# LEARNING, ARTS, AND THE BRAIN

## The Dana Consortium Report on Arts and Cognition

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The Dana Foundation is a private philanthropic organization with particular interests in brain science, immunology, and education.

In addition to making grants for research in neuroscience and immunology, Dana produces books and periodicals from the Dana Press; coordinates the international Brain Awareness week campaign; and supports the Dana Alliance for Brain Initiatives, a nonprofit organization of more than 250 neuroscientists, including ten Nobel laureates, committed to advancing public awareness of the progress of brain research

In 2000 the Foundation extended its longtime aid to education to fund innovative professional development programs leading to increased and improved teaching of the performing arts.

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# Learning, Arts, and the Brain

*The Dana Consortium Report on Arts and Cognition*

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# Arts Education, the Brain, and Language

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## Summary

We conducted two main areas of investigation. One was to study the impact of intensive dance education on higher cognition, including attention and biological motion perception abilities (Part 1). The second was to study the impact of extensive music education in childhood on learning a second language in adulthood (Part 2).

To explore the impact of intensive dance education on higher cognition, we undertook behavioral, brain imaging, and genetic studies. This included the development and pilot-testing of tools for identifying and differentiating expert dancers from non-dancers (and expert musicians and non-musicians). We also assessed dancers and non-dancers' performance on language and other cognitive tasks behaviorally, as well as while they underwent functional Near Infrared Spectroscopy (fNIRS) brain imaging. This brain imaging system detects changes in concentrations of blood oxygen levels that are associated with neural activity in the brain's cerebral cortex. We also developed software for standardizing the analysis and interpretation of fNIRS data, which has been tested in several laboratories.

Artistic education and expertise, such as in dance or in music, requires highly skilled motor control and the ability to selectively attend to, inhibit, and select appropriate sensory cues (such as when performing in a group). Our behavioral studies revealed that dancers were significantly more accurate than non-dancers on an attentional task. This finding suggests that early dance education may positively transfer to other cognitive areas, such as the ability to selectively focus attention and resist interference from competing signals.

Our behavioral studies showed that dancers also were faster on a Biological Motion Perception task. This finding suggests that early dance education benefits the processing of biological motion and benefits the speed of short-term memory processing of motion stimuli. In a separate experiment of dancers and non-dancers, in which both behavioral

and fNIRS data were collected, we found a similar pattern.

To study possible genetic influences on these observed differences between dancers and non-dancers, as well as possible genetic influences on a person's likelihood of pursuing arts education, we identified seven candidate genes that might help to explain such differences. Our research to date on four of the seven candidate genes has shown only one possible relationship, supporting the hypothesis that differences in higher cognitive performance between dancers and non-dancers may be due to their education in the Arts rather than to a genetic predisposition. Research on the remaining three genes is ongoing.

In Part 2 of our research, we tested the hypothesis that monolingual expert musicians would learn a second language better than matched non-musicians. This hypothesis is based on findings that musicians have enhanced selective attention on particular higher cognitive tasks, and learning another language involves the ability to attend to one language, inhibit the other, and rapidly switch between them. We studied monolingual English-speaking students enrolled in introductory Italian or Spanish classes, who were tested at the beginning and end of the academic term.

Musicians (those who received early extensive and continued music education) were compared to non-musicians on English language performance, new language performance, cognitive attentional processing, end-of-term self-evaluation, and class final grade. While the two groups showed no differences in general academic performance measures, or on cognitive attentional assessments, we found that the musicians exhibited significantly increased second language performance (greater improvement in expressive fluency and competence) compared to non-musicians. These results suggest that there may be an enduring cognitive advantage afforded by early and extensive music education on adult learning of a new language in an instructional setting.

## Introduction

The overarching goal of the Dana Foundation's Arts and Cognition Consortium is to understand the impact of intensive education in the Arts on the human brain – especially regarding the acquisition and learning of other core content knowledge. For the past three years, the Petitto Laboratory has addressed this question by studying: 1) the impact of intensive education in dance on higher cognition, including attentional and biological motion perception abilities (Part I); and, 2) the impact of extensive music education in childhood on learning a second language in adulthood (Part 2).

**… we examined the possible genetic influences on individuals' higher cognitive task performance and their likelihood of pursuing arts education.**

We used a variety of populations (e.g., dancers and musicians) and advanced techniques in brain imaging and human genetics. Our methods included the use of behavioral measures, and of the new functional Near Infrared Spectroscopy (fNIRS), a state-of-the-art brain imaging tool that is ideally suited for use in studies of higher cognition. Additionally, as an important design innovation, we conducted crucial co-registration validation checks of the fNIRS system with MRI/anatomical scans.

In the third funding year, we cast an additional exciting lens on our research questions by adding a third level of scientific analysis, the Genetic level, whereupon we examined the possible genetic influences on individuals' higher cognitive task performance and their likelihood of pursuing arts education. Together, our research program offers innovative advances by bringing to bear a trilogy of

three core levels of analysis to assess the impact of intensive education in the Arts on the human brain: mind, brain, and genetics.

Artistic education and expertise (e.g., dance or music) requires highly skilled motor control and the ability to selectively attend to, inhibit, and select appropriate sensory cues, such as when performing in musical groups (e.g., Bever & Chiarello, 1974; Keller, 2001; Large & Jones, 1999; Schellenberg, 2005). Here, we tested the following "transfer of learning" hypotheses: Extensive education in the Arts may yield higher cognitive executive function advantages during the processing of other non-arts information (tested in our Dance study described below)—and/or during the learning and processing of other non-Arts knowledge (our Music and Language Learning study below; referred to as the Music study).

Immediately below is a brief summary of Part I research during Years 1 and 2, including (i) innovations, (ii) key personnel/collaborations, and (iii) results. Extensive detailed discussion of these studies was provided previously. Thereafter, we describe our third-year research, a Mind-Brain-Genetic study of dancers versus non-dancers. At the close of this section is a list of the Tangible Products emanating from year three of this research, while similar lists from the first two years were provided in earlier reports. Thereafter, we briefly summarize Part 2 of the research, the Music Study, which explored the impact of extensive music education in childhood on learning a second language in adulthood. This study was described in detail in earlier reports.

# Part I: Brief Summary of Dance Research in Years 1 and 2

## *Year 1: Dance Research Design and Methods*

### Innovations

Petitto and team both designed and extensively piloted all: (i) Dance/Music screening and background questionnaires (to be used as one of the standardized tools to identify and differentiate expert, compared to novice, experimental groups); (ii) language screening and background questionnaires; and, (iii) language and cognitive tasks to be administered both behaviorally and during brain scanning. Additionally, Petitto and team completed the (i) scripting, filming, and editing of the experimental video clips to be used for the Dance study, and (ii) creating/designing of the selection criteria for differentiating expert compared to novice participants, as another key tool to establish participant groups. Petitto and team then began recruiting, screening, and studying participants for both the Dance and Music studies, and they also started data analyses for the Music study.

### Key Personnel

Professor Laura-Ann Petitto, graduate student Ioulia Kovelman, and undergraduates Rachael Degenshein, Ryan Gramacy, Aekta Shah. We further held several outside meetings with Dartmouth College Professor Scott Grafton and graduate student Emily Cross (Dana consortium members). Importantly, other Dana consortium collaborations that were invaluable during the first two years of our research included consultation with Professor John Jonides (University of Michigan), who provided feedback on and input to our criteria for "expert" vs. "novice" participant groups. Professor Jonides also shared his Stimulus Response Compatibility (SRC) task with us. Further, Professor Michael

Posner (University of Oregon) generously shared his Flanker Task/attention network task.

**… the fNIRS system … comes with no standard means for enabling cognitive neuroscientists to analyze its data output.**

### *Year 2: Dance Research Design and Methods*

**Innovations**

Petitto and team completed the behavioral part of the Dance study, the Music study, and also completed all of the data analyses for both of these studies. Further, Petitto and team received a new fNIRS brain imaging system, and completed piloting of the fNIRS brain imaging part of the Dance study. While the fNIRS system has outstanding brain imaging and recording capabilities, remarkably, the system comes with no standard means for enabling cognitive neuroscientists to analyze its data output. Therefore, it was necessary to search for and hire a new Post-Doctoral Fellow, Dr. Mark Shalinsky, an electroneurophysiologist, to write software that would allow us both to analyze and to interpret the fNIRS system data. Dr. Shalinsky, with Petitto and Ioulia Kovelman, created and tested the new software, which was subsequently tested across several major fNIRS labs over 2006-2007 (Year 3).

We have submitted and revised a paper on this important "first-step" research activity to an international journal, in which we describe this new universal analysis program to analyze/interpret the data that the fNIRS system records. Cognitive neuroscience labs throughout the world that utilize fNIRS can use this analysis system. We also completed MRI/anatomical co-registration with fNIRS, to ensure high confidence in the neuroanatomical precision of our fNIRS probe placements.

**Key Personnel**

Professor Laura-Ann Petitto, Post-Doctoral Fellows Dr. Melody Berens and Dr. Mark Shalinsky, and graduate student Ioulia Kovelman (see also Year 1 above).

**… dancers were significantly more accurate than non-dancers on an attentional task …**

## Part 1 Results: Dance Foundational Behavioral Studies - Years 1 and 2

As important background to our Year 3 research, our completed behavioral studies of dancers versus non-dancers revealed that dancers were significantly more accurate than non-dancers on an attentional task ($p < .03$). This finding, in turn, suggested that early dance education does benefit (that is, may positively transfer to) other domains of higher cognition, such as attentional processing, or more specifically, resistance to interference from competing signals, compared to participants who were not educated in the Arts.

We also found that dancers were faster on the Biological Motion Perception Task ($p < .001$). This finding suggests that early dance education benefits both biological motion processing and working memory of biological motion stimuli, in terms of the speed with which these stimuli are processed.

## *Part 1: "Mind-Brain-Gene" Dance Study Year 3*

### Innovations—Genetics (Genotyping Analyses)

To achieve the goal of studying possible genetic influences underlying observed performance differences on higher cognitive tasks in dancers versus non-dancers, as well as possible genetic influences on the likelihood of pursuing arts education, we collaborated with Dana consortium scholars Drs. Kevin Dunbar and Michael Posner.

**Indeed, to answer this question we needed to tackle, head-on, the elusive decades-old question of nature versus nurture.**

### Year 3 Key Personnel

Professor Laura-Ann Petitto, Post-Doctoral fellows Dr. Melody Berens and Dr. Katherine White (Petitto Lab), Dr. Ioulia Kovelman (now at MIT, John Gabrieli's Lab), Dr. Mark Shalinsky (now at Harvard/MGH, David Boas' Lab) and research assistant Douglas McKenney (now at Jerusalem University). Invaluable assistance and consultation about specific genes *that might be* associated with specific higher cognitive processes were provided by Drs. Kevin Dunbar and Michael Posner. Moreover, Dr. Dunbar also reviewed the Petitto team's proposed list of genes to study and offered important feedback that led to our final list of genes under investigation. We remain grateful to these scholars for their wisdom and time.

As discussed (above) in the summary of Year 1 and 2 Dance study results, we discovered significant performance differences on select higher cognitive tasks in persons with extensive education in the performing arts (dancers) versus those with minimal or no education in the performing arts (non-dancers). One exciting hypothesis that followed from these findings—one of the core hypotheses being tested by the Dana Arts and Cognition Consortium—is that such group differences derived from the impact of education in the Arts on the brain, and its positive transfer to the acquisition/learning and processing of other core content knowledge.

The tantalizing unanswered question from the Petitto team's Year 1-2 Dance Study findings, however, was this: Were such group differences specifically due to one group's extensive education in the arts versus the other group's lack of education in the arts, or were the group differences due to other biologically/genetically-based self-selection factors? Indeed, to answer this question we needed to tackle, head-on, the elusive decades-old question of nature versus nurture. Was it the sustained education—the environmental experience—with the arts that rendered dancers with a greater "cognitive edge" over non-dancers? Or, was it just that people who ended up being dancers were born with a complex composite of genetic predispositions—or "nature"— that generally afforded them select higher cognitive capacities, which, in turn, yielded a greater likelihood of their self-selection to enter this particular life path? Said another way, were such group differences between dancers and non-dancers due to differences in their education, per se, or instead to differences in genetic predispositions that caused one group (the dancers) to choose to undertake the arts?

### Significance

Moving beyond the fact that we observed group differences between dancers and non-dancers on select higher cognitive tasks (Years 1-2), in Year 3 we sought to gain new insight into why this finding might be so. Answering this "why" question was not only a scientific imperative—the logical next-step in achieving the most complete answer to the

questions posed in our Dana research program—but it was an educational policy imperative. Only by unraveling the factors that contributed to our group differences can we provide compelling evidence to support educational policy in the United States. It is well known that cuts in school budgets often lead first to cuts in school's arts curriculum (over, say, cuts in the math curriculum). By sorting out whether the higher cognitive performance of dancers in our study was due to educational versus biological factors, we can contribute new evidenced-based knowledge to United States educational policy makers on which they may base decisions about whether to cut arts education from young children's curricula during the developmentally crucial elementary school years.

**Participants were tested behaviorally and all were also tested with the fNIRS brain imaging system …**

### Background

Recently, Bachner-Melman, Dinal, Zohar, Constantini, Lerer, Hoch, et al., (2005) found that dancers have a particular polymorphism on two of their genes. In addition, consortium member Dr. Michael Posner and collaborators have found evidence of genetic influences on performance on attentional tasks (e.g., Posner, Rothbart, & Sheese, 2007). To study whether there might be possible genetic influences underlying any performance differences during higher cognitive tasks in persons highly educated in the arts versus those not educated in the arts—as well as the likelihood of pursuing an arts education—buccal (cheek) swabs were collected from all participants, both while performing a battery of behavioral cognitive tasks and while simultaneously undergoing fNIRS brain imaging.

Seven candidate genes were selected for polymorphism analyses after extensive review of the literature and after important consultation with scholars Drs. Dunbar and Posner. Our particular choice of these seven candidate genes was established on the basis of specific linkages of previously identified genes with specific behavioral profiles. In one such study concerning dance, Bachner-Melman, et al. (2005) found that trained creative dancers had polymorphisms on their serotonin transporter gene SLC6a4 and vasopressin receptor gene AVPR1a—interestingly, polymorphisms not found in athletes and non-dancers.

In such genetics studies concerning attention/higher cognition, consortium scholar Dr. Michael Posner and colleagues have identified polymorphisms in several dopaminergic genes associated with attention and higher cognitive functioning: DAT1, DRD4, MAOA, and COMT. The DAT1 gene has been shown to be related to executive cognitive function and performance on a conflict task (Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005). DRD4 and MAOA genes have been shown to be associated with performance on conflict-related tasks (Fan, Fosella, Sommer, Wu, & Posner, 2003). The COMT gene has been associated with performance on attention and working memory-related tasks (Raz, Fan, & Posner, 2006). In genetics studies concerning memory/learning, BDNF (brain-derived neurotrophic factor) has been shown to be associated with episodic memory, LTP (long-term potentiation), and also with learning (Goldberg & Weinberger, 2004).

### Participants

Participants in the study were adult English monolinguals who had early (before age 7), sustained, and intensively maintained education in the performing arts (dance) versus participants with very little or no performing arts education (non-dancers). Participants were tested behaviorally

and all were also tested with the fNIRS brain imaging system (a further subset of participants also underwent MRI/fNIRS co-registration).

## Methods

Extensive measures were taken to equate our participants across multiple dimensions to ensure that the only major difference between groups was in their arts (dance) expertise. Overall, participants in the study underwent questionnaires for group assignment, followed by the administration of cognitive and perceptual assessment tasks. Two steps were applied to all participants that constituted the basis for expert "dancer" versus novice "non-dancer" group assignment, including an (i) email questionnaire and an (ii) Expert Dance questionnaire or Performing Arts Experience questionnaire. The Performing Arts Experience questionnaire also included a detailed "Personal Pleasure Scale" regarding the performing arts, as well as general information about their propensity to engage in other daily/weekly activities and-or intensive education/training regimes (e.g., house cleaning, shopping activities, sports and exercise education/training regimes, etc.). We collected standardized academic performance measures (SAT scores). Regarding assessment, participants underwent standardized assessments, including measures of non-verbal relational reasoning, language competence, cognitive and attentional processing, and biological motion perception (consisting of whole body dance and walk visual processing).

Selection of those to participate in the dancer, and non-dancer, groups was made on the basis of this information—and following from the Petitto team's rigorous Expert-Novice criteria—as well as in Berens, Kovelman, White, Shalinsky, Gramacy & Petitto, (2007), and in our submitted manuscript for journal submission. Briefly, participants in the "dancers" group had (i) >8 years dance education, (ii) begun education in dance before age 7, (iii) continued dance education/training into adulthood, (iv) extensive professional performance experience, and (v) reported dance as "pleasurable."

## Procedures for the "Mind-Brain-Gene" Study

Regarding behavioral assessment of cognitive performance, participants underwent several standardized assessments, including measures of their English language expression and proficiency (language performance assessment), cognitive and attentional processing, and whole body biological motion visual perception processing. Regarding fNIRS brain imaging assessment, participants' brain activity was recorded while they performed the cognitive and attentional processing task and the biological motion perception tasks. Regarding gene assessment, cheek swabs were obtained from all participants immediately prior to the simultaneous behavioral and fNIRS assessments. All swabs were assigned a random, 4-number-4 letter anonymous code, so that no participant could ever be tied to a specific cheek swab. This process also ensured that the genetic study scientists were "blind" to the participants' background during data analyses.

The collected buccal swabs from all dance and non-dance group fNIRS participants were stored in an Isotemp freezer while waiting to be analyzed. Collected buccal swabs from both the Petitto and Dunbar laboratories were then driven to the "Center for Functional Genomics" at SUNY Albany for standard PCR-based amplification and genotyping analyses.

To ensure accuracy and neuroanatomical precision across new fNIRS technology, as compared to existing MRI technology, in Year 3 we completed the collection and analyses of co-registration data between the MRI/anatomical and fNIRS in a subset of our adult participants. This important procedure is required whenever data across two technologies are compared. By doing so, we gain the greatest confidence with regard to recording from the neuroanatomical sites

that precisely correspond to our brain regions of interest (ROI), thus permitting the most accurate study of higher cognitive functions and specific brain regions. During Year 3 (and end of Year 2), entirely new participants were rigorously screened, and new adult dancer and non-dancer groups were established. These participants then participated in our cognitive attentional and Biological Motion Perception behavioral tasks, while undergoing fNIRS brain imaging. In Year 3 we completed fNIRS system imaging of these new participants.

**In a striking contrast of neural activity and behavior, both groups exhibited similar activation patterns ...**

### Preliminary Results and Status of Analyses of fNIRS

First, the behavioral data collected from participants while undergoing this new round of fNIRS brain recordings during the Biological Motion Perception tasks showed a similar pattern of results as those collected without simultaneous scanning (off-line). That is, the present behavioral results replicated the behavioral findings observed in the Year 1-Year 2 study described above.

Second, the fNIRS brain imaging data collected during the visual Biological Motion Perception task showed that dancers had greater right than left hemisphere parietal brain activation, while non-dancers showed the reverse pattern ($p < .02$). In a striking contrast of neural activity and behavior, both groups exhibited similar activation patterns during Biological Motion trials depicting walking, with lateralization differences emerging only on trials depicting dancing.

Third, regarding the genetics data, we have received results for four genes from our target list of seven. Due to the labor-intensive nature of these genotyping analyses, the Center for Functional Genetics (SUNY Albany) is still working on the remaining three genes. Nonetheless, we have now received genotyping results for four of our candidate genes. Most intriguingly, the preliminary results suggest that there are no differences between our dancer and non-dancer groups on COMT, MAOA, and 1 of the DRD4 polymorphisms. (Recall that COMT, MAOA, and DRD4 have been associated with performance on attention and working memory related tasks; Raz, Fan, & Posner, 2006.)

Although exceedingly preliminary, these exciting results suggest support for the hypothesis that the differences between our two groups may be due to their education in the arts, rather than to genetic predispositions. We are currently awaiting the outstanding genotyping data and are in the data interpretation stage of this Mind-Brain-Gene (genotyping) study of dancers versus non-dancers.

## Summary and Preliminary Conclusions: Dance Study

The above combined "Mind-Brain-Gene" study of the impact of education in the arts on the mind (as revealed through behavioral measures of cognitive processing), the brain's functional architecture, and genes, may soon have important educational implications. Additional results corresponding to the preliminary results described above have the potential to provide educators, policy makers, and parents with evidence that early and sustained education in the arts may afford young students long-lasting advantages in other core cognitive domains—thereby providing a powerful "translational benefit" from scientists to the greater society.

### *Year 3 Tangible Products from Dance, fNIRS, and Music Studies*

A journal manuscript of the Dance Behavioral study has now been submitted for publication and is under review. A poster of both the Dance Behavioral and the Dance fNIRS studies was presented at the annual Cognitive Neuroscience Society meeting held in New York, NY, May, 2007. Our fNIRS manuscript, in which we offer the discipline a universal analysis method, has been revised and resubmitted. In depth Dance fNIRS analyses are presently in progress. Once data analyses are complete, a journal manuscript of the Dance fNIRS study will be submitted. Over the course of the coming year, we will prepare the genotyping data both for presentation at a major scientific and an educational conference as well as for journal manuscript submission. Clearly, the completion of this important Dana research activity awaits the return of the final genotyping data results from the Center for Functional Genomics scientists at SUNY Albany.

Following from this Dana Foundation genotyping work, Kevin Dunbar (Dana recipient) and Laura-Ann Petitto are writing a manuscript for journal submission in which they lay bare this new method, its theoretical power, and its implications for the study of higher cognition, as well as the arts and education. Final closure on all work (involving, for example, revisions and publication of submitted manuscripts, final analyses of genotyping results, publication of Dance and fNIRS results, presentation and publication of genotyping results, and combined presentation/publication of Dance-fNIRS-Genotyping results) will occur over the next year.

## References


### *2007 Dance*

Berens, M.S., Kovelman, I., White, K.S., Shalinsky, M.H., Gramacy, R. & Petitto, L.A., (May 5-8, 2007). "Cognitive benefits and neural processing following early and continued arts education in Dance." Abstracts for the Cognitive Neuroscience Society. New York, NY.

Berens, M.S., Kovelman, I., Grammacy, R.S., & Petitto, L.A. (under review). Evaluation of the benefits dance expertise has on higher cognition.

### *2007 fNIRS Brain Imaging (Advancement in brain imaging Methods)*

Shalinsky, M., Kovelman, I., and Petitto, L.A. (Revise and Resubmit, 2007). Analysis method to shed new light on the brain's cognitive functions using fNIRS.

### *2007-2008 Genes (Advancement in genetic Theory and Methods)*

Dunbar, K. and Petitto, L. (Manuscript in preparation). Molecular Epigenesis: A new microarray-based method for determining the interactions of genes and environment.

### *2007 Music*

Berens, M.S., Kovelman, I., & Petitto, L.A. (May 24-27, 2007). "Benefits of Childhood Music Education on New Language Learning." Association for Psychological Science conference, Washington, DC.

Berens, M.S., Kovelman, I., Shah, A., & Petitto, L.A. (forthcoming). Does early childhood exposure to Music provide cognitive enhancement?

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## Research Part 2: Music Education and Its Impact on Second Language Learning

### *Study Hypothesis*

In this Dana Consortium study involving music, our goal was to understand whether extensive childhood musical education impacts higher cognitive attentional abilities and second language learning in adulthood. Because learning another language involves the ability to attend to one language, inhibit the other language, and rapidly switch between them, and because musicians have been shown to have enhanced selective attention on particular higher cognitive tasks (e.g., Crawley, Acker-Mills, Pastore, and Weil, 2002; Schellenberg, 2005), this study tested the following hypothesis: Monolingual expert musicians would learn their new/second language better than non-musicians (equated on all other factors).

### *Study Participants*

Participants in the study were monolingual English-speaking students enrolled in Introductory Italian or Spanish classes (Spanish 001 or Italian 001). Participants were tested twice, once at the beginning of the academic term (T1) and once at the end of the academic term (T2).

### *Study Procedures*

Extensive measures were taken to equate our participants across multiple dimensions to ensure that the only major difference between groups was in their arts (music) expertise. Overall, participants in the study underwent questionnaires for group assignment, followed by the administration of cognitive/linguistic and attentional assessment tasks. Two steps were applied to all participants that constituted the basis for "music" versus novice "non-music" group assignment, including an (i) e-mail questionnaire, and an (ii) Expert Music questionnaire or Performing Arts Experience questionnaire. We collected standardized academic performance measures (SAT scores). Regarding assessment, participants underwent standardized assessments, including measures of language competence, cognitive and attentional processing. Based on responses on these questionnaires about their music education, participants were divided into musician and non-musician groups, with those who received early extensive and continued music education classified as musicians; see summarized details in Dance studies above.

For assessment, participants were measured on their English competence/expressive proficiency (language performance assessment), new language competence/expressive proficiency, cognitive attentional processing, end-of-term self-evaluation, and class final grade. Native Italian, Spanish, and English speakers conducted data transcription, coding, and reliability checks/measures, and all analyses.

## Summary of Music Study Results Years 1, 2, 3

### *Behavioral*

Analyses of these data found no differences in general academic performance measures—the SAT, Final Class Grade, and Self-Evaluation. This is what we had predicted. We observed that there were also no differences between groups on the cognitive attentional assessments.

Importantly, our findings demonstrate that

musicians exhibited significantly increased language competence and proficiency in their new (second) language as compared to non-musicians, even after only one term of language instruction ($p < .05$).

**… there may be an enduring cognitive advantage afforded by early and extensive music education on adult learning of a new language …**

## Conclusions

The Music study results suggest that there may be an enduring cognitive advantage afforded by early and extensive music education on adult learning of a new language in an instructional setting. Specifically, musicians showed greater improvement in expressive fluency and competence in their new language than non-musicians.

### *Tangible Products of Music Study Years 1, 2, 3*

A manuscript of the Music study is in progress. A poster of the Music study was presented at the annual Association for Psychological Science conference, held in Washington DC, May, 2007. The Petitto Laboratory recently moved to the University of Toronto, where they will continue research in the Performing Arts and where additional collaborative opportunities exist (e.g., Dr. Glenn Schellenberg's aboratory).

## References


Bachner-Melman, R., Dina, C., Zohar, A.H., Constantini, N., Lerer, E., Hoch, S. et al. (2005). AVPR1a and SLC6A4 gene polymorphisms are associated with creative dance performance. *PLOS Genetics*, 1(3), 394-403.

Bever, T.G. & Chiarello, R.J. (1974). Cerebral dominance in musicians and nonmusicians. *Science*, 185(4150), 537-539.

Fan, J., Fosella, J. Sommer, T., Wu, Y., & Posner, M.I. (2003). Mapping the genetic variation of executive attention onto brain activity. *Proceedings of the National Academy of Sciences*, 100(12), 7406-7411.

Crawley, E.J., Acker-Mills, B.E., Pastore, R.E. & Weil, S. (2002). Change detection in multi-voice music: The role of musical structure, musical training, and task demands. *Journal of Experimental Psychology: Human Perception and Performance*, 28(2), 367-378.

Goldberg, T.E. & Weinberger, D.R. (2004) Genes and the parsing of cognitive processes. *TRENDS in Cognitive Sciences*, 8(7), 325-335.

Keller, P.E. (2001). Attention resource allocation in musical ensemble performance. *Psychology of Music*, 29(1), 20-38.

Large, E. W. & Jones, M. R. (1999). The dynamics of attending: How people track time-varying events. *Psychological Review*, 106 (1), 119-159.

Posner, M.I., Rothbart, M.K., & Sheese, B.E. (2007). Attention genes. *Developmental Science*, 10(1), 24-29.

Raz, A., Fan, J., & Posner, M.I. (2006). Neuroimaging and genetic associations of genetic and hypnotic processes. *Journal of Physiology*, 99, 483-491.

Rueda, M.R., Rothbart, M.K., McCandliss, B.D., Saccomanno, L. & Posner, M.I., (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences*, 102(41), 14931-14936.

Schellenberg, E.G. (2005). Music and cognitive abilities. *Current Directions in Psychological Science*,14(6), 317-320.