Effects of Music Training on Brain and Cognitive Development in Under-Privileged 3- to 5-Year-Old Children: Preliminary Results

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Summary

This study tested the hypothesis that music training causes improvements in several diverse aspects of cognition, and that one way music training produces these effects is by improving attention. We tested this hypothesis using a "pre-post" intervention study design, in which we measured children's test scores at baseline, prior to the intervention, and again following the intervention. We enrolled a total of 88 children from Head Start preschools. All were three-to-five years old, from low socio-economic status (SES) families, right handed, monolingual English speakers, and free of neurological or behavioral disorders. The children were randomly assigned to be in either regular Head Start or in one of three smaller groups. Each small group met for instruction within the regular class time for 40 minutes per day, five days per week, over an eight-week period.

The experimental group (N=26 children) had a small class size (a 5:2 student/teacher ratio) and focused on music activities. These included listening to, moving to, and making music, as well as singing. The three control-comparison groups consisted of: 1) a large class control group (N=19), where students received regular Head Start instruction with a student/teacher ratio of 18:2; 2) a small class control group (N=20), where children were

engaged in regular Head Start classroom activities, but in a smaller class, with a student/teacher ratio of 5:2; and 3) a small attention class group (N=23), in which children received training in focusing attention and becoming more aware of details.

Children in each of the four groups were tested prior to and after enrollment in the eight-week period. They were tested on six measures: language fundamentals, vocabulary, letter identification, IQ, visuospatial intelligence (or spatial cognition), and developmental numeracy (numbers used in daily living).

There were strong and significant improvements in non-verbal IQ and numeracy and spatial cognition within a group measured before and after training (i.e., within-group differences) in children who received music training and those who received attention training. The small Head Start class group also displayed large improvements in these same areas from before to after the eight-week period. These improvements were not seen in children who received regular Head Start in the large class control group.

The extent of improvements in non-verbal IQ and numeracy and spatial cognition was similar in children receiving music training, attention training, and regular Head Start instruction in small classes. These findings suggest that increased time in a small group with intense adult attention may be the underlying element in improving children's skills in these cognitive areas, and that music and attention training in these small group classes produces similar beneficial results.

The central and powerful role of adult attention and guidance is also underscored by the results of a separate study conducted by us, in which children did not receive any intervention. Their parents, however, received training that improved parenting practices, which in turn improved children's conduct and produced large and significant improvements in each of the measures reported here (Fanning et al. 2007). These changes were highly significant within the group from before to after training and also when compared to changes made in the large control group (i.e. between-group differences).

Taken together, these findings suggest that attention from adults, including attention focused through providing music training, produces improvements in young children's cognitive abilities in non-verbal IQ, and in numeracy and spatial cognition, with the latter two being important in math abilities.

Learning music requires focused attention, abstract, relational thinking and fluid intelligence (called "executive control").

Introduction

There is universal agreement that learning to make music and experiencing meaningful musical events are inherently and uniquely valuable. Recently, motivated in part by cuts to school budgets for education in arts and music, a burgeoning literature has sought to provide evidence of the potential benefits of music instruction on cognitive and academic development in children.

The vast majority of these studies has assessed cognitive functions in trained musicians compared to people with no musical training. Several studies have reported that musicians have higher scores than non-musicians on tests of verbal, visual-spatial, and "numeracy" skills (those measuring competence in math skills needed for everyday living and for understanding graphs and charts); and that musicians scored higher on IQ tests compared to non-musicians. (These studies are summarized in Schellenberg 2006 and Norton et al. 2005.)

While many such reports interpret these correlations as showing that music **causes** improvements in cognition, it is equally likely that people with strong cognitive skills are more likely to make the considerable cognitive effort to learn music. Learning music requires focused attention, abstract, relational thinking and fluid intelligence (called "executive control"). It is highly likely, therefore, that a major factor producing the positive correlations between music and cognition is that people with better cognitive skills choose to learn music.

Nonetheless, it is also likely that learning music trains and builds cognitive resources. To test this hypothesis, it is necessary to randomly assign individuals to three groups, receiving: 1) music training; 2) training in some other comparable area; and 3) no special training. Very few studies have taken this approach. Moreover, the few studies that have used this approach typically measured a limited number of cognitive abilities. For example, Rauscher reports that individual piano lessons result in improvements on spatial and spatial- temporal skills in young children (Rauscher et al. 1997, 2002). Gardiner et al. (1996) report that six-year olds who receive music and visual arts training display a larger improvement on standardized tests of reading and arithmetic than children receiving the standard curriculum. Schellenberg (2004) reported that six-year-old children who received music lessons (voice or keyboard) in a small group displayed larger improvements in all verbal and non-verbal subtests of the Wechsler Intelligence Scale than children receiving drama lessons or no lessons.

If these results are upheld in further well-controlled studies, they would suggest that music training causes improvements in cognition. Additionally, they would raise the question of how music training might produce such effects.

The effects reported in the studies described above are not specific to one type of cognitive skill. Rather, they appear across a diverse array of cognitive abilities. These results suggest that music training may result in improvements of cognitive processes that operate to strengthen skills in several areas. One such cognitive process is attention.

In our research, we tested the hypothesis that music training causes improvements in several diverse aspects of cognition and that one way music training produces these effects is by improving attention.

It is important in interpreting our findings to understand what is known about the architecture, development, plasticity, vulnerability, and training of attention. Before describing our results, therefore, we briefly review these issues.

What is Attention?

Over the last several decades, research in the cognitive and neurocognitive sciences has converged on an understanding of the different components of attention (Driver et al. 2001, Raz and Buhle 2006, Shipp 2004). Different research groups, and their models, differ somewhat in the way they subdivide and term components of attention. However, they all recognize the importance of: 1) a basic level of arousal and alerting; and 2) a selective focus on specific stimuli and signals, to further process these signals either transiently or in a sustained manner. Such "attentional" selection involves brain processes that are engaged in increasing the strength of selected signals (called signal enhancement). It also involves suppression of signals that are irrelevant information or distractions. Suppression of distractions is a part of early attentional selection. The brain's suppression of distractions is also considered to be part of its "executive," or inhibitory, control functions, which include self-regulation. The brain's executive control functions are important in suppressing predominant responses generally, and also in switching attention between different sets of signals and in dividing attention between different tasks.

How does Attention Develop?

Several studies attest to the centrality and relevance that models of attention have to child development in general, and to school readiness in particular (Blair 2002, Early Child Care Research Network 2003, Posner and Rothbart 2000). Studies exploring how the process of attention develops have documented that it matures over a prolonged period of time. This is the case even for aspects of attention that may be present in some form in infancy. Therefore, while alertness is clearly present in infancy, the ability to maintain alertness for effortful processing has a protracted developmental time course that extends into young adulthood (Gomes et al. 2000, Rueda et al. 2004).

This finding suggests that, if given strong attentional cues, children as young as three years old can selectively attend to auditory information.

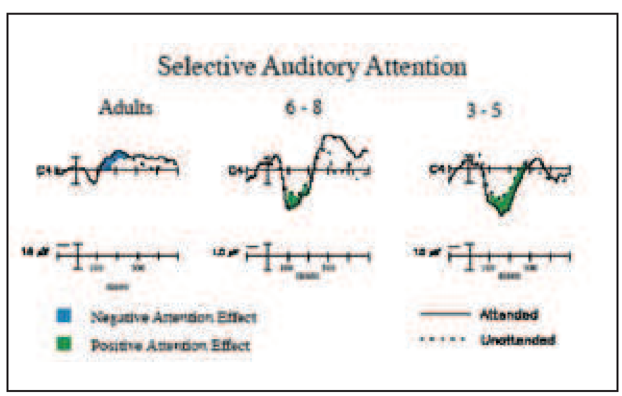
While exogenously driven transient attentional selection may mature within the first decade of life (Rueda et al. 2004), development of endogenous (internal and covert) selection continues until at least the third decade of life (Schul et al. 2003). Our understanding of these maturational differences derives in part from studies of behavior and from "event-related potential" (ERP) studies. In ERP studies, electrodes are placed on the surface of the scalp. Following a visual or auditory stimulus presented to the infant or child, using particular recording paradigms, the electrical currents that are produced by the brain activity can be specifically related to the neural systems important for focused attention.

In a review of both behavioral and ERP studies of the development of selective attention, Ridderinkhof and van der Stelt (2000) proposed that the abilities to select among competing stimuli and to preferentially process the more relevant information are essentially available in very young children. They further proposed that the speed and efficiency of these behaviors, and the systems contributing to these abilities, improve as children develop.

We tested this hypothesis more directly. We adapted the ERP paradigm employed by Hink and Hillyard (1976) to make "dichotic" listening (where each ear hears a different sound) more interesting and engaging for three- to eight-year-old children (Coch et al. 2005; Sanders et al. 2006). As seen in the figure below, the structure of the auditory ERP brain responses to these stimuli differed markedly as a function of age.

Nonetheless, when these listeners were asked to selectively attend to one of two simultaneously presented stories that differed in location (left/right), voice (male/female), and content, children as young as three years of age showed an auditory selective attention effect (an increase of the ERPs in response to the stimuli to which they were asked to attend). Furthermore, the timing at which this selective attention effect is observed was the same for the children as for adults (100 ms after stimulus presentation), as shown in the figure.

This finding suggests that, if given strong attentional cues, children as young as three years



old can selectively attend to auditory information. Moreover, the nature and timing of these effects on processing auditory information are similar to those found in adults.

Plasticity and Vulnerability of Attention

Previously, we have used functional magnetic resonance imaging (fMRI) in combination with behavioral and ERP studies and found that the brain displays considerable plasticity (functional reorganization) of the neural systems that are important in selective attention. For example, we have found that visual selective attention is markedly enhanced in deaf compared to hearing individuals (Bavelier et al. 2000, 2001, Neville and Lawson 1987a, 1987b, 1987c). We have reported similar enhancement of auditory selective attention in congenitally blind adults (Röder et al. 1999, 2003).

However, as we recently reported, there appears to be limits on the time- period during development when the early (100 ms) processes of auditory selective attention can be enhanced. This finding is based on studies that show that people who become blind in later years do not display these same, early enhanced selective attention effects (Fieger et al. 2006).

The finding that particular aspects of selective attention can be modified in congenitally deaf and blind individuals raises the possibility that these aspects of attention may develop relatively slowly and may be particularly vulnerable during development. Using the ERP model of selective attention that we described above, we recently observed deficits in attention in at-risk populations, including children who are "specifically-language impaired" (Stevens et al. 2006) and those from lower socio-economic families (Lauinger et al. 2006).

How do people develop improved attention through training?

Cognitive rehabilitation research undertaken since the late 1980s has assessed the effects of training designed to improve aspects of attention in adults with traumatic brain injury, those treated for brain cancers, and those who have incurred strokes and other cerebral vascular accidents (including Sohlberg and Mateer 1987, 2001, 2003, Niemann et al. 1990). Many of these studies report that patients showed improvements in sustained attention and executive function (Ethier et al. 1989, Finlayson et al. 1987, Gray and Robertson 1989). However, it has been difficult to compare results across studies, since different investigators have focused on training different aspects of attention in order to tailor the training to various specific deficits of individual patients. An analysis of this literature suggests that studies need more stringent comparison of the rehabilitation groups to healthy "control" groups (Park and Ingles 2001).

According to recent studies, healthy adults show pronounced effects of training (video game playing) on virtually every aspect of attention (Green and Bavelier 2003). Additionally, a small number of studies in children with attention deficit/hyperactivity disorder (ADHD) who were trained in attention and working memory report significant gains following several weeks of daily or every-other-day training (Kerns et al. 1999, Klingberg et al. 2002).

Recently, Posner and colleagues investigated the impact of attention training in typically developing, higher socioeconomic status (SES) preschoolers (Rueda et al. 2005). The computer-based activities were adaptive—they provided progressively increased challenges on attentional skills. The research design was based on a study that showed significant gains in attention skills by non-human primates (Rumbaugh and Washburn 1995). In the Posner study, the group that received the computer-based activity attention training (the experimental group) for only five days showed significantly greater pre-post experiment change in their executive control and non-verbal IQ scores compared to changes in the control group, which received no special training.

As reported above, the specifically-language impaired children aged six years display deficits on the ERP measures of selective attention described above (Stevens et al., 2006). We recently reported that with daily computerized training over a period of six weeks, measures of receptive language and ERP measures of attention are normalized (Stevens et al., in press).

… research has shown that processes of attention are central to every aspect of cognition and school performance.

Summary of what attention studies show

In sum, research has shown that processes of attention are central to every aspect of cognition and school performance. Moreover, processes of attention display a high degree of neuroplasticity. That is, processes of attention display both enhancements (following sensory deprivation in people who are blind or deaf) and vulnerabilities/deficits in many at-risk populations, including those with developmental disorders and those from lower SES backgrounds. A handful of carefully designed studies suggest that attention can be significantly improved in both at-risk and neurologically intact and typically developing adults and children, following specialized training.

In view of these results, the goal of our Dana Arts and Cognition Consortium research was to determine whether music training in preschoolers would produce significant improvements in cognition and school performance that are comparable to the effects produced by attention training.

The Study Hypotheses

We tested the hypothesis that, following eight weeks of 40 minutes per school day of either music or attention training in small groups, Head Start preschoolers would display gains in a number of cognitive areas, including language, pre-literacy and visual-spatial skills, numeracy and nonverbal IQ; and that these gains would be larger than those observed in preschoolers who were in either large or small control groups who did not receive either of the trainings.

The Study Design

A total of 88 children were included in the study. The children were recruited from local Head Start preschools, which are federally funded and available to children in families with very low household income. All children were from low SES families, three to five years old, right-handed, monolingual English speakers, and free of neurological or behavioral disorders.

One of the four groups was a music intervention class, in which children received eight weeks of music training in a small group (5:2 student/teacher ratio). Music activities included listening to music, moving to music, making music, and singing. Classes ran for 40 minutes a day, four days per week, during the regular Head Start school day.

The other three groups were "control-comparison" classes to enable us to examine whether any effects observed in the music intervention group were specific to music training or whether other types of training would have similar effects.

The control-comparison groups included: 1) a large group of children receiving regular Head Start instruction, with an 18:2 student/teacher ratio; 2) a small group of children who participated in regular Head Start activities, but in a small group format, with a 5:2 student/teacher ratio; and, 3) a small group of children who received instruction in focusing attention and being aware of details.

All small control-comparison groups (except the large group control) were taught by the same teachers who taught in the music intervention group. The control-comparison classes lasted for the same amount of time as the music intervention class training.

The specificity of the effects of music training can be inferred, depending upon the extent to which students in the three control-comparison groups (including a large comparison group) show different (or fewer) gains in the outcomes measured. If students in control-comparison groups display a similar pattern of outcomes to those observed in the music group, the results would suggest brain processes whereby music training improves cognition. For instance, if learning music trains attention, the effects of these two interventions (music training and attention training) may be similar.

The effects of the interventions in all four groups were assessed employing a range of reliable and valid measures of cognition and literacy. The measures were administered by testers who were blind to the groups to which the children belonged.

Within one month prior to and following the interventions, children were administered the following tests:

1. The Clinical Evaluation of Language Fundamentals-Preschool 2nd Ed. (CELF-P2) (Wiig et al. 2004).

The CELF-P:2 test is an individually administered assessment of language building-blocks that are considered fundamental to the development of effective communication. (We used the "receptive" and "expressive" subtests, which comprise the Receptive and Expressive Language Indices.)

2. Stanford-Binet Intelligence Scales-5th Ed. (SB-5) (Roid 2003).

The SB-5 is an individually administered assessment of intelligence and cognitive abilities. It is normed (i.e. it measures and scores age-appropriate performance) for examinees ranging from two years old through 85 years old. We administered only the Nonverbal Intelligence Scale. This is based on five nonverbal subtests associated with each of five cognitive factors that are measured by the SB-5: fluid reasoning, knowledge, quantitative reasoning, visual-spatial processing, and working memory.

3. The Peabody Picture Vocabulary Test-Third Edition (PPVT-III) (Dunn and Dunn 1997).

The PPVT-III is an individually administered assessment of "receptive" single-word vocabulary knowledge. A target vocabulary word is verbally presented by the tester while the child views a field of four black and white sketch pictures. The child points to the picture that best matches the meaning of the target word. The test is normed for examinees ranging from toddlers aged two years to six months to older children.

4. Letter Identification

This individually administered test assesses the percentage of uppercase and lowercase letters, provided on a page, which a child identifies correctly. The page of letters is from the Observation Survey of Early Literacy Achievement (Clay 1993). The child views the presented page and labels any letters he or she knows.

5. Wechsler Preschool and Primary Scale-3rd Ed. (WPPSI-III) (Wechsler 2002).

One subtest from the WPPSI-III, the "Object Assembly," is used. The tester presents pieces of a puzzle and asks the child to complete the puzzle as quickly as possible. After 90 seconds, the tester can remove the puzzle so that the child does not get frustrated. The Standard Score for the subtest is used, and the cumulative number of seconds taken, and the number of puzzles completed, is tracked.

6. Developmental Numeracy Assessment

We developed a test to screen emerging numeracy abilities in preschool children. The math assessment that we developed is based on educational, cognitive developmental, and cognitive neuroscientific research. We assess digit naming, verbal counting, and magnitude estimation.

Following the music training program, children displayed significant improvements on the CELF tests of … receptive … and expressive language

The Study Outcomes

Since these are preliminary results, based on a small sample size, we begin to analyze the data by looking at changes from before to after training within each group.

Music Training Group (Experimental Group: N=26 children)

Following the music training program, children displayed significant improvements on the CELF tests of language, including receptive language ($p<.01$) and expressive language ($p<.001$). (Results of .05 or better, such as these results of .01 or .001, are considered "statistically significant.") Children also improved significantly in letter identification ($p<.01$) and receptive vocabulary ($p<.01$); and they displayed robust increases on the puzzle assembly subtest of Wechsler Intelligence Test ($p<.01$).

In addition, the music training group improved significantly ($p<.007$) on the test we developed to assess numeracy in preschoolers. The specific subtests in which they improved were verbal counting and estimating magnitudes. Finally, this group also improved on the overall Stanford Binet non-verbal IQ test ($p<.03$), including the fluid and quantitative reasoning subtest of the Stanford Binet IQ test ($p<.03$) and the "knowledge" or "critical thinking" subtest ($p<.01$). An example of an item on the latter subtest is to ask the child what is amiss in a picture showing two children in sunshine who cast shadows in different directions.

Large Group (Control Group: N=19 children)

The children in the regular Head Start classrooms, which have an 18:2 student/teacher ratio, also displayed similar improvements in the CELF tests of receptive ($p<.01$) and expressive ($p<.01$) language, and of phonological awareness ($p<.03$). They showed no significant improvements, however, on the other tests.

Small Group (Control Group: N=20 children)

The children who spent 40 minutes per day in a group smaller than the regular Head Start classroom, but engaging in similar activities, also displayed gains in receptive ($p<.01$) and expressive ($p<.002$) language and in phonological awareness ($p<.01$). In addition, they improved on the object assembly test ($p<.004$), and on overall non-verbal IQ ($p<.001$), including several subtests.

Attention Training Group (Control Group: N=23 children)

The children who were trained in attention displayed gains of comparable magnitude, and in similar areas, as the children trained in music. They improved significantly in receptive ($p<.01$) and expressive ($p<.004$) language and phonological awareness ($p<.01$). They also improved in the object assembly test of visual cognition ($p<.007$), in numeracy ($p<.001$) and in the Stanford Binet subsets of fluid reasoning, quantitative reasoning, visual-spatial and working memory, and critical thinking (all $p<.01$).

Conclusions

Taken together, these results suggest that the gains in language observed in the music group (and also in the control groups) may have been due to Head Start itself, or to test-retest effects. Further controls will be necessary to determine which variables are key to language improvement in children in each of the four groups. While these results are preliminary, one interpretation of the data is that the improvements in spatial cognition (puzzle assembly) and IQ observed in children in all small groups (music, attention, and small Head Start class) but not in children in the large control group in this study may derive from the fact that music training typically involves time being individually tutored, or being in a small group, which may itself increase opportunities for training attention. Alternatively, when the numbers of children in each group are larger, it may show that there are meaningful differences between groups in the magnitude of the effects.

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