Assessment of the Effects of Artistic Training and Experiences on Cognition

A research program joining traditional measures of learning and problem solving ability with neuro-imaging and cognitive neuroscience

Example Proposal for a Planning Grant

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Opportunity and Need – The Arts, Learning, and Neuro-imaging

The late 1990s witnessed two explosions of published research that can be joined to substantial mutual advantage. One is a flurry of studies over the past decade showing connections between involvement and training in the arts and both academic and social development.[1] The other is an exponential increase in studies of relationships between various types of cognitive processing on the one hand (such as memory encoding and recall, or acquisition and use of mental imagery) and brain function on the other.[2]

The recent stream of research on the arts and learning was catalyzed by mid-1990s studies demonstrating ties between certain types of learning in music and spatial-temporal reasoning. Related work also showed links to academic skills, such as mathematics, which benefit from spatial-temporal reasoning skills. At the same time, research using neuro-imaging to help understand cognitive processes was propelled by the increasing use of advanced technologies allowing enhanced resolution of neuro-function. We are gaining increasingly refined understandings of how the brain functions when individuals accomplish various tasks – many tasks ultimately associated with academic success and other human developments.[3]

There is need for our work on two fronts: (1) the research would support more scientifically grounded inferences about relationships between the arts and human development than are presently available, and (2) the research would contribute to the cognitive neuro-science field by producing information about changes in brain function over time and what, including artistic experiences, contributes to such changes.

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[1] The leading examples of this body of work are the *Champions of Change* studies published in 1999 and supported by the GE Fund, the MacArthur Foundation, The Arts Education Partnership (AEP) and others. Professor Catterall was principal investigator for two of the seven studies described in this book. We also anticipate the imminent publication of Harvard's Project REAP, a research review of the academic outcomes of arts education, and a compendium of recent research on the arts and both academic and social outcomes. This National Endowment for the Arts and AEP-funded compendium is co-authored by Professor Catterall of UCLA and Professor Ellen Winner of Harvard University's Project Zero.

[2] The 1999 review of studies of imaging cognition (Cabeza and Nyberg) published in the *Journal of Cognitive Neuroscience* shows graphic increases in the production of cognitive studies using brain-mapping techniques: 10 studies between 1988 and 1991; 73 studies between 1992 and 1995; and 275 studies between 1996 and 1998, the last only a three period.

[3] For example, the latest and most powerful imaging technology is the 3-tesla scanner at the UCLA Brain Mapping center, a device manufacture by GE.

The Goal of This Proposal

Our long-term goal. Our ultimate goal is to design and carry out a series of longitudinal experiments with school age children and youth which would align traditional psychometric assessments of learning with concomitant changes in brain-function over time.

The immediate goal. Because there is no direct precedent for the studies we anticipate, we propose to engage in an expertly informed planning process before crafting a detailed plan of trial studies and more extended research. In short, we would like our designs to undergo significant review *before* they are carried out.

Our proposed planning process will serve many purposes benefiting the research ultimately carried out:

(1) Expert discussion and advice would lead to better research designs and instruments. And help to anticipate and avoid problems in the execution of the research.

(2) The vetting process will allow expert colleagues to consider potential roles in the design and execution of the actual research.

(3) The process will also promote mutual awareness among a small group of principal investigators heading incipient research projects in the domain of the arts and cognition. These investigators should learn from each other and possibly team-up for future research.

(4) Our preliminary explorations indicate that there are several arts/learning/ and cognitive neuro-science research projects on the drawing board or starting-up at different universities across the United States. These include a partnership among anthropologist/linguist Shirley Brice Heath and neuro-imaging colleagues at Stanford, a new training program in Science, Art, and neuro-function at CalTech, and a developing neuro-science and music project at Harvard.

It is conceivable that a consortium of funders would support a cluster of research projects over a several year period and bring the principals together periodically for briefings, discussions, and critiques. This was the model used in the *Champions of Chang*e project, and participants would agree that each project became stronger through mutual interaction.

Proposed Planning Process.

Professors London and Catterall, drawing informally on colleagues and leading researchers, would produce a preliminary research design document. Upon confirmation of a planning grant, we would schedule an advisory meeting lasting a full day and involving approximately 8 expert colleagues in cognitive neuro-science and educational psychology and assessment. The funder's program officer (s), executives, or board members would be welcome at this meeting.

This meeting will be designed to get the best thinking available on critical aspects of the project – ranging from what sort of initial trials would provide the best foundation for future research, overall research design, the characteristics of sample subjects best suited to the research questions and methods proposed. We would also discuss the types of neuro-imaging best suited to the desired measures, discussion of the best existing research that would inform various aspects of our work, and explore the funding needs for the trial phase, and for a more mature, longer term program of research.

An added topic of our meeting would be potential roles of the gathered experts in the research itself – either in the early trials, or in the longer run. One definite prospect for collaboration has emerged already. Professor John Bransford of Vanderbilt is considered the nation's leading scholar on human learning. Bransford is editor of the seminal new book, *How People Learn*; he also has written a new provocative piece on the transfer of knowledge from one domain to another, a work that has reconceptualized the field in very positive ways that could impact our research.

Informed by the expert advisory proceedings, Professors London and Catterall would then produce a full research proposal with two distinct, and sequentially funded components: one or more trial studies lasting approximately one year, and an anticipated longer term program of research building on the results of the early trials – with probably a three year time horizon.

More specific briefings on tentative designs, elements.

General purpose of this research. Our proposal is to join through experimental research the domains of learning in and through the arts with neuro-imaging to help comprehend the effects of artistic training on neuro-function. A second and important purpose is to promote scientific capacity to translate observed changes in neuro-function associated with learning experiences to generalizable increases in cognitive skills.

Imaging techniques would serve to scientifically anchor more traditionally observed or suspected cognitive effects of the arts. In addition, our proposed work is very well timed to participate in two important developments in the brain-mapping domain. One is contributing to the general refinement of neuro-imaging techniques in their ability to promote understanding the effects of human activities (such as the arts) on neuro-function. The other contribution goes the other way around: to enhance understanding of the implications of observed brain function for cognitive task performance related to human development.

A possible trial study. A promising way to begin this research would be to replicate a published study which found strong cognitive effects of artistic experience, and to overlay the replication with neuro-imaging of subjects both before and after engagement in the arts. An obvious choice would be the studies of Shaw, Rauscher, and colleagues demonstrating strong positive associations between keyboard training over a little as 9 months with significant increases in spatial-temporal reasoning skills. Glenn Schellenberg's recent work on music training and IQ provides another music training model that could be used for the purposes of our work. Students would be randomized into a music training group and a control group, which might receive computer training paralleling Shaw's studies, or no intervention at all. A neuro-imaging trial could examine brain function of subjects at the start while performing a task (or perhaps a set of tasks of increasing complexity) reliant on spatial-temporal processing skills. Traditional measures of task performance would also be administered before and after the music training.

After a school year's worth of keyboard training, subjects would perform equivalent tasks a second time and be assessed both through traditional measures and neuro-imaging. Increased spatial-temporal reasoning skills, the expected outcome, would show up both on traditional measures and in specific changes in neuro-function.

Such a trial could demonstrate neuro-function-change analogues to change in traditional measures of cognitive functioning. The trial would help calibrate our instruments, help guide the selection of task response formats, and help plan future work.

If funded in the trial phase, a second more speculative trial might be run in parallel during the first project year, one perhaps involving training in the visual arts, or perhaps in theatre. A product of the planning and advisory process would be to identify a second trial study to complement the first.

Note: All of our designs would be intentionally consistent with the sorts of arts training and experiences that could be thought feasible in the context of public education. That is, we do not wish to prove the worth of programs so exotic or expensive that they could never be implemented widely even if shown to be very effective. Some of our designs would try to push the envelope a bit, nevertheless. Just because schools in a particular district now have only a half day with a music teacher every other week, it is not out of the question to imagine a more intensive program of music within reasonable bounds. And we imagine reasons for testing the effects of a richer but feasible set of experiences.

A layperson's introduction to cognitive neuro-imaging.

What skills are explored? A broad range of cognitive skills are under exploration by neuroscientists. These include attention, perception, language, visual perception, mental imagery, memory encoding, memory retrieval, semantic memory encoding and retrieval, episodic (short term) memory, and processes involved in evaluating complex tasks, such as dealing with incongruities or ambiguities in problem situations – just to begin. In general, the field of cognitive neuroscience is in agreement that the latest imaging technologies have permitted understandings of large-scale neuro-function processes associated with higher-order cognitive processes.

What are these neuro-imaging techniques and what do they "show?"

There are two predominant approaches to neuro-imaging, both non-invasive and considered unquestionably safe for subjects. One group of methods is hemo-dynamic; this refers to identifying activated regions in the brain through measures of blood flow. The latest of these techniques is functional magnetic resonance imaging (fMRI). Another more long-standing hemo-dynamic technique is positron emission tomography, or PET scans. Each identifies areas and intensity of brain-region activity due to increasing blood flow associated region activation.

Another class of imaging techniques is electromagnetic rather than hemo-dynamic. Among these are magneto-encephalography (MEG; related to the brain encephalogram used in medical diagnoses) and event-related potential assessment (ERP).

Without delving into the specifics, the hemo-dynamic techniques most common to cognitive neuroscience have good spatial resolution (they point accurately to where activity is occurring or has occurred), but relatively poor temporal resolution (exactly when did an activation occur?). The electromagnetic technologies exhibit the reverse – higher temporal resolution and poor spatial resolution. In the present state of cognitive neuroscience research, the "where" of brain activity seems more important. For many such studies of cognition, the fMRI or PET scan techniques are relied upon. For some studies, reliance on combined techniques that produce both high spatial and temporal resolution would be beneficial, and will probably become more common in future years.

Approaches. There are three fundamental approaches to understanding neuro-function through imaging technologies. The first and most long-standing is a <u>local</u> approach – understanding the role of each brain region in the performing of a cognitive process or reaction to a stimulus. The second is a <u>global</u> approach – understanding the role of specific regions in a general process that draws on tasks in different domains. And a third is a <u>network</u> approach. This is the role of specific regions of the brain in relation to the region engaged by a specific task (i.e. the accomplishment of a task within the context of a neural network). One future direction in cognitive neuroscience anticipates increasing ability to synthesize these three approaches; at the present time, most studies rely predominantly on one approach.

In general, the field of cognitive neuroscience aims at unifying the separate views produced thus far, to establish the consistency of specific brain region activity associated with specific tasks, and to increase awareness of the shared activities of cognitive regions. An important recent contribution to the understanding of shared brain region activities in cognition is the just published study of MacDonald (*Science*, June 9, 2000). MacDonald identifies what he calls "cognitive controls," or brain regions that activate apparently to assist another region when a task escalates in complexity. The notion of cognitive controls is a possible focus of our long-term work because of our interest in complex problem solving, and in the transfer of complex problem solving ability across domains. (See Bransford, 1999, for a discussion and promising re-conceptualization of the transfer of learning that has influenced our explorations of possible research.)

Our work is likely to utilize generally a network approach consistent with the work of MacDonald – i.e. focusing on the development of region activities and functional communication between and among regions within neural networks. Our focus will be on changing activations and changing neural pathways associated with learning. For example, what happens at the neuro-function level when we are able to solve problems more efficiently or more accurately? What experiences promote such growth? What changes in brain function related to cognition are promoted by what sorts of artistic learning or other more general training interventions?

Speculating on future studies – visual imagery for one. A particular area of attention possible in our longer term studies could be work built on studies of visual perception and visual imaging – the first flowing from beheld images outside the brain, and the other relying on neuro-function to produce mental or imagined images. (See especially the works of Prof. Steve Kosslyn at Harvard.) Because much of what we call art has relations to imagery of one sort or another (the literal images of visual artists to be sure, or the feeling-based images of artistic experiences such music or dance), the nature and function of imagery seem a good but highly complex prospect for investigation.

Imagery and science as a potential application. This line in our thinking is supported by the fundamental observations of scientists that they perceive their respective "fields" as structures, or as maps, rather than as long lists of terms, formulae, inventors, and dates. Thus the ability of children to comprehend, imagine, and produce visual images that map domains they are trying to learn or master might be impacted by training in the arts, especially but not exclusively training in the visual arts. This may prove worth investigating.

Conclusion

It is all too easy to speculate concerning what might be known about learning in and through the arts with the addition of neuro-imaging technologies. In this planning grant proposal, we have articulated our general intentions and rough ideas of designs. We seek this planning grant in order to assure that our first steps in this research are sound and as well- informed as they can possibly be, given the current states of relevant knowledge and imaging technologies.

A note on this current state: cognitive neuroscience is an embrionic field, with no papers reported as little as eleven years ago. Now there is a dedicated journal, *Cognitive Neuroscience*, and more thousands of research papers published. Most studies are pursued through single scanning sessions, with no follow-up or longitudinal change designs. Our work is directed to long-term change in neuro-function driven by specific learning experiences and explored through true experiments. This alone will put out team in an excellent position to take a leading role in cognitive neuroscience more generally over the coming years.