thousands of muscle fibers and muscle groups creates feedback from what has happened. And learning and memory are involved in every single step, not to mention the involvement of emotional systems. Making music is excellent brain exercise.

Brain scans have been done on humans under three conditions: resting, listening to language, and listening to music. The tests show that when one listens to language, there is a lot more activity than when one is not listening to anything. Also, if one is listening to music, there is more activity than while one is resting. Thus, merely listening to music activates a good deal of the brain as well as the auditory cortex.

The brain has building blocks for music. The left hemisphere of the brain is mainly for language, which excites mainly the left temporal lobe, whereas in listening to music, the right temporal lobe is often more involved than the left. This is an area now known to be deeply involved in the processing of melody, as well as some other elements of music. There are other brain areas that also seem to be more or less specialized to deal with those elements of music. In fact, there is no "music center," but rather many distributed brain modules that are concerned with the effects of music.

The Future

The research findings on transfer effects of listening to music are not just about music, but are about the arts in general. The major concern that needs immediate attention is the decline of arts in the schools. To reinvigorate the arts in education, we must formulate action plans based on our goals, and we must deal with any obstacles to those goals.

The first goal is the collaboration between artists, arts educators, and scientists. It is one thing to have published studies. Professionals in arts and in sciences read the articles and note the findings. Occasionally they make news in the media, but they do not make it much further. We need to have follow-up among the arts and educational communities to implement findings. We should not expect school superintendents or school boards to read the journals and to initiate curriculum changes, such as placing arts in their proper place as essential aspects of education.

Some of the obstacles to these goals are that the arts and the sciences are different cultures. These two cultures sometimes use the same words differently and have somewhat different sets of assumptions. We need to recognize these differences, so that we can deal with them to be able to work together. Sometimes we may not be able to agree, but we should be very clear on where we disagree. We have common concerns about the decline of the arts in education, so we must coordinate our efforts. We should be sufficiently aware of each other's efforts, look for relationships, and also reinforce a message when the message is there. And if the message is that some research shows that arts education is beneficial, then that message ought to be reinforced. We have to develop a sense of community that does not now exist, and it will take much work.

One of the concerns of many prominent arts educators has been the justification of the arts in the curriculum only on the basis of scientific studies that show that there are transfer effects from the arts to math or something else. This would be very bad for arts education. For example, it would have two negative effects. It would render the arts as unimportant themselves. And it would create a co-dependence that might fail if the science was deemed insignificant. The reason for having arts in the schools would be non-existent. So reliance upon arguments for arts in the educational curriculum, based upon only transfer effects from other domains, is surely a bad idea.

The problem is that this is a false argument. No one advocates justifying arts education only on the basis of transfer effects. I have never heard of such a ridiculous advocacy argument. Perhaps certain arts educators have built a straw man position, which is easily defeated, to "rally the troops" against an unwanted "invasion" of arts education by cognitive scientists. However, arts inquiry is a normal development of science. Continued study of the arts will enrich human understanding and clarify the roles of the arts in education and throughout a person's life span.

People in both the arts and the sciences must understand each other and must remember that the students are suffering while no progress is made. Of course, honest differences of opinion are to be expected and even welcomed. But we must pledge to work together to achieve the proper role of music and the arts in the school curriculum, and thereby help all students to achieve their full potentials.

To implement change, the two sub-cultures must stay in contact with each other. Part of this contact should involve the two areas educating each other. This may involve behavioral neuroscientists doing objective research in the classroom to see what realities are there.

If we want to work together, we need money to do studies, which will involve locating sources of support. To form collaborative studies, we have to get together, identify sources in a coherent manner, and then combine our efforts. The more people who are involved, the more likely we are to have success in getting funds. We should have a coordinating organization that speaks with one voice.

To begin to implement change, we can individually initiate small steps. But we eventually need to form a central organization with a Web site to coordinate efforts and to provide information exchange. This organization could also serve as a way to develop resources as a group. Locally, efforts might be centered at universities, colleges, school districts, or other organizations. There might be more than one project at a particular institution, and the central organization would help procure the funding for these kinds of activities. It would be best if groups did not compete with each other for the same resource.

The greatest resource of the planet is not oil or gasoline, but rather, it is the potential power of the human brain and intellect. The economic times are very good now. I do not know how long they will stay good, but they always get worse. Now is the time to accomplish something for this country. I have often been reminded, "There is nothing more powerful than an idea whose time has come." It is apparent that the time for boosting arts education has come.