Frances Rauscher

John McNaughton Rosebush Professor of Psychology
University of Wisconsin Oshkosh

Nominated by

Sarah Jerome

Biosketch: Frances Rauscher

Frances Rauscher, Ph.D., is an Associate Professor of Cognitive Development at the University of Wisconsin Oshkosh. Her research focuses on the relationship of music cognition to other domains of intelligence. She holds an undergraduate bachelor's degree in cello performance from The Juilliard School, bachelor's, master's and doctoral degrees in experimental psychology from Columbia University. Her discovery of the "Mozart effect" with Dr. Gordon Shaw at the University of California Irvine has earned her international acclaim. Fran has since received the W.T. Grant Foundation Faculty Scholars Award for a five-year project exploring the effects of piano, rhythm, and singing on the spatial intelligence of Head Start preschoolers, and has also secured funding to study the effects of instrumental instruction on cognitive, social, and academic performance in two inner-city Milwaukee public schools. Recent awards include the John McNaughton Rosebush Professorship Award for excellence in scholarship, and the Distinguished Teaching Award for excellence in teaching. She has provided oral and written testimony before the U.S. House of Representatives and the U.S. Senate regarding the effects of music on early cognitive and brain development. Fran has published extensively in the areas of music cognition, child development, cognitive psychology, animal behavior, and social psychology. She is currently working on a book co-authored by Dr. Wilfried Gruhn entitled "Neurosciences in Music Pedagogy," in addition to her own book entitled "Music and the Mind Beyond the Mozart Effect" to be published by Oxford University Press. Fran's lectures on music and intelligence in North America, Europe, Asia, and Australia have gained her an international reputation as a speaker and advocate for music education.

Research Summary: Frances Rauscher

Dr. Frances Rauscher studies the effects of music instruction on children's cognitive development. She has found that early music instruction can increase children's abstract reasoning and arithmetic scores. These findings have had a strong impact on educational practice in the U.S. and overseas, with several public elementary schools implementing instrumental instruction to improve spatial intelligence. Her vision is to teach all children, regardless of musical or economic background, how to think and reason creatively.

FRANCES H. RAUSCHER

(FORMERLY BILOUS)

102 DYLAN ROAD
WALES, WI 53183
HOME: (262) 968-5972
WORK: (920) 424-7172
CELL: (920) 203-1756
FAX: (920) 424-2401
EMAIL: rauscher@uwosh.edu

EDUCATION

PhD	Columbia University, Psychology	1992
MPhil	Columbia University, Psychology	1988
MA	Columbia University, Psychology	1986
BA	Columbia University, Psychology, *summa cum laude*	1984
BM	The Juilliard School, Cello Performance	1979

GRANTS/AWARDS/HONORS

Ella Fitzgerald Charitable Foundation grant for manuscript on the effects of music on children's cognitive development. $5,000 2005

University of Wisconsin, Oshkosh Faculty Development Board Research Grant for investigating the behavioral consequences of enrichment in rats: effects of age and testing delay. Principal Investigator. Summer salary. Summer, 2005

University of Wisconsin, Oshkosh Faculty Development Board Research Grant for investigating the behavioral consequences of enrichment in rats: effects of age and testing delay. Principal Investigator. $15,000 Summer, 2004

Distinguished Teaching Award for excellence in teaching. University of Wisconsin, Oshkosh 2003

VH1 Save the Music Foundation grant for longitudinal research on cognitive and social effects of music instruction in Milwaukee public elementary school children. Principal Investigator. $300,000 2002-2005

John McNaughton Rosebush Professorship Award for excellence in teaching, scholarship, and service. University of Wisconsin, Oshkosh 2002

William T. Grant Foundation Faculty Scholars Award for longitudinal research on music training and Head Start preschoolers' abstract reasoning. Principal Investigator. $260,000. 1997-2002

University of Wisconsin, Oshkosh Faculty Development Board Research Grant for investigating neural mechanisms of perceptual discrimination in musicians and nonmusicians. Co-investigator. $15,000 Summer, 2002

Spencer Foundation grant for Early Childhood Symposium in collaboration with the Pittsburgh Symphony Orchestra, Pittsburgh, PA. Co-Coordinator. $25,000. March, 2000

University of Wisconsin, Oshkosh Faculty Development Board Research Grant for research on the effects of auditory exposure on spatial processing sites in rats. Co-Principal Investigator. $10,000. Summer, 1998

University of Wisconsin, Oshkosh Graduate Student and Faculty Collaborative Grant for research on the effects of music exposure on spatial task performance: Exploring task validity. Co-Principal Investigator. $500. Summer, 1998

University of Wisconsin, Oshkosh Faculty Development Board Research Grant for research on children's gestures. Principal Investigator. $10,000. Summer, 1997

University of Wisconsin, Oshkosh Undergraduate Student and Faculty Collaborative Grant for research on the effects of gestures on speech production. Co-Principal Investigator. $500. Summer, 1997

University of Wisconsin, Oshkosh Faculty Development Board Research Grant for research on music and maze learning in rats. Principal Investigator. $10,000. Summer, 1996

National Association of Music Merchants Gift for research on music and spatial reasoning. Co-Principal Investigator. $200,000. 1992-1995

Ralph and Leona Gerard Family Trust Fund Fellowship for research in cognitive neuroscience. $80,000. 1992-1995

National Piano Foundation Gift for music and spatial reasoning research. Co-Principal Investigator. $10,000. 1993-1994

National Academy of Recording Arts and Sciences Gift for music and spatial reasoning research. Co-Principal Investigator. $5,000. 1993-1995

Columbia University Faculty Fellowship 1984-1989

Phi Beta Kappa 1984

Surdna Foundation Scholarship for overall academic excellence. 1983

Helena Rubenstein Scholarship for academic excellence in the sciences. 1982

Beaux-Arts Chamber Music Award for string quartet performance. 1980

Leonard Rose Performance Award for cello performance. 1978

EXPERIENCE

Associate Professor of Child Development, Department of Psychology, University of Wisconsin, Oshkosh. Specialize in relationship between music and cognitive development. Director of the Masters of Science Experimental Psychology program. Teach Infant and Child Development, Human Development, Social Psychology, History of Psychology, Psychology Research Seminar, Graduate Seminar in Research Methods, Graduate Seminar in Social Psychology, and Graduate Seminar in Developmental Psychology. Supervise honors undergraduate and graduate theses and independent study projects. 2002-present

Assistant Professor of Child Development, Department of Psychology, University of Wisconsin, Oshkosh. Specialize in relationship between music and cognitive development. 1995-2002

Assistant Researcher, Center for the Neurobiology of Learning and Memory, University of California, Irvine. Designed and conducted research on music and preschoolers' spatial-temporal reasoning. Explored neuroscientific and educational implications of experimental data. Analyzed data and co-authored research papers. Supervised laboratory personnel. Wrote grant proposals. 1994-1995

Postdoctoral Research Fellow to Dr. Gordon Shaw, University of California, Irvine. Designed and conducted research on the effects of music on abstract reasoning skills. Analyzed data and co-authored research papers. Supervised laboratory personnel. Wrote grant proposals. Organized music cognition seminars. 1992-1994

Instructor, University of California, Irvine Extension. Taught classes in music cognition. 1993-1995

Postdoctoral Research Fellow to Dr. Stanley Schachter, Columbia University. Designed and conducted research on filled pauses and gestures. Analyzed data and co-authored research papers. Supervised laboratory personnel. 1991-1992

Marketing Decision Systems Associate, DDB Needham & Harper Worldwide. Performed multivariate analyses on primary and secondary data. Conducted survey research. Taught computer seminars. 1989-1990

Teaching Assistant, Columbia University, to Dr. Julian Hochberg, Dr. Leonard Matin, Dr. Judith Harackiewicz, and Dr. Robert Krauss. 1984-1989

Faculty Member, Manhattan School of Music Preparatory Division. Taught classes in music theory, dictation and sightsinging to preschool and elementary school-age children. 1982-1984

Assistant Music Therapist. Observed effects of music performance on schizophrenic patients. 1979-1981

Faculty Member, Lincoln Center Institute. Developed and taught graduate courses in music aesthetics. 1979-1981

Performed as cello soloist with Mstislav Rostropovich conducting the National Symphony Orchestra. 1980

Rauscher, F.H. (2002). Mozart and the mind: Factual and fictional effects of musical enrichment. In J. Aronson (Ed.), *Improving academic achievement: Impact of psychological factors on education* (pp. 269-278). New York: Academic Press.

Gruhn, W., & Rauscher, F.H. (2002). The neurobiology of music cognition and learning. In R. Colwell & C. Richardson (Eds.), *Second handbook on music teaching and learning* (pp. 445-460). New York: Oxford University Press.

Rauscher, F.H. (2001). Current research in music, intelligence, and the brain. In M. McCarthy (Ed.), *Enlightened advocacy: implications of research for arts education policy and practice* (pp. 5-16). College Park, MD: University of Maryland Press.

Rauscher, F.H., & Zupan, M. (2000). Classroom keyboard instruction improves kindergarten children's spatial-temporal performance: A field experiment. *Early Childhood Research Quarterly, 15*, 215-228.

Rauscher, F.H. (1999). Music exposure and the development of spatial intelligence in children. *Bulletin of the Council for Research in Music Education, 142*, 35-47.

Rauscher, F.H. (1999). Reply: Prelude or requiem for the 'Mozart effect'? *Nature, 400*, 827-828.

Rauscher, F.H., Robinson, K.D., & Jens, J. (1998). Improved maze learning through early music exposure in rats. *Neurological Research, 20*, 427-432.

Rauscher, F.H., & Shaw, G.L. (1998). Key components of the "Mozart Effect." *Perceptual and Motor Skills, 86*, 835-841.

Rauscher, F.H., Shaw, G.L., Levine, L.J., Wright, E.L., Dennis, W.R., & Newcomb, R. (1997). Music training causes long-term enhancement of preschool children's spatial-temporal reasoning abilities. *Neurological Research, 19*, 1-8.

Sarnthein, J., von Stein, A., Rappelsberger, P., Petsche, H., Rauscher, F.H., & Shaw, G.L. (1997). Persistent patterns of brain activity: an EEG coherence study of the positive effect of music on spatial-temporal reasoning. *Neurological Research, 19*, 107-116.

Rauscher, F.H. (1997). A cognitive basis for the facilitation of spatial-temporal cognition through music instruction. In Verna Brummett (Ed.), *Ithaca Conference '96 Music as Intelligence: A Sourcebook* (pp. 31-44). Ithaca: Ithaca College Press.

Rauscher, F.H., Robinson, K.D., & Jens, J. (1997, June). Spatial performance as a function of early music exposure in rats (*Rattus norvegicus*). In A. Gabrielsson (Ed.), *Third triennial conference of the European Society for the Cognitive Sciences of Music*. Uppsala, Sweden: Uppsala University Press.

Rauscher, F.H., Krauss, R.M., & Chen, Y. (1996). Gesture, speech and lexical access: The role of lexical movements in speech production. *Psychological Science, 7* (4), 226-231.

Krauss, R.M., Dushay, R.A., Chen, Y., & Rauscher, F.H. (1995). The communicative value of conversational hand gestures. *Journal of Experimental Social Psychology, 31*, 533-552.

Rauscher, F.H., Shaw, G.L., & Ky, K.N. (1995). Listening to Mozart enhances spatial-temporal reasoning: Towards a neurophysiological basis. *Neuroscience Letters, 185*, 44-47.

Schachter, S., Rauscher, F., Christenfeld, N., & Crone, K. (1994). The vocabularies of academics. *Psychological Science, 5*, 37-41.

Rauscher, F.H., Shaw, G.L., & Ky, K.N. (1993). Music and spatial task performance. *Nature, 365*, 611.

Christenfeld, N., Schachter, S., & Bilous, F. (1991). Filled pauses and gestures: It's not coincidence. *Journal of Psycholinguistic Research, 20* (1), 1-10.

Schachter, S., Christenfeld, N., Ravina, B., & Bilous, F. (1991). Speech disfluency and the structure of knowledge. *Journal of Personality and Social Psychology, 60* (3), 362-367.

Bilous, F., & Krauss, R.M. (1988). Dominance and accommodation in the conversational behaviours of same- and mixed-gender dyads. *Journal of Language and Communication, 8*, 183-194.

CONFERENCE PAPERS/POSTERS

Rauscher, F.H., LeMieux, M.M., & Hinton, S.C. (2006, August). *Quality piano instruction affects at-risk elementary school children's cognitive abilities and self-esteem.* Paper to be presented at the Ninth International Conference on Music Perception and Cognition, Bologna, Italy.

Rauscher, F.H. (2006, August). Discussant for symposium organized by Dr. David Hargreaves entitled *Musical Communication*, to be presented at the Ninth International Conference on Music Perception and Cognition, Bologna, Italy.

Rauscher, F.H., Kent, L., & Heller, G. (2006, April). *Longitudinal effects of early versus late enrichment in rats.* Paper presented at the annual meeting of the Cognitive Neuroscience Society, San Francisco, CA.

Rauscher, F.H., LeMieux, M., & Hinton, S.C. (2005, August). *Selective effects of music instruction on cognitive performance of at-risk children.* Paper presented at the bi-annual meeting of the European Conference on Developmental Psychology, Tenerife, Canary Islands.

Hinton, S.C., Rauscher, F.H., Hoffman, R.G., & Kabele, M. (2005, April). *Using behavioral measures to predict temporal reproduction strategy.* Paper presented at the annual meeting of the Cognitive Neuroscience Society, New York, NY.

Li, H.H., Cai, Y., Ying, Z., Gomez-Pinilla, F., Cooper, R.I., Rauscher, F.H. (2004, April). *Music exposure improves maze learning and up-regulates genes related to synaptic plasticity.* Poster submitted to the annual meeting of the Cognitive Neuroscience Society, San Francisco, CA.

Cooper, R.I., Rauscher, F.H., & Hinton, S.C. (2004, April). *Strategic and performance differences between young children and adults on the peak-interval timing procedure.* Poster submitted to the annual meeting of the Cognitive Neuroscience Society, San Francisco, CA.

Rauscher, F.H., & LeMieux, M. (2003, April). *Piano, rhythm, and singing instruction improve different aspects of spatial-temporal reasoning in Head Start children.* Poster presented at the annual meeting of the Cognitive Neuroscience Society, New York, NY.

Hinton, S.C. & Rauscher, F.H. (2003, April). *Auditory duration and frequency discrimination are selectively enhanced by different types of music instruction.* Poster presented at the annual meeting of the Cognitive Neuroscience Society, New York, NY.

Rauscher, F.H., Bowers, M.K., Dettlaff, D.M., & Scott, S.E. (2002, April). *Effects of environmental, social, and auditory enrichment on maze learning in rats: Implications for arousal.* Poster presented at the Cognitive Neuroscience Society, San Francisco, CA.

Rauscher, F.H. (2001). *From music to math? Understanding the relationship between music instruction and spatial abilities in young children.* Paper presented at the Australia Music Educators Association, Adelaide, Australia.

Rauscher, F.H., & LeMieux, M. (2000, August). *Piano lessons enhance spatial imagery of at-risk children.* Paper presented at the bi-annual meeting of the International Conference on Music Perception and Cognition, Keele University, Keele, UK.

Rauscher, F.H., & Zupan, M.A. (2000, August). *Long-term effects of music instruction on kindergarteners spatial-temporal reasoning: A field study.* Paper presented at the bi-annual meeting of the International Conference on Music Perception and Cognition, Keele University, Keele, UK.

Rauscher, F.H. (2000, August). *Is the "Mozart effect" debunked?* Poster presented at the bi-annual meeting of the International Conference on Music Perception and Cognition, Keele University, Keele, UK.

Rauscher, F.H. (2000, April). *Musical influences on spatial reasoning: Experimental evidence for the "Mozart effect."* Invited keynote given at the Effects of Music Conference, University of Leicester, Leicester, UK.

Rauscher, F.H. (1999, August). *Musical enhancement of spatial-temporal task performance.* Invited address given at the annual meeting of the American Psychological Association, Boston, MA.

Rauscher, F. (1999, June). *Current research on music and spatial abilities.* Invited keynote given at the Cognitive Processes of Children Engaged in Musical Activity Conference, University of Illinois, Urbana, IL.

Rauscher, F. (1999, April). *Implications of research for music education policy.* Invited keynote given at the Charles Fowler Colloquium on Innovation in Arts Education, University of Maryland, College Park, MD.

Rauscher, F. (1998, July). *Music and intelligence: Studies in humans and rats.* Invited address given at the Leopoldskron Conference on Music and Cognition, Salzburg, Austria.

Pitzen L.J., & Rauscher, F.H. (1998, May). *Choosing music, not style of music, reduces stress and improves task performance.* Poster presented at the American Psychological Society, Washington DC.

LeMieux, M., Carlson, C., Stetter, K., Rauscher, F., & Bowers, M.K. (1998, May). *Effects of post-weaning gentling on activity in SHR, WKY and Wistar rats.* Poster presented at the Midwestern Psychological Association, Chicago, IL.

Rauscher, F. (1998, April). *Is Music a panacea? Myths and mysteries.* Invited keynote given at the Music Educators National Conference's 56th Biennial Convention, Phoenix, AZ.

Marquart, M.S., Horner, D.T., & Rauscher, F.H. (1997, May). *Individual differences in perceptual tasks across modalities.* Poster session presented at the meeting of the American Psychological Society, Washington DC.

Sarnthein, J., von Stein, A., Shaw, G.L., Rauscher, F.H., Rappelsberger, P., & Petsche, H. (1996, November). *Interareal EEG synchronization during spatiotemporal reasoning.* Poster presented at the annual meeting of the Society of Neuroscience, Washington DC.

Rauscher, F.H., Hughes, J.L., & Miller, R.J. (1996, June). *Music-induced mood affects spatial task performance.* Poster presented at the annual meeting of the American Psychological Society, San Francisco, CA.

Rauscher, F. H. (1995, July). *Gestural contributions to lexical retrieval.* Paper presented at the Language and Gesture: Unity or Duality Conference, Linguistic Institute, University of New Mexico, Albuquerque, NM.

Rauscher, F. H., Shaw, G.L., Levine, L.J., Ky, K.N., & Wright, E.L. (1994, August). *Music and spatial task performance: A causal relationship.* Paper presented at the meeting of the American Psychological Association, Los Angeles, CA.

Rauscher, F., & Shaw, G. (1994, June). Neural representations of musical reasoning. In H. Petsche (Chair), *Music and the Brain.* Symposium conducted at the meeting of the Herbert von Karajan Foundation, Vienna, Austria.

Rauscher, F.H., & Krauss, R.M. (1993, August). *The role of gestures in speech production: Gestures enhance lexical access.* Poster session presented at the annual meeting of the American Psychological Association, Toronto, Ontario.

Rauscher, F., & Shaw, G. (1992, December). *The effects of early music training on abstract reasoning skills.* Paper presented to Sigma-Xi, The Scientific Research Society, Anaheim, CA.

Bilous, F., & Krauss, R.M. (1986). *Male dominance and accommodation in the vocal production of same- and mixed-sex dyads.* Paper presented at the annual meeting of the Eastern Psychological Association, Boston, MA.

DISSERTATION

Bilous, F.R. (1992). The role of gestures in speech production: Gestures enhance lexical access. Dissertation Abstracts International, 1992 Dec, v53 (n6-B):3204.

OTHER PAPERS

Rauscher, F. H. (1998). "I used to play the piano, but...". *Wisconsin School Musician, 69(2)*, 22-23.

Rauscher, F. H. (1998). Is assessment in music appropriate in the early childhood years? *Wisconsin School Musician, 69(1)*, 8-9,25.

Rauscher, F. H. (1998). Responses to Katie Overy's paper, "Can music really 'improve' the mind?". *Psychology of Music, 26*, 197-199.

Rauscher, F. H. (1998). Controversy: Does IQ matter? *Commentary, 106*, 17.

Rauscher, F. H. (1998). Music education and child development: A symbiotic relationship. *Fotnoten*, 1/98, 28-29.

Rauscher, F. H. (1997). The importance of preschool music: Enhancing cognitive development. *National Council of Jewish Women, 16*, 1-4.

Rauscher, F. H. (1997). Composition: Suggestions for the elementary school child. *Wisconsin School Musician, 67(2)*, 20-21, 58.

Rauscher, F. H. (1997). The power of music therapy. *Wisconsin School Musician, 68(1)*, 14-15, 31.

Rauscher, F. H. (1997). Motivation to make music. *Wisconsin School Musician, 67(4)*, 12-13.

Rauscher, F. H. (1997). Toward discovering the universals of music. *Wisconsin School Musician, 67(3)*, 12, 16-17..

Rauscher, F. (1996). What educators can learn from science: The case for music in the schools. *Early Childhood Connections, 2*, 12-15.

Rauscher, F. H. (1995) Extra-musical effects of music making: A psychological perspective. *Journal of the Music Masters and Mistresses Society, 8, 123-126.*

Rauscher, F.H. (1994) The role of music education in educational reform. *KOS, 10(194)*, 17-19.

SELECTED INVITED ACADEMIC PRESENTATIONS

Rauscher, F.H. & Hinton, S.C. (May, 2006) *The effects of music instruction on children's brain development, health, and cognition: Implications for Educators.* Keynote lecture series sponsored by the Rakluke Family Group, Bangkok, Thailand.

Rauscher, F.H. (October, 2006). *The Mozart effect*. Paper to be presented at the Mozart and Science Symposium, Baden, Austria.

Rauscher, F.H. (2005, October). *Musical influences on children's cognitive development*. Royal College of Music, London, UK.

Rauscher, F.H. (2005, June). *The effects of music instruction on young children's cognitive development*. Marian College, Fond du Lac, WI.

Rauscher, F.H. (2004, October). *The effects of arts education on academic abilities: Fact or fiction*? Paper presented at the annual meeting of the Society for the Advancement of Arts Education, Milwaukee, WI.

Rauscher, F.H. (2003, August). *Research design for the instructionally gifted/statistically challenged*. Seventh International Research Symposium on Talent Education. Stevens Point, Wisconsin.

Rauscher, F.H. (2003, August). *The effects of music instruction on children's spatial intelligence*. Seventh International Research Symposium on Talent Education. Stevens Point, Wisconsin.

Rauscher, F.H. (2002, October). *The development of spatial and temporal cognition through music instruction: Longitudinal research on the Mozart effect.* Lakeland College, Sheboygan, WI.

Rauscher, F.H. (2001, October). *Music instruction and spatial-temporal reasoning: A longitudinal study.* Boston College, Chestnut Hill, MA.

Rauscher, F. (2001, February). *Enhancing children's spatial abilities through music instruction.* Southwest Missouri State University, Springfield, MO.

Rauscher, F. (2000, July). *Music and spatial-temporal reasoning: Lessons from the "Mozart effect."* St. Thomas University, Minneapolis, MN.

Rauscher, F. (2000, March). *The effects of listening to music on spatial-temporal reasoning: Experimental evidence for the Mozart Effect.* Harvard University, Cambridge, MA.

Rauscher, F. (2000, March). *Children's reasoning: Music, space, and time.* Leicester University, Leicester, UK.

Rauscher, F. (2000, February). *Statistical treatment of the Solomon four-group design: Music and intelligence.* Paper presented to Sigma Xi, the Scientific Research Society, University of Wisconsin Oshkosh, Oshkosh, WI.

Rauscher, F. (2000, February). *Methods and strategies in music cognition research.* Employee Assessment Program, University of Wisconsin, Oshkosh, Oshkosh, WI.

Rauscher, F. (2000, January). *Music from the standpoint of a psychologist.* Virginia Commonwealth University, Richmond, VA.

Rauscher, F. (1999, May). *Applications of music research to education.* MacPhail University, Minneapolis, MN.

Rauscher, F. (1999, January). *Higher brain function and music cognition: A developmental approach.* Illinois Wesleyan University, Bloomington, IL.

Rauscher, F. (1998, June). *Music and spatial-temporal abilities: The research/practice interface.* St. Thomas University, St. Paul, MN.

Rauscher, F. (1998, April). *Music training and the development of spatial intelligence.* Georgia State University, Atlanta, GA.

Rauscher, F. (1998, January). *The role of music in educational reform.* Johns Hopkins University Institute for Policy Studies, Baltimore, MD.

Rauscher, F. (1997, November). *A comparative approach to music and spatial performance: What can rats teach us about human intelligence?* Michigan State University Early Childhood Music Conference, E. Lansing, MI.

Rauscher, F. (1997, October). *Why are so many people musically illiterate?* Lawrence University, Appleton, WI.

Rauscher, F.H. (1996, November). *Cognitive enhancement through music instruction.* University of Nebraska, Omaha, NE.

Rauscher, F.H. (1996, November). *Music and early childhood development.* Northwestern University, Evanston, IL.

Rauscher, F.H. (1994, October). *How does music training affect spatial reasoning?* The Juilliard School, New York, NY.

Rauscher, F.H. (1994, May) *Music and cognitive development.* California State University, Fullerton, CA.

OTHER

Panelist on *Jazz, Culture, and Democracy* symposium sponsored by Jazz at Lincoln Center. Fellow panelists included Wynton Marsalis and former president Bill Clinton. December, 2003.

U.S. Senate public testimony on the education of disadvantaged children. Senate Subcommittee on Health, Education, Labor and Pensions. March, 1999.

U.S. House of Representatives public testimony on the effects of music on early brain development. House Appropriations Subcommittee on Labor, Health and Human Services, Education. April, 1997.

White House Conference on Early Childhood Development and Learning. Invited guest of Bill and Hillary Clinton. April, 1997.

U.S. Senate public testimony on music and neural development. Senate Subcommittee on Children and Families. June, 1997.

Over 300 presentations given to music educator organizations, outreach programs, school districts, etc..

MEMBERSHIPS/ORGANIZATIONS

Society for Music Perception and Cognition
Society for Research in Child Development
American Psychological Association
American Psychological Society
Champions for the Arts (Treasurer)
Cognitive Neuroscience Society
Music Educators National Conference
European Society for the Cognitive Sciences of Music
Sigma-Xi, the Scientific Research Society (Former President, Oshkosh Chapter)
Music Education Task Force
Wisconsin Music Educators Association (Former State Research Chair)
State Superintendent's Blue Ribbon Commission on Arts Education

HARVARD
GRADUATE SCHOOL OF EDUCATION

June 14, 2006

Attn: Sarah Jerome (sarah@kmsd.edu)

Letter of Recommendation for Dr. Frances Rauscher

I am pleased to write in support of Dr. Frances Rauscher, who has been nominated for the Brock International Prize in Education. I consider Dr. Rauscher to be an unusually gifted scholar—careful in approach and strikingly original; she has my enthusiastic recommendation.

I first met Dr. Rauscher in the middle 1990's at a conference at Ithaca College and have since seen her a few times at other meetings. I also agreed to serve as an informal advisor on her ambitious Grant Foundation-funded five-year longitudinal study of young children who have had musical lessons. We have also corresponded periodically. I can say that I know her published and unpublished work quite well and that I have come to know her moderately well as a presenter at conferences and as a colleague.

I consider Dr. Rauscher to be a most impressive scholar, teacher, and colleague. She has a rich background in music (as a concert cellist) and she draws on this background appropriately in her studies. (Because she performed on stage for a decade or more, she did not complete her doctoral studies until she was in her thirties and her postdoctoral studies only a decade ago). She is a highly original experimentalist, who has not only conceived of some of the most innovative studies of recent years, but has not hesitated to extend to new areas, ranging from social psychology to neuropsychology to educational interventions. Her demonstration that musical stimulation affects spatial performance in adults literally sparked a revolution in cognitive psychology. She is an outstanding speaker. She is not a polemicist and avoids excessive claims but she is able to defend her turf energetically and appropriately.

I feel the need to address two questions that come up in any discussion of Frances Rauscher. First of all, from everything I know, Dr. Rauscher is a scrupulous researcher. She reports what she finds and is open to disconfirming data. From my own perspective as an advocate of "multiple intelligences', I had every reason to be skeptical about her findings. Indeed, I still am uncertain whether the Mozart effect she discovered will hold up with adults. On the other hand, I think that the findings with young students are likely to be robust and revealing. And even in the area of my own doubts, my colleagues Ellen Winner and Lois Hetland have undertaken by far the most extensive meta-analysis of all the studies on the Mozart effect and they have both come to the conclusion that it is a genuine if rather small effect in adults.

The second issue has to do with publicity in the media. Dr. Rauscher has been subjected to a media barrage that is literally impossible for most other scholars to understand. She has often gotten hundreds of requests in a week. Naturally she turns down most requests and spends considerable time correcting erroneous summaries and interpretations. She feels that she has a social responsibility to accept some interviews and she is passionately interested in issues of music education and so she has sought some venues in that regard. As one who personally laments the decline of art and music education in this country, I wish that more scholars would join her in this effort.

I believe that Dr. Rauscher has handled the publicity and the debate in a very impressive manner. She has not let this attention distract her from her research agenda. She has been tireless in securing funding and in working with colleagues. She has handled criticism in a very professional manner. I am frankly dismayed by the mean (no lesser word will do) way in which some individuals have disparaged her and her work. It is hard to avoid the conclusion that at least some of this hostility is due to jealousy. I have seen nothing in Dr. Rauscher's work or in her manner which would justify the treatment that she has received at the hands of several psychologists. This treatment would have been enough to break the spirit of many less confident investigators.

Let me add that Dr. Rauscher is a very fine colleague. We have had good in-person and electronic discussions about her work. And she has spent many hours with Winner and Hetland, sharing with them her data and her interpretations thereof. And I also want to emphasize that she is one of the best lecturers that I have seen among younger scholars in psychology.

In sum, then, Dr. Rauscher stands out from among her colleagues in terms of the importance of her work, the interest it has commanded, and the effective way in which she communicates it in written and oral form. She is an unusual scholar, drawing skillfully on several areas of psychology and the arts. The educational implications for the work are patent—Dr. Rauscher has clarified the nature of musical talent, the impact of training, and possible transfer to other cognitive domains. I believe that her work merits the Prize for which she has been nominated.

Please let me know if I can provide any further information.

Sincerely,

Howard Gardner.
John H. and Elisabeth A. Hobbs Professor of Cognition and Education
Adjunct Professor of Psychology

School of Education
Dean of School
Dr Jeanne Keay BEd MEd PhD

Roehampton University
Southlands College
80 Roehampton Lane
London SW15 5SL
Tel 020 8392 3000
Fax 020 8392 3238
www.roehampton.ac.uk

Roehampton University

Dr. Sarah Jerome
Superintendent, Kettle Moraine Schools
563 AJ Alan Circle
Wales, WI 53183 USA

28.5.06

Dear Dr Jerome

Dr Frances H. Rauscher

It is a great pleasure and indeed an honour for me to write in support of Dr Rauscher's nomination for the Brock International Prize in Education. There can be very few people who have not heard of the so-called 'Mozart effect', a term coined by the media which aroused widespread interest in Dr Rauscher's research when she published a seminal paper with Shaw and Ky in the pre-eminent scientific journal Nature in 1993. This relatively small-scale study showed that college students who listened to10 minutes of Mozart's Sonata for Two Pianos in D Major showed a temporary improvement on spatial reasoning scores as compared with those who listened either to a relaxation tape or to silence: and these results created immediate and widespread public interest.

The study gave rise to many replications and developments of the original study, and the debate about the validity and application of the so-called 'Mozart effect' continues today. This work, along with Dr Rauscher's subsequent research, has influenced scientific thinking about cognitive and educational development at a worldwide level, and has shaped educational policy at state and national level in the USA. It has also given rise to the growth of training aids, self-help books and so-called 'intelligence-boosting' CDs such a Sony's 'Build Your Baby's Brain Through the Power of Music'. Many of these subsequent commercial enterprises are have little foundation in science, and in Dr Rauscher's research, but their existence nevertheless demonstrates the enormous impact of her work.

As a psychologist working on musical development, I was asked to comment by the media on Dr Rauscher's work, and first met her when we jointly appeared as keynote speakers at a conference hosted by the University of Gothenburg, Sweden, in 1998. This was followed in the following year by another joint keynote appearance at a conference at the University of Illinois at Urbana Champaign, and since then I have got to know Dr Rauscher well through our joint attendance at international conferences in psychology, music and education. I have developed an immense respect for the scientific integrity and experimental rigour of her work, and there is absolutely no doubt that its implications for music and arts education have been immense. Her work is so well known internationally that she has given invited presentations and keynotes at universities and conferences throughout North America, Europe and Australia, and its national importance was highlighted by an invitation to a seminar hosted by then President Bill and Mrs. Hillary Clinton.

After a career as a concert cellist, Dr Rauscher took a Ph.D. in psychology, and then went to work as a post doctoral fellow with Dr Gordon Shaw at the Center for the Neurobiology of Learning and Memory, University of California. Subsequently moving to a post as the University of

Wisconsin, she has continued to pursue excellent scientific research which has taken her original work on music and spatial reasoning into several new directions, and which has developed the educational implications of it. She has worked on a five-year project with Head Start children, and on the relationship between music instruction and cognition in disadvantaged preschool children. These research interests have taken her to the Milwaukee Public School district, investigating at-risk children in a public school setting. She has also continued research on the effects of auditory exposure on spatial cognition in rats using both behavioural and microanatomical methods.

This research has been supported by grants and gifts from numerous bodies including the Spencer Foundation, the William T. Grant Foundation, the National Association of Music Merchants, the Ella Fitzgerald Charitable Foundation, and many others. She is currently working on 2 books, both to be published by Oxford University Press: Music and the mind beyond the Mozart Effect, an original account of her research and its developments, and Neurosciences in Music Pedagogy (an edited text with Professor Wilfried Gruhn). I am sure that both will have a massive impact, and will 'set the record straight' about many aspects of the 'Mozart effect'.

There can be no doubt that experiences with music and the arts have profound effects on children's development and learning in many domains – social, cognitive and emotional – and it is for drawing attention to some of the fundamental biological, and neuropsychological mechanisms underlying these important effects that Dr Rauscher can truly be said to have had made a specific contribution to the science of education, which will correspondingly provide long-term benefit to all humanity through change and improvement in education throughout the world.

I am very happy to give my strongest support to her nomination for the Brock International Prize.

Yours sincerely

David Hargreaves

Professor David Hargreaves
Centre for International Research on Creativity and Learning in Education (CIRCLE)
Roehampton University
Southlands College
Roehampton Lane
London SW15 5SL
UK

UNIVERSITY OF CALIFORNIA, LOS ANGELES UCLA

BERKELEY • DAVIS • IRVINE • LOS ANGELES • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

Graduate School of Education & Information Studies
P.O. Box 951521
Los Angeles, CA 90095-1521

June 2, 2006

Dr. Sarah Jerome
Superintendent, Kettle Moraine School District
563 AJ Alan Circle
Wales, WI 53183

Dear Dr. Jerome,

I am writing to support Professor Frances Rauscher's candidacy for the Brock International Prize in Education. I have known and admired Dr. Rauscher's work for ten years; she has made path-breaking contributions to the learning sciences and influenced a generation of scholars interested in artistic expression and cognitive development.

I consider her work on music and spatial-temporal reasoning to have caused her peers as well as scholars in related sciences to think differently about the neuro-physiology and neuro-function of cognition. Her work is affirming of very strong traditions in the learning sciences – e.g. the constructivist model of Bruner – and at the same time stretches behavior-based theories of knowledge acquisition into the realm of actual brain-function.

Professor Rauscher's work with UC Irvine Professor of Physics Gordon Shaw advanced the trion model of cortical organization that helps explain the coding of musical structure in human composition. Her early music listening and spatial-temporal reasoning studies opened up vistas for cognitive scientists as well as for researchers in music and arts education. Her research showed intriguing ways to conceptualize learning – and inspired a decade of research in her own and allied fields that probably would not have occurred in the absence of her pioneering work. I count myself among the inspired. And the work continues to move forward.

Voice: (310) 825-5572 Fax: (310) 206-6293 E-mail: jamesc@gseis.ucla.edu

Links between music, artistic expression, and brain function are now pursued in mainstream neuroscience. The Dana Foundation in Washington DC recently awarded more than $12 million to a small number of teams of neuroscientists across the USA to investigate connections between the visual and performing arts and cognition. Striking developments in neuro-imaging aside, such a program of work would have caused blank stares in academe in 1995.

As I read the purposes of the Brock International Prize in Education, Frances fits as an eminent contributor to the understanding of learning processes. She was courageous in moving the stage to the world of music, and the field hasn't been the same since.

If I can comment further, please do not hesitate to ask.

Yours sincerely,

James S. Catterall
Professor

Voice: (310) 825-5572 Fax: (310) 206-6293 E-mail: jamesc@gseis.ucla.edu

Music for All
FOUNDATION

16 Mount Bethel Road, Suite 202 · Warren, NJ 07059-5604 · (908) 542-9396 · FAX: (908) 542-9476 · music-for-all.org

June 1, 2005

Dr. Sarah Jerome
Superintendent, Kettle Moraine Schools
563 AJ Alan Circle
Wales, WI 53183

Dear Dr. Jerome

This letter is in support of the nomination of Dr. Frances Rauscher for the Brock International Prize in Education. I have had the great honor of working with Dr. Rauscher throughout much of her career. I can honestly say that her work created an educational and societal shift regarding the role of music in education.

Plato spoke of it. Einstein speculated about it. Dr. Rauscher discovered it. "It" being how music impacts the development of the brain. It was Dr. Rauscher and Dr. Gordon Shaw who uncovered the first causal link between music and spatial temporal reasoning in the brain leading to explosive growth in the study of music and cognition. This singular act, and the line of discovery Dr. Rauscher has pioneered ever since have reverberated throughout education and culture around the world.

Dr. Rauscher was never satisfied with this first discovery. She knew this was just the start. She committed herself to uncovering the real world implications of these findings by moving out of the laboratory setting and into the classroom. Specifically focusing on at-risk youth. This work has built upon the original discoveries by showing the special way music helps children in other aspects of their learning. She was, and continues to be, determined to optimize music's educational and developmental impact on children.

Beyond her direct work at unlocking one of the great mysteries of the ages has also had significant policy ramifications. Presidents and First Ladies, Congressmen and Senators, US Secretaries of Education and educational policy makers around the nation have quoted, crafted policies, and directed additional studies, from Dr. Rauscher unprecedented work.

Most importantly, I have seen first hand how decision-makers, faced with educational budget cuts have saved music and arts programs from being eliminated because of Dr. Rauscher's work. When a music program is threatened, someone will inevitably quote in some way from Dr. Rauscher's work. Just this year her research was one of the reasons music was saved in the Atlanta Public Schools. This is just one of the thousands of instances over the past decade where her work has had an impact in the real world. Literally, tens of thousands of children are able to gain from the educational benefits music provides to them because of the work of Dr. Rauscher.

Dr. Rauscher's work clearly embodies the spirit of the Brock Prize regarding the "potential to provide long-term benefit to all of humanity through change and improvement in education." In fact, it already has.

She is a worthy and deserving candidate.

Sincerely,

Robert B. Morrison
Chairman and C.E.O.

Wales Elementary

A Recognized School of Excellence

Rick Grothaus • Principal
(262) 968-6400
FAX (262) 968-6405

May 26, 2006

To Whom It May Concern:

I am honored to write this letter to support Dr. Frances Rauscher's nomination for the Brock Award. Her highly regarded work in the area of music's effect on cognition has significantly contributed to higher quality learning environments in schools throughout the country. Dr. Rauscher's influence has sparked a "learning through music" mindset as a tool for cognitive and emotional development in countless numbers of children. Largely because of Dr. Rauscher's achievements musical study is now recognized for its impact on learning in other areas of the curriculum as well as for its positive social impact on the school community and greater community as well. I have known Frances Rauscher since 1996 and collaborated with her on a variety of projects that have had a profound effect on the way parents and educators view the value of music education. I believe I have a unique perspective on Dr. Rauscher's contributions as I had the opportunity to serve as a consultant on a project with her in the inner city of `Milwaukee in which she performed a research study on the effect of piano instruction on spatial reasoning and self-esteem in underprivileged elementary aged children. Because of the attention brought to this issue many thousands of children have received specialized music instruction they would normally not have access to. An intervention program like this, of learning in and through the arts can help "level the playing field" for youngsters from disadvantaged circumstances. I witnessed first-hand the kind of impact this made on the school environment. As a parent in the district I see the dramatic difference it has made in my own children's lives and the lives of so many students.

Dr. Rauscher's sincere passion for science and learning shine through her gentle and generous character. Her contributions have inspired learning and dramatically affected the lives of those around her. I cannot imagine a more deserving candidate for the prestigious recognition of the Brock Award than Dr. Frances Rauscher.

Sincerely,

Mary Anne Zupan

Mary Anne Zupan
K-5 Music Specialist
Wales Elementary School
(262) 968-6400 zupanm@kmsd.edu

May 29, 2006

Dr. Trent Gabert
Chair, Brock Prize Executive Committee
University of Oklahoma
Norman, OK

Dear Dr. Gabert:

It is my great pleasure to write in support of the nomination of Dr. Frances Rauscher for this year's Brock International Prize in Education. She is an outstanding example of the important connections that need to be made between scientific research and educational practices. As you know, she has earned an international reputation for her many studies of music education and the cognitive development of children. Her longitudinal research has been funded by several large grants and has demonstrated the important and positive outcomes of music education for preschool and school age children. Without going into detail about individual studies, I'd like to note several aspects of her research that are particularly impressive:

- Dr. Rauscher is superbly skilled at designing her research so that she can draw the most reliable and valid scientific conclusions. This is a talent I observe not only in the design of her own studies, but I have often seen it when she advises undergraduate and graduate students about experimental methods (and indeed, she teaches our graduate Research Methods course).
- Dr. Rauscher's scientific integrity motivates her to avoid claiming too much from the results of her research. Although some researchers "tweak" their interpretations of their results for maximum popular impact, Dr. Rauscher is very cautious about drawing conclusions from her findings. She is quite aware of the tension between the need for getting science into the public arena and the tendency for over-simplification once research becomes a part of public discourse.
- Dr. Rauscher truly cares about children! I have observed this is many ways, from hearing her talk about the reason she's doing her research on music education as well as from conducting peer evaluations of her teaching in a course she developed on Infant and Child Psychology.
- Dr. Rauscher believes that all children—regardless of their parents' economic status—should have the benefit of early music education. Thus, the first large grant she wrote specifically focused on children in Head Start programs. I read that grant proposal and was impressed not only with its scientific soundness but also with the way she communicated her strong commitment to social justice.
- Although Dr. Rauscher has now amassed considerable evidence both neurological and behavioral about music's effect on the organization of the brain, and the

DEPARTMENT OF PSYCHOLOGY
UNIVERSITY OF WISCONSIN OSHKOSH • 800 ALGOMA BLVD • OSHKOSH WI 54901-8670 • (920) 424-2300

expression of intelligence, she never forgets the aesthetic importance of music. In other words, she knows that music is something that human beings *love* and *enjoy* and that our ability to appreciate music is an important component of our humanity.

- Finally, Dr. Rauscher has been remarkably generous in sharing her knowledge and expertise with music educators. If you look carefully at her CV, you'll see the number of presentations she made to various groups starting in 1995 when she came to the University of Wisconsin Oshkosh. These were not presentations that "counted" for merit, reappointment, tenure, or promotion like presentations at academic conferences. Nevertheless, as a new Assistant Professor, Dr. Rauscher tirelessly traveled to give talks about music education and the role it plays in children's cognitive development. Dr. Rauscher felt that she had a responsibility to "give psychology away" in the words of psychologist, George A. Miller, because in the 1990s, many school districts were eliminating music education. I have talked to a number of music educators who agree that her research, and her willingness to present it in a variety of venues, had a significant impact on the field.

I understand that the application for the Brock International Prize is quite extensive so I trust your selection committee will have access to Dr. Rauscher's papers. It should be noted that the books she is working on this year, during her sabbatical, will undoubtedly have a major impact on how musicians, psychologists, educators, neuroscientists, and others understand "music and the mind." Dr. Rauscher's reputation will continue to grow and it would be wonderful to have her good work affirmed through receiving the Brock Prize.

The final thing you should know about Dr. Rauscher is that she is an excellent colleague. Comprehensive universities like the University of Wisconsin Oshkosh do not attract many world-class researchers like Dr. Rauscher. We have a heavy teaching load (3/3), many undergraduate students to serve, and great pressure for service due to the loss of faculty lines. Nevertheless, busy as she is with her research and teaching, she contributes in a number of important ways to the department, college, and university. Although she is by far the most well-known member of our department, with frequent invitations to speak at national and international conferences, she is willing to put in time on the unglamorous tasks that all departments face (e.g., ordering books for the library, serving on the curriculum committee, chairing searches, writing program reviews). She does this all with considerable collegiality. Her warmth, sense of humor, energy, attention to detail, kindness toward all, and devotion to a life of scholarship and teaching, all combine to make her one this university's most valued faculty members. It would be a wonderful honor to all of us to have her achievements recognized by receiving the Brock Award.

Sincerely,

Susan H. McFadden, Ph.D.
Professor and Chair

BOSTON COLLEGE

PSYCHOLOGY DEPARTMENT

May 3, 2006

Letter of Recommendation for Frances Rauscher for the Brock International Prize in Education

I have known Frances Rauscher for seven years, as we both work in the area of arts and cognition. I have read her work, heard her present at conferences, and had many dialogues with her about our research. I am well acquainted with her work and it is stellar.

Frances Rauscher is one of the few cognitive developmental psychologists today to have made an original discovery. Rauscher is well-known as the originator of the "Mozart effect," a finding showing that after listening to 10-15 minutes of Mozart, college students raise their spatial reasoning scores significantly compared to those who listen only to white noise or to a relaxation tape. This finding was picked up by the media which then misinterpreted her finding as showing that music raises IQ levels, or that babies exposed to music in the womb will have better SAT scores 18 years later. Despite the media hype about her work, Frances has remained a deeply serious and careful researcher/scholar. She has gone on to develop two related but independent programs of research, one looking at the effects of music *listening* on spatio-temporal reasoning, the other looking at the effects of music *training* on spatio-temporal reasoning. For the past decade or so, she has published study after study, all carefully designed with appropriate controls, showing that music has a strong effect on young children's cognition. She has even demonstrated an effect on rats: those exposed to music performed better on maze learning!

Rauscher's work is relevant to two areas of psychology: (1) transfer of learning; and (2) the role of the arts in cognition. Transfer has always been notoriously difficult to demonstrate, but Rauscher has succeeded. Transfer from music to spatial cognition helps us understand what is spatial about music, and helps us understand that spatial and musical cognition are closely related. Her work is also relevant to our understanding of the role of the arts in cognition. This is an area often misunderstood, with arts advocates claiming that the arts are important only or primarily because they improve learning in traditional academic domains. While Rauscher demonstrates that one art form, music, does improve learning in one non-music area, spatial reasoning, she never fell into the trap of concluding from her findings that music education should be justified in terms of its effects on spatial cognition. She has remained clear that she is investigating a cognitive phenomenon that tells us about the organization of knowledge in the brain/mind, and that helps us understand the relationship between musical cognition and spatial cognition.

Rauscher is one of a small group of psychologists who has made a genuine contribution to psychology by making a creative discovery. Her contribution is truly original, it is high in quality, and she has published many papers on the phenomenon she discovered, working it out in all its details and attempting to explain the mechanism by which which phenomenon works. Because Rauscher has made an important discovery in psychology with strong relevance to education, she is eligible for -- and highly deserving of -- the Brock prize.

Rauscher's work has generated controversy and I believe that her work has inspired jealousy. When you have a scholar who at a relatively young age publishes a counter-intuitive and surprising finding, people

MCGUINN HALL, 140 COMMONWEALTH AVENUE, CHESTNUT HILL, MASSACHUSETTS 02467

TEL: 617 – 552– 4100 FAX: 617– 552– 0523

want to prove you wrong. Thus Fran has generated a host of researchers whose goal appears to be to "debunk" her. However, they have not succeeded. Fran has stood her ground, and her studies have stood the test of time and have been extended to young children from impoverished backgrounds (they too show the effect). I myself was highly skeptical of her claims and therefore along with my colleague Lois Hetland at Harvard Project Zero, I conducted two meta-analyses of all of the studies (both by Rauscher and many others) looking at the effects of music listening and the effects of music training on spatial reasoning. Both of these analyses yielded strong and statistically significant effects (published in the *Journal of Aesthetic Education, 2000*), allowing us to conclude that Rauscher was indeed right.

I write many letters of recommendation. But this one is special because I believe that Frances Rauscher is one of the best researchers today in cognitive development and education. Her work is controversial because her findings are counter-intuitive. But this is what makes her discoveries truly innovative. It is for these very reasons that I ask you to consider her most seriously for the Brock Prize.

Sincerely,

Ellen Winner
Professor of Psychology, Boston College
Senior Research Associate, Project Zero, Harvard Graduate School of Education

DR. WILFRIED GRUHN
Emeritus Professor of Music Education
UNIVERSITY OF MUSIC FREIBURG

home address:
Laerchenstr. 5
79256 Buchenbach, Germany
phone +49-7661-1624
fax +49-7661-99653
e-mail mail@wgruhn.de

Prof. Dr. Gruhn, Lärchenstr. 5, 79256 Buchenbach, Germany

Dr. Sarah Jerome
Superintendent, Kettle Moraine Schools
563 Alan J Circle
Wales, WI 53183
USA

4 May, 2006

RE: Recommendation of Frances Rauscher for the nomination of the Brock International Prize in Education

Dear Dr. Jerome!

It is my privilege to write something regarding my colleague Frances Rauscher with whom I have collaborated and still continue a good collaboration. Therefore, I was excited to hear that she is nominated for the *Brock International Prize in Education*.

Although Frances Rauscher is often associated with the Mozart Effect, it is quite clear that she has never been part of the commercialised Mozart Effect industry, rather she is an internationally recognized researcher with high reputation entirely dedicated to music education. Her outstanding research focuses on music learning and cognitive development. The revolutionary study in collaboration with Gordon Shaw (Nature 1993) on the impact of music on spatial-temporal reasoning opened a worldwide ongoing debate and stimulated many further studies. This was one of the most innovative studies in the field of music cognition and education. Since then, she came up with several follow-up studies which investigated the effect of music on maze learning in rats, on spatial intelligence of pre-school children and school children with a special focus on the effects of piano and singing instruction on at-risk children. These longitudinal studies represent fine examples of serious empirical research that has had an enormous impact on the understanding and practice of music education.

With respect to the demands of the *Brock International Prize in Education* it seems absolutely clear to me that Frances Rauscher has made an innovative contribution to music education with the potential to cause long-term benefits to the teaching and learning in schools. Her findings support music in schools and in education and provide a better foundation for the integration of music into the school curriculum. Her expertise in cognitive psychology includes neuropsychological aspects of music learning and teaching.

Therefore, it is my pleasure to confirm that the nomination of Frances Rauscher fits the requests of the Brock Prize. I highly recommend her as an excellent researcher and nominee for the prize.

I hope this will help to support her nomination providing some information to the jurors.

Yours sincerely!

Wilfried Gruhn

The Mozart Effect: Music Listening is Not Music Instruction

Frances H. Rauscher

Department of Psychology

University of Wisconsin Oshkosh

Sean C. Hinton

Department of Neurology

Medical College of Wisconsin

Abstract

"The Mozart effect" originally referred to the phenomenon of a brief enhancement of spatial-temporal abilities in college students after listening to a Mozart piano sonata (K. 448). Over time, this term was conflated with an independent series of studies on the effects of music instruction. This occurrence has caused confusion that has been perpetuated in scholarly articles, such as the one by Waterhouse (2006, this issue) and that persists in the minds of the general public. Here we emphasize the distinction that must be made between research on music listening and research on the more cognitively complex and educationally significant phenomena of music instruction. We stress that improvements in spatial-temporal skills associated with music instruction are not "free." We also discuss theories of transfer and mechanisms of learning as they relate to this topic.

The Mozart Effect: Music Listening is Not Music Instruction

In her paper, Lynn Waterhouse (2006, this issue) advises educators to exercise caution when attempting to apply the theories of multiple intelligence, the Mozart effect, and emotional intelligence to educational practice. She urges educators to consider alternative explanations from both the neuroscientific and psychological literatures before basing educational practice on these theories. The current paper addresses Waterhouse's concerns regarding the Mozart effect.

We suggest that Waterhouse's representation of the Mozart effect confuses two separate avenues of research, one involving the effects of *listening* to a particular Mozart sonata on spatial-temporal cognition and the other exploring the effects of music *instruction* on cognitive performance. The initial listening study (Rauscher, Shaw, & Ky, 1993) received widespread attention from the popular media, who first coined the term "Mozart effect" (Knox, 1993). The main finding of this study was that one specific composition of Mozart enhanced adult spatial test performance for up to about 15 min. There was no indication that other Mozart pieces would have this effect or that the effect was in any way specific to Mozart. Unfortunately, as Waterhouse correctly asserts, this discovery created a "scientific legend" (Bangerter & Heath, 2004) with the edict "Mozart makes you smarter." This led to a Mozart effect industry and eventually to Georgia Governor Zell Miller's proposal to send every newborn baby home from the hospital with a classical music CD.

Music Listening: The "Mozart Effect"

Much of the controversy concerning the Mozart effect is due to the misconception that Mozart's music can enhance general intelligence (Newman et al., 1995; Rauscher, 1999; Stough, Kerkin, Bates, & Magnan, 1994; Steele, Ball, & Runk, 1997). Waterhouse states that the Mozart effect has since proven difficult to replicate and cites "a meta-analysis [Chabris, 1999] of 16

Mozart effect studies [that] found no change in IQ or spatial reasoning ability" (p. ?). Unfortunately, the majority of the studies analyzed by Chabris used inappropriate tasks, music, and diverse research methods. However, a more recent meta-analysis of 36 studies involving 2,465 subjects found that the Mozart effect is moderate and robust but that "it is limited...to a specific type of spatial task that requires mental rotation in the absence of a physical model" (Hetland, 2000a, p. 136) – i.e., spatial-temporal tasks. Waterhouse also cites a paper by McKelvie and Lowe (2002) which found that "compared to control participants, there was no improvement in the spatial IQ scores of children who listened to a Mozart sonata" (Waterhouse, 2006, p. ?). The children's spatial scores were compared before and after they listened to Mozart, popular children's songs, or relaxing music. No differences between conditions were found, despite the finding that the children preferred listening to the popular music. Waterhouse failed to cite a study that did find significant improvement in the spatial-temporal scores of primary school children after listening to both a Mozart sonata and a composition by J.S. Bach. The children's musical backgrounds had no effect on the outcome. (Ivanov & Geake, 2003). A third study also using children as subjects compared the effects of listening to Mozart, popular music, or engaging in a discussion about the experiment (Schellenberg & Hallam, 2005). The researchers found that the children scored higher on a spatial-temporal task following the popular music, but not following the Mozart sonata or discussion. They concluded that "positive benefits of music listening on cognitive abilities are most likely to be evident when the music is enjoyed by the listener" (p. 6). Other studies also support the conclusion that the Mozart effect is largely due to arousal or mood rather than to Mozart or the specific composition (Chabris, 1999; Nantais & Schellenberg, 1999; Schellenberg, Takayuki, Hunter, & Tamoto, in press; Thompson, Schellenberg, & Husain, 2001). However, given the contradictory findings of the studies on children, we agree with Waterhouse that educational practice should not be influenced by this area of research. Few studies used child participants, the effect may be limited to certain types of tasks, and the outcome is exceedingly brief.

Music Instruction

A second area of investigation, however, deserves further consideration by educators: the effects of music instruction on children's cognitive abilities. To avoid confusion, and because they have nothing at all to do with Mozart, we prefer that the instruction studies NOT be referred to as the "Mozart effect," although others have unfortunately generalized the term to refer to any effect of music on behavior (e.g., Campbell, 1997). The instruction studies, unlike the listening studies, have profound implications for educational practice. Our research consistently shows that young children provided with instrumental instruction score significantly higher on tasks measuring spatial-temporal cognition, hand-eye coordination, and arithmetic (Rauscher, 2001; Rauscher, 2002; Rauscher, LeMieux, & Hinton, 2005; Rauscher et al., 1997; Rauscher & Zupan, 2000). Other researchers have found similar effects (see Hetland, 2000b, for review). More recently, a study by Schellenberg (2004) showed small but significant increases in generalized IQ for children randomly assigned to receive music instruction compared to control groups of children who received drama instruction or no special training. Effects of music instruction have been found to persist for at least two years *after* the instruction was terminated (Rauscher, LeMieux, & Hinton, 2005). Although the age of the participants, the methods used, and the outcomes achieved are distinctly different from those of the listening studies, Waterhouse also refers to this phenomenon as the "Mozart effect." She asserts that "the research findings from 1993 [referring to the original listening study] onward led to the conclusion that experience of music, and especially of Mozart's music, whether for a brief time or over a longer period, whether listened to or played, significantly improved spatial cognitive skills" (p. ?). We know of no studies, anecdotal evidence, or popular press accounts suggesting that performing Mozart's music affects spatial cognition or any other domain of intelligence. Waterhouse further confuses the two sets of findings when she states that "Rauscher (2002) suggested that the Mozart effect might work either through transfer of learning from the music domain to the visual-spatial domain, or through changing the physical structure of the brain" (p. ?). Rauscher's reasoning concerned the effects of music *instruction*, not the effects of listening to a Mozart sonata—the so-called "Mozart effect." We do not suggest that listening to Mozart's music transfers to spatial task performance, or that it changes the physical structure of the brain. In fact, the paper Waterhouse cited to support her conclusion (i.e., Rauscher, 2002) included nothing about possible mechanisms for the effects of listening to Mozart. The paper reported a study on the effects of music instruction, and possible mechanisms for instruction's effects on cognition. We believe that Waterhouse's conflating the listening studies with the music instruction studies will lead to greater misinterpretation of the research by educators, politicians, and laypeople. Care must be taken to distinguish these independent research findings so as not to compound the misunderstandings that already exist.

Spatial Skill Improvements Are Not "Free"

Much of Waterhouse's critique of the Mozart effect is based upon her misinterpretation of a statement made by Rauscher (2002). Waterhouse claims that "when asked whether children's spatial skills might be better improved directly through practice rather than indirectly through music, Rauscher argued that music...offers 'free' improvement of spatial skill—i.e., the enhancement of skill without any practice" (p. ?). This is not the case. Rauscher's response to that question emphasized that she instructs her music specialists to "teach the children using their best musical judgment, and the effects will follow" (Rauscher, 2002, p. 276). This does not imply, however, that the effects are "free," or that they will magically appear without practice. The children are, after all, learning to play a musical instrument, which requires sophisticated spatial-temporal training. Brochard, Dufour, & Després (2004) suggest that "…learning to play a musical instrument and/or read musical scores involve the development of specific perceptual, cognitive, and motor skills which are likely to transfer to other behaviors" (p. 103). These researchers found improved visuospatial skills in musicians compared to non-musicians using a reaction time task. Vertical discrimination was tested by presenting subjects with a small target dot either above or below a horizontal reference line. Horizontal discrimination was tested by presenting the dot either to the left or to the right of a vertical reference line. Two different experimental conditions were employed. In one condition ("line on"), the reference line was present during the presentation of the dot. In the other condition ("line off"), the reference line was absent. The subjects' task was to indicate which side of the reference line the dot was flashed. The researchers predicted that "…if musical expertise has a long-term influence on visual-spatial abilities, …musicians' performance on both perceptual "line on" and imagery "line off" conditions [would] be significantly better than nonmusicians. Moreover, if this effect relies on a more efficient use of visual representations, an advantage of musical expertise should be greater in the imaging ("line off") conditions" (p. 104). The data fully supported these predictions. In addition, the researchers found superior performance for the musicians on the vertical dimension in the imaging ("line off") condition and attribute this finding to musicians' long-term practice of reading a musical score. "Reading a musical score is far less linear than reading a text and relies more on processing information on the vertical axis…" (p. 106). The authors suggest that the emphasis on the vertical dimension when one reads a musical score affected mental representations on that portion of the visual field. They conclude that "such perceptual and imagery advantages partly explain why music instruction generally increases children's scoring in visuospatial tasks (such as paper folding, mental rotation, and tridimensional reasoning) which all involve the mental manipulation of visual representations on several dimensions" (p. 106). Thus, the knowledge gained from studying a musical instrument may transfer to spatial-temporal (or mathematical) problem solving without specific practice in the target domain. However, substantial learning must occur in the musical domain. Hence the spatial task improvement is not "free" or without effort.

Transfer

Transfer is defined as the ability to extend what has been learned in one context to new contexts (e.g., Byrnes, 1996). Researchers interested in transfer were initially guided by theories that emphasized the similarities between the initial learning experience and later learning. Thorndike (1913) proposed that the amount of transfer that could occur between two domains was dependent upon the similarity of the elements of the domains. The more equivalent the elements of the two domains, the greater the likelihood of positive transfer. The primary emphasis was on drill and practice. Modern transfer theories also take learner characteristics (e.g., whether relevant principles were extrapolated) into account (e.g., Singley & Anderson, 1989). Thus, transfer is always a function of the relationship between what is learned and what is tested. Measuring the overlap between the original domain of learning and the novel one requires a theory of how knowledge is represented and conceptually mapped across the domains. Singley and Anderson argue that transfer between tasks is a function of the degree to which the tasks share *cognitive* elements. This hypothesis is hard to test experimentally until the task components are identified. Thus, a complete understanding of spontaneous transfer from music to another domain of reasoning (e.g., spatial-temporal reasoning or arithmetic) is possible only to the extent that the cognitive elements of the two domains can be identified. For example, the part-whole concept is a very important construct for many mathematical problems. This concept requires understanding the relationship between parts to wholes, such as when learning percents, decimals, and fractions. In music, the part-whole concept is especially relevant in the conceptualization of rhythm. A literate musician is required to continually mentally subdivide the beat to arrive at the correct interpretation of rhythmic notation. The details of the problem are certainly different, the context has changed, but the structure of the problem is essentially the same as any part-whole problem posed mathematically. Perhaps this relationship helps explain the finding that children who received instruction on rhythm instruments scored higher on part-whole mathematics problems than those who received piano or singing instruction (Rauscher, LeMieux, & Hinton, 2005). We believe that further investigation into the components common to musical and mathematical knowledge will aid in the understanding of these transfer effects.

Mechanisms of Learning

Waterhouse states that "cognitive neuroscience research has discovered six processes that influence the establishment of long term procedural and declarative memory" (p. ?): repetition, excitation, reward, carbohydrate consumption, sleep after a learning session, and avoidance of drugs and alcohol. We believe there is more to learning than the six constructs Waterhouse identified. For example, in order for learners to gain insight into their learning and their understanding, frequent feedback is critical (Ericsson, Krampe, & Tesch-Romer, 1993). This feedback need not be rewarding. Students need to monitor their learning and actively evaluate their strategies. Playing a musical instrument requires vigilant instantaneous examination of what has already occurred in the performance (e.g., up-bow vs. down-bow; fingering) as well as thinking ahead to prepare for future challenges. Students are continually reflecting on their performance and that of others, and they are learning from their own and others' mistakes. At the end of most music lessons, student and teacher discuss what the student did, how he/she did it, and why. This metacognitive approach engages students as active participants in their learning by focusing their attention on critical elements, encouraging abstraction of procedures, and evaluating their own progress toward understanding—all processes that have been shown to encourage transfer across domains (Singley & Anderson, 1989). Perhaps the reflective and analytical skills involved in learning an instrument encourage the transfer of musical knowledge to spatial domains.

Waterhouse emphasizes that procedural skills improve as a function of repetition and that "there is no evidence, other than evidence for the Mozart effect, to suggest that significant cognitive skill improvement can take place without...repetition of that skill; or excitement associated with the skill activity" (p. ?). Because she continually confuses the listening studies with the music instruction studies, we are not certain which "Mozart effect" Waterhouse refers to in this context. Our comments here pertain to the instruction studies. We agree that the development of expertise occurs only with major investments of time. For example, a study of 250 musically trained young people found strong correlations between proficiency in a musical instrument and the number of hours per day spent practicing (Sloboda, Davidson, Howe, and Moore, 1996). Children who were later accepted to specialized music schools practiced approximately 2 hours per day by age 12. This represents a 400 – 800% increase compared to average children learning a musical instrument, who at that age practiced only approximately 15 - 30 minutes per day. We suggest that practicing a musical instrument, even for a few minutes each day, engages spatial-temporal cognition and thereby contributes to spatial-temporal learning.

Waterhouse's second criterion for improved cognitive skill, also discussed in her section on arousal, is "excitation associated with the skill activity." We contend that playing a musical instrument also satisfies this criterion. In his treatise on the art of playing keyboard instruments, C.P.E. Bach stated that "a musician cannot move others unless he too is moved" (1985, p. 152). Emotions are clearly important to musicians wishing to communicate to an audience or to express their own feelings. Motivation to become a musician is characterized by hedonism—i.e., cherishing music as a means to generate positive emotion (Persson, Pratt, & Robson, 1996). Furthermore, performing a composition for an audience of even one person (which all music students have done when playing for their teachers) is inherently an arousing activity. Thus, playing a musical instrument is accompanied by excitation, and the transfer of musical knowledge to spatial-temporal knowledge does not "contradict the current cognitive neuroscientific understanding of the basis of skill improvement" (p. ?) as Waterhouse asserts.

In her section entitled "Other Proposed Brain Mechanisms for the Mozart Effect," Waterhouse states that "no evidence for the cross-domain transfer of learning from music to spatial skill has been found" (p.?) and cites Schellenberg (2003) to support this contention. We believe this statement misrepresents Schellenberg's position. In fact, Schellenberg (2003) suggests that "positive transfer effects to nonmusical domains, such as language, mathematics, or spatial reasoning could be similarly unique for individuals who take music lessons" (p. 444), and further states that "...the ability to attend to rapidly changing temporal information, skills relevant to auditory stream segregation, the ability to detect temporal groups, sensitivity to signals of closure and other gestalt cues of form, emotional sensitivity and fine motor skills ...

should be particularly likely to transfer to a variety of nonmusical domains" (p. 444). Research grounded in near-transfer theory has indeed shown relationships between music instruction and a variety of cognitively-related skills (see, for example, Gromko, 2004). Although studies specifically testing transfer as a mechanism are extremely difficult to implement due to an insufficient understanding of the overlap of the cognitive components inherent in the two domains (as discussed above), we suggest that transfer remains a potential explanation for improved cognitive abilities following music instruction.

Waterhouse's critique includes a brief mention of a study that found improved maze learning following music exposure in rats (Rauscher, Robinson, & Jens, 1998). Citing Steele's (2003) critique of the study, she reports that "the rats [in Rauscher et al., 1998]...were unlikely to have improved their maze learning from hearing a Mozart sonata because ... adult rats are deaf to the majority of tones in a Mozart sonata" (p. ?). Waterhouse's conclusion is unwarranted. Steele's analysis of rat auditory thresholds was incorrect, as was the note count and fundamental frequencies he recorded for the Mozart sonata. The rats likely heard a substantially higher percentage of notes than Steele reported, and other musical factors that he did not consider may be important as well. These factors, as well as Steele's other criticisms of Rauscher et al., have been addressed in depth elsewhere (Rauscher, in press). Moreover, Rauscher et al.'s behavioral data have been replicated by other researchers who have shown that improved maze performance following exposure to the Mozart sonata is related to synaptic plasticity (Chikahisa et al., 2006). Although we do not claim that the mechanism for cognitive enhancement in rats is the same as for that in humans, we believe the research with rats suggests a neurophysiological basis for improved spatial performance following music exposure, perhaps related to cognitive transfer.

Conclusions

Like Waterhouse, we recommend caution when applying the findings of music instruction to educational practice, although they certainly seem worthy of further investigation in educational settings. Indeed, this research represents an excellent example of what has become known as a "design experiment." Design experiments are described as educational research experiments carried out in a complex learning context to determine how an innovation affects student learning and educational practice (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). Real-life educational contexts are, in turn, excellent settings for experimental tests of an intervention. We believe such experiments are a crucial research approach within the broader context of partnerships involving teachers, educational researchers, and scientists. We do not, however, advocate teaching music to students in order to improve their visuospatial or mathematical skills. We agree with Hetland and Winner (2001): "If the arts are given a role in our schools because people believe the arts cause academic improvement, then the arts will quickly lose their position if academic improvement does not result…The arts must be justified in terms of what the arts can teach that no other subject can teach" (p. 3). Although findings of a Mozart effect (i.e., the listening studies) may be of little educational value, the music instruction studies hold much more educational promise. Both sets of studies are of scientific importance because they suggest that music and spatial task performance share common elements and may be psychologically and neurologically related. We believe researchers should continue to search for links between music instruction and cognitive performance because disregarding these effects may overlook a potentially important educational intervention.

References

Bach, C.P.E. (1985). *Essay on the true art of playing keyboard instruments.* (W.J. Mitchell, Trans.). London: Eulenberg Books. (Original work published 1778.)

Bangerter, A., & Heath, C. (2004). The Mozart effect: Tracking the evolution of a scientific legend. *British Journal of Social Psychology, 43*, 605-623.

Brochard, R., Dufour, A., & Després, O. (2004). Effect of musical expertise on visuospatial abilities: Evidence from reaction times and mental imagery. *Brain and Cognition, 54*, 103-109.

Byrnes, J.P. (1996). *Cognitive development and learning in instructional contexts.* Boston: Allyn and Bacon.

Campbell, D. (1997). *The Mozart effect.* New York: Avon Books.

Chabris, C. (1999). Prelude or requiem for the Mozart effect? *Nature, 402*, 826-827.

Chikahisa, S., Sei, H., Morishima, M., Sano, A., Kitaoka, K., Nakaya, Y., & Morita, Y. (in press). Exposure to music in the perinatal period enhances learning performance and alters BDNF/TrkB signaling in mice as adults. *Behavioural Brain Research.*

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9-13.

Ericsson, K.A., Krampe, R.T., & Tesch-Romer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*, 363-406.

Gromko, J.E. (2004). Predictors of music sight-reading ability in high school wind players. *Journal of Research in Music Education, 52*, 6-15.

Hetland, L. (2000a). Listening to music enhances spatial-temporal reasoning: Evidence for the "Mozart Effect." *Journal of Aesthetic Education, 34*, 105-148.

Hetland, L. (2000b). Learning to make music enhances spatial reasoning. *Journal of Aesthetic Education, 34,* 179-238.

Hetland, L. & Winner, E. (2001). The arts and academic achievement: What the evidence shows. *Arts Education Policy Review, 102,* 3-6.

Ivanov, V.K., & Geake, J.G. (2003). The Mozart effect and primary school children. *Psychology of Music, 31*, 405-413.

Knox, R. A. (1993). Mozart makes you smarter, Calif. Researchers suggest. *Boston Globe,* October 14th 1993.

McKelvie, P., & Low, J. (2002). Listening to Mozart does not improve children's spatial ability: Final curtains for the Mozart effect. *British Journal of Developmental Psychology, 20,* 241-258.

Nantais, K.M., & Schellenberg, E.G. (1999). The Mozart effect: An artifact of preference. *Psychological Science, 10,* 370-373.

Newman, J., Rosenbach, J.H., Burns, I.L., Latimer, B.C., Matocha, H.R., & Vogt, E.R. (1995). An experimental test of "the Mozart effect": Does listening to his music improve spatial ability? *Perceptual and Motor Skills, 81*, 1379-1387.

Persson, R.S., Pratt, G., & Robson, C. (1996). Motivational in influential components of musical performance: A qualitative analysis. In A.J. Cropley and D. Dehn (Eds.), Fostering the growth of high ability: European perspective (pp. 287-301). Norwood, NJ: Ablex.

Rauscher, F.H. (1999). "Prelude or requiem for the Mozart effect: Reply. *Nature, 400*, 827-828.

Rauscher, F.H. (2001). Current research in music, intelligence, and the brain. In M. McCarthy (Ed.), *Enlightened advocacy: implications of research for arts education policy and practice* (pp. 5-16). College Park, MD: University of Maryland Press.

Rauscher, F.H. (2002). Mozart and the mind: Factual and fictional effects of musical enrichment. In J. Aronson (Ed.), *Improving academic achievement: Impact of psychological factors on education* (pp. 269-278). New York: Academic Press.

Rauscher, F.H. (in press). The Mozart effect in rats: Response to Steele. *Music Perception.*

Rauscher, F.H., LeMieux, M., & Hinton, S.C. (2005, August). *Selective effects of music instruction on cognitive performance of at-risk children.* Paper presented at the bi-annual meeting of the European Conference on Developmental Psychology, Tenerife, Canary Islands.

Rauscher, F.H., Robinson, K.D., & Jens, J. (1998). Improved maze learning through early music exposure in rats. *Neurological Research, 20,* 427-432.

Rauscher, F.H., Shaw, G.L., & Ky, K.N. (1993). Music and spatial task performance. *Nature, 365,* 611.

Rauscher, F.H., Shaw, G.L., Levine, L.J., Wright, E.L., Dennis, W.R., & Newcomb, R. (1997). Music training causes long-term enhancement of preschool children's spatial-temporal reasoning abilities. *Neurological Research, 19,* 1-8.

Rauscher, F.H., & Zupan, M.A. (2000). Classroom keyboard instruction improves kindergarten children's spatial-temporal performance: A field experiment. *Early Childhood Research Quarterly, 15,* 215-228.

Schellenberg, E.G. (2003). Does exposure to music have beneficial side effects? In I. Peretz and R. Zatorre (Eds.), *The cognitive neuroscience of music* (pp. 430-448). New York: Oxford University Press.

Schellenberg, E.G. (2004). Music lessons enhance IQ. *Psychological Science, 5,* 511-514.

Schellenberg, E.G., & Hallam, S. (2005). Music listening and cognitive abilities in 10 and 11 year olds: The Blur effect. *Annals of the New York Academy of Sciences, 1060*, 1-8.

Schellenberg, E.G., Takayuki, N., Hunter, P.G., & Tamoto, S. (in press). Exposure to music and cognitive performance: Tests of children and adults. *Psychology of Music.*

Sloboda, J. A., Davidson, J. W., Howe, M. J. A., & Moore, D. G. (1996). The role of practice in the development of expert musical performance. *British Journal of Psychology. 87,* 287-309.

Singley, K., & Anderson, J.R. (1989). *The transfer of cognitive skill.* Cambridge, MA: Harvard University Press.

Steele, K.M. (2003). Do rats show a Mozart effect? *Music Perception, 21*, 251-265.

Steele, K.M., Ball, T.N., & Runk, R. (1997). Listening to Mozart does not enhance backwards digit span performance. *Perceptual and Motor Skills, 84*, 1179-1184.

Stough, C., Kerkin, B., Bates, T., & Magnan, G. (1994). Music and spatial IQ. *Personality and individual differences, 17*, 695.

Thompson, W.F., Schellenberg, E.G., & Husain, G. (2001). Arousal, mood, and the Mozart effect. *Psychological Science, 12*, 248-251.

Thorndike, E.L. (1913). *Educational psychology.* New York: Columbia University Press.

Waterhouse, L. (2006). Multiple intelligences, the Mozart effect, and emotional intelligence: A critical review. *Educational Psychologist,*

ERIC Clearinghouse on Elementary and Early Childhood Education

University of Illinois • 51 Gerty Drive • Champaign, IL 61820-7469
(217) 333-1386 • (800) 583-4135 (voice/TTY) • ericeece@uiuc.edu • http://ericeece.org

ERIC DIGEST
September 2003 • EDO-PS-03-12

Can Music Instruction Affect Children's Cognitive Development?

Frances H. Rauscher

Several studies have examined the effects of music instruction on children's abilities in other disciplines. Other studies have explored the effects of *listening* to music on *adults'* spatial abilities. Findings from these two sets of studies have been confused, leading to claims that listening to music can improve children's academic abilities. This Digest evaluates these claims and discusses the evidence exploring music *instruction's* effects on children's spatial-temporal, mathematical, and reading abilities.

The "Mozart Effect": Listening to Music

The term "Mozart Effect" refers to the finding that 36 college students who listened to 10 minutes of a Mozart sonata scored higher on a subsequent spatial-temporal task than after they listened to relaxation instructions or silence. The effect lasted approximately 10 minutes (Rauscher, Shaw, & Ky, 1993). Although the effect was replicated by several researchers, other researchers were unable to reproduce it (Hetland, 2000a). Research on the causes and limitations of the effect in adults is ongoing (Husain et al., 2002).

The Mozart Effect was studied only in adults, lasted only a few minutes, and was found only for spatial-temporal reasoning. Nevertheless, the finding has spawned a Mozart Effect industry that includes books, CDs, and Internet sites claiming that listening to classical music can make children "smarter." In fact, no scientific evidence supports the claim that listening to music improves children's intelligence. Two related studies tested the Mozart Effect with 103 children ages 11 to 13 years (McKelvie & Low, 2002). The researchers found no experimental support for the effect in children, concluding that "it is questionable as to whether any practical application will come from it" (p. 241). Although the Mozart Effect is of scientific interest, its educational implications appear to be limited.

Music Instruction and Spatial-Temporal Ability

A meta-analysis of 15 studies involving 701 children ages 3 to 12 years suggests that children provided with music instruction score higher than controls on spatial-temporal tasks (Hetland, 2000b). Spatial reasoning is important to many fields and to core concepts in mathematics, such as proportions and fractions. Effects of keyboard instruction have been found for children ranging in age from 3 to 9 years, with the largest effects found for the youngest children (Bilhartz, Bruhn, & Olson, 2000; Costa-Giomi, 1999; Gromko & Poorman, 1998; Rauscher et al., 1997; Rauscher & Zupan, 2000). Although most studies have employed keyboard instruction, a recent study examined the effect of keyboard, singing, and rhythm instruction separately on the spatial perception of 123 economically disadvantaged 3- and 4-year-old children (Rauscher & LeMieux, 2003). The three music groups scored higher on spatial tasks following music instruction than did a control group, with the rhythm group scoring higher than all other groups on sequencing and arithmetic tasks. Verbal, matching, and memory tasks were not significantly affected, demonstrating the specificity of the effect to tasks requiring spatial abilities. This finding suggests that different types of music instruction affect different aspects of cognition.

There has been some question as to the durability of cognitive enhancements found for children who receive music instruction. One study found that 9-year-old children who were provided with piano instruction indeed scored higher than controls on a spatial-temporal task immediately following the instruction. However, no differences between the music and control groups were found after two years of instruction (Costa-Giomi, 1999). A follow-up study revealed that participants who began music instruction before age 5 scored significantly higher on spatial tasks than those who began later or did not receive instruction (Costa-Giomi, 2000). This study did not address the possibility that other non-musical factors, such as musical aptitude, parental involvement, or socioeconomic factors may have affected the outcome. The author concluded that children who be(music instruction very early in life are likely to show t.. greatest benefits in spatial development. Supporting this conclusion are studies that explored the effect of classroom keyboard instruction (Rauscher & Zupan, 2000; Rauscher, 2002). Children who began instruction at age 5 scored higher on spatial-temporal tasks than children who did not receive the instruction. The scores of children who began instruction after age 7 did not differ from controls. Finally, a recent study found that children who received keyboard instruction for two years beginning at age 3 (n = 31) continued to score higher on spatial-temporal and arithmetic tasks two years after the instruction was terminated (Rauscher & LeMieux, 2003). The age at which children begin instruction appears to affect the duration of extra-musical cognitive outcomes, and longitudinal research suggests that at least two years of music instruction are required for sustained enhancement of spatial abilities (Rauscher, 2002).

Music Instruction and Mathematics

Some studies have found that music instruction can also affect certain mathematical abilities. Researchers compared the proportional reasoning scores of several groups of children (n = 136, ages 7 to 9 years), including one group who received computer-generated spatial-temporal training alone and another group who received the same spatial-temporal training coupled with piano keyboard instruction (Graziano, Peterson, & Shaw, 1999). The proportional reasoning of the children was then tested. Although both groups scored higher than a control group, the group that included piano training scored significantly higher than t' group that did not.

A more recent study found that at-risk children who received two years of individual keyboard instruction scored higher on a standardized arithmetic test than children in control groups, including a group that received computer instruction to rule out a possible Hawthorn effect (Rauscher & LeMieux, 2003).

Children who received singing instruction also scored higher than controls. Children who received instruction on rhythm instruments performed best on a mathematical reasoning task.

A meta-analysis combining six experimental studies provides tentative support for the notion that music training affects mathematical achievement (Vaughn, 2000). However, six is a very small number, and more research is clearly needed. Several correlational studies do, however, suggest a relationship. For example, one study involving 96 children, ages 5-7 years, found that those who received 7 months of supplementary music and visual arts classes achieved higher standardized mathematics scores than children who received the schools' typical music and arts training (Gardiner et al., 1996). Unfortunately, random assignment was not possible due to logistics and the school administrators' need to keep classes intact. Furthermore, the music instruction was provided in conjunction with arts training, making it impossible to determine if the effects found were due to music instruction or arts training.

Music Instruction and Reading

A meta-analysis of a set of 24 correlational studies, some involving sample sizes of over 500,000 high school students, found a strong and reliable association between music instruction and reading test scores (Butzlaff, 2000). A more recent study found that ninety 6- to 15-year-old boys with music training had significantly better verbal memory than children without such training (Ho, Cheung, & Chan, 2003). The longer the training, the better the verbal memory. These studies provide some support for a correlation between music instruction and verbal abilities.

However, a meta-analysis conducted on six experimental studies provided little evidence of a causal relationship (Butzlaff, 2000). The effect sizes were highly variable, indicating that the overall finding is not stable. Therefore, it is unwise to conclude that music affects reading ability based on this analysis.

Experimental research performed with 8- to 11-year-old children with reading problems found that the reading skills of children who received music instruction ($n = 6$) were significantly higher than those of children who did not receive the instruction ($n = 6$) (Douglas & Willatts, 1994). However, a study of nine dyslexic boys with a mean age of 8.8 years found that music instruction improved rapid temporal processing skills, phonological skills, and spelling skills, but not reading skills (Overy, 2002). Overall, the studies suggest that it is premature to conclude that music instruction affects reading ability.

Conclusion

The research suggests that music may act as a catalyst for cognitive abilities in other disciplines, and the relationship between music and spatial-temporal reasoning is particularly compelling. However, several concerns remain unaddressed. Little is known regarding the exact aspects of music instruction that contribute to the transfer effects. Also, further longitudinal studies are needed to determine the duration of these effects. Another concern is that currently available tests of reading and math achievement may not be sufficiently sensitive to the complexity of language and mathematical learning potentially affected by music instruction. Although it appears that parents, educators, and policy makers can now consider enhanced spatial-temporal ability to be a viable outcome of music instruction, the evidence supporting enhanced mathematical or reading ability is equivocal. Finally, although the research has strong implications for policy and practice, care must be taken to ensure that scientific goals do not displace developmentally appropriate music instruction (see, e.g., Music Educators National Conference [1994]).

For More Information

Bilhartz, T. D., Bruhn, R. A., & Olson, J. E. (2000). The effect of early music training on child cognitive development. *Journal of Applied Developmental Psychology, 20*(4), 615-636.

Butzlaff, R. (2000). Can music be used to teach reading? *Journal of Aesthetic Education, 34*(3-4), 167-178.

Costa-Giomi, E. (1999). The effects of three years of piano instruction on children's cognitive development. *Journal of Research in Music Education, 47*(3), 198-212. EJ 604 142.

Costa-Giomi, E. (2000). The relationship between absolute pitch and spatial abilities. In C. Woods, G. Luck, R. Brochard, F. Seddon, & J. A. Sloboda (Eds.), *Proceedings of the Sixth International Conference on Music Perception and Cognition.* Keele, UK: Keele University, Department of Psychology.

Douglas, S., & Willatts, P. (1994). The relationship between musical ability and literacy skills. *Journal of Research in Reading, 17*(2), 99-107. EJ 492 757.

Gardiner, M. F., Fox, A., Knowles, F., & Jeffrey, D. (1996). Learning improved by arts training. *Nature, 381*, 284.

Graziano, A. B., Peterson, M., & Shaw, G. L. (1999). Enhanced learning of proportional math through music training and spatial-temporal training. *Neurological Research, 21*(2), 139-152.

Gromko, J. E., & Poorman, A. S. (1998). The effect of music training on preschoolers' spatial-temporal task performance. *Journal of Research in Music Education, 46*(2), 173-181. EJ 612 202.

Hetland, L. (2000a). Listening to music enhances spatial-temporal reasoning: Evidence for the "Mozart Effect." *Journal of Aesthetic Education, 34*(3-4), 105-148. EJ 658 281.

Hetland, L. (2000b). Learning to make music enhances spatial reasoning. *Journal of Aesthetic Education, 34*(3-4), 179-238. EJ 658 284.

Ho, Y., Cheung, M., & Chan, A. S. (2003). Music training improves verbal but not visual memory: Cross-sectional and longitudinal explorations in children. *Neuropsychology, 17*(3), 439-450.

Husain, G., Thompson, W. F., & Schellenberg, E. G. (2002). Effects of musical tempo and mode on arousal, mood, and spatial abilities. *Music Perception, 20*(2), 151-171.

McKelvie, P., & Low, J. (2002). Listening to Mozart does not improve children's spatial ability: Final curtains for the Mozart effect. *British Journal of Developmental Psychology, 20*(2), 241-258.

Music Educators National Conference (MENC). (1994). *The school music program: A new vision.* Reston, VA: Author.

Overy, K. (2002). *Dyslexia and music: From timing deficits to music intervention.* Unpublished doctoral dissertation, University of Sheffield.

Rauscher, F. H. (2002). Mozart and the mind: Factual and fictional effects of musical enrichment. In J. Aronson (Ed.), *Improving academic achievement: Impact of psychological factors on education* (pp. 269-278). New York: Academic Press.

Rauscher, F. H., & LeMieux, M. T. (2003, April). *Piano, rhythm, and singing instruction improve different aspects of spatial-temporal reasoning in Head Start children.* Poster presented at the annual meeting of the Cognitive Neuroscience Society, New York.

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature, 365*, 611.

Rauscher, F. H., Shaw, G. L., Levine, L. J., Wright, E. L., Dennis, W. R., & Newcomb, R. L. (1997). Music training causes long-term enhancement of preschool children's spatial-temporal reasoning. *Neurological Research, 19*(1), 1-8.

Rauscher, F. H., & Zupan, M. (2000). Classroom keyboard instruction improves kindergarten children's spatial-temporal performance: A field experiment. *Early Childhood Research Quarterly, 15*(2), 215-228. EJ 633 368.

Vaughn, K. (2000). Music and mathematics: Modest support for the oft-claimed relationship. *Journal of Aesthetic Education, 34*(3-4), 149-166. EJ 658 282.

This project has been funded at least in part with Federal funds from the U.S. Department of Education, Office of Educational Research and Improvement, under contract number ED-99-CO-0020. The content of this publication does not necessarily reflect the views or policies of the U.S. Department of Education, nor does mention of trade names, commercial products, or organizations imply endorsement by the U.S. Government.

EFFECTS OF PIANO, SINGING, AND RHYTHM INSTRUCTION ON THE SPATIAL REASONING OF AT-RISK CHILDREN

Frances H. Rauscher
Department of Psychology, University of Wisconsin Oshkosh, USA

1. ABSTRACT

Previous research has demonstrated that preschool children score higher on spatial tests following piano instruction. Three studies were conducted to answer three questions regarding these effects: (1) Which cognitive processes are enhanced by piano instruction? (2) Do different types of instruction have differential effects? (3) Are these effects durable and generalizable? In Study 1, at-risk preschool children were provided with weekly piano instruction, computer instruction, or no instruction for two years. Children were pre- and post-tested using a large battery of standardized cognitive tests. Results indicated that children who received piano instruction scored significantly higher than control children on tests requiring spatial and/or temporal abilities. In Study 2, children received instruction in piano, singing, or rhythm instruments. A control group of children received no instruction. We administered the same battery of tests as in Study 1. All music groups scored higher than controls on spatial and temporal tasks. The rhythm group scored higher than the piano and singing groups on temporal tasks. The piano and singing groups' scores did not differ. Study 3 compared the scores of the children who received music lessons to those of Head Start children who did not receive instruction, at-risk children who were not enrolled in Head Start, and middle-income elementary school children. The music groups continued to score higher than all other groups on spatial and temporal tasks two years after instruction ended. The rhythm group continued to score higher than controls on temporal and mathematics tests. No effects were found for verbal, memory, or reading tests.

2. BACKGROUND/AIMS

Several studies have suggested that music instruction improves preschool and elementary school children's spatial abilities (1). In a typical study, the "treatment" group received private instrumental or school music instruction, while "control" groups either received no treatment or special training in something other than music. Children were usually pre-tested prior to the instruction and post-tested several months or years later. Outcome measures included tests measuring spatial-temporal abilities (i.e., tasks defined as those requiring mental rotation and/or multiple solution steps for two- or three-dimensional figures in the absence of a physical model). The mean effect size found by Hetland's meta-analysis involving 15 independent studies and 709 subjects was d = .79, with 100% of the effect sizes greater than zero.

It has been suggested that these findings may be due to differences between musicians and non-musicians in brain structure and function as a result of their music instruction (2, 3, 4, 5). Researchers have found that musicians who began piano instruction before age 7 had a larger cross-section of the anterior corpus callosum (6). Furthermore, dipole moments of the digits of the left hand were found to be significantly larger in violinists compared to non-musicians, with the greatest effects found for musicians who began instruction before age 12 (7). A follow-up MEG study found auditory cortex dipole moments for piano tones were enlarged by about 25% in musicians relative to non-musicians (8). Again, there was a positive correlation between effect size and when participants initiated instruction: musicians who began instruction before age 9 showed the largest effects. Pantev et al. concluded that "use-dependent functional reorganization extends across the sensory cortices to reflect the pattern of sensory input processed by the participant during development of musical skill" (p. 811). Finally, researchers using MEG measured violinists' and trumpeters' cortical representations for violin and trumpet tones compared to sine wave tones (9). The researchers found enhanced representations for timbres associated with the instrument of training, with trumpeters showing enhancement for trumpet tones and violinists showing enhancement for violin tones. This study suggests that experience with different musical instruments may affect brain function in different ways.

The research reported here is the product of three closely related studies involving economically disadvantaged preschool children. All children were enrolled in Head Start, a federally funded preschool program designed to prepare economically disadvantaged children for public school. Modal household incomes in our sample ranged between \$10,400 and \$15,600. The first study, conducted over two years, attempted to replicate and extend the finding that piano instruction provided to preschool children improved spatial-temporal scores compared to children who received computer instruction or no special training. The purpose of the second two-year study was to determine if the type of music instruction children received had measurably different effects on cognition. Most researchers agree that musical skill is an alliance of a number of separate and relatively independent abilities. We proposed that early music instruction emphasizing different musical skills would produce correspondingly differential effects on cognitive performance. Supporting this proposition, a recent study suggests that several years of string and percussion instruction selectively improved auditory frequency and duration discrimination thresholds compared to no instruction (10). The second study thus compared the effects of three types of music training—piano, singing, and rhythm—each of which highlights a partially non-overlapping set of musical properties. Finally, the third study was conducted to investigate if the effects found in the first and second studies endured into elementary school, and further to examine the effects of the previously-initiated instruction on academic skills.

3. METHODS/RESULTS

3.1. Study 1

The first experiment was designed to test three- and four-year-old at-risk children's spatial and temporal skills before (T1) and after (T2) two academic years of weekly individual piano instruction. Two further groups of children were included in the design to control for the Hawthorne Effect. One group received individual computer instruction matched in frequency and duration to the piano instruction, and the other group received no special training. Five standardized tests were administered to assess the specific cognitive processes that are enhanced through music training. Specific predictions were made regarding the children's performance on each test. Overall, we predicted that the children who received the piano instruction would improve more and score significantly higher than the children in the comparison and control groups on tasks classified as having spatial and/or temporal content. We further predicted that tasks that do not tap spatial or temporal abilities would not be affected by the instruction.

3.1.1. Methods

Eighty-seven children (mean age 3 years 3 months at T1, 45 girls, 42 boys) were randomly assigned to three groups: Piano (n=33), computer (n=28) and control (n=26). We pre- and post-tested all the children using subtests of the Kaufman Assessment Battery for Children (K-ABC), the Developmental Test of Visual Perception (DTVP-2), the Test of Auditory Perceptual Skills-Revised (TAPS-R), and the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPSSI-R). These tests measure different aspects of spatial-temporal, visuo-spatial, and auditory skills. Overall, we administered twenty-six sub-tests. All testing was performed by research assistants blind to experimental conditions and hypotheses.

3.1.2. Results

An alpha level of .05 was used for all statistical tests. As predicted, children who received music instruction scored significantly higher than those who received computer or no instruction only on tasks requiring spatial and temporal skills. Consider, for example, the WPPSI-R's Object Assembly (OA) task (Figure 1).

A two-factor (condition, testing) mixed analysis of variance (ANOVA) found a main effect for condition ($F_{(2,84)} = 8.99$, $p < .000$), a main effect for testing ($F_{(1,84)} = 97.58$, $p < .000$), and an interaction between condition and testing ($F_{(2,84)} = 49.10$, $p < .000$). Although the three groups' scores did not differ in T1, the piano group scored significantly higher than computer or control groups ($p < .000$ both) in T2.

Tasks that also improved significantly following piano instruction included four tasks from the K-ABC (Hand Movements, Magic Window, Gestalt Closure, and Arithmetic), five tasks from the DTVP (Eye-Hand Coordination, Spatial Relations, Form Constancy, Visual Closure, and Figure-Ground), and two tasks from the TAPS (Auditory Sentence Memory (Sequencing) and Auditory Processing (Thinking and Reasoning)). In short, spatial and/or temporal tasks were improved following piano instruction, whereas verbal tasks, matching tasks, copying tasks, and memory tasks were not significantly affected. None of these tasks were significantly improved by the computer instruction, although children who received computer lessons did score significantly higher on the K-ABC's Expressive Vocabulary and Faces and Places tasks than children in the piano or control groups.

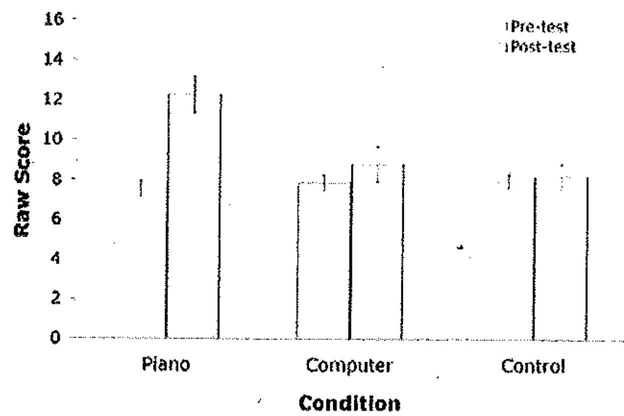


Figure 1. Mean Object Assembly (OA) pre- and post-test standard scores for piano, computer, and control groups. OA is a spatial-temporal task that requires the child to assemble a series of cardboard pieces into a familiar whole in the absence of a physical model. Error bars represent 1 standard error of the mean (SEM).

3.2. Study 2

At-risk preschool children received piano, singing, rhythm, or no instruction for two years. All children were pre- and post-tested using the same standardized tests as in Study 1. We predicted improvement in spatial-temporal tasks following all types of music instruction, improvement in mental imagery tasks following singing instruction (due to singing's strong reliance on auditory imagery), and improvement in temporal tasks following rhythm instruction (due to rhythm training's emphasis on the temporal qualities of music).

3.2.1. Methods

One-hundred-twenty-three male and female Head Start preschool children of mixed ethnicity were randomly assigned to four conditions: Piano (n=34), singing (n=28), rhythm (n=35) and control (n=26). As in Study 1, children in the music groups received weekly individual instruction at their Head Start school for a period of 48 weeks over two years. Children in the control group received no special training. We pre- and post-tested all the children using the same tests used in Study 1: K-ABC, DTVP-2, TAPS-R, and WPSSI-R. Again, we administered twenty-six sub-tests.

3.2.2. Results

Due to the large number of sub-tests administered, here we present only the data from one spatial-temporal task (Object Assembly—OA), one mental imagery task (Form Constancy—FC), and one temporal task (Magic Window—MW) to demonstrate the veracity of our predictions. The data represent typical results for these three task categories.

ISBN 3-931852-67-9

An alpha level of .05 was used for all statistical tests. A two-factor (condition, testing) mixed analysis of variance (ANOVA), with condition as the between-subjects factor and testing as the within-subjects factor, was performed on the pre- and post-test scores of the OA (spatial-temporal) task. The data are presented in Figure 2.

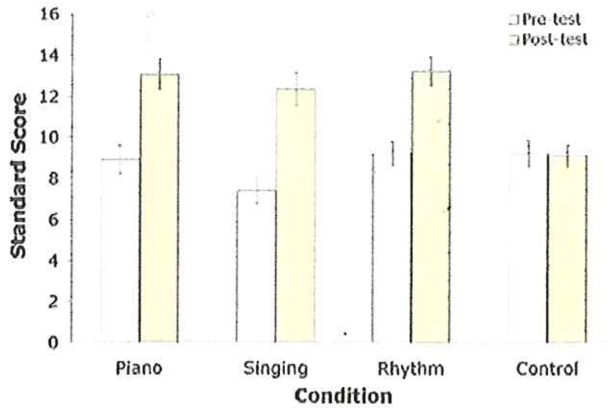


Figure 2. Mean Object Assembly (OA) pre- and post-test standard scores for piano, singing, rhythm, and control groups. Error bars represent 1 SEM.

We found a main effect for testing ($F_{(3,119)} = 129.44, p < .001$) and an interaction between testing and condition ($F_{(1,119)} = 14.52, p < .001$). The main effect for condition was not significant ($F_{(3,119)} = 2.50, p = .06$). The pre-test scores for the four groups did not differ. However, LSD tests revealed that the post-test scores of the piano, singing, and music groups were significantly higher than those of the control group ($p < .001$, all). The standard scores of the three music groups improved significantly from pre-test to post-test ($p < .001$). The post-test scores of the three music groups, however, did not differ from each other.

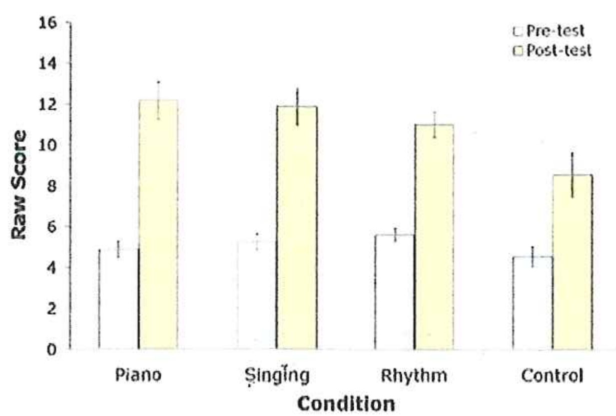


Figure 3. Mean Form Constancy (FC) pre- and post-test raw scores for piano, singing, rhythm, and control groups. FC is a mental imagery task that requires the child to recognize the central features of an object when it appears in different sizes, shapes, shadings, textures, and positions. Error bars represent 1 SEM.

To illustrate the effects of music instruction on mental imagery, we present here the data for the FC task. We performed a two-factor (condition, testing) mixed ANOVA on the pre- and post-test raw scores of this task. These data are graphed in Figure 3.

We used standard scores rather than raw scores because the FC task is standardized for children age 4 to 11. We found main effects for condition ($F_{(3,119)} = 3.05, p < .04$) and testing ($F_{(1,119)} = 175.56, p < .001$). The interaction between condition and testing did not reach significance ($F_{(3,119)} = 2.57, p = .06$). The pre-test scores of the four groups did not differ from each other. Because raw scores were used rather than scaled scores, LSD tests found significant differences between the pre- and post-test scores for all groups of subjects ($p < .001$, all). The improvement for the control group was presumably due to maturation. However, the post-test scores of the three music groups were significantly different from the post-test scores of the control group (piano vs. control and singing vs. control: $p < .001$; rhythm vs. control: $p > .01$). The post-test scores of the three music groups did not differ significantly.

Finally, we performed a two-factor (condition, timing) mixed ANOVA on the scaled pre- and post-test scores of the Magic Window (temporal) task. The data are shown in **Figure 4.**

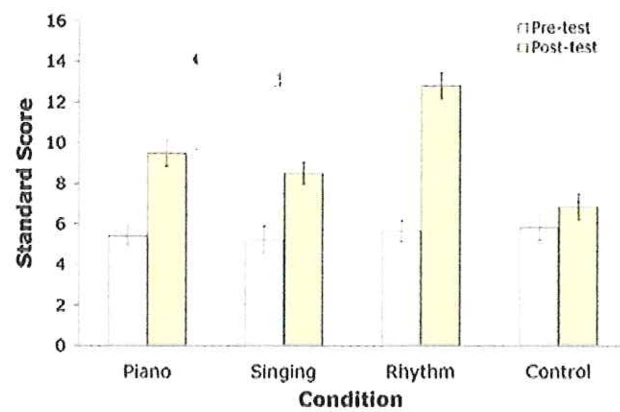


Figure 4. Mean Magic Window (MW) pre- and post-test standard scores for piano, singing, rhythm, and control groups. MW is a temporal task that measures the child's ability to identify and name an object whose picture is rotated behind a narrow slit, so that the picture is only partially exposed at any given point in time. Error bars represent 1 SEM.

The analysis revealed main effects for condition ($F_{(3,119)} = 6.63, p < .001$) and testing ($F_{(1,119)} = 138.97, p < .001$), and an interaction between condition and testing ($F_{(3,119)} = 14.83, p < .001$). Although the four groups' pre-test scores did not differ, all music groups scored significantly higher in post-tests than in pre-tests ($p < .001$, all). The control group's pre- and post-test scores did not differ significantly ($p < .15$). The post-test scores of the three music groups were significantly higher than those of the control group (singing vs. control and rhythm vs. control: $p < .001$; piano vs. control: $p < .03$). Although the post-test scores of the piano and singing groups did not differ significantly ($p < .13$), the post-test

ISBN 3-931852-67-9
ISSN 1617-6847

scores of the rhythm group were higher than both the piano and singing groups ($p < .001$, both). This trend was also found for the other temporal tasks we administered–the Number Recall, Magic Window, and Arithmetic tasks of the KABC, the Figure Ground task of the DTVP, and the Auditory Number Memory Forward, Auditory Number Memory Backward, and Auditory Sentence Memory (Sequencing) tasks of the TAPS.

3.3. Study 3

The third study was designed to compare the scores of the children who received music lessons in studies 1 and 2 to three groups of grade-matched children: (1) Head Start children who did not receive music instruction; (2) at-risk children who were not enrolled in Head Start, and (3) middle-income children.

3.3.1. Methods

We re-tested the children who participated in the control (n=24) and piano (n=31) groups in Study 1 (now in second grade) as well as the music children who participated in Study 2 (now in kindergarten). We were able to track 76 of the 97 music children from Study 2 (piano, n=27, singing, n=20, rhythm, n=29). All children were tested individually in their homes or schools.

The children in Studies 1 and 2 were administered the K-ABC and the Wechsler Individual Achievement Test (WIAT), a test that measures basic reading, mathematics reasoning, spelling, reading comprehension, numerical operations, listening comprehension and oral expression. We also administered the K-ABC and the WIAT to 27 at-risk kindergartners, 24 at-risk second-graders, 32 middle-income kindergartners, and 28 middle-income second graders.

3.3.2. Results

In brief, we found that the children who received music instruction in Study 1 (now in second grade) continued to score higher on three of the four K-ABC tasks that were previously enhanced by the instruction (Hand Movements, Gestalt Closure, and Arithmetic). The fourth task, Magic Window, was not standardized for children older than age 5, and so was not administered. In addition, these children scored significantly higher on these tasks compared to second grade Head Start children who did not receive music instruction. When compared to grade-matched at-risk children who were not enrolled in Head Start, the music group also scored significantly higher on the Expressive Vocabulary and Faces and Places tasks. The children who were enrolled in Head Start but did not receive music instruction scored significantly higher than at-risk children who were not enrolled in Head Start programs on the Arithmetic, Expressive Vocabulary, and Faces and Places tasks. This suggests that although Head Start has little effect on spatial-temporal reasoning, it does influence children's abilities on other non-spatial tasks (and arithmetic). Finally, although no groups scored significantly higher than the middle income children on any of the tasks we administered, the scores of the children in the music group were roughly the same as those of the middle-income children on the spatial-temporal and arithmetic tasks. The other groups scored significantly lower than the middle-income children on all tasks. **Figure 5** shows the data for all groups for the Arithmetic task.

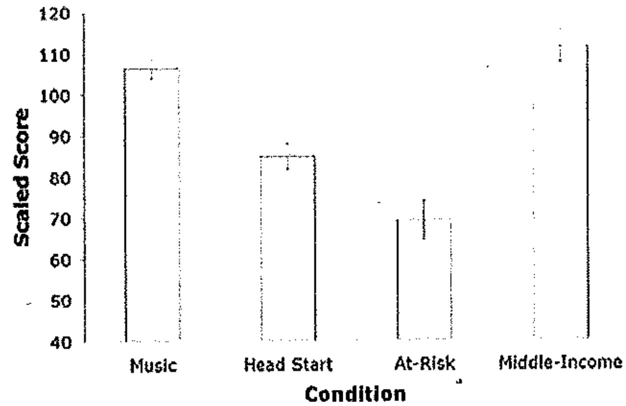


Figure 5. Mean Arithmetic standard scores for music, Head Start, at-risk, and middle income groups. Music and Head Start children participated in Study 1. Error bars represent 1 SEM.

For the WIAT, we found that the music group scored significantly higher than the Head Start and at-risk children on the reading, spelling, reading comprehension, mathematical reasoning, numerical operations, and listening tasks. The Head Start children scored higher than the at-risk children on the reading, spelling, and reading comprehension tasks (but not the mathematical reasoning or numerical operations tasks). These findings demonstrate the specificity of the transfer of musical knowledge to numeracy and aural abilities. Finally the music children scored at the same level as the middle-income children on the mathematical reasoning and numerical reasoning tasks.

When we tested the children who participated in Study 2 (now in kindergarten), we found that the singing, piano, and rhythm groups scored higher on the K-ABC's Arithmetic, Expressive Vocabulary, Faces and Places, Hand Movements, and Gestalt Closure tasks than Head Start and at-risk children, whereas children in the rhythm group scored higher on the arithmetic subtest than the singing and piano groups. This suggests that rhythm instruction has the strongest impact on mathematical reasoning. As with the second grade children, the kindergarten Head Start children scored higher than the at-risk children on the Arithmetic, Expressive Vocabulary and Faces and Places tasks. Remarkably, although the piano and singing groups scored equal to the middle-income group on the spatial-temporal and arithmetic tasks, the rhythm group actually scored significantly higher than the middle-income children on the arithmetic test. They also scored higher than the middle-income children on the mathematical reasoning and numeracy tests of the WIAT.

4. CONCLUSIONS

This research suggests that learning music is an important developmental activity that may help at-risk children compete academically on a more equal basis with their middle-income peers. Although the Head Start program did improve children's performance on several of the tasks we administered, improvement on the spatial-temporal tasks was confined to those children who received music instruction. The presence of a Hawthorne effect was ruled out by the control groups employed in Study 1, and the effects of the music instruction were found to continue for at least two years after the intervention ended.

The data reported here provide partial support for our hypothesis that different types of music instruction affect different aspects of spatial-temporal cognition. Consistent with previous research and Study 1, Study 2 found that children who received music instruction scored significantly higher on spatial-temporal tasks than children who did not. However, our prediction that the mental imagery scores of children who study singing would be higher than children who study piano or rhythm instruments was not borne out. For example, the singing group's scores on the Form Constancy task, a measure of mental imagery, were not higher than those of the other two music groups. However, all groups did score higher than the control group.

We further predicted that children who studied rhythm instruments would score higher on temporal tasks than children who studied either piano or singing. This prediction was supported by the data. For example, although the Magic Window post-test scores of children in the piano and singing groups were higher than those of controls, children in the rhythm group scored significantly higher in post-tests on this and other temporal tasks than either the piano, singing, or control groups. This suggests that training in a rhythm instrument may influence the neural circuitry involved in judging temporal duration. Future research exploring the neurophysiological basis of these findings will determine whether these selective effects are accompanied by changes in the structure and function of the brain.

5. REFERENCES

1. Hetland, L. (2000). Learning to make music enhances spatial reasoning. *Journal of Aesthetic Education, 34*, 179-238.

2. Gruhn, W., & Rauscher, F.H. (2002). The neurobiology of music cognition and learning. In R. Colwell & C. Richardson (Eds.), *Second handbook on music teaching and learning* (pp. 445-460). New York: Oxford University Press.

3. Rauscher, F.H. (2002). Mozart and the mind: Factual and fictional effects of musical enrichment. In J. Aronson (Ed.), *Improving academic achievement: Impact of psychological factors on education* (pp. 269-278). New York: Academic Press.

4. Rauscher, F.H., Shaw, G.L., Levine, L.J., Wright, E.L., Dennis, W.R., & Newcomb, R. (1997). Music training causes long-term enhancement of preschool children's spatial-temporal reasoning abilities. *Neurological Research, 19*, 1-8.

5. Rauscher, F.H., & Zupan, M. (2000). Classroom keyboard instruction improves kindergarten children's spatial-temporal performance: A field experiment. *Early Childhood Research Quarterly, 15*, 215-228.

6. Schlaug, G., Jancke, L., Huang, Y., Staiger, J.F., & Steinmetz, H. (1995). Increased corpus callosum size in musicians. *Neuropsychologia, 33*, 1047-1055.

7. Elbert, T., Pantev, C., Wienbruch, C., Rockstroh, B., & Taub, E. (1995). Increased cortical representation of the fingers of the left hand in string players. *Science, 270*, 305-307.

8. Pantev, C., Oostenveld, R., Engelien, A., Ross, B., Roberts, L.E., & Manfried, H. (1998). Increased auditory cortical representation in musicians. *Nature, 392*, 811-813.

9. Pantev, C., Roberts, L.E., Schulz, M., Engelien, A., & Ross, B. (2001). Timbre-specific enhancement of auditory cortical representations in musicians. *NeuroReport, 12*, 169-174.

10. Hinton, S.C. & Rauscher, F.H. (2003, March). *Auditory duration and frequency discrimination are selectively enhanced by different types of music instruction.* Poster presented at the annual meeting of the Cognitive Neuroscience Society, New York, NY.

6. ACKNOWLEDGMENT

This research was funded by the W.T. Grant Foundation Faculty Scholars program.

Early Childhood Research Quarterly, 15, No. 2, 215–228 (2000)
ISSN: 0885-2006

Classroom Keyboard Instruction Improves Kindergarten Children's Spatial-Temporal Performance: A Field Experiment

Frances H. Rauscher
Department of Psychology, University of Wisconsin Oshkosh

Mary Anne Zupan
School District of Kettle Moraine

The purpose of this study was to determine the effects of classroom music instruction featuring the keyboard on the spatial-temporal reasoning of kindergarten children. Sixty-two kindergartners were assigned to one of two conditions, keyboard or no music. All children were pretested with two spatial-temporal tasks and one pictorial memory task. The keyboard group was provided with 20-min lessons two times per week in groups of approximately 10 children. Children were then retested at two 4-month intervals. The keyboard group scored significantly higher than the no music group on both spatial-temporal tasks after 4 months of lessons, a difference that was greater in magnitude after 8 months of lessons. Pictorial memory did not differ for the two groups after the lessons. These data support studies that found similar skills enhancements in preschool children, despite vast differences in the setting in which the instruction occurred. The results have strong implications for school administrators and educators.

Strongly held beliefs among music educators about the benefits of music instruction for young children are supported by anecdotal reports but less clearly by data. Recently, however, studies have demonstrated that preschool children provided with individual music instruction score significantly higher on tests measuring spatial-temporal abilities than do children provided with computer instruction (Rauscher, Shaw, Levine, Wright, Dennis, & Newcomb, 1997) or no lessons

This research was supported by the School District of Kettle-Moraine and by a research fellowship from the Wisconsin School Music Association made to Mary Anne Zupan.

Direct correspondence to: Dr. Frances H. Rauscher, Department of Psychology, University of Wisconsin Oshkosh, 800 Algoma Boulevard, Oshkosh, WI 54901; Phone: (920) 424-7172; E-mail: rauscher@uwosh.edu.

(Costa-Giomi, 1999; Gromko & Poorman, 1998; Mallory & Philbrick, 1995; Rauscher, Shaw, Levine, Ky, & Wright, 1994; Rauscher et al., 1997). The purpose of this study was to extend these findings to kindergarten children in an elementary public school setting. The findings will provide information relevant to pedagogical decisions and help policymakers prioritize investments among competing curricula.

Spatial Ability

A well-developed spatial ability has several advantages. Arnheim (1969) argued that our perceptions of the world underlie and constitute our most important cognitive processes. As he put it, "The remarkable mechanisms by which the senses understand the environment are all but identical with the operations described by the psychology of truly productive thinking in whatever area of cognition takes place in the realm of imagery" (p. v). Arnheim (1969) further suggested that we are unable to reason clearly about an idea for which we do not possess a mental image. Thus, spatial abilities are relevant to decision making (Johnson-Laird, 1983). A more liberal view would hold that spatial abilities enable scientific and artistic thought (Gardner, 1983, 1993). In either case, children with adequate spatial abilities are more likely to function successfully in their lives and as adults.

The term "spatial cognition" is broadly defined as a specific type of mental processing involving objects that exist in space. Although several subcategories of spatial ability have been documented (Elliot, 1980; Elliot & Smith, 1983; Nicolopoulou, 1988), there is little consensus among psychologists as to how to best classify spatial skills (McGee, 1979). Neurologists examining spatial deficits in adults have shown that the spatial factor is not a unidimensional concept, but includes spatial perception, memory, operations (e.g., rotation or reflection of spatial representations), and construction (putting the parts of an object together to create a whole) (Barlow, 1961; Biederman, 1987; Kritchevsky, 1988; Newsome, Britten, & Movshon, 1989). It thus seems that spatial ability is an amalgamation of loosely related components whose exact number and definition are still under investigation.

Studies exploring the effects of music on spatial abilities point to a dichotomous classification of spatial abilities consisting of *spatial-temporal* processes and *spatial recognition* (Rauscher & Shaw, 1998; Rauscher et al., 1994, 1997). Spatial-temporal processes are used in tasks that require combining separate elements of an object into a single whole by arranging objects in a specific spatial order to match a mental image. Rauscher and Shaw (1998) suggested that spatial-temporal tasks require both spatial imagery and the temporal ordering of objects, abilities they propose are necessary for proportional reasoning used in mathematics and scientific endeavors. This component is distinguished from spatial recognition, which requires the individual to recognize and classify physical similarities of spatial objects (Rauscher & Shaw, 1998; Rauscher et al., 1994, 1997). Neither spatial imagery nor temporal ordering is required of tasks relying solely on spatial recognition.

Knowledge gained from musical training seems to be relevant to spatial-temporal processes (Gromko & Poorman, 1998; Mallory & Philbrick, 1995; Rauscher et al., 1994, 1997), perhaps because the elements of a musical piece are organized both spatially and temporally. Playing a melody involves reconstructing a pattern in which the elements, the notes, are organized in a highly specialized spatial-temporal code. The overlap of skills required for music and spatial cognition may form the basis for what Tunks (1992) refers to as cross-sensory perception and response, which involves "relating information entering through one sense mode to analogous information in another mode" (p. 443). Perhaps the knowledge gained through music training transfers to spatial-temporal task performance.

Theoretical Background

Howard Gardner's (1983) theory of multiple intelligences challenges the widely held belief that intelligence can be reduced to a single quotient. Gardner proposes the existence of at least eight "intelligences," including musical intelligence and spatial intelligence, and provides converging evidence for the uniqueness of these domains. An ongoing study with Head Start children supports Gardner's theory: Musical aptitude and spatial reasoning scores of 3- and 4-year-old children were not correlated in pretests (Rauscher, 1999), suggesting the independence of these two intelligences. Although it might seem that research demonstrating enhancement of spatial abilities through music instruction runs contrary to Gardner's (1997) theory, Gardner himself asserts that "music may be a privileged organizer of cognitive processes, especially among young people" (p. 9). This interpretation permits one to embrace the concept of autonomous intelligences as well as the possibility that experience in one domain may influence performance in another.

The cortical model of Shaw et al. provides a neuroscientific framework for the relationship between music and spatial cognition (see, for example, Leng & Shaw, 1991). Shaw's structured neuronal model proposes that certain neural firing patterns organized in a complex spatial-temporal code over large regions of cortex are exploited by both musical and spatial reasoning tasks. According to the model, music training strengthens these common neural firing patterns through Hebbian (Hebb, 1949) learning principles. Several studies examining electroencephalogram (EEG) provide support for this model (Hughes, Daaboul, Fino, & Shaw, 1998; Rideout & Laubach, 1996; Sarnthein, von Stein, Rappelsberger, Petsche Rauscher, & Shaw, 1997). Leng & Shaw's (1991) model, taken together with children's early sensitivity to music (Gardner, 1983; Krumhansl & Jusczyk, 1990; Olsho, Schoon, Sakai, Turpin, & Sperduto, 1982; Papousek, 1982) and knowledge about the plasticity of the child's brain (Rakic, 1997) suggests that musical training may affect the development of neural pathways relevant to abilities that are influenced by environmental stimulation, such as certain spatial abilities (Rakic, 1997; Rosenzweig & Bennett, 1996). Specifically, Leng and Shaw (1991) proposed that music instruction provided to young children should enhance spatial–temporal task performance.

Empirical Studies

Studies exploring the relationship between music and spatial abilities have focused on correlations between the two cognitive domains or have compared the spatial scores of musicians and nonmusicians (Barret & Barker, 1973; Hassler, Birbaumer, & Feil, 1985; Kalmár, 1982; Manturzewska, 1978). These studies have generally found that individuals with musical talent or training score higher on spatial tasks. Unfortunately, although correlational studies can suggest the existence of a relationship, they cannot determine the cause. Recent studies have investigated the causal nature of the relationship by actually implementing the music lessons to a random sample of children. For example, Rauscher et al. (1997) provided 3-year-old children with 6 months of individual piano keyboard lessons, casual group singing sessions, computer lessons, or no lessons. Spatial–temporal and spatial recognition tasks were administered before and after instruction began. Although the pretest scores of the children in the four groups did not differ, the posttest spatial-temporal scores of the keyboard group were significantly higher than those of the other groups after the lessons. Spatial recognition scores did not improve. Similarly, Costa-Giomi (1999) found that the spatial scores of 9-year-old children who were provided with 2 years of private keyboard lessons were significantly higher than those of children who did not receive the lessons. Gromko and Poorman (1998), Mallory and Philbrick (1995), and Rauscher et al. (1994) found similar results with 3- to 5-year-old children. And finally, an intriguing study performed by Gardiner, Fox, Knowles, and Jeffrey (1996) found that first- and second-grade children who received 7 months of supplementary music and visual arts classes achieved higher standardized mathematics scores than did children who received the schools' typical music and arts training. However, because the two treatments were initiated together it is difficult to determine which intervention caused the improvement.

Although the effects of private keyboard instruction on spatial task performance have been previously established (Costa-Giomi, 1997; Gromko & Poorman, 1998; Mallory & Philbrick, 1995; Rauscher et al., 1994, 1997), no studies have examined whether these effects are sustainable in the turmoil of a public school kindergarten classroom in which groups of children simultaneously engage in either music instruction or other activities. The aim of the present study was to assess the effect on spatial-temporal task performance and pictorial memory of keyboard lessons provided to kindergarten children in a group school setting compared with children who did not receive the lessons. We predicted that the keyboard groups' spatial-temporal scores would improve significantly more than those of the no music group, and the two groups' memory task scores would not differ. Although sex differences in spatial test scores have frequently been reported, with boys scoring higher than girls on spatial tests (e.g., Halpern, 1992: Linn & Peterson, 1985), previous studies with preschoolers found no differences between boys' and girls' spatial-temporal task scores after music instruction (Gromko & Poorman, 1998; Mallory & Philbrick, 1995; Rauscher et al., 1994, 1997). A further goal of this study was to determine whether the spatial-temporal scores of kindergarten children also fail to demonstrate significant sex effects.

Table 1. Distribution of Children in Groups and Schools

	Group	
	Keyboard	No music
School	*n*	*n*
Wales Elementary	18	9
Magee Elementary	16	19

METHOD

Participants

Sixty-two middle-income kindergarten children (36 boys and 26 girls) of mixed ethnicity attending four kindergarten classes at two Midwestern public elementary schools participated. The children ranged in age from 5 years, 1 month to 6 years, 1 month at the start of the study.

Procedure

Children were assigned to one of two groups, keyboard (n = 34) or no music (n = 28). Random assignment was not possible because of logistics and the school administrators' need to keep classes intact. Table 1 shows the assignment of students in the two participating schools to experimental and control groups. A music specialist visited each classroom to administer 20 min keyboard lessons to the keyboard group two times per week. Ten Kawai XG130 keyboards (Hamamatu, Japan) were arranged in a row against one wall of the classroom. The children assigned to the no music group were engaged in journaling by their kindergarten teacher in a separate area of the classroom during lesson time.

Instruction

The children in the keyboard group participated in groups of approximately 10. In a typical lesson, the music specialist assembled the children in a semicircle on the floor away from the keyboards to sing and move to the previous week's keyboard composition. This was followed by singing and moving to the compositions of the current and subsequent weeks, leading to a brief discussion of keyboard hand position. The children were then seated individually at the keyboards to play the previous week's piece alone and in ensembles, followed by an introduction to a new composition accompanied by rhythmic clapping and solfege, culminating in keyboard performance. These activities were interspersed with ear training, notation, rhythm, improvisation, interval, and dynamic exercises. The lesson ended with a review of the day's activities and repertoire. The children assigned to the keyboard group were encouraged to play the keyboards throughout the day. The children in the no music group were not permitted access to the keyboards.[1]

Testing

Prior to the instruction, all children were pretested with two tasks, Puzzle Solving and Pictorial Memory, taken from the McCarthy Scales of Children's Abilities (McCarthy, 1972), and one task, Block Building, taken from the Learning Accomplishment Profile Standardized Assessment test (LAP-D) (*Learning Accomplishment Profile*, 1992). The children were tested individually at their schools.

The Puzzle Solving task, a spatial-temporal task, consisted of four items of increasing difficulty. To successfully complete each item the child was required to arrange cardboard pieces of a puzzle to create a familiar object. As with the Object Assembly task used in previous studies (Gromko & Poorman, 1999; Mallory & Philbrick, 1995; Rauscher et al., 1994, 1997), the child's task was to join the puzzle pieces together in particular orders to match a mental image. This task contains both elements required for spatial-temporal reasoning—the formation of a mental image and temporal ordering (Rauscher & Shaw, 1998). The Block Building task, also a spatial-temporal task, consisted of two items. The child was required to reproduce from memory a simple stair-step structure previously created by the test administrator from 10 1-inch blocks. Both mental image formation and temporal ordering are also required for this spatial-temporal task. Finally, the Pictorial Memory task (six items) required the child to recall and identify previously viewed picture objects. A test of visual memory, this task required neither mental image formation nor temporal ordering.

Testing was conducted following procedures specified by the McCarthy (1972) and LAP-D (*Learning Accomplishment Profile Standardized Assessment*, 1992) test manuals. Testing sessions lasted approximately 15 min and were carried out at the schools before lessons and again at two subsequent 4-month intervals, totaling three testing sessions altogether. The keyboard lessons commenced immediately following pretesting. Thus, the final testing session occurred 8 months after the keyboard group's first lesson. Testing was conducted by M. A. Zupan and a colleague blind to the experimental hypotheses and condition assignment.[2]

Scoring

Puzzle Solving The number of correctly joined puzzle pieces was divided by the number of minutes taken to complete each puzzle within a specified time limit for a dependent measure of joins per minute.

Block Building The total number of seconds taken to complete the structure was recorded. A maximum of 120 sec was permitted. Children who did not complete the structure received a score of 120.

Pictorial Memory The total number of pictured items recalled out of a total of six items was recorded.

Table 2. Mean Task Scores and Standard Deviations for Keyboard (n = 34) and No Music (n = 28) Groups

	Task					
	Puzzle Solving[a]		Block Building[b]		Pictorial Memory[a]	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*
Keyboard						
Pretest	4.52	3.05	77.68	48.76	3.32	1.09
4 months	9.17	4.97	39.74	38.46	4.26	0.86
8 months	11.97	6.02	27.72	29.67	4.82	1.24
No Music						
Pretest	3.93	2.26	77.66	44.70	3.79	1.20
4 months	5.75	3.26	74.54	48.29	3.50	1.35
8 months	6.87	3.63	58.70	45.49	4.36	1.06

Notes: [a] The higher the score is, the better the performance.
[b] The lower the score is, the better the performance.

RESULTS

Means and standard deviations for all variables are presented in Table 2. An α level of 0.05 was used for all statistical tests. The first set of analyses focused on the group factors that may have predicted the skills enhancements found. Because the children's scores on the Puzzle Solving and Block Building tasks were significantly correlated (pretest: $r = -0.25$, $p \leq .05$; 4 months: $r = -0.54$, $p \leq .01$; 8 months: $r = -0.49$, $p \leq .01$),[3] a multivariate analysis of variance (MANOVA) with sex (boy, girl) and group (keyboard, no music) as between-subject factors, and time (pretest, 4 months, 8 months) as a within-subject factor was performed on the three dependent measures. We found significant multivariate main effects for group ($\eta^2_{(3,56)} = 0.20$, $p < .005$) and time ($\eta^2_{(6,53)} = 0.86$; $p < .001$) and a significant interaction between group and time ($\eta^2_{(6,53)} = 0.27$, $p < .009$). There was no significant main effect for sex ($\eta^2_{(3,56)} = 0.03$, $p > .05$), and no other significant interactions were found.

We next performed separate two-factor group (keyboard, no music) $\times$time (pretest, 4 months, 8 months) mixed analyses of variance (ANOVAs) with time as the repeated measure on each task. The outcome of this analysis is reported in Table 3. The ANOVA performed on the Puzzle Solving task showed significant main effects for both group and time and a significant interaction between group and time. Similar effects were found for the Block Building task. The ANOVA performed on Pictorial Memory yielded a main effect for time only and an interaction between group and time. Because we were unable to randomly assign children to groups, we next performed a two-factor (sex, group) MANOVA on the pretest scores for the Puzzle Solving, Block Building, and Pictorial Memory tasks to be absolutely certain that the children's scores prior to treatment were equiv-

Table 3. Two-Factor (Group, Time) Analyses of Variance for Puzzle Solving, Block Building and Pictorial Memory Tasks

		F		
Source	*df*	Puzzle Solving	Block Building	Memory
Group (G)	1	11.63*	7.13*	1.28
Time (T)	2	61.45**	17.16**	24.53**
G × T	2	10.55**	4.71*	8.3**
S within-group error	120	(7.51)	(1190.07)	(0.76)

Notes: Values enclosed in parentheses represent mean square errors.
S = subjects.
$*p \leq .001$; $**p < .0001$.

alent across group and sex. No significant main effects for group ($\eta^2_{(3,56)} = 0.01$, $p > .05$) or sex ($\eta^2_{(3,56)} = 0.01, p > .05$) were found, nor was there a significant interaction between group and sex ($\eta^2_{(3,56)} = 0.05, p > .05$).

Scheffe *t* tests further revealed that the pretest scores of the keyboard and no music groups did not differ significantly for any variable (Puzzle Solving: $t = 0.15, p > .05$; Block Building: $t = 0.1.98, p > .05$; Pictorial Memory: $t = 0.1.43, p > .05$). However, the children in the keyboard group scored significantly higher on the Puzzle Solving and Block Building tasks after 4 months of lessons than did the children in the no music group (Puzzle Solving: $t = 4.90, p \leq .05$; Block Building: $t = 5.99, p \leq .001$). After 8 months of lessons the difference in spatial-temporal task scores between the keyboard and no music groups had further increased (Puzzle Solving: $t = 10.9$ $p \leq .001$; Block Building: $t = 4.7, p \leq .001$). No significant differences between groups were found for the Pictorial Memory task (4 months: $t = 3.74$, N.S.; 8 months: $t = 1.37$, N.S.).

An additional method for assessing learning over time is to calculate and analyze gain scores (posttest minus pretest). This method, however, fails to control for the common observation that children who score the lowest on cognitive pretests tend to improve the most over time (Bereiter, 1963; Linn & Slinde, 1977), in which case their posttest scores are somewhat dependent on their pretest scores. We, therefore, used a covariance approach to factor out the pretest scores' effect on the outcome measures. Using posttest scores as an outcome measure with the pretest scores as a predictor, we performed a one-factor (group) multivariate analysis of covariance (MANCOVA) by using pretest scores as the covariate and gain scores (8 months − pretest, presented in Table 4) as the dependent measure. This analysis yielded a significant main effect for group ($\eta^2_{(3,53)} = 0.35, p < .001$), indicating that the effect for group revealed by the MANOVA performed earlier was not an artifact of the children's pretest scores. The MANCOVA also revealed that the effect for sex ($\eta^2_{(3,56)} = 0.04, p > .05$) and the interaction between group and sex ($\eta^2_{(3,56)} = 0.02, p > .05$) were not significant.

Table 4. Mean Gain Scores (Pretest − 8 Months) for Keyboard (n = 34) and No Music (n = 28) Groups

Group	Puzzle Solving[a] *M*	Puzzle Solving[a] *SD*	Block Building[b] *M*	Block Building[b] *SD*	Pictorial Memory[a] *M*	Pictorial Memory[a] *SD*
Keyboard	7.43	4.94	−49.97	51.17	1.5	1.46
No Music	2.94	3.05	−18.95	52.44	.57	1.29

Notes: [a] The higher the score is, the greater the improvement.
[b] The lower the score is, the greater the improvement.

DISCUSSION

The primary contribution of this study was to demonstrate the effects of music instruction on the spatial–temporal reasoning of kindergarten children in the chaotic setting of the public school classroom. The results revealed that the children exposed to keyboard lessons improved significantly on the two spatial-temporal tasks administered, regardless of group instruction and a hectic classroom environment. The enhancements found in this study were similar in magnitude to those found in similar studies (Rauscher et al., 1994, 1997), despite vast differences in the setting in which the instruction occurred and the participation of older children. Although no differences in pretest scores were found between the keyboard and no music groups, the keyboard group scored significantly higher than the no music group after only 4 months of lessons, a difference that was greater in magnitude after 8 months of lessons. As predicted, pictorial memory did not differ for the two groups following lessons.

Although the Pictorial Memory task did not improve as a function of music instruction, the MANOVA revealed a significant interaction between group and time for this variable. This interaction was caused by a slight (insignificant) decrease in the no music group's scores after 4 months of instruction, followed by a significant increase after 8 months, as predicted. Although the keyboard and no music groups did not differ for any testing period, the nonlinear pattern of results for the no music group produced the interaction. Because the dip in scores for the no music group was not significant (t = 1.55, $p > .05$), it is unlikely that this interaction suggests a meaningful trend.

These data support Leng and Shaw's (1991) hypothesis that early music training enhances spatial–temporal reasoning and are consistent with studies that found improved spatial–temporal task scores in preschoolers after music instruction (Gromko & Poorman, 1998; Mallory & Philbrick, 1995; Rauscher et al., 1994, 1997). Costa-Giomi's (1999) findings were also supported. However, unlike previous studies the children in the present study were provided with the lessons in groups of 10 rather than individually. It seems that private lessons are not needed to induce the enhancement, an important financial consideration for researchers planning further studies in this area.

Although these findings would be strengthened by the inclusion of a control group receiving lessons in something other than music, we suggest that the between-group uniformity of Pictorial Memory scores (see Table 2) minimizes the presence of a Hawthorne effect for the spatial-temporal tasks. Furthermore, Rauscher et al. (1994, 1997) found no differences between effects observed in prior studies conducted both with and without the inclusion of an additional control. Nevertheless, further work is needed to eliminate this alternative explanation.

Deriving implications for practice from these experimental data has its pitfalls because this study was designed with an eye towards determining the parameters of a scientific effect rather than with an eye towards application. The picture portrayed by these data are of children who score significantly higher on mathematically relevant tasks after only 4 months of classroom keyboard lessons, a trend that increased over time. This finding has strong implications for educators. However, several pedagogical questions remain unanswered.

First, the optimal age to begin the training is unknown. Whereas effects have been demonstrated for both preschoolers and 9-year-olds, no studies have determined differences in effect size for these age groups. Although we expect to find the enhancement throughout early childhood, younger children's (≤3 years) cortical plasticity (Rakic, 1997) may induce the largest effects. A cross-sectional study in which children are administered the same tasks would help resolve this.

Second, little is known regarding the duration of the enhancement. Although studies have found that the effect lasts at least 1 day (Rauscher et al., 1997), curricular applications can only be derived if persistent effects are demonstrated. Rauscher, Robinson, and Jens (1998) found that early music exposure can induce long-term improved spatial performance in rats. If this improvement was precipitated by anatomical alterations in the brain's spatial processing sites, as recent pilot data suggest (Rauscher & Koch, 1999), it is possible that the effects reported for the children are also neuroanatomically induced. Longitudinal studies are needed to determine whether the behavioral effects found for children are lasting, as were those found for the rats. It is also important to learn if the enhancement remains after termination of the lessons. Gardiner et al. (1996) found that the number of years of music and arts training was positively correlated with math achievement. Perhaps extensive instruction is required for optimal effects on brain development and learning.

Third, little is known regarding the contributions of either the curriculum or musical instrument. Previous studies have explored the effect of keyboard lessons or songbells on spatial-temporal reasoning (Costa-Giomi, 1999; Gromko & Poorman, 1998; Mallory & Philbrick, 1995; Rauscher et al., 1994, 1999). The keyboard confers a linear relationship of the spatial distances between the pitches aurally, visually, and motorically (Rauscher et al., 1997). Perhaps any instrument (e.g., xylophone, songbells) providing spatial information across modalities is suitable. A child playing (for example) a cello, tuned in fifths, is not privy to this type of linear feedback. Alternatively, it is possible that training in music, regardless of the medium, is the catalyst. Indeed, unlike previous studies the curriculum used in the present study incorporated several components of musical instruction along with the keyboard training, including singing, movement, ear training, music literacy, and solfege. Moving to music involves, among other things, the integration of kinesthetic and aural abilities. Learning to read music involves symbolic reasoning and planning skills. It may be that proficiency in some or all of these musical activities is integral to improved spatial-temporal task performance. A limitation of the current study's design is that it did not address the relative contributions of individual musical activities, making it impossible to attribute the enhancements to any one aspect of the curriculum, including keyboard instruction. Studies exploring the effect by isolating the various components of music instruction are clearly needed.

Finally, although significant correlations have been found between spatial-temporal task performance and mathematical ability (Gordon, 1997), studies are needed to determine whether music affects mathematical reasoning as it affects spatial-temporal reasoning, as Gardiner's (1996) study suggests. A study by Shaw et al. (Graziano, Peterson, & Shaw, 1999) addressed this hypothesis. The researchers compared the proportional reasoning abilities of second-grade children assigned to four groups: (1) keyboard instruction coupled with exposure to a computer game designed to develop spatial-temporal reasoning; (2) English instruction coupled with the same spatial-temporal training; (3) spatial-temporal training only; (4) no treatment. Results indicated that the proportional reasoning scores of the children whose treatment included the music instruction was significantly higher than that of the children in the other groups. This suggests that music instruction may enhance proportional reasoning relating to certain mathematical abilities, such as understanding fractions and ratios, and confirms the role of spatial–temporal reasoning in some mathematical operations (Gordon, 1997).

By demonstrating music-induced enhancement of spatial-temporal task performance in two public elementary schools, this study greatly broadens the range of potential application. Whereas prior studies using the keyboard have demonstrated enhancements through private instruction (Costa-Giomi, 1999; Rauscher et al., 1994, 1997), this research showed that enhancements are achievable through class instruction, strengthening the case for the inclusion of music in the classroom curriculum. The impact of the music instruction was immediate, beginning after only 4 months of instruction and increasing with the duration of instruction. Although there are several hypotheses remaining for investigation, the effects found in this study were large enough and persistent enough to encourage further work on the relationship between music education and cognitive development. We urge the commencement of "educational trials," as recommended by Weinberger (1998), to "bring theory, from academia, and practice, in the front lines of the schools, together in an equal partnership on a large scale"(p. 34). Care must be taken, however, to ensure that scientific goals do not displace developmentally appropriate instruction. Consistent with recent recommendations of the National Association for the Education of Young Children (Bredekamp & Copple, 1997), a position statement containing guidelines for the establishment of age-appropriate music curriculum has been published by the Music Educator's National Conference ([MENC] ,1994). MENC recommended a focus on singing, listening, movement, instrumental instruction, creativity, and music literacy as well as the development of musical knowledge of melody, rhythm, timbre, and form. Musical play is also highly recommended, as is the encouragement of individual creativity. Kenney (1997) outlined specific teaching strategies relevant to these instructional goals for newborns to children age 8. We encourage scientists and educators to attend carefully to these guidelines when considering the application of these research findings.

Although we feel this research is an important step toward understanding the extramusical benefits of music instruction in public school settings, further systematic research is needed to investigate how music education relates to other academic areas. For many children, particularly the disadvantaged, the quality of an elementary public school education can mean the difference between success and failure in life. We suggest that research exploring the effects of music instruction on cognitive development can contribute to the academic and social welfare of these children.

Acknowledgment: We thank all the administrators and teachers whose interest and support made this work possible. We are especially grateful to Sarah Jerome for her dedication and encouragement, to Lori Custodero and Margaret Fiedler for their musical expertise, to Megan Sorenson for assistance with testing the children, and to James E. Koch and Robert Newcomb for reviewing earlier drafts of this manuscript. We are also grateful for the helpful comments of Craig H. Hart and three anonymous reviewers.

NOTES

1. Information on curriculum is available from Mary Anne Zupan at Wales Elementary, 219 Oak Crest Drive, P.O. Box 130, Wales, WI 53183.
2. Pretesting was conducted solely by Mary Anne Zupan; the 4-month testing session was conducted by Mary Anne Zupan aided by a colleague; the 8-month testing session was conducted by the colleague alone.
3. Please note that the Puzzle Solving and Block Building tasks are reverse scored, resulting in negative correlations.

REFERENCES

Arnheim, R. (1969). *Visual thinking.* Berkeley: University of California Press.

Barlow, H. B. (1961). Possible principles underlying the transformation of sensory messages. In S. W. Rosenblith (Ed.), *Sensory Communication* (pp. 217–234). Cambridge, MA: MIT Press.

Barret, H., & Barker, H. (1973). Cognitive pattern perception and musical performance. *Perceptual and Motor Skills, 36,* 1187–1193.

Bereiter, C. (1963). Some persisting dilemmas in the measurement of change. In C. W. Harris (Ed.), *Problems in measuring change* (pp. 35–52). Madison, WI: University of Wisconsin Press.

Biederman, I. (1987). Recognition by components: A theory of human image understanding. *Psychological Review, 94,* 115–147.

Bredekamp, S., & Copple, C. (Eds.). (1997). *Developmentally appropriate practice in early childhood programs: Revised edition.* Washington, DC: National Association for the Education of Young Children.

Costa-Giomi, E. (1999). The effects of three years of piano instruction on children's cognitive development. *Journal of Research in Music Education, 47*(5), 198–212.

Elliot, J. (1980). Classification of figural spatial tests. *Perceptual and Motor Skills, 51,* 847–851.

Elliot, J., & Smith, I. M. (1983). *An international directory of spatial tests.* Windsor, UK: NFER-Nelson.

Gardiner, M. F., Fox, A., Knowles, F., & Jeffrey, D. (1996). Learning improved by arts training. *Nature, 381,* 254.
Gardner, H. (1983). *Frames of mind.* New York: Basic Books.
Gardner, H. (1993). *Multiple intelligences: The theory in practice.* New York: Basic Books.
Gardner, H. (1997). Is musical intelligence special? In V. Brummett (Ed.), *Ithaca Conference '96: Music as Intelligence* (pp. 1–12). Ithaca, New York: Ithaca College Press.
Gordon, L. (1997). *Relationships between spatial reasoning and mathematical ability.* Unpublished manuscript.
Graziano, A., Peterson, M., & Shaw, G. L. (1999). Enhanced learning of proportional math through music training and spatial-temporal training. *Neurological Research, 21,* 139–152.
Gromko, J. E., & Poorman, A. S. (1998). The effect of music training on preschooler's spatial-temporal task performance. *Journal of Research in Music Education, 46,* 173–181.
Halpern, D. F. (1992). *Sex differences in cognitive abilities* (2nd ed.). Hillsdale, NJ: Erlbaum.
Hassler, M., Birbaumer, N., & Feil, A. (1985). Musical talent and visual-spatial abilities: A longitudinal study. *Psychology of Music, 13,* 99–113.
Hebb, D. O. (1949). *The organization of behavior.* New York: Wiley.
Hughes, J. R., Daaboul, Y., Fino, J. J., & Shaw, G. L. (1998). The "Mozart Effect" on epileptiform activity. *Clinical Electroencephalography, 29,* 109–119.
Johnson-Laird, P. N. (1983). *Mental models.* Cambridge, MA: Cambridge University Press.
Kalmár, M. (1982). The effects of music education based on Kodaly's directives in nursery school children—from a psychologist's point of view. *Psychology of Music Special Issue* (pp 63–68).
Kenney, S. H. (1997). Music in the developmentally appropriate integrated curriculum. In C. H. Hart, D.C. Burts, & R. Charlesworth (Eds.), *Integrated curriculum and developmentally appropriate practice* (pp 103–144). Albany, NY: SUNY Press.
Kritchevsky, M. (1988). The elementary spatial functions of the brain. In J. Stiles-Davis, M. Kritchevsky, & U. Bellugi (Eds.), *Spatial Cognition: Brain Bases and Development* (pp. 111–140). Hillsdale, NJ: Lawrence Erlbaum Associates.
Krumhansl, C. L. & Jusczyk, P. W. (1990). Infants' perception of phrase structure in music. *Psychological Science, 1,* 70–73.
Learning Accomplishment Profile Standardized Assessment. (1992). Louisville, NC: Kaplan Press.
Leng, X., & Shaw, G. L. (1991). Toward a neural theory of higher brain function using music as a window. *Concepts in Neuroscience, 2,* 229–258.
Linn, M. C., & Peterson, A. C. (1985). Emergence and characterization of sex differences in spatial ability. *Child Development, 56,* 1479–1498.
Linn, R. L., & Slinde, J. A. (1977). The determination of the significance of change between pre- and posttesting periods. *Review of Educational Research, 47,* 121–150.
Mallory, M. E., & Philbrick, K. E. (1995, June). *Music training and spatial skills in children.* Paper presented at the meeting of the American Psychological Society, New York.
Manturzewska, M. (1978). Psychology in the music school. *Psychology of Music, 6,* 36–47.
McCarthy, D. (1972). *McCarthy scales of children's abilities.* San Antonio, TX: The Psychological Corporation.
McGee, M. G. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin, 86,* 889–918.
Music Educators National Conference. (1994). *The school music program: A new vision.* Music Educators National Conference: Reston, VA.
Newsome, W. T., Britten, K. H., & Movshon, J. A. (1989). Neuronal correlates of a perceptual decision. *Nature, 341,* 52–53.
Nicolopoulou, A. (1988). Interrelation of logical and spatial knowledge in preschoolers. In J. Stiles-Davis, M. Kritchevsky, & U. Bellugi (Eds.), *Spatial cognition: Brain bases and development* (pp. 207–230). Hillsdale, NJ: Lawrence Erlbaum Associates.
Olsho, L. W., Schoon, C., Sakai, R., Turpin, R., & Sperduto, V. (1982). Auditory frequency discrimination in infancy. *Developmental Psychology, 18,* 721–726.
Papousek, M. (1982, March). *Musical elements in mother-infant dialogues.* Paper presented at the International Conference on Infant Studies, Austin, TX.

Rakic, P. (1997). Corticogenesis in human and nonhuman primates. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 127–145). Cambridge, MA: MIT Press.

Rauscher, F. H. (1999). *Enhancing abstract reasoning in disadvantaged children.* Unpublished raw data.

Rauscher, F. H., & Koch, J. E. (1999). *The effects of exposure to music on spatial processing sites in rats.* Unpublished raw data.

Rauscher, F. H., Robinson, K. D., & Jens, J. J. (1998). Improved maze learning through early music exposure in rats. *Neurological Research, 20,* 427–432.

Rauscher, F. H., & Shaw, G. L. (1998). Key components of the Mozart effect. *Perceptual and Motor Skills, 86,* 835–841.

Rauscher, F. H., Shaw, G. L., Levine, L. J., Ky, K. N., & Wright, E. L. (1994, August). *Music and spatial task performance: A causal relationship.* Paper presented at the meeting of the American Psychological Association, Los Angeles, CA.

Rauscher, F. H., Shaw, G. L., Levine, L. J., Wright, E. L., Dennis, W.R., & Newcomb, R. L. (1997). Music training causes long-term enhancement of preschool children's spatial-temporal reasoning. *Neurological Research, 19*(1), 1–8.

Rideout, B. E., & Laubach, C. M. (1996). EEG correlates of enhanced spatial performance following exposure to music. *Perceptual and Motor Skills, 82,* 427–432.

Rosenzweig, M. R., & Bennett, E. L. (1996). Psychobiology of plasticity: Effects of training and experience on brain and behavior. *Behavioral Brain Research, 76,* 57–65.

Sarnthein, J., von Stein, A., Rappelsberger, P., Petsche, H., Rauscher, F. H., & Shaw, G. L. (1997). Persistent patterns of brain activity: An EEG coherence study of the positive effect of music on spatial-temporal reasoning. *Neurological Research, 19*(April), 107–116.

Tunks, T. W. (1992). The transfer of music learning. In R. Colwell (Ed.), *Handbook of research on music teaching and learning* (pp. 437–447). New York: Schirmer Books.

Weinberger, N. (1998). Brain, behavior, biology, and music: Some research findings and their implications for educational policy. *Arts Education Policy Review, 99,* 28–36.

Music Exposure and the Development of Spatial Intelligence in Children

Frances H. Rauscher
University of Wisconsin
Oshkosh, Wisconsin

A serious challenge facing music cognition researchers is the problem of how to fit the discipline into traditional theories of child development, theories that do not easily account for the huge range of reasoning and behaviors used by people performing musical activities. In *Frames of Mind*, Howard Gardner (1983) has drawn from a wide body of knowledge to provide us with a new framework for thinking about cognition—a framework that holds a special place for music. Musical ability is seen as its own discrete domain of intelligence, not particularly associated with linguistic, mathematical, or spatial intelligence.

However, despite the fact that music appears to be a distinct area of learning that may be unrelated to other developmental accomplishments of young children, musical abilities and certain spatial abilities do seem to be allied. It seems that musical experiences, perhaps due to neurophysiological mechanisms, can help develop a small but important facet of spatial ability in adults, children, and even in rats. This paper presents my colleagues' and my recent research on the effects of music instruction on a specific type of spatial reasoning, spatial-temporal reasoning, in children.

Neurophysiological Insights

Leng and Shaw's (1991) structured neuronal model of cortex proposes that certain neural firing patterns organized in a complex spatial-temporal code over large regions of cortex are exploited by both musical and spatial reasoning tasks. "We see the brain's innate ability to relate (through symmetry operations) patterns developing in space and time as the unifying physiological mechanism" (Shaw, 1999, p. xv). Based on their model, Leng and Shaw (1991) predicted that music training could strengthen the neural firing patterns used in both music and spatial-temporal tasks through Hebbian (1949) learning principles. Music instruction provided to young children, they proposed, should enhance spatial-temporal task performance.

Knowledge regarding the development and plasticity of the young child's brain (Huttenlocher, 1984; Johnson & Gilmore, 1996; Rakic, 1997) is highly relevant to Leng and Shaw's (1991) hypothesis. At birth, most of the brain's 100 billion neurons are not yet connected in networks. Connections among neurons are formed extremely rapidly in the early years of life as the growing child experiences and forms attachments to the surrounding world. If these synapses are used repeatedly in the child's day-to-day life, they are reinforced and become part of the brain's permanent circuitry. If they are not used repeatedly, or often enough, they are gradually eliminated during the second decade of life (Huttenlocher, 1984). In this way, as a child grows, an overabundance of connections gives way to a complex, powerful system of neural pathways. How the child thinks and learns appears to depend largely on the nature and extent of these pathways.

Rauscher, Shaw, Levine, & Wright, 1993. Ten 3-year-old children enrolled in either a middle-income school or a school for at-risk children participated. We pre-tested spatial-temporal and spatial recognition skills using a sub-test from an age-standardized intelligence test (Wechsler Preschool and Primary Scale of Intelligence-Revised). We then provided music training for nine months, and post-tested their spatial reasoning skills. Findings indicated that the spatial-temporal scores of the children following music training improved by an average of 47% compared to national norms. The at-risk children improved by 91%. Spatial recognition scores did not improve. However, the small sample size and lack of control groups restricted us from drawing strong conclusions from these data.

Rauscher, Shaw, Levine, Ky, & Wright, 1994. Nineteen 3-year-olds (music group) received 8 months of music lessons; 14 3-year-olds (control group) received no lessons. We pre-tested the children's spatial-temporal and spatial recognition skills, again using the WPPSI-R. The children were then provided with weekly piano keyboard lessons and daily singing sessions for 8 months. We then post-tested the children's spatial skills. The music group's spatial-temporal scores were significantly higher following training compared to the control group. Again, spatial recognition scores did not improve for either group.

One might reasonably argue that the improvement of scores for the music group is because of a Hawthorne effect. (The Hawthorne Effect is the generalization that anything new works: new programs, new curricula, etc.—at least for a little while. The existence of the Hawthorne Effect makes a true evaluation of any new program a difficult affair.) We believed that the lack of significant improvement of the *other* tasks (the spatial recognition tasks) made this alternative explanation unlikely. However, we increased our fund-raising efforts and were finally able to include a group of children who received computer instruction, rather than music instruction, to control for this possibility.

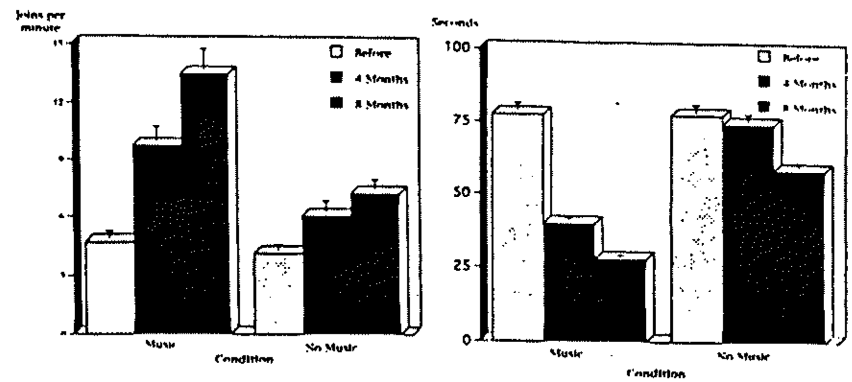
Rauscher, Shaw, Levine, Wright, Dennis, & Newcomb, 1997. We pre-tested the spatial-temporal and spatial recognition skills of 78 children using the WPPSI-R, and then assigned them to one of four conditions. Thirty-four children received 8 months of piano lessons along with casual daily singing; 10 children participated in the singing sessions only; 20 children received computer lessons; 14 children received no lessons. Keyboard and computer lessons were matched in frequency and duration. Post-testing revealed that the spatial-temporal task scores of the keyboard group were significantly higher compared to those of the children who received computer lessons, casual singing, or no lessons. The scores of the children in these three latter groups did not differ. Spatial recognition scores did not improve for any group.

Ongoing research. Our next goal was to determine if the effects we were finding with preschoolers through private instruction could be achieved in the chaotic setting of the public school classroom using group instruction. The study outlined below reports data showing that kindergarten children who were exposed to keyboard lessons in a hectic classroom environment improved significantly on two spatial-temporal tasks administered. A test of pictorial memory did not improve following lessons.

Rauscher & Zupan, in press. Sixty-two Kindergarten children participated. Thirty-four children received 8 months of keyboard lessons (music group); 28 children received no lessons (no lessons group). We pre-tested the spatial-temporal skills and pictorial memory of all children, and then provided bi-weekly 20-min keyboard lessons to the music group in groups of eight to ten. The lessons continued for 8 months. We post-tested the children at four month intervals. The spatial-temporal task scores of children who received music training were 48% higher after eight months of instruction than those of the children who did not receive music training. Pictorial memory scores did not differ.

Further details of the Rauscher and Zupan (in press) study are given to provide context for a follow-up study reported next. Four kindergarten classrooms from two public elementary schools took part. The curriculum, developed by Lori Custodero of Columbia University Teachers College, consisted of (a) movement to the musical material based on pitch and rhythmic structure; (b) association of fingers and numbers (for identification purposes); (c) creative projects; (d) association of keyboard geography with sung musical pitches; (e) playing tunes by ear; (f) playing tunes by reading simple contours, leading to music literacy; (g) ear training and improvisation games (rhythmic and melodic).

Prior to the instruction, all children were pre-tested with two spatial-temporal tasks, Puzzle Solving and Block Building, and one other task, Pictorial Memory. As before, we predicted improvement only for the spatial-temporal tasks, Puzzle Solving and Block Building. We did not expect Pictorial Memory to improve as a function of lessons. There were two post-testing sessions, spaced four months apart. Figure 1 presents the data for the two spatial-temporal tasks, Puzzle Solving and Block Building. To obtain a score for the Puzzle Solving task we divided the number of correctly joined puzzle pieces by the number of minutes taken to complete each puzzle. The higher the score, the better the performance. For Block Building we tabulated the total number of seconds taken to complete the structure. The lower the score, the better the performance. For both tasks, the children who received the lessons scored significantly higher than the children who did not. After training, their scores had improved significantly.



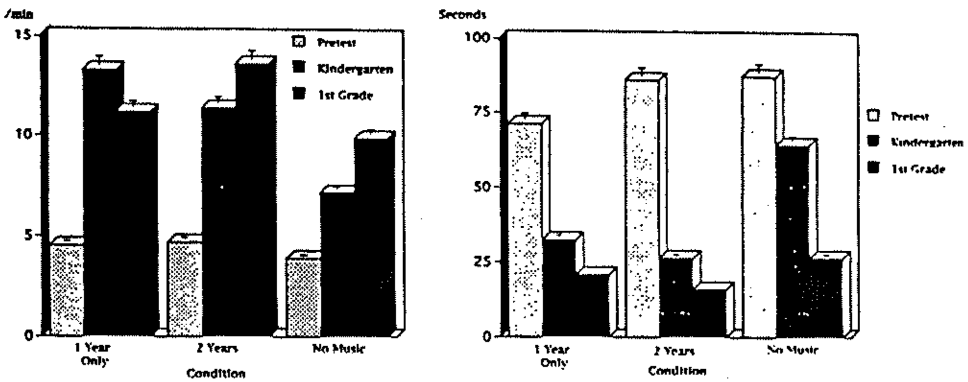
Puzzle solving

Block building

Figure 1. Puzzle solving and block building scores for the music and no music conditions before, four months, and eight months after treatment.

These data indicate that kindergarten children who were provided with just 4 months of lessons scored 42.5% higher than the children who did not receive lessons. After 8 months the average difference between the groups for these tasks was 48%. The music group improved by 63% following lessons, whereas the no music group improved by only 33.5%. As predicted, the difference between the scores on the Pictorial memory task for the two groups of children was not significant.

The following year the school district continued to provide keyboard instruction to some children in the first grade. Logistics of classroom assignment left us with three groups of children to re-test. Fourteen children had received music instruction for one year, and were then graduated to a first-grade classroom in which the instruction was not provided (one year only group). Seventeen children received the keyboard instruction for 2 years, in both kindergarten and first grade (2 years group), and seventeen children received no music instruction at all (no music group). All children were re-tested after completing the first grade. Figure 2 shows the data for the Puzzle Solving and Block Building tasks.



Puzzle solving   Block building

Figure 2. Puzzle solving and block building scores for children in the 1-year, 2-year, and no music training conditions.

Analyses of variance followed by Scheffé tests revealed significant differences between the groups. The Puzzle Solving scores of the children who received music training in kindergarten only (one year only group) were significantly lower when tested one year after their lessons were terminated. In fact, after one year their scores were not significantly different from those of the children who received no lessons. However, the scores of the children who continued lessons through the second year (2 years group) increased significantly. Finally, the children who received no lessons showed only the improvement one would expect from age.

The Block Building task showed no significant improvement for either the one year only or the two years groups, although the trends were in the expected direction. This may be due to a ceiling effect. As with the Puzzle Solving task, the no music group continued to improve with age. These data suggest that the effects found by Rauscher & Zupan (in press) for Block Building were not maintained. We hope to follow these children over a period of years using different age-appropriate tests.

A similar study was conducted at Franklin Elementary School in Oshkosh, Wisconsin. To control for the Hawthorne Effect, this study compared a keyboard training group to a control group of children who received special reading instruction instead of no lessons. The dependent variable was a computer animated software program (FISH™) designed by Matthew Peterson of the University of California Berkeley to measure proportional reasoning.

Participants were 66 Kindergarten children. We pre-tested the children's proportional reasoning skills using a computer animated assessment program (FISH™). We then provided weekly 40-min keyboard lessons to 35 children in groups of eight to ten. 31 children received the animated reading instruction for eight months. We then post-tested all the children. The data are graphed in Figure 3 (Rauscher, 1999).

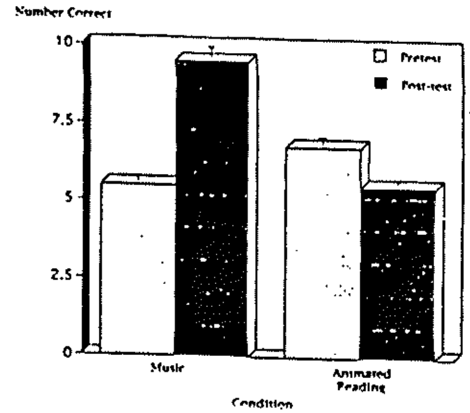


Figure 3. STAR™ scores for children in music and animated reading conditions.

An analysis of covariance performed on the children's post-test scores (with pre-test entered as the covariate) found a main effect for condition ($F_{(1, 63)} = 11.31$, $p = .001$). Scheffé tests revealed that the children in the music group scored significantly higher following the music instruction, whereas those in the reading group actually scored lower, although the decrease was not significant. After the instruction, the music group scored 42% higher than the reading group. This study is currently being replicated and extended.

The enhancing effect of music instruction on spatial-temporal task abilities in young children has been found by other researchers as well (Costa-Giomi, 1998; Graziano, Peterson, & Shaw, 1999; Gromko & Poorman, 1998; Hurwitz, Wolff, Bortnick, & Kokas, 1975; Mallory and Philbrick, 1995), and we are confident that these effects are robust. However, very little is known regarding the nature of the effect. One approach to examining the nature of the relationship between music and spatial-temporal reasoning is to analyze the cognitive requirements that they share. According to Whohlwill (1973), the most fruitful new efforts of this sort begin by offering descriptions of dimensions—in this case, those of the cognitive skills used in musical performance and in spatial-temporal reasoning, as found in the tasks which were enhanced.

Researchers have proposed several theories to describe the cognitive skills involved in music and in other abilities (Dillon & Sternberg, 1986; Perkins, 1989; Serafine, 1988). Space limitations do not permit an extensive review of these theories. My approach to the problem focuses on extending Serafine's (1988) analysis of the cognitive skills in music to an analysis of spatial-temporal skills. In brief, Serafine describes *temporal processes* (succession and simultaneity) and *nontemporal processes* (closure, transformation, abstraction, and hierarchical levels) as the central measures of the cognitive skills in music. I would add mental imagery as a skill that is also essential to musical performance.

The goals of the ongoing study presented below are to determine if music training can significantly improve the abstract reasoning of economically disadvantaged preschoolers, and to understand why spatial-temporal tasks improve after music lessons whereas other spatial tasks do not. Data are being analyzed from the first 2 years of a 5-year study currently being conducted at 10 Head Start sites located throughout northeast Wisconsin.

Head Start is a federal local matching grant program intended to improve the skills of economically disadvantaged children, so that they can begin schooling on an equal footing with their more advantaged peers. The program began in 1964 as part of the War on Poverty, and it now serves over 700,000 children in predominantly part day programs, or roughly 30% of eligible 3- to 5-year-olds. Most recently, President Clinton has proposed increasing the number of children served to 1 million by the year 2000.

The 5-year study has three main goals: (a) to identify the specific cognitive processes that are enhanced by music training; (b) to determine the properties of the music training that are responsible for these effects; (c) to determine the extent, durability and generalizability of these effects. To address the first goal, during the first 2 years of the study we assessed the tasks on which children display enhanced performance after piano keyboard training. We tested an extremely broad array of cognitive abilities, started providing piano versus computer versus no lessons, and are in the process of re-testing the children's cognition. The second 2 years of the study will address the second goal. We will vary the type of music training the children receive by providing them with keyboard lessons, rhythm instrument lessons, or singing lessons. And finally, toward the last goal, we will follow the children into their public schools, re-test them, test their middle income peers, and assess academic achievement. Over 5 years the study will involve over 400 Wisconsin children. We have completed the first 2 years of the study (Rauscher & LeMieux, 1999).

We began by pre-testing 120 three-year-old Head Start children's spatial abilities and musical achievement. By the end of the second year of the study, we had lost 32 children to attrition, leaving us with 87 children to re-test. Of these, 32 were randomly assigned to a keyboard group, 29 received computer instruction, and 26 received no special training for a period of 48 weeks. The instruction was provided individually at the Head Start schools. We then re-tested all the children.

We used several age-standardized tests: The Kaufman Assessment Battery for Children (KABC), the Developmental Test of Visual Perception, the Test of Auditory Perceptual Skills, the WPPSI, which we had used earlier, and Ed Gordon's Primary Measures of Music Audiation. We have thus far analyzed only the data from the KABC, of which we administered all sub-tests appropriate for 3-year-olds, totaling nine:

1. The **Hand Movements** task requires the person to copy a precise sequence of taps on the table with the fist, palm, or side of the hand. It measures aspects of motor functioning. Success is usually contingent upon a good attention span and concentration.
2. The **Number Recall** task measures the child's ability to repeat in sequence a series of numbers spoken by the examiner.
3. The **Magic Window** task is a spatial-temporal task. It measures the ability to identify and name an object whose picture is rotated behind a narrow slit, so that the picture is only partially exposed at any given point in time. It supposedly measures cerebral hemispheric integration, because it involves a complex integration of spatial information presented temporally.
4. The **Face Recognition** task involves selecting from a group photograph the one or two faces that were exposed briefly on the preceding page.
5. **Gestalt Closure** measures the child's ability to mentally "fill in the gaps" in a partially completed inkblot drawing, and to name and describe the drawing. It measures the child's ability to convert an abstract stimulus into a concrete object
6. **Expressive Vocabulary** measures the child's ability to state the correct name of objects pictured in photographs.
7. **Faces and Places** has the child naming a fictional character or place, such as Snow White, as seen in a photograph.
8. The **Arithmetic** sub-test demonstrates the child's knowledge of numbers and mathematical concepts, counting and computational skills, and other school-related math abilities.
9. The **Riddles** sub-test has the child infer the name of a concrete or abstract concept when given a list of its characteristics.

Preliminary analyses revealed that four of the sub-tests we administered, Magic Window, Gestalt Closure, Hand Movements, and Arithmetic, improved significantly following music training. These data are graphed in Figure 4. Five sub-tests, Number Recall, Face Recognition, Expressive Vocabulary, Faces and Places, and Riddles did not improve significantly.

Three of the tasks that did improve following training, Magic Window, Gestalt Closure, and Arithmetic, lend themselves remarkably well to Serafine's (1988) analysis of musical reasoning, particularly regarding the *nontemporal* processes of closure, transformation, and abstraction. (Improvement of the Hand Movements task may be due to enhanced motor control produced by the music instruction.) The puzzle tasks that were enhanced in previous studies also involve these processes, as well as the *temporal* process of succession she describes. These tasks also rely heavily on mental imagery skills. I suggest that it is these abstract qualities that make spatial-temporal tasks susceptible to enhancement through music training.

The tasks that failed to improve following music instruction do not lend themselves well to her analysis. Although Leng and Shaw's (1991) neural model of higher brain function provides a viable neurophysiological explanation for the transfer effects we are observing, I suggest that Serafine's model (1988) provides a useful framework for understanding the cognitive mechanisms involved. We anticipate our forthcoming analysis of the other cognitive and perceptual tests we administered to yield a better understanding regarding the nature of these transfer effects.

We suggest that the following (tentative) conclusions may be drawn from the studies presented here:

1. Music instruction enhances spatial-temporal abilities in children.
2. The effects are found for children as "old" as five years, perhaps older.
3. One year of instruction is probably not enough for long-term-enhancement
4. The effects in young children may be limited to spatial imagery tasks which can be described by the terms Serafine (1988) used to describe the *temporal* and *nontemporal* processes of musical knowledge.

I conclude with some final thoughts on what these types of studies might mean for music advocacy, followed by a quote from a source unknown to me.

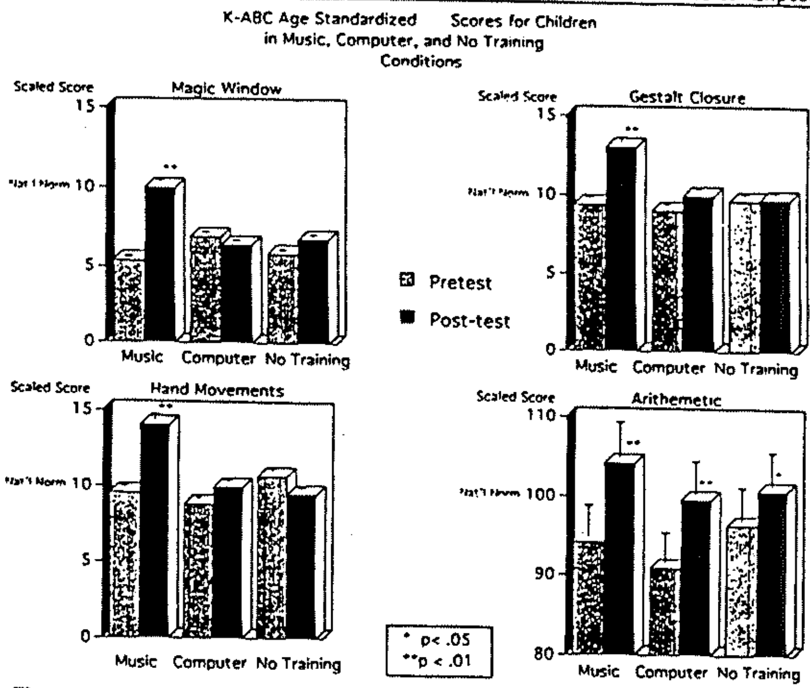


Figure 4. Magic Window, Gestalt Closure, Hand Movements, and Arithmetic scores for children in music, computer, and no training conditions.

The recent flurry of excitement over the extra-musical benefits of music instruction comes at a time when public school administrators are being forced to justify their public school music programs in order to prevent these programs' annihilation. These studies are sometimes being cited to support the claim that music is important. The thinking is that if music instruction can be shown to have extra-musical benefits, then perhaps school boards will keep their music programs around a bit longer, in the hope that these programs will improve their students' scores in other academic areas.

Although I feel strongly that it is at the least disgraceful and at worse dangerous to have to justify music's inclusion in the public school curriculum by citing *only* its extra-musical benefits, I suggest that an argument in favor of music in the curriculum based *only* on its artistic benefits is equally dangerous. Such an argument is going to seem absurd to most administrators, faced with the budget cuts that they are faced with these days, and is sadly ineffectual. Fewer than 25% of all 8th-grade students participate in music making activities of any kind, including singing (R. Morrison, personal communication, March 5, 1999).

Although many music educators and others are outraged (and rightly so) that the justification for music may lie in research revealing its extra-musical benefits, I believe that to exclude these studies from discussions arguing for music in the schools is to "cut off one's nose to spite one's face." Even worse, to ignore such findings is to do a disservice to the children whose lives will be affected when music programs are eliminated. Economically disadvantaged children, whose caregivers can often afford neither the time nor the money to provide their children with music instruction, stand to lose the most from the elimination of school music programs. Yes, there is much more research

needed to provide converging evidence and no, music is not a panacea for poor academic achievement. However, it seems clear that music has benefits to intellectual development that transcend music itself. I suggest that music education is important for optimal development, and that we use all available information to ensure a quality education for our children.

> Whether by voice or by instrument, musical performance requires physical control and precision of a high order. A child working at mathematics or a language can sit back, mentally, for minutes before facing difficulty. The same child, singing or playing a part, must both obey exactly and artistically the present behests of the music, and at the same time think ahead to prepare himself to deal equally faithfully with what is coming. In no other subject is a child called upon to make four or five decisions a second and act on them continuously for such stretches of time. This combination of constant, continuous vigilance and forethought with ever-changing physical responses constitutes an educational experience of unique value. Moreover, by its nature and traditions, the art lends itself more readily than most activities to the pursuit of excellence, to which there is no nobler aim of education.

—Author unknown

References

Costa-Giomi, E. (1998, April). *The McGill Piano Project: Effects of three years of piano instruction on children's cognitive abilities, academic achievement, and self-esteem.* Paper presented at the Meeting of the Music Educators National Conference, Phoenix, AZ.

Deutsch, D. (1975). Musical illusions. *Scientific American, 233*, 92–104.

Dillon, R. F., & Sternberg, R.J. (1986). *Cognition and instruction.* San Diego: Academic Press.

Elbert, T., Pantev, C., Wienbruch, C., Rockstrub, B., & Taub, E. (1995). Increased cortical representation of the fingers of the left hand in string players. *Science, 270*, 305–307

Elliot, J. (1980). Classification of figural spatial tests. *Perceptual and Motor Skills, 51*, 847–851.

Elliot, J., & Smith, I.M. (1983). *An international directory of spatial tests.* Windsor, UK: NFER-Nelson.

Gardner, H. (1983). *Frames of mind.* New York: Basic Books.

Graziano, A., Peterson, M., & Shaw, G.L. (1999). Enhanced learning of proportional math through music training and spatial-temporal training. *Neurological Research, 21*, 139–152.

Gromko, J. E., & Poorman, A.S. (1998). The effect of music training on preschooler's spatial-temporal task performance. *Journal of Research in Music Education, 46*, 173–181.

Hebb, D.O. (1949). *The organization of behavior.* New York: Wiley.

Hurwitz, I., Wolff, P. H., Bortnick, B. K., & Kokas, K. (1975). Nonmusical effects of the Kodaly music curriculum in primary grade children. *Journal of Learning Disabilities, 8*(3), 167–174.

Huttenlocher, P. R. (1984). Synapse elimination and plasticity in developing human cerebral cortex. *American Journal of Mental Deficiency, 88*, 488–496.

Johnson, M. H., & Gilmore, R. O. (1996). Developmental cognitive neuroscience: A biological perspective on cognitive change. In R. Gelman & T. Au (Eds.), *Handbook of perception and cognition: Perceptual and cognitive development.* Orlando, FL: Academic Press.

Kritchevsky, M. (1988). The elementary spatial functions of the brain. In J. Stiles-Davis, M. Kritchevsky, & U. Bellugi (Eds.), *Spatial Cognition: Brain Bases and Development* (pp. 111–140). Hillsdale, NJ: Lawrence Erlbaum Associates.

Krumhansl, C. L., & Jusczyk, P. W. (1990). Infants' perception of phrase structure in music. *Psychological Science, 1*, 70–73.

Leng, X., & Shaw, G. L. (1991). Toward a neural theory of higher brain function using music as a window. *Concepts in Neuroscience, 2*, 229–258.

Mallory, M. E., & Philbrick, K.E. (1995, June). *Music training and spatial skills in children*. Paper presented at the meeting of the American Psychological Society, New York.

McGee, M. G. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin, 86*, 889–918.

Nicolopoulou, A. (1988). Interrelation of logical and spatial knowledge in preschoolers. In J. Stiles-Davis, M. Kritchevsky, & U. Bellugi (Eds.), *Spatial cognition: Brain bases and development* (pp. 207–230). Hillsdale, NJ: Lawrence Erlbaum Associates.

Olsho, L. W., Schoon, C., Sakai, R., Turpin, R., & Sperduto, V. (1982). Auditory frequency discrimination in infancy. *Developmental Psychology, 18*, 721–726.

Pantev, C., Oostenveld, R., Engellen, A., Ross, B., Roberts, L. E., & Hoke, M. (1998). Increased auditory cortical representation in musicians. *Nature, 392*, 811–814.

Papousek, M. (1982, March). *Musical elements in mother-infant dialogues*. Paper presented at the International Conference on Infant Studies, Austin, TX.

Peretz, I., Kolinsky, R., Tramo, M., Labrecque, R., Hublet, C., Demeurisse, G., & Belleville, S. (1994). Functional dissociations following bilateral lesions of auditory cortex. *Brain, 117*, 1283–1301.

Perkins, D. (1989). Art as understanding. In H. Gardner & D. Perkins (Eds.), *Art, mind and education: Research from Project Zero* (pp. 111–131). Urbana: University of Illinois Press.

Rakic, P. (1997). Corticogenesis in human and nonhuman primates. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 127–145). Cambridge, MA: MIT Press.

Rauscher, F. H. (1999). [Musical enhancement of proportional reasoning in kindergarten children]. Unpublished raw data.

Rauscher, F. H., & Hayes, L. J. (1999). *The effects of music exposure on spatial-temporal task performance: Exploring task validity*. Manuscript submitted for publication.

Rauscher, F. H., & LeMieux, M. (1999). [Enhancing abstract reasoning in Head Start children.] Unpublished raw data.

Rauscher, F. H., & Shaw, G. L. (1998). Key components of the Mozart effect. *Perceptual and Motor Skills, 86*, 835–841.

Rauscher, F. H., & Zupan, M. A. (in press). Classroom keyboard instruction improves kindergarten children's spatial-temporal performance: A Field Experiment. *Early Childhood Research Quarterly*.

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature, 365*, 611.

Rauscher, F. H., Shaw, G. L. & Ky, K. N. (1995). Listening to Mozart enhances spatial-temporal reasoning: Toward a neurophysiological basis. *Neuroscience Letters, 185*, 44–47.

Rauscher, F. H., Shaw, G. L., Levine, L. J., & Wright, E. L. (1993). *Pilot study indicates music training of three-year-olds enhances specific spatial reasoning skills*. Paper presented at the 1st Economic Summit of the National Association of Music Merchants, Newport Beach, CA.

Rauscher, F. H., Shaw, G. L., Levine, L. J., Ky, K. N., & Wright, E.L. (1994, August). *Music and spatial task performance: A causal relationship*. Paper presented at the meeting of the American Psychological Association, Los Angeles.

Rauscher, F. H., Shaw, G. L., Levine, L. J., Wright, E. L., Dennis, W. R., & Newcomb, R. L. (1997). Music training causes long-term enhancement of preschool children's spatial-temporal reasoning. *Neurological Research, 19*(1), 1–8.

Rosenzweig, M. R., & Bennett, E.L. (1996). Psychobiology of plasticity: Effects of training and experience on brain and behavior. *Behavioral Brain Research, 76*, 57–65.

Schlaug, G., Jancke, L., Huang, Y., & Steinmetz, H. (1995). In vivo evidence of structural brain asymmetry in musicians. *Science, 267*, 699–701.

Serafine, M. L. (1988). *Music as cognition: The development of thought in sound*. New York: Columbia University Press.

Shaw, G. L. (1999). *Keeping Mozart in mind*. San Diego, CA: Academic Press.

Tunks, T. W. (1992). The transfer of music learning. In R. Colwell, (Ed.), *Handbook of research on music teaching and learning* (pp. 437–447). New York: Schirmer Books.

Wohlwill, J. F. (1973). *The study of behavioral development*. New York: Academic Press

Reprinted from

Neurological Research

Volume 19 Number 1 February 1997

Music training causes long-term enhancement of preschool children's spatial–temporal reasoning

Frances H. Rauscher, Gordon L. Shaw*, Linda J. Levine, Eric L. Wright†, Wendy R. Dennis‡ and Robert L. Newcomb#**

*Department of Psychology, University of Wisconsin, Oshkosh, WI, *Center for the Neurobiology of Learning and Memory and Department of Physics, **School of Social Ecology, Department of Psychology and Social Behavior, University of California, Irvine, †Irvine Conservatory of Music, ‡Department of Psychology, University of Southern California, Los Angeles, #School of Social Science, University of California, Irvine, CA, USA*

Predictions from a structured cortical model led us to test the hypothesis that music training enhances young children's spatial–temporal reasoning. Seventy-eight preschool children participated in this study. Thirty-four children received private piano keyboard lessons, 20 children received private computer lessons, and 24 children provided other controls. Four standard, age-calibrated, spatial reasoning tests were given before and after training; one test assessed spatial–temporal reasoning and three tests assessed spatial recognition. Significant improvement on the spatial–temporal test was found for the keyboard group only. No group improved significantly on the spatial recognition tests. The magnitude of the spatial–temporal improvement from keyboard training was greater than one standard deviation of the standardized test and lasted at least one day, a duration traditionally classified as long term. This represents an increase in time by a factor of over 100 compared to a previous study in which listening to a Mozart piano sonata primed spatial–temporal reasoning in college students. This suggests that music training produces long-term modifications in underlying neural circuitry in regions not primarily concerned with music and might be investigated using EEG. We propose that an improvement of the magnitude reported may enhance the learning of standard curricula, such as mathematics and science, that draw heavily upon spatial–temporal reasoning. [Neurol Res 1997; **19**: 2–8]

Keywords: Columnar cortical model; piano keyboard lessons; computer lessons; spatial recognition; educational implications; EEG

INTRODUCTION

Theoretical and empirical reports have suggested a relationship between musical and spatial reasoning abilities[1–6]. Leng and Shaw's model provides a neurobiological argument for a causal link between music and spatial–temporal reasoning[7]. Based on Mountcastle's[8] columnar[8–9] organizational principle for cortical function, the trion model[10–12] proposes that the inherent spatial–temporal firing patterns of highly structured, interconnected groups of neurons have the built-in ability to recognize, compare and find relationships among patterns[12]. This neural process may be responsible for the performance of spatial recognition tasks, such as classifying and recognizing physical similarities among objects. According to the model[7], the evolution of these relationships among neural firing patterns into specific temporal sequences for tens of seconds over large portions of cortex allows for the performance of other more complex spatial tasks requiring spatial–temporal reasoning. Spatial–temporal reasoning involves maintaining and transforming mental images in the absence of a physical model and is required for higher brain functions such as chess, mathematics and engineering.

Music cognition, it was argued, should also require these temporal sequences of neural activity[7,13–14]. A fundamental property of these evolving patterns of neural activity is that they can be readily strengthened through experience or learning[10–11]. Although higher brain functions are typically associated with specific, localized regions of cortex, all higher cognitive abilities draw upon a wide range of cortical areas[15]. Leng and Shaw[7] proposed that exposure to music might excite and enhance the cortical firing patterns used in spatial–temporal reasoning, thus affecting cognitive ability in tasks that share this complex spatial–temporal neural code. Behavioral research based on these predictions found that college students scored significantly higher on spatial–temporal reasoning tasks after listening to a Mozart sonata (K. 448), but not after listening to silence or to minimalist music[16–17]. While these studies established the existence of a causal relationsh between music and spatial–temporal reasoning, t effect lasted only ten minutes. Leng and Shaw suggested that music training of young children, whose cortices are

Correspondence and reprint requests to: Gordon L. Shaw PhD, Center for Neurobiology of Learning and Memory, and Department of Physics, UCLA, Irvine CA 92697-4575, USA. Accepted for publication September 1996.

0161–6412/97/010002–07

highly plastic, should produce long-term enhancement of spatial–temporal reasoning[7]. The aim of the present study was to test this hypothesis.

Our unpublished pilot study (in 1993) supported this prediction. After nine months of weekly individual piano keyboard lessons, a group of three-year-old children, enrolled at a music school, improved on a spatial–temporal task significantly more than was predicted by age-standardized norms[18]. A second group of three-year-old children from disadvantaged families, enrolled in an inner-city daycare center, received 30 min group singing lessons daily for nine months. This group also improved on the spatial–temporal task significantly more than predicted by age-standardized norms. Neither group improved significantly on spatial recognition tasks[18]. Encouraged by these results, we began a study in which we provided the music training under controlled conditions.

METHODS

Subjects

A total of 111 children were initially recruited. Thirty-three children withdrew from the preschools during the course of the study, and were not included in the analyses. The children who withdrew were fairly evenly distributed among the experimental groups. This left 78 children, 42 boys and 36 girls, for analysis. All children were of normal intelligence. The participants ranged in age from 3 years, 0 months to 4 years, 9 months at the start of the study. Three children were left-handed.

The study was conducted over a two year period using classes from three preschools. We provided 34 children, the Keyboard group, with private piano keyboard lessons and group singing sessions, and assigned the remaining children to one of three groups: Singing, Computer and No Lessons (*Figure 1*). The Singing group ($n=10$) took part in the same singing activities as the Keyboard group. The Computer group ($n=20$) received private computer lessons matched in length and number to the piano keyboard lessons. The No Lessons group ($n=14$) did not receive any training. None of the children had prior music lessons or computer lessons, and parental involvement was minimal.

All children in participating classrooms whose parents consented took part in the study. Children from the SA preschool were randomly assigned to either the Keyboard or the Computer groups (see *Figure 1*). The logistics of classroom schedules influenced group assignment in the other two preschools. Because the preschools assigned children to classrooms according to age, the children in the No Lessons group were older than the children in the other three groups (4 years, 1 month to 4 years, 9 months vs. 3 years, 0 months to 3 years, 11 months respectively). This was necessary to keep classes intact, to optimize sample size, and to avoid singling out children for participation in one treatment group over another. It is important to note, however, that the children's test scores were standardized by age, and no significant differences in test scores were found between groups prior to training.

Lessons given at each preschool

School year	LB	WC	SA
1993–1994	Keyboard & No Lessons	Keyboard & No Lessons	—
1994–1995	Computer & Singing	Computer & Singing	Keyboard & Computer

Figure 1: Experimental design showing preschools and treatment groups. Seventy-eight children of diverse ethnicity and normal intelligence (42 males and 36 females) participated. The data were collected over two years from three preschools, LB, WC, and SA. SA participated in 1994–1995 only, and did not contribute to the No Lessons or Singing groups. No group differed significantly prior to training. LB and WC received lessons once per week for eight months: SA received lessons twice per week for six months. No effect was found for number of lessons ($F_{(10,23)}=0.65$, ns), so these data were pooled. For clarity, we henceforth refer to the interval between testing periods as six months

Training

We provided piano keyboard lessons rather than lessons on some other instrument because the keyboard gives a visual linear representation of the spatial relationships between pitches. We felt that coupling visual information with aural information might assist the neural pattern development relevant to spatial–temporal operations. Further support for using the keyboard came from our pilot study. We had no information regarding other instruments. We recruited professional keyboard instructors from the Irvine Conservatory of Music to provide the lessons at the preschools using Yamaha Portasound PSS 190 keyboards arranged on child-size tables. The 10-min private keyboard lessons consisted of performance exercises derived by the fourth author from traditional approaches (*Figure 2*). The children studied pitch intervals, fine motor coordination, fingering techniques, sight reading, music notation and playing from memory. After six months, all the children were able to perform basic primer-level melodies and simple melodies by Beethoven and Mozart. The preschools reserved an hour each day for keyboard practice.

Because many classes in the three schools already included some group singing activities, the Singing group was included to standardize these activities and to determine if such singing instruction would produce an effect in the absence of piano keyboard instruction, as indicated by the pilot study. The 30-min singing sessions were held five days a week, led by a music instructor. Songs included popular children's tunes and folk melodies.

The Computer training controlled for the motor and visual coordination provided by the piano keyboard, personal attention, and the child's engagement with the activity. A professional computer instructor brought a

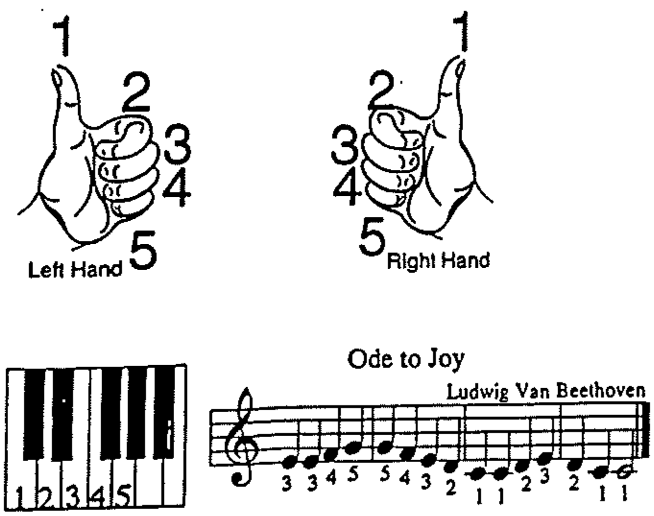


Figure 2: Numerical finger association used in the piano keyboard instruction. The children are taught to associate their fingers as numbered in A with the numbered keys on the piano keyboard as shown for the right hand in B. Shown in C is an example of a melody for the right hand that the children are able to play by the third month of lessons. Right and left hand coordination exercises are introduced at the outset of training. Hands together exercises are incorporated in the second and third months. Position changes or shifting to a different tonal center are introduced in the fourth and fifth months

personal home computer to the preschools for the 10-min private lessons. The children were taught to open entertaining, age-appropriate, commercial software programs by copying simple DOS commands. Most of the children mastered this after one month. The software was designed to teach reading and simple arithmetic skills. Letter recognition varied for each student. Some children could identify many letters at the start, whereas most children could identify 8 to 10 letters after three months. The children also learned sentence structure by completing sentences such as 'I am thankful for ...'. Counting skills and number recognition were also taught. On average, children were able to count three objects after one month and six objects after three months. The lessons did not involve the use of the mouse or software programs which centrally featured music.

The No Lessons group controlled for task artifacts. For example, a particular task score may improve because the children enjoy it more with age, rather than as a function of treatment.

Testing

Prior to training, we tested all the children's spatial reasoning with four tasks from the Performance sub-test of the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R)[18]. Children were tested individually at the preschools. In the Object Assembly (OA) task, which measured spatial–temporal skill, the child arranged pieces of a puzzle to create a meaningful whole. Performing this task required forming a mental image of the completed object and rotating the puzzle pieces to match the image. Performance was facilitated by putting the pieces together in particular orders, defining the spatial–temporal nature of the task. For example, in the animal puzzle (*Figure 3A*), beginning with the head facilitated performance, but placing the head and tail together first led to difficulty in correctly placing the middle pieces. The other five WPPSI-R tasks measured spatial-recognition. We used the following three: (i) Geometric Design required children to visually match and draw displayed model figures (*Figure 3B*), (ii) Block Design required the child to match depicted patterns using flat, two-colored blocks, and (iii) Animal Pegs required children to place the correctly colored pegs in holes below a series of pictured animals. These spatial-recognition tasks required matching, classifying, and recognizing similarities among displayed objects. Sequential order was not relevant. Children were re-tested on all tasks after six to eight months of lessons. The No Lessons group was re-tested at the same time as the other children.

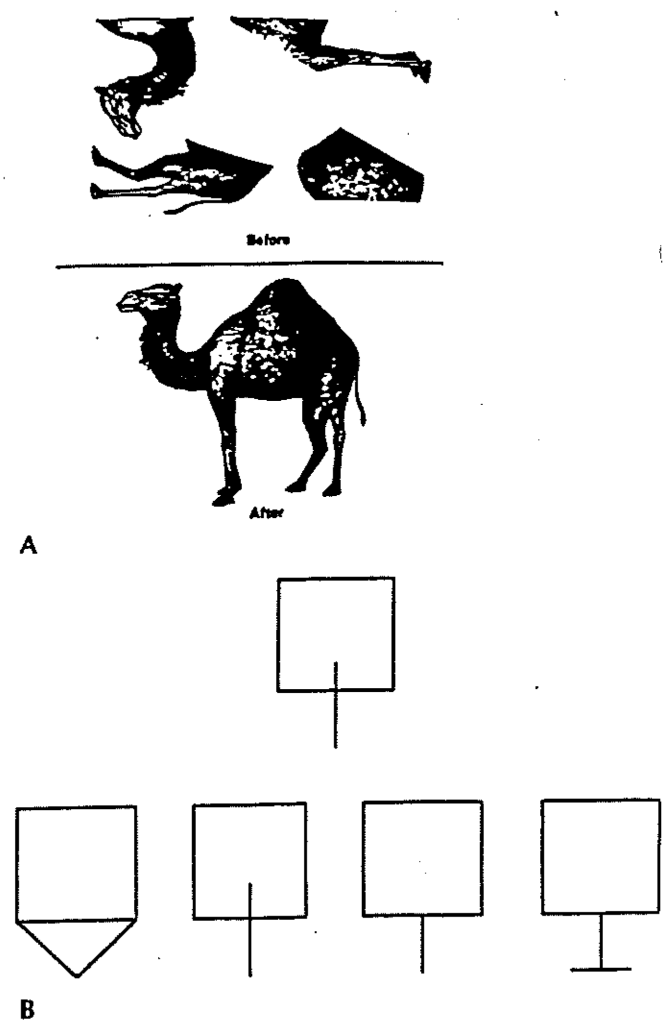


Figure 3 A: Schematic representation of the Object Assembly tas requiring spatial–temporal reasoning. The child arranges pieces of a puzzle to create a meaningful whole. **B:** Schematic representation of the Geometric Design task, requiring spatial recognition. The child points to the bottom-row figure that matches the figure in the top row

Scoring

As specified by the WPPSI-R scoring instructions[18], raw scores were based on the number of errors made within a specified time period, and bonus points were awarded for accuracy and speed. Scaled scores were calculated for children at three-month age intervals. The established mean for all WPPSI-R tests (*M*) is 10 points, with all standard deviations (σ) equal to 3.

Testing procedures followed those recommended by the Wechsler test manual[18]. Testing sessions lasted 60–75 min, and were conducted in the morning. Children who became distracted during testing were given a 5-min break before testing was resumed. Testing during the first year was performed by the first author. During the second year, testing was performed by research assistants blind both to the hypothesis of the experiment and to group assignment. Preliminary analysis conducted on these two sets of data showed no differences, so the data were pooled. All tasks were independently scored by two researchers blind to condition assignment. Inter-rater reliability ranged from $r = 0.995$ to $r = 1.0$.

RESULTS AND DISCUSSION

Figure 4A shows how each of the four different types of training effect spatial–temporal abilities by presenting the before and after training Object Assembly (OA) means for each of the four training groups. This figure reveals that music training for the Keyboard group produced a dramatic overall increase in OA scores (as evidenced by a pre-training mean of 9.79 and a post-training mean of 13.41) while none of the other training groups showed any appreciable change. To verify the obvious difference, a One-Way ANOVA was performed on the change scores with the four training groups (Keyboard, Computer, Singing, No Lessons) as treatments. As expected, this analysis produced highly significant differences between the four groups ($F(3,74) = 3.87$, $p < 0.0001$).

Even more revealing were the results derived from a subsequent assessment of multiple paired comparisons between treatment groups where Bonferroni (Dunn) T tests were used to assess differences between means of pre–post difference scores for pairs of treatment groups. Using this conservative method, the Keyboard group nonetheless differed significantly ($p < 0.01$) from each of the other three groups. No pairing of the remaining three treatment groups produced a rejection of the associated null hypothesis, even when the alpha level was set as high as 0.99 ($\alpha = 0.99$). As shown in *Table 1*, the pattern of these results is quite striking.

ANOVAs performed on the children's scores on the other tests (Geometric Design, Block Design and Animal

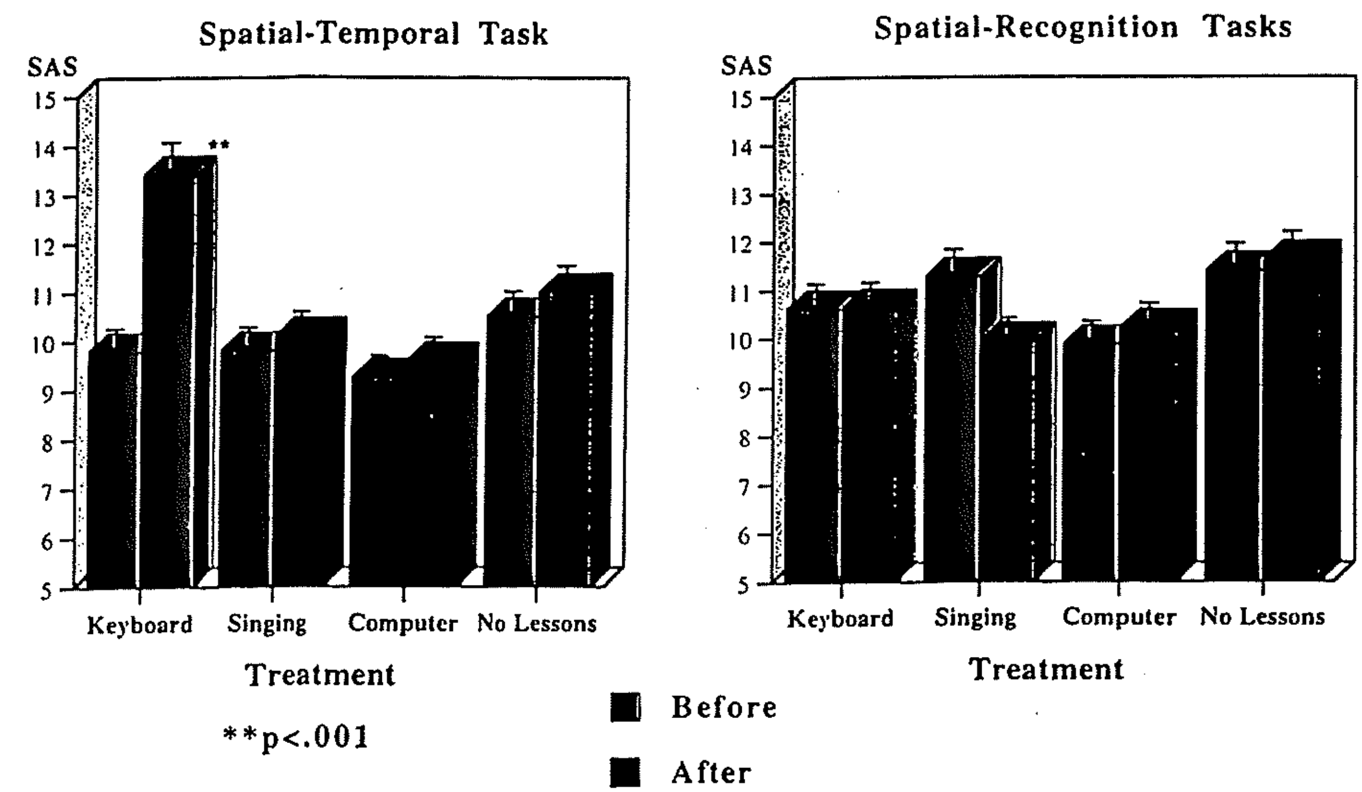


Figure 4 A: The means for the OA standard age scores (SAS) with standards errors are plotted measuring spatial–temporal reasoning for the Keyboard, Singing, Computer and No Lessons groups before and after treatment. The standard deviations for each of these groups, before and after training, respectively, are 2.61 and 2.91, 3.91 and 3.07, 3.27 and 3.07, 2.77 and 2.25. The Keyboard group improved significantly following lessons whereas the other groups did not. B: The spatial-recognition SAS means with standard errors for the four groups before and after treatment. The standard deviations for each of these groups, before and after training, respectively, are 2.25 and 1.86, 1.68 and 1.97, 2.53 and 2.82, 1.55 and 1.57. No groups improved significantly

Pegs), were not significant, indicating that the children's scores on the items which measured spatial-recognition did not improve significantly after lessons (*Figure 4B*).

The OA scores of the Singing, Computer and No Lessons groups did not improve significantly, nor did their scores on the spatial-recognition tasks. The lack of significant improvement of the Singing group on the OA task (9.80 before and 10.10 after) suggests that either a more structured singing program is required or that experience with a musical instrument, with its visual and motor representation of spatial–temporal relations between sequences of pitches, may be crucial to the effect. We cannot rule out the possibility, however, that the singing lessons contributed to the enhancement of spatial–temporal reasoning found for the Keyboard group. We suspect that the significant improvement found in the pilot study by the inner-city children who received group singing lessons may have been due to the school's demographic composition. Clearly, the effects of demographics need to be investigated.

The stability of the Computer group's OA scores (9.25 before lessons vs. 9.60 after lessons), rules out attention, motivation and motor coordination as primary contributors to the Keyboard group's improvement. This, we believe, is a substantial finding given the captivating nature of the animated images used in the computer training. Finally, the OA scores of the No Lessons group did not improve significantly after eight months ($M = 10.50$ before vs. 11.00 after). This indicates that the Keyboard group's improvement was not due to task artifacts.

To convey the extent of the Keyboard group's improvement on the OA task, we plotted the histogram of SAS after treatment minus SAS before treatment (ΔOA) for the Keyboard group (*Figure 5A*). Twenty-four of the 34 children, or 71%, improved by 3 or more points

Table 1: Bonferroni (Dunn) T tests for variable: OA(post) - OA(pre)

Condition comparison	Simultaneous lower confidence limit	Difference between means	Simultaneous upper confidence limit
Keyboard – No Lessons	0.2662	3.1176	5.9691 *
Keyboard – Computer	0.7373	3.2676	5.7980 *
Keyboard – Singing	0.0875	3.3176	6.5478 *
No Lessons – Computer	−2.9790	0.1500	3.2790
No Lessons – Singing	−3.5178	0.2000	3.9178
Computer – Singing	−3.4277	0.0500	3.5277

This test controls the type I experiment wise error rate but generally has a higher type II error rate than Tukey's for all pairwise comparisons. Alpha = 0.01; Confidence = 0.99; df = 74; MSE = 7.569992; Critical Value of T = 3.26358; Comparisons significant at the 0.01 level are indicated by *

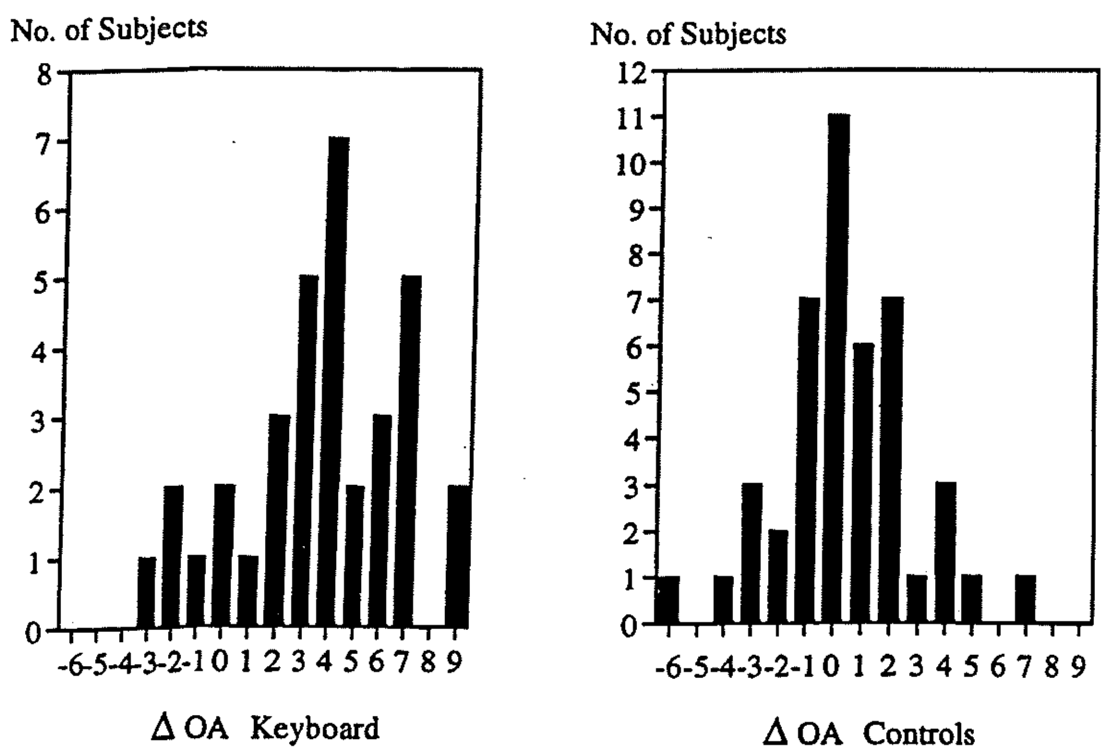


Figure 5 A: Histogram of SAS for OA after treatment minus SAS before treatment (ΔOA) for the 34 children in the Keyboard group. **B:** The corresponding histogram for the 44 children in the combined three control groups

(WPPSI-R's $\sigma = 3$), as compared to the expected 5 or 6 children (16%) by the Gaussian model. *Figure 5B* shows the histogram for the three combined control groups. Only six of the 44 children (14%) improved by 3 or more points.

Memory researchers differentiate between short-term and long-term memory[19]. The latter, lasting hours or longer, is associated with enduring synaptic changes, perhaps long-term, potentiation[20–21]. To determine if the enhancement found in this study was long-term, we compared the ΔOA scores of the children who were tested one day or more after their last keyboard lesson to those of the children who were tested less than one day afterwards. We found no significant difference. A *t*-test for independent samples performed on the ΔOA scores of the 27 children who were tested one day or more after their last piano keyboard lesson ($M = 3.59$) vs. the ΔOA scores of the 7 children who were tested less than one day afterwards ($M = 3.71$) was not significant ($t_{(1,32)} = 0.09$, ns). This indicates that the enhancement on the OA spatial–temporal task from piano keyboard training lasted at least one day, and is considered by memory researcher standards to be long-term[19–21].

Our previous findings of enhanced short-term spatial–temporal reasoning in college students after listening to a Mozart sonata suggest that music can prime regions of cortex responsible for spatial–temporal reasoning[16–17]. (An EEG coherence study of this short-term enhancement of spatial–temporal reasoning has been performed[22].) The long-term enhancement found in the current study represents an increase by more than a factor of 100 over the previous listening experiments[16–17]. This study suggests that music training, unlike listening, produces long-term modifications in underlying neural circuitry (perhaps right prefrontal and left temporal cortical areas as indicated in EEG coherence studies[22]) in regions not primarily concerned with music. The magnitude of the improvement in spatial–temporal reasoning from music training was greater than one standard deviation, equivalent to an increase from the 50th percentile on the WPPSI-R standardized test to above the 85th percentile.

The precise duration of the enhancement and the possible existence of a critical period need to be examined. An exploration of the aspects of music training that are responsible for the enhancement must be undertaken, so that the optimum training method can be identified. Although our study was limited by the resources we had available, the ideal study would draw participants from the same preschool at the same time, thereby eliminating any possible confounds due to preschool demographics or age. It should be noted, however, that we found no significant differences on measures of task improvement based on these factors. Further research is necessary to identify other spatial-temporal reasoning tasks that may be enhanced by music training. And finally, explorations into the cortical representation[22] of spatial–temporal and musical reasoning coupled with supporting behavioral data are necessary.

It has been clearly documented[23] that young students have difficulty understanding the concepts of proportion (heavily used in math and science) and that no successful program has been developed to teach these concepts in the school system. We predict that an enhanced ability to evolve temporal sequences of spatial patterns as a result of music training will lead to an enhanced conceptual mastering of proportional reasoning. This is a strong proposal which should be investigated in future research.

The high proportion of children who evidenced this dramatic improvement in spatial–temporal reasoning as a result of music training (*Figure 5A*) should be of great interest to scientists and educators, particularly because the duration of the effect lasts at least one day. We suggest that an improvement of this magnitude may enhance the learning of standard school curricula that draw heavily upon spatial–temporal reasoning abilities, such as mathematics and science.

ACKNOWLEDGEMENTS

This research was supported by grants from the National Association of Music Merchants, the Ralph and Leona Gerard Foundation, The Seaver Institute, the Orange County Philharmonic Society, Walter Cruttenden and Associates, the National Academy of Recording Arts and Sciences and the National Piano Foundation. The Yamaha Corporation of America supplied the keyboards. We thank the preschool directors J. Kolinsky, G. Morgan-Beazell, M. Rice and D. Rippetoe and their staffs for their patience, cooperation and support. We thank B. Grice of KUSC Radio and J. Fuerbringer of the O.C. Philharmonic Society for help in recruiting the preschools. We are indebted to keyboard instructors C. Jones, D. Schultheiss, and M. Wright; computer instructor T. Earl; singing instructors T. Lundeen, L. Mendoza, M. Navarro and R. Wise; testers L. Cheung, L. Goldhammer, S. Jethwa and J. Johnson; and laboratory assistant K. Gitchoff for their invaluable contributions. Finally, we are grateful to L. Brothers, D. Dooley, J. McGaugh, G. Palm and C. Stephens for reviewing earlier drafts of this manuscript, and to K. Bruhn and J. Kabakov for their enthusiastic encouragement.

REFERENCES

1 Allman GJ, *Greek Geometry from Thales to Euclid*. New York: Arno, 1976
2 Barlett HC, Barker HR. Cognitive pattern perception and musical performance. *Percept Motor Skills* 1973; 36: 1187–1193
3 Hassler M, Birbaumer N, Feil A. Musical talent and visual–spatial abilities: longitudinal study. *Psych Music* 1985; 13: 99–113
4 Hurwitz I, Wolf PH, Bortnick CB, Kokas K. Nonmusical effects of the Kodaly curriculum in primary grade children. *J Learning Disabil* 1975; 8: 167–174
5 Kalmar M. The effects of music education based on Kodaly's directives in nursery school children from psychologist's point of view. *Psychol Music Proc 9th Int Seminar Res Music Educat* 1982; pp. 63–68
6 Parente JA, O'Malley JJ. Training in musical rhythm and field dependence of children. *Percept Motor Skills* 1975; 40: 392–394
7 Leng X, Shaw GL. Toward a neural theory of higher brain function using music as a window. *Concepts Neurosci* 1991; 2: 229–258
8 Mountcastle VB. An organizing principle for cerebral function: The unit module and the distributed system. In: Edelman GM, Mountcastle VB, eds. *The Mindful Brain*, Cambridge: MIT, 1978; pp. 1–50
9 Goldman-Rakic PS. Modular organization of prefrontal cortex. *Trends Neurosci* 1984; 7: 419–424

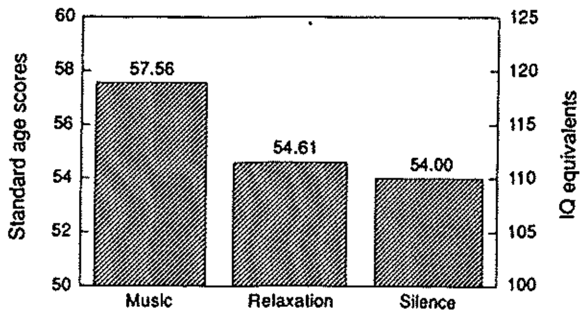
10 Shaw GL, Silverman DJ, Pearson JC. Model of cortical organization embodying a basis for a theory of information processing and memory recall. *Proc Nat Acad Sci USA* 1985; 82: 2364–2368
11 Shenoy KV, Kaufman J, McGrann JV, Shaw GL. Learning by selection in the trion model of cortical organization *Cerebral Cortex* 1993; 3: 239–248
12 McGrann JV, Shaw GL, Shenoy KV, Leng X, Mathews RB. Computation by symmetry operations in a structured model of the brain. *Phys Rev* E49: 5830–5839
13 Leng X, Shaw GL, Wright E. Coding of musical structure and the trion model of cortex. *Music Perception* 1990; 8: 49–62
14 Brothers L, Shaw GL, Wright E. Durations of extended mental rehearsals are remarkably reproducible in higher level human performances. *Neurol Res* 1993; 15: 413–416
15 Petsche H, Richter P, von Stein A, Etlinger S, Filz O. EEG coherence and musical thinking. *Music Perception* 1993; 11: 117–151
16 Rauscher FH, Shaw GL, Ky KN. Music and spatial task performance. *Nature* 1993; 365: 611
17 Rauscher FH, Shaw GL, Ky N. Listening to Mozart enhances spatial–temporal reasoning: Towards a neurophysiological basis. *Neurosci Lett* 1995; 185: 44–47
18 Wechsler D. *Preschool and Primary Scale of Intelligence—Revised.* San Antonio: The Psychological Corporation, 1989
19 McGaugh JL. Time-dependent processes in memory storage. *Science* 1966; 153: 1351–1358
20 Bliss TVP, Lomo T. Long-lasting potentiation of synaptic transmission in the dentate area of the anaesthetized rabbit following stimulation of the perforant path. *J Physiol* 1973; 232: 331–356
21 Baudry M, Massicotte G. Physiological and pharmacological relationships between long-term potentiation and mammalian memory. *Concepts Neurosci* 1992; 3: 79–98
22 Sarnthein J, Stein A von, Rappelsberger P, Petsche H. Rauscher RH, Shaw GL. Persistent patterns of brain activity: An EEG coherence study of the positive effect of music on spatial–temporal reasoning. *Neurol Res* 1997; 19: in press
23 Karplus R, Pulos S, Stage K. Early adolescents' proportional reasoning on 'rate' problems. *Educational Studies Math* 1983; 14: 219–233

Music and spatial task performance

SIR — There are correlational[1], historical[2] and anecdotal[3] relationships between music cognition and other 'higher brain functions', but no causal relationship has been demonstrated between music cognition and cognitions pertaining to abstract operations such as mathematical or spatial reasoning. We performed an experiment in which students were each given three sets of standard IQ spatial reasoning tasks; each task was preceded by 10 minutes of (1) listening to Mozart's sonata for two pianos in D major, [redacted] (2) listening to a relaxation tape; or (3) silence. Performance was improved for those tasks immediately following the first condition compared to the second two.

Thirty-six college students participated in all three listening conditions. Immediately following each listening condition, the student's spatial reasoning skills were tested using the Stanford–Binet intelligence scale[4]. The mean standard age scores (SAS) for the three listening conditions are shown in the figure. The music condition yielded a mean SAS of 57.56; the mean SAS for the relaxation condition was 54.61 and the mean score for the silent condition was 54.00. To assess the impact of these scores, we 'translated' them to spatial IQ scores of 119, 111 and 110, respectively. Thus, the IQs of subjects participating in the music condition were 8–9 points above their IQ scores in the other two conditions. A one-factor (listening condition) repeated measures analysis of variance (ANOVA) performed on SAS revealed that subjects performed better on the abstract/spatial reasoning tests after listening to Mozart than after listening to either the relaxation tape or to nothing ($F_{2,35} = 7.08$; $P = 0.002$). The music condition differed significantly from both the relaxation and the silence conditions (Scheffe's $t = 3.41$, $P = 0.002$; $t = 3.67$, $P = 0.0008$, two-tailed, respectively). The relaxation and silence conditions did not differ ($t = 0.795$; $P = 0.432$, two-tailed). Pulse rates were taken before and after each listening condition. A two-factor (listening condition and time of pulse measure) repeated measures ANOVA revealed no interaction or main effects for pulse, thereby excluding arousal as an obvious cause. We found no order effects for either condition presentation or task, nor any experimenter effect.

The enhancing effect of the music condition is temporal, and does not extend beyond the 10–15-minute period during which subjects were engaged in each spatial task. Inclusion of a delay period (as a variable) between the music listening condition and the testing period would allow us quantitatively to determine the presence of a decay constant. It would also be interesting to vary the listening time to optimize the enhancing effect, and to examine whether other measures of general intelligence (verbal reasoning, quantitative reasoning and short-term memory) would be similarly facilitated. Because we used only one musical sample of one composer, various other compositions and musical styles should also be examined. We predict that music lacking complexity or which is repetitive may interfere with, rather than enhance, abstract reasoning. Also, as musicians may process music in a different way from non-musicians, it would be interesting to compare these two groups.



Standard age scores for each of the three listening conditions.

Testing procedure. In the music condition, the subject listened to 10 min of the Mozart piece. The relaxation condition required the subject to listen to 10 min of relaxation instructions designed to lower blood pressure. The silence condition required the subject to sit in silence for 10 min. One of three abstract reasoning tests taken from the Stanford–Binet intelligence scale[4] was given after each of the listening conditions. The abstract/spatial reasoning tasks consisted of a pattern analysis test, a multiple-choice matrices test and a multiple-choice paper-folding and cutting test. For our sample, these three tasks correlated at the 0.01 level of significance. We were thus able to treat them as equal measures of abstract reasoning ability.

Scoring. Raw scores were calculated by subtracting the number of items failed from the highest item number administered. These were then converted to SAS using the Stanford–Binet's SAS conversion table of normalized standard scores with a mean set at 50 and a standard deviation of 8. IQ equivalents were calculated by first multiplying each SAS by 3 (the number of subtests required by the Stanford–Binet for calculating IQs). We then used their area score conversion table, designed to have a mean of 100 and a standard deviation of 16, to obtain SAS IQ equivalents.

Frances H. Rauscher
Gordon L. Shaw*
Katherine N. Ky
Center for the Neurobiology of Learning and Memory, University of California, Irvine, California 92717, USA

* Also at Department of Physics.

1. Hassler, M., Birbaumer, N. & Feil, A. *Psychol. Music* **13**, 99–113 (1985).
2. Allman, G. J. *Greek Geometry from Thales to Euclid* p. 23 (Arno, New York, 1976).
3. Cranberg, L. D. & Albert, M. L. in *The Exceptional Brain* (eds Obler, L. K. & Fein, D.) 156 (Guilford, New York, 1988).
4. Thorndike, R. L., Hagen, E. P. & Sattler, J. M. *The Stanford–Binet Scale of Intelligence* (Riverside, Chicago, 1986).

VIA SATELLITE

USA TODAY

Life

MONDAY, AUGUST 15, 1994

Music lessons may open mind to math, science

By Marilyn Elias
USA TODAY

LOS ANGELES — Parents take heart: If weekly music lessons show no sign of turning your kid into a young Leonard Bernstein, they could be stoking the talents of a future Marie Curie or Galileo.

Just 15 minutes a week of private keyboard instruction, along with group singing at preschool, dramatically improve a kind of intelligence needed for high-level math and science, suggests a new study.

Music lessons appear to strengthen the links between brain neurons and build new neural bridges needed for good spatial reasoning, says psychologist Frances Rauscher of University of California-Irvine.

"Music instruction can improve a child's spatial intelligence for long periods of time — perhaps permanently," Rauscher told the American Psychological Association meeting here.

Her study compared 19 preschoolers who took the lessons and 14 classmates enrolled in no special music programs. After eight months, she found:

▶ A 46% boost in spatial IQs for the young musicians.

▶ 6% improvement for children not taught music.

"If parents can't afford lessons, they should at least buy a musical keyboard ... or sing regularly with their kids and involve them in musical activities," Rauscher says.

She's next going to test grade-schoolers. "If we can show it enhances spatial IQ in primary kids, this is a very powerful method to assure that every child reaches his or her potential in math and science," Rauscher says.

UCI Study Ties Rise in IQ to Classical Music

By ROBERT LEE HOTZ
TIMES SCIENCE WRITER

Those who hope to seem smarter by listening to Mozart may be on to something. At least temporarily.

Researchers at the Center for the Neurobiology of Learning and Memory at UC Irvine have determined that 10 minutes of listening to a Mozart piano sonata raised the measurable IQ of college students by up to 9 points.

The effect on the intelligence of the students in the study, however, barely lasted longer than the echo of the piano chords. The IQ boost dissipated within 15 minutes, the team reported

Please see MUSIC, A20

ORANGE COUNTY
Los Angeles Times
THURSDAY, OCTOBER 14, 1993

MARK BOSTER / Los Angeles Times

UCI research fellow Frances H. Rauscher said study "fits everyone's intuition about music and mathematics."

MUSIC: Study Finds Link to Rise in IQ

Continued from A1

today in the journal Nature.

The researchers suggested that classical music may enhance abstract reasoning, such as that involved in mathematics or chess, by reinforcing certain complex patterns of neural activity. They suspect that the complexity of the music itself is the key. Simpler, repetitive rhythms of grunge rock or minimalist New Age jazz may actually interfere with abstract reasoning.

Moreover, making music, rather than simply listening to it, may have a more permanent impact on intelligence, they said.

"Everybody is intrigued by this study because it fits everyone's intuition about music and mathematics," said Frances H. Rauscher, a research fellow at the UC Irvine center involved in the study.

"We think that really repetitive music will have a very negative effect," Rauscher said. "It would sort of burn out those [neural] patterns instead of enhancing them or exercising them."

Efforts to increase intelligence are as controversial as the IQ tests themselves. Breast-feeding and increased income have been shown to raise IQ scores, while the disruption of summer vacations has been shown to lower scores. But none of those studies are conclusive.

"It is remarkable, if it is true," said Nicholas Christenfeld, a social psychologist at UC San Diego whose research focuses on emotion and mental effort. "The finding is surprising. . . . The whole point of an IQ is that it supposed to be unchanging from conception to death."

However provocative the new music study seems, other psychologists warned, it is still inconclusive and, the researchers themselves acknowledged sheepishly, open to misinterpretation or abuse by over-anxious parents and educational hucksters. "You can never control what the marketers will do. It is a very scary thought," Rauscher said.

The research grows out of theoretical neurobiology and ideas about how different parts of the brain may communicate with each other.

"There is a common language the different parts of the brain use to communicate," said Gordon Shaw, a physics professor at UC Irvine who studies the structure of the brain's cortex and who was involved in the project. "There are certain neurological firing patterns that occur when people are doing high levels of abstract reasoning. We take those as describing the internal language of the brain.

"The music presumably excites these same very structured patterns," he said.

In the study, described in a letter to Nature, 36 college students were given standard IQ tests after listening to Mozart, a recorded relaxation tape or meditating in silence for 10 minutes. Each student was tested after each listening exercise.

Every student's test score was higher after he or she listened to the classical passage from Mozart's Sonata for Two Pianos in D Majo the researchers reported.

"The music is priming thes other regions of the brain that ma be involved with other tasks Shaw said. "It is not that th Mozart will make you permanentl smarter; it may be a warm-u exercise for parts of the brain."

The team hopes to determir whether early music training pe manently increases IQ. Their wor is funded by the National Assn. Music Merchants and the Yamal Corp. of America—which donate keyboards for the experiments— well as the university's Ralph ar Leona Gerard Foundation.

To gauge the long-term effec of music on the brain, Shaw ar Rauscher are studying 75 3-yea old children, teaching them son and keyboard playing.

"We are looking to see if mus training might induce some perma nent enhancements," Shaw said.

International Herald Tribune
Published With The New York Times and The Washington Post
平成元年4月14日第3種郵便物認可 日刊(日曜休) * TOKYO, FRIDAY, OCTOBER 15, 1993 Price in Japan - 450 Yen

Mozart's Notes Make Good Brain Food

By Malcolm W. Browne
New York Times Service

NEW YORK — Can it be that the music of Mozart is not only exalting but can also improve intelligence?

An experiment on students at the University of California at Irvine suggests that listening to 10 minutes of Mozart's piano music significantly improves performance in intelligence tests taken immediately afterward.

The finding was reported Thursday in the British scientific journal Nature by researchers from the university.

The researchers found that after students listened to Mozart's Sonata for Two Pianos in D Major (K. 448), as performed by Murray Perahia and Radu Lupu, their test scores were a mean of eight or nine points higher than the scores the same students achieved after a period of silence, or after listening to a recorded message suggesting that they imagine themselves relaxing in a peaceful garden.

The effect was only temporary, however.

One of the researchers, Frances H. Rauscher, said that all the students were asked about their tastes in music, and that although some liked Mozart and some did not, their test scores generally improved after the music session, with no measurable differences attributable to varied tastes.

The pulse rates of the subjects did not change under any of the tests, so physiological arousal was not a factor in the test scores, she said.

"We are testing a neurobiological model of brain function with these experiments, which proposes certain neural firing patterns in the brain," Dr. Rauscher said.

"We hypothesize that these patterns may be common in certain activities — chess, mathematics and certain kinds of music.

"Listening to such music may stimulate neural pathways important to cognition," Dr. Rauscher said, adding, "Incidentally, Mozart himself often scribbled numbers and mathematical expressions on his manuscript scores."

Thirty-six students, half men and half women, took part in the experiment. After each listening period they were given standard nonverbal I.Q. tests of spatial reasoning, involving questions about the geometry of paper objects shown as they would look after being folded or cut.

Dr. Rauscher said researchers in her group, including Gordon L. Shaw and Katherine N. Ky, intended to test the effects of other kinds of music, like rock and the minimalist music of the contemporary composer Phillip Glass, for example. They also plan to test preschool children, and to compare musically trained people with untrained people.

การบรรยายระดับโลกครั้งแรกในเอเชียอาคเนย์

The Symposium of

MOZART MUSIC AND INTELLIGENCE

คนตรี สมอง ความฉลาด

วันที่ 10-11 พฤษภาคม 2549
ณ ห้องแกรนด์ฮอลล์ ชั้น 2 THE IMPERIAL QUEEN'S PARK
สุขุมวิท 22 กรุงเทพมหานคร

โดยผู้ค้นพบทฤษฎี **"Mozart Effect"**
ที่ว่าด้วยดนตรีมีผลต่อการพัฒนาความฉลาดของมนุษย์

วันพุธที่ 10 พฤษภาคม 2549 เวลา 08.30-16.00 น.
ดร. ฟรานซิส เราส์เชอร์ และ ดร. ฌอน ฮินตัน
Music and Intelligence
Discovery of the Mozart Effect in Children
Mozart Effect in Primary School
บัตรราคา 3,000 บาท

วันพฤหัสบดีที่ 11 พฤษภาคม 2549 เวลา 08.30-12.00 น.
ดร. ฟรานซิส เราส์เชอร์
Music and Intelligence
Discovery of the Mozart Effect in Children
บัตรราคา 1,500 บาท

Fransces H. Rauscher, Ph.D.
ดร. ฟรานซิส เราส์เชอร์
ภาควิชาจิตวิทยา
มหาวิทยาลัยวิสคอนซิน สหรัฐอเมริกา

Sean C. Hinton, Ph.D.
ดร. ฌอน ฮินตัน
ภาควิชาประสาทวิทยา
วิทยาลัยแพทยศาสตร์
แห่งวิสคอนซิน สหรัฐอเมริกา

สอบถามรายละเอียดเพิ่มเติมได้ที่
บริษัท รักลูกแฟมิลี่กรุ๊ป จำกัด 932 ถ.ประชาชื่น แขวงบางซื่อ เขตบางซื่อ กรุงเทพฯ โทร. 0 2831 8400, 0 2913 7555 ต่อ 2221-2 โทรสาร 0 2831 8422
E-mail address : member@raklukefamilygroup.com www.raklukefamilygroup.com

สร้างสรรค์กิจกรรมเพื่อส่งเสริมศักยภาพสมองของเด็กไทย โดย
นิตยสารรักลูก รักลูก

สนับสนุนโดย
Babi Mild
PRUDENTIAL
เอนฟาโกร