Final Workshop Report

Art, Creativity and Learning

June 11-13, 2008

National Science Foundation

Organizers

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EXECUTIVE SUMMARY

The NSF Workshop on "Art, Creativity and Learning", held at the National Science Foundation Headquarters in Arlington Virginia and The Phillips Collection on June 11-13, 2008, brought together a pool of the world's leading investigators interested in the relations between the enhancement of learning, the transfer of cognitive abilities, and art education. The **goals** of the workshop were (i) to establish if there is a sufficient basis for initiating a field of study of the **Enhancement of Learning through Art** to the Science of Learning, (ii) to explore the **current status** of related research, and (iii) to determine the **potential for future research** in this arena from the neuroscientific, cognitive and educational perspectives. There exist scattered studies on the effect of learning in specific fields of artistic endeavor, particularly in the case of music, but little systematic work on the issue of transfer from experience with the arts to proficiency in other fields of human activity. These interdisciplinary goals required the assembly of distinguished researchers from a diverse array of interrelated fields, including neuroscience, visual art, music, dance, sensory physiology, psychophysics, developmental psychology, education, and philosophy. The participants were selected as those reaching out from their traditional academic disciplines to study the role of art in enhancing learning capability and effectiveness throughout the stages of life.

Organization of the Workshop

The format of the workshop was designed to enhance creative and effective discussions. Prior to the event, the organizers distributed ***seed questions*** to all participants to promote conceptualization of the issues; and in order to facilitate active independent positions, the participants were required to prepare and submit ***one page projections*** of their individual ideas for research.

At the meeting, fifteen short ***20 min presentations*** were followed by ***Research Goals Brainstorms*** in each topic area, which proved to be a very effective strategy. The Brainstorm sessions became a creative focus promoting integration of the diverse group, and generating significant reconceptualization in several of the topics of the preceding talk sessions.

The ***Keynote Speaker,*** principal dancer Jacques d'Amboise, has spent his post-dance lifetime developing formats in which engagement with the art of dance can promote enhancement of learning in other fields of life. The stated goal of his National Dance Institute is to use dance as a catalyst to engage children and motivate them towards excellence, including improved thinking ability, development of self-esteem and confidence, and higher order skills tied to cognitive, affective, and kinesthetic domains of learning.

A ***Creative Social*** evening session immersed everybody into a direct exposure to the creative artistic process. The renowned performer Parthenon Huxley from the classic rock music group "Electric Light Orchestra" came, and in an intimate format surrounded by the participants gave uniquely introspective answers to questions about the creative process of composing songs. He also generated a live composition based on ideas thrown out by the participants. This was followed by the experience of learning a group 'hora' dance, in which the participants discovered that there is a major difference between the concept and implementation!

On the final day the participants formed three ***Breakout Groups (Visual Arts; Music and Dance; Art and Education)*** to work on summarizing recommendations for new research directions in the neuroscience of learning enhancement by art training and experience. The diversity of the participants' backgrounds ensured that these discussions would not go entirely smoothly, however. There were significant debates such as: how parallel are the results across art modalities, how far particular aspects of emerging research have developed, and whether the experience of art was primarily a matter of processing within a particular sensory domain, (such as music or visual art) or was a full-scope multimodal learning process (as in a dance performance).

Main Outcomes from the Workshop

Evaluation of the Current Status

The Workshop was motivated by the current expansion of interest in the science of learning and the expanded possibilities of conceptual interrelationships offered by training and exposure to the arts. As a high priority for the national interest, the difficult task of understanding and effectively enhancing learning across disciplines, ages and cultural specificities was thought to be particularly benefited by training in and even exposure to the arts.

Both the workshop presentations and discussions demonstrated how contemporary research is beginning to explore new neuroscientific hypotheses concerning the effects of learning in activities (such as musical performance, drawing, visual aesthetics, and dance) on learning in non-artistic domains. For example, early evidence suggests that experience in the arts may facilitate creative thinking and effective problem solving across a broad range of domains, and plausible neural underpinnings are beginning to be identified. Results were presented revealing that musical experience and short-term auditory training can enhance subcortical representation of the acoustic elements known to be important for reading and speech encoding, and that such learning outcomes can be objectively assessed. The presenters also described neuroimaging support for the idea that there exists a frontal brain region that processes the general property of 'structure', when that structure is conveyed over time (i.e., the property in common across musical structure, language structure or the visual organization of words conveyed through American Sign Language). Thus, experience with musical structure can be expected to enhance the learning of language structure. Moreover, long-term musical experience on development is known to last for years and it is possible that such experience may provide protective effects against aging and the disruptive effects of hearing loss.

Dance integrates the rhythmicity of music and the representational capacity of language. Neuroimaging studies of dance were presented that have examined brain areas involved in both the production and perception of dance. Perception studies have evaluated neural "expertise effects", demonstrating brain activations that occur preferentially in people who are competent to perform the dance movements. Neuroscientific evidence was presented suggesting that music and dance may activate two parts of the same motor-action-imitation system through mirror neurons. Music and dance also evoke emotions and stimulate visual images that expand the scope of the material being learned by maintaining attention and allowing a higher level of memory retention.

Visual art learning is reliant on a complex system of perceptual, higher cognitive and motor functions, suggesting a shared neural substrate and strong potential for cross-cognitive transfer in learning and creativity. For instance, recent neuroimaging studies have started to reveal that the process of drawing shares cortical processing areas with many specific cognitive processes, such as those involved in writing, access to the semantic system, naming, imagery, constructional abilities and the ability to estimate precise spatial relations. A case study was discussed that has revealed significant processing differences between the brains of a professional artist and a novice during drawing in the scanner; the comparative analysis of the activation patterns suggests a more effective network of cognitive processing for the brain of the artist. Neuroanatomical underpinnings of visual art production and appreciation from observations of brain damage in established artists were described, as well as the relationship between art and other communicative displays by biological organisms, and the role that beauty plays in art.

Speakers introduced some of the principles of visual neuroscience and showed how artists have implicitly (and occasionally explicitly) taken advantage of these principles in developing works of visual art. On that basis, a specific undergraduate syllabus was proposed, with the goal not only to advance an understanding of the neural systems that underlie vision but also to cultivate observational skills and critical thinking. It was emphasized that more sophisticated and contemporary models are needed of what art is, models that should also be based on the tools of psychology and psychoanalysis. Art should be regarded as a cognitive process in which artists engage the most perplexing issues in present experience and try to find a way of symbolizing them visually so that they can bring coherence to their experience. In consequence, the definition of art is constantly changing in relation to its time. Understanding how we symbolize our experience, how we use symbolic form to organize our thinking processes, and what are the neuroanatomical corollaries to these processes, will have obvious implications for learning.

From pre-historical times, visual art has been a form of communication deeply embedded inhuman nature. The participants discussed how compositional universals govern the design of visual artworks across ages and cultures, and how the act of art experience and appreciation in the "receiver" also has the power of cross-cognitive effect during any time point in individual development. These findings have implications not only for biomedical sciences, but also for learning, pedagogical principles and general social and educational policies.

Recommendations for Future Research

Strategic Principles

Are there **general strategic principles** that should be applied to future research in the enhancement of learning through the arts? Some of the principles that were brought out in the discussions were:

- Art is fundamentally a **communicative medium**: the processes of creation and appreciation of art constitute a special kind of communication; thus future research needs to study both the creators of the art and the consumers (enjoyers) of the artistic products; a focus on one or the other alone would be incomplete.
- Such a **dual focus** is fundamental to understanding and developing theories of how we *learn to create and appreciate art*. An adequate theory must account for both the holistic and componential factors that contribute to activities in the arts.
- Both art learning and art production involve a complex interplay between multiple sensory-motor and higher cognitive mechanisms. To achieve full understanding of the processes involved in any art, as well as the way they influence learning in other domains, the focus of future investigations should **not be restricted within one level of**

the system, but include consideration of the whole complex of interactions between the levels of learning, art creating and appreciation.

Key Research Directions

Consensus was reached in terms of agreed sets of the most worthwhile research questions to pursue in three areas: i) music, dance and the science of learning; ii) visual arts and the science of learning; and iii) the role of the arts in learning strategies.

From the extensive array of questions that were identified, certain **common themes** emerged from the Breakout Sessions, encapsulated by broad questions as the following:

- How can the dimensionality of the domain be scientifically defined in each of the arts? An important step is to develop common vocabulary and operational definitions in each domain of enquiry.
- What are the measurable cognitive and biological underpinnings of learning in specific art forms, such as visual arts, music, dance, theater? How can the relative importance of those learning components be quantified and understood in terms of the neurobiological mechanisms?
- What processing "modules" does art learning "share" with other cognitive functions, in particular such as those known to be involved in learning and creativity in non-artistic domains?
- What are the implicit benefits and cross-cognitive transfer effects of training and experience in the arts? How can the transformative process of the art experience be studied?
- What is the plasticity of the component abilities across the lifespan? What aspect(s) of art training help(s) people become better artists?
- What is it that the learner in the arts is actually learning? What specific skills do musical, visual art, or dance training impart? What is the link between such training and outcomes in language, social, and cognitive functions?
- Neuroscientific studies have identified "mirror neurons" forming a mirror-matching system that responds similarly when an act is performed by the individual studied or when observing a separate person performing the same act. Does the mirror neural system form the neural substrate of the embodied cognition experienced when viewing a work of art? Can the positive or negative valence of the art-induced form of empathy be harnessed to enhance learning in related fields of endeavor?
- Inspiration is an aspect of mental experience that involves not just cortical circuitry but its integration with the limbic system and medial frontal structures that are understood to mediate the experience of emotions, motivational rewards and the appreciation of the aesthetic values of the impinging stimuli. What is the mechanism underlying the role of inspiration in long-term learning? How is inspiration related to the mechanisms of attention and reward?
- Does learning in an art form always "transfer" to learning in science? (e.g., does the learning of drawing foster the ability to learn geometry, or the learning of music foster the ability to learn language or mathematics?) What factors support or invalidate the operation of such a transfer process?

- When the arts are integrated with other related disciplines in schools, is there evidence that learning in these other disciplines is enhanced? Does the answer to this question depend upon the type of learner (e.g., learning disabled; typical)?
- There is a need to evaluate the underlying processes to determine what specific mechanisms for such transfer of learning the brain has developed. What are the main principles of learning transfer and how could they be implemented to effectively enhance educational strategies?

Methodological Recommendations

Key **methodological issues** need to be considered, such as what kinds of neuroscientific and behavioral research would qualify to provide a rigorous basis for advancing the role of artistic endeavors in the enhancement of cognitive capabilities. The participants proposed a set of methodological recommendations, including the following:

- To understand the cross-modal effects of art training, it is necessary to study the basic perceptual processing of the artistic objects that give rise to these experiences. The extent to which different key parameters play a role in the artistic experience should be investigated parametrically, and it should be determined how these functions map onto the spectrum of artistic expertise.
- Non-invasive neuroimaging techniques and transcranial magnetic stimulation to generate a reversible blockage of neural activation should be used to address the questions of learning transfer, enhanced creativity and enriched aesthetic experience.
- Causal network modeling of the information flow amongst cortical regions should be employed to provide new insights into the neural mechanisms of brain plasticity, which are important for the development of cognitive training strategies.
- Integration of advanced methods must be utilized to measure psychophysiological reactions to the artistic experience. New analytic techniques will be necessary for understanding the whole physiological reaction, and open the opportunity for converging approaches
- An appropriate set of standardized measures and vocabulary for studying how non-professionals talk about and describe different aspects of the arts should be developed. Formalization of such categorization is fundamental to any meaningful integrative work.
- Future investigations should recognize that art is a dynamic cognitive process in which the definition of art is constantly changing in relation to its time. A more comprehensive approach should be used to explore the physiological characteristics and learning functions of this inherently chaotic modality.

Consensus for a New Field of Learning Enhancement through Art

The overall consensus of the group was that, despite our professional diversity and the short time available for us to work together, we achieved substantial coherence, common language and integrity. The communication and mutual interest in the work of each others' specialized disciplines, and the wish to embrace the complementary frameworks were impressive. The final sense of the group was that this Workshop represented a worthwhile opportunity to derive the maximum benefit from the deep need of art that is inherent to the human nature to enhance the learning capabilities and cognitive skills of people at all aspects of society.

The main focus of the Workshop, the enhancement of learning, remains a challenge, particularly in the school setting. While direct explanation seems the best approach to teaching any specific subject on the curriculum, the ability to absorb facts and concepts is greatly enhanced by placing them in a broader context of the quality of life and human advancement to a more evolved status of society as a whole. It is these larger goals that underlie the mission of NSF (“*To promote the progress of science; to advance the national health, prosperity, and welfare”)* and that evoke the need for research in the relationship between learning and experience in the arts. The Workshop successfully brought together an interdisciplinary group of leading thinkers in order to determine whether is a sufficient basis for initiating a new domain of **learning enhancement through art** within the Science of Learning, and to identify appropriate directions and methods for research in this arena.

In summary, the main large-scale result from the ACL Workshop was the achievement of general agreement that the emergence of a new field of the effects of art training in the science of learning can play an important role in the future development of a globally effective society. This communal enterprise would simultaneously transcend the borders of professions, countries and continents. Moreover, this meeting itself represents the initiation of art/science community that can effectively communicate through a common language of cross-disciplinary interaction, that is timely and meets a significant need in the contemporary learning environment.

Acknowledgment

The organizers and the participants of the “Art, Creativity and Learning” workshop are very grateful to the National Science Foundation for the extraordinary opportunity to explore and discuss the future of this new interdisciplinary research domain of learning which opens a great potential for enhanced learning, and especially to Soo-Siang Lim, Program Director for the Science of Learning Centers**,** who suggested this new domain of investigation.

PARTICIPANTS

(see Appendix II for contact information)

NSF Program Officers

Soo-Siang Lim, Program Director and Chair of Coordinating Committee, Science of Learning Centers Program

Joan Straumanis, Program Director, Science of Learning Centers Progam

Organizers:

Christopher Tyler, Smith-Kettlewell Institute
Daniel Levitin, McGill U
Lora Likova, Smith-Kettlewell Institute

Speakers

Jacques d'Amboise, National Dance Institute
Bulent Atalay, Princeton Institute for Advanced Study
Steven Brown, Simon Fraser U
Bevil Conway, Wellesley College
Dennis Dake, Iowa State U
Jonathan Fineberg, U of Illinois, Urbana-Champaign
Stefan Koelsch. U of Sussex, UK
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Michael Schutz, U of Virginia
Anna Tirovolas, McGill U.
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WORKSHOP SCHEDULE

Wed, June 11: Stafford 1, Room 1235

2.00 pm Welcome: Jeannette Wing, NSF Assistant Director (CISE),
Workshop Goals: Soo-Siang Lim, NSF Program Director, Science of Learning Centers
Workshop Organization: Christopher Tyler, Lead Organizer

2:15 pm Group Introduction with Refreshments

3:00 pm Session 1: The Domain of the Arts: What Aspects are Relevant to Cognitive Processing?

Inspiration in art and neuroscience
Christopher Tyler, Smith-Kettlewell Institute, San Francisco

Musical structure and the frontal lobes: Implications for creativity
Daniel Levitin, McGill U, Montreal

Some empirical observations about art, childhood, and the brain
Jonathan Fineberg, U of Illinois, Urbana-Champaign

4:00 pm Coffee Break

4:15 pm Research Goals Brainstorm
Key questions:
- Do art and music have cognitive structure?
- How is creativity expressed in the artistic domain?
- How do the “non-cognitive” aspects of art – color, Gestalt organization, evocative power – relate to cognitive processing?
- What is the relationship of the arts to mathematical thinking?

5:00 pm Creative Social

7:00 pm Dinner

Thurs, June 12: Stafford 1, Room 1235

8:45 am Session 2: Visual Art and Neuroscience

Vision and art: a hands-on inter-disciplinary approach to teaching both
Margaret Livingstone, Harvard Med, Boston
and Bevil Conway, Wellesley College, Boston

What are we trying to explain: the phenomenology of aesthetic pleasure
Michael Kubovy, U Virginia, Charlottesville

Art and neuroscience through the lens of perceptual organization
Lora Likova, Smith-Kettlewell Institute, San Francisco

9:45 am Research Goals Brainstorm
Key questions:
- How do cortical interactions contribute to visual art processing?
- Does neuroscience reveal enhancement of learning through visual arts?
- How is the reward system of the brain involved in visual arts experience?
- Does art exposure affect language and mathematical thinking, and what is their specificity?

10:15 am Coffee Break

10:30 am Session 3: Music and Neuroscience

Shared neural resources for music and reading: Implications for learning
Nina Kraus, Northwestern U, Chicago

Dance and the brain
Steven Brown, Simon Fraser U, Vancouver

Functional neuroanatomy of music perception in children
Stefan Koelsch, U of Sussex, Brighton

11:30 pm Research Goals Brainstorm
Key questions:
- How do cortical interactions contribute to music processing?
- What do brain measures contribute to the enhancement of learning through music?
- What is the status of the “domain-specificity” debate regarding music and intuition as ‘right-hemisphere’ vs language and focal attention as ‘left-hemisphere’ functions?
- Does training in a specific art alter our notions of space and time?

12:00 pm Lunch

12:45 pm Session 4: Multi-Arts Perspectives on Learning

Neuropsychology of visual art & music: Lessons from brain damage, biology, and beauty.
Dahlia Zaidel, UCLA, Los Angeles

Leonardo's model

Bulent Atalay, Institute for Advanced Study, Princeton U

Applied research projects in brain compatible visual education
Dennis Dake, Iowa State U, Ames

1:45 pm Research Goals Brainstorm

Key questions:

- Why does art influence everybody? Is art a universal 'language', a means of deep communication?
- Is there a universal 'system' across art media?
- Does exposure/learning one or more arts influence developing of cognitive skills in other domains?
- Which cognitive systems are most involved?

2:15 pm Tea break

2:30 pm Session 5: Emotion, Intuition and Knowledge Acquisition

Improvisation and learning
Keith Sawyer, Washington U, St Louis

Emotional intelligence, education and the brain
Andrea Shindler, The Foundation for Human Potential, Chicago

Thinking in and outside of the arts
Ellen Winner, Boston College, Chestnut Hill

3:30 pm Research Goals Brainstorm

Key questions:

- Is the creative act an inherent motivation for learning?
- Is the ability to perform some art linked to emotional state?
- Are emotional and intuitive processing forms of cognition?
- What are the brain systems underlying intuition and emotional decision making?

4:00 pm Travel to Phillips Collection.

4:30 pm Reception

6:00 pm Keynote Address: Art-Science Interplay: The Future of Creativity
Jacques d'Amboise, *National Dance Institute, NY*

7:30 pm Working Dinner

Action item: Deciding topics and moderators for breakout groups on Friday am

Fri, June 13: Stafford II, Room 555

Session 6: Development of Recommendations for New Research Directions

8:30 am – 12:30 am Breakout Groups: *Stafford II, Rooms 535 & 545*

Breakout groups to draft the initiation and planning of research goals in the neuroscience of learning enhancement by experience with the arts.

12:30 pm Lunch

1:30 pm – 4 pm Consortium Consensus: *Stafford II, Rooms 555*

Breakout groups present their proposals for evaluation by the full group.

OVERVIEW

> "How can we develop techniques in learning to engage the emotions? Learning should not be driven by fear but by desire. Why are the arts considered separate from the sciences? What were the first arts? How did the scientific enquiring mind arise?"
>
> Jacques d'Amboise (2008)

EVALUATION OF THE CURRENT STATUS

Introduction

In a significant respect, our future will be determined by how well we deal with the unprecedented explosion of knowledge with which we are presently confronted. Although more information has been generated in the last 100 years than in all of human history before it, the gulf between science and the arts has grown ever greater, and students are identified early on as being of one type or the other, creating self-fulfilling prophesies. In a world of hypertechnological advancement, there tends to be an intense focus on the technical and scientific aspects of the world around us, with a consequent neglect of other aspects of life that can enhance the learning of complex material, social skills, and overall capabilities in all the activities of life. Even with all the wealth of scientific modalities, there remains a certain stigma associated with careers in science, as a result of the inevitable concentration on narrow specializations that are inaccessible to general understanding. This disconnect between art and science may have had unintended consequences. Apart from the danger of creating a generation of scientists who lack an aesthetic sense or appreciation of metaphorical expression and of artists without scientific literacy, opportunities for cross-pollination and mutual benefits are not realized to their full extent.

The main focus of the Workshop was *the enhancement of learning*, which remains a challenge particularly in the school setting. While direct explanation seems the best approach to teaching any specific subject on the curriculum, it is well-recognized that the ability to absorb reams of facts and concepts is greatly enhanced by placing them in a broader context of relevance to the issues of everyday life and the larger goals of improvement of the quality of life and human advancement to a more evolved status of society as a whole. It is these larger goals that underlie the mission of NSF ("To promote the progress of science; to advance the national health, prosperity, and welfare") and that evoke the need for research in the relationship between learning and experience in the arts.

The purpose of the Workshop was thus to bring together leading thinkers in related fields in order to determine whether there is a sufficient basis for initiating a new domain of **learning enhancement through art** within the Science of Learning, and to identify appropriate directions and methods for research in this arena from the neuroscientific, cognitive and educational perspectives. The need is urgent because arts education and scientific literacy remain at a low level in the U.S. and educational interventions are sorely deficient. To the extent that the sciences can be associated with relevant areas of artistic endeavor, they may be viewed as more accessible and more favorable as a topic of study. Moreover, there is an increasing level of neuroscience research that supports the idea of enhancing transfer of learning abilities from the arts to other cognitive domains.

Prior Studies of Arts, Creativity and Learning

A growing body of data suggests that connections between the art and science of learning are rigorously supportable by quantitative studies. Contemporary research is beginning to explore explicit neuroscientific hypotheses concerning the beneficial effects of activities such as musical performance, drawing, visual aesthetics and dance observation.

Correlational studies suggest further that a mastery of instrumental music may lead to a positive self-concept (Costa-Giomi, 1999; Schmidt, 2005) but carryover effects to other domains have not yet been demonstrated. Childhood music lessons have a small but long-lasting positive correlation with IQ and with academic performance (Schellenberg, 2006). Brain imaging studies suggest that early training has its greatest effect on neural systems involved in sensorimotor integration and timing (Watanabe, Savion-Lemieux & Penhune, 2007). Preliminary work on rhythmic training suggests that it may help to ameliorate dyslexia (Overy, 2003). Although the results have not yet reached the publication stage, controlled experiments underway by Helen Neville at the University of Oregon suggest that early music training may lead to earlier onset of reading and faster reading speeds among young children.

The idea that music shares some neural resources with other high cognitive functions such as language has been proposed most cogently by Patel (2003) in his shared syntactic integration resource hypothesis (SSIRH). Such shared neural resources may provide a basis for enhanced learning effects across cognitive modalities by training in one modality. Neuroimaging studies by Levitin & Menon (2005) have provided evidence for Patel's SSIRH. They found a frontal brain region that processes the general property of structure when that structure is conveyed over time – i.e., the property in common between such as a musical structure, language structure or the visual organization of words conveyed through American Sign Language. Recent studies by Nina Kraus and her group (Wong et al., 2007; Musacchia et al., 2007) have provided the first concrete evidence that playing a musical instrument significantly enhances the brainstem's sensitivity to speech sounds. These results not only implicate a common subcortical manifestation for two presumed cortical functions, but also suggest a possible reciprocity of corticofugal speech and music tuning. In particular, this work provides evidence for the positive effect of long-term music exposure on speech encoding. Long-term musical experience on development is known to last for years and it is therefore possible that such experience may provide protective effects against aging and the disruptive effects of hearing loss.

It also appears that music and dance can assist our memory processes in many ways. Neurological evidence suggests that music and dance may activate two parts of the same motor-action-imitation system through the mediation of "mirror neurons" (Cross et al., 2006). Mirror neurons are found mainly in the parietal and posterior frontal cortex, and are defined by the property that they fire similarly either to an action performed by the animal itself or to the observation of the same action performed by another animal (Gallese et al., 1996; Rizzolati & Craighero, 2004), thus forming the basis for imitation learning. In this way, observation of performance may enhance our ability to perform the corresponding actions, both within the same and different domains of activity. Within just a few weeks, human infants can stick out their tongues in response to someone else sticking out his tongue at them (Meltzoff & Moore, 1977) – how does the infant know just what motor action sequences to implement based only on a visual input? Mirror neurons may account for this ability, translating visual input to motor output, underlying a connection between visual arts and movement, and the auditory arts and music. Musical sounds also help to maintain attention and allow a higher level of retention of information. Music and dance also evoke emotions and stimulate visual images that expand the scope of the material being learned (Molnar-Szakacs & Overy, 2006). Teachers have found that they can increase sensory input during learning by using music intentionally during memory activities.

Music is also proposed to act as an affective (or emotional) filter that operates to improve learning and memory capacity. Specifically, the affective filter hypothesis (Krashen, 1987) states that optimum learning occurs in an environment of high stimulation and low anxiety. Krashen sees the learner's emotional state as an adjustable filter that may pass or impede input needed for acquisition. For instance, many ESL students come to class in a state of uncertainty. They often feel cut off from their native cultures and struggle to adapt, causing a disturbance in their affective filters, and degrading their learning capability. What is missing from the extant work, however, is a plausible account of why music may have these calming effects. Huron (2006) and Levitin (2006) have proposed that it is because of the balance between predictability and surprise, familiarity and novelty, and the effective manipulation of overlearned schemas for musical structure that gives music its comforting effects, along with a putative connection to the release of the tranquilizing hormone prolactyn.

Visual art learning is reliant on a complex system of perceptual, higher cognitive and motor functions, thus suggesting a shared neural substrate and strong potential for cross-cognitive transfer in learning and creativity. From pre-historical times, visual art has been a form of communication deeply imprinted in the human nature, the act of art experience and appreciation in the "receiver" also has the power of cross-cognitive effect during any time point in individual development. Compositional universals have been shown to govern the design of visual artworks across ages and cultures (Arnheim, 1988; Tyler, 1998; Ramachandran & Hirstein, 1999; Tyler, 2007). A case study (Solso, 2001) has revealed significant processing differences between the brains of a professional artist and a novice during drawing in the scanner; the comparative analysis of the activation patterns suggested a higher degree of cognitive processing for the brain of the artist.

Prior research on neurological patients has shown a conceptual link between drawing and language (Gainotti et al., 1983; Kirk & Kertesz, 1989; Swindell et al., 1988), and these researchers hypothesized that drawing may access the semantic system in a manner that improves naming abilities. Studies exploring the issue of mechanisms shared between different cognitive modalities revealed that mechanisms used to process spatial representations in the visual modality are shared with other modalities, such as the processing of pitch in music (Douglas & Bilkey, 2007). These findings have implications not only for biomedical sciences, but also for learning, pedagogical principles and general social and educational policies.

All too often, the arts are marginalized in our schools. In response to this marginalization, educators have sought to justify the arts in terms of their instrumental value in promoting thinking in non-arts subjects considered more important, such as reading or mathematics (Murfee, 1995). However, to date there has been little convincing research that the study of the arts promotes academic performance or elevates standardized test scores (Winner & Hetland, 2000). Really to understand whether art learning transfers to academic performance, we need first to assess what is actually learned in the arts and then to specify the mechanisms that underlie a transfer hypothesis. Hetland, Winner, Veenema, & Sherican (2007) therefore undertook a qualitative, ethnographic meta-analysis of the kinds of cognitive skills actually taught in the arts classroom, choosing the visual arts as their point of departure. The goal was to understand the dimensionality of what is taught, in order to be able to develop a plausible theoretical transfer hypothesis. Eight "studio habits of mind" were identified as the skills being taught in visual arts classes. Students are taught (1) to observe -- to see with acuity; (2) to envision -- to generate mental images and imagine; (3) to express – to find their personal voice; (4) to reflect -- to think meta-cognitively about their decisions, make critical and evaluative judgments and justify them; (5) to engage & persist – to work through frustration; (6) to stretch & explore – to take risks, “muck around,” and profit from mistakes; and of course (7) to develop craft and (8) to understand the art world. This work was the first to demonstrate objectively the kinds of thinking skills and working styles taught in arts classes. The group is now investigating the possibility that the skill of envisioning, as taught in visual arts classes, may foster geometric reasoning ability in mathematics.

Prior Studies of Intersensory Connections and the Arts

It is generally found that the more senses we involve in our learning, the greater is our understanding and retention. Complex auditory experience strengthens corticofugal feedback loops in the auditory system, enhancing the frequency and duration tuning of subcortical auditory nuclei (Wong, Skoe, Russo, Dees & Kraus, 2007). Concurrent non-auditory sensory stimulation augments these enhancements. The multisensory nature of music engages multiple sensory systems (visual, tactile and auditory) and appears to have profound influences on corticofugal mechanisms engendering auditory plasticity (Musacchia, Sams, Skoe & Kraus, 2007). Musical experience influences neural development in various domains, even when children have had only one year of training (Song, Skoe, Wong & Kraus, (2008).

Neuroimaging studies have revealed that visual arts as well as music engage many aspects of brain function, and involve nearly every neural subsystem identified so far (Solso, 2001; Levitin, 2006; Zeki 1995; Brown, Martinez & Parsons, 2006; Cross, Hamilton & Grafton, 2006). Could this account for claims that arts exercise other part of the brain and improve other cognitive abilities? Experience with the visual arts may be expected to produce similar facilitatory effects through the learning of artistic styles (Hess & Wallsten, 1987), although there is less formal research on the effect of visual art on learning enhancement in general. The visual system is legendary for its ability to analyze the complex interplay among spatial structures in 2D and 3D space, from primary figure/ground categorization (Likova & Tyler, 2008), through facial expressions (Chen, Kao & Tyler, 2006; Kanwisher, McDermott & Chun, 1997; Zaidel & Cohen, 2005) to dynamic athletic performances such as dance (Brown & Parsons, 2008; Brown, Martinez & Parsons, 2006; Cross, Hamilton & Grafton, 2006). These powerful analytic capabilities are far in advance of what can be achieved by even the most sophisticated computer algorithms, but they are central to any achievement in visual arts (Kubovy, 1986; Gombrich, 1994, 2000; Tyler, 1998; Ramachandran & Hirstein, 1999; Livingstone, 2002; Atalay, 2004). Indeed, neuroscience studies have begun to develop important techniques for the study of the neural circuitry mediating the appreciation of aesthetic qualities (Zeki, 2001, 2004; Kawabata & Zeki, 2004; Tononi, 2004). Such experience with the complex structures utilized in the visual arts is likely to make an important contribution to the enhancement of learning in all fields of endeavor.

The analysis of such complex spatial and dynamic spatial structures is one of the key aspects underlying the creativity of advanced thinking. Creative learning is a key aspect of the human thought processes that crosses many domains of neural functioning (Gardner, 1982; Glover, Ronning & Reynolds, 1989; Csikszentmihalyi, 1997). Damasio (1994) has emphasized the role of emotional evaluation in the cognitive processes underlying creativity, a theme that he has elaborated into other domains of human endeavor in subsequent work. Indeed, Dietrich (2004) has proposed that there are four basic types of creative learning, each mediated by a distinctive neural circuit. Creativity may arise either from a basis of deliberate control or from spontaneous generation. When creativity is the result of deliberate control the prefrontal cortex instigates the creative process. The spontaneous generation may arise from activation of the temporal cortex. Both processing modes, deliberate and spontaneous, can guide neural computation in structures that contribute emotional content and in structures that provide cognitive analysis, yielding the four basic types of creativity. This theoretical framework systematizes the interaction between knowledge and creative thinking, and how the nature of this relationship changes as a function of domain and age.

Defining art as a communicative system that conveys ideas and concepts (Couey, 1991) can explain why it is possible for the same brain structures that support other cognitive functions such as human language to be involved in arts such as music or drawing. This characterization presuppose millions of years of brain evolution and biological adaptive strategies. As a multidisciplinary communicative system, the arts provide an ideal platform for learning about the pleasure of knowing (Kubovy, 2008), which in turn provides the motivational inspiration to explore further, to ask questions, analyze and synthesize, and engage in convergent and divergent thinking.

Inspiration is an aspect of mental experience that is believed to involve not just cortical circuitry but its integration with the limbic system and medial frontal brain structures that are understood to mediate the experience of emotions, motivational rewards and the appreciation of the aesthetic values of the impinging stimuli (Damasio, 1994). This system goes beyond classical concepts of beauty to incorporate the elegance of theoretical concepts, the appreciation of the emotive power of the diverse array of post-modern art installations, the grace and dynamism of athletic performances, the economy and evocativeness of political addresses, the interconnected synergy of natural ecological systems, and innumerable other examples throughout the sphere of our world knowledge. In a sense, inspiration can turn almost any occupation in life into an avocation, a source of satisfaction in achieving life goals. It is when individuals feel themselves part of larger enterprise that they are inspired to learn, to achieve and to pursue a meaningful career. Conversely, when their job involves performing the same daily drudgery, inspiration is lacking and they lack motivation to learn, adapt and prosper.

The need for inspiration is something that is well understood by the best teachers, who have the knack for conveying it to their students. In the words of George Lopez as the teacher in a recent sci-fi Disney movie: “OK, class, I’m just a teacher, and I’m here to *inspire* the answers from you!”. Without inspiration, learning is a dull and insipid affair. A list of facts may be memorized in time for a test, but they will soon be forgotten because there is no involvement of the learner in the meaning and significance of the material. When taught by an inspiring teacher, on the other hand, the same facts are brought into play in relation to the students’ lives, their power and beauty is captured in metaphor and nuance, the domain of enquiry is given rhythm and inflection. Ironically, it seems that the more relationships are attached to individual facts, the easier the whole is to learn. The learner derives a sense of understanding the domain, of seeing how the system works, of exploring the logic of its relationships. This is why the complexity and multifarious nature of art works and the creative process engenders a depth of appreciation and involvement that has the capability of enhancing learning when correctly employed.

However, there is continual educational pressure to cover specified ranges of exacting material, making it inappropriate for the learning environment to be nothing but entertainment. Thus, the happy medium between sufficient inspiration and the requisite level of proficiency is difficult to achieve, and is made particularly difficult by the wide range of cognitive styles exhibited by the population of learners. There is a strong need to identify the effective motivational styles and the dimensionality of the domain of motivational inspiration, in order to expand the repertoire of strategies for learning enhancement. Moreover, one such form of inspiration is the opportunity to go beyond the predigested material that is presented to develop original insights and contributions to the domain of interest. This form of creativity can be highly motivating to the learner, who feels part of the enterprise of accumulating the knowledge, rather than a passive recipient of the structured material.

RECOMMENDATIONS

Research Strategy for a New Field of Learning Enhancement through Art

- The Workshop presentations and ensuring discussions led to a sense that a **new field of the science of learning** may be ready to emerge, and that it could play a significant role in the future development of a globally effective society.
- For this new field to coalesce there is a strategic need for more **comprehensive and systematic investigations** of the neural substrates of art and its relations to brain processing across a spectrum of cognitive domains. For example, reading requires accurate neural transcription of key acoustic elements common to both speech and music. Additionally, both reading and music are inherently multisensory. The common pathways in speech and music processing, and the ubiquitous human appeal of music and its inherent emotional and social functions, make it an attractive avenue for enhancing the teaching of reading and for remedial treatments.
- **Longitudinal studies** are needed, but currently lacking, to disentangle the roles of a) biological predisposition, b) artistic training; c) artistic experience, d) the persistence of associated neural effects, and e) optimal (or sensitive or critical) periods for training in the arts.
- A basic premise determined at the Workshop was that researchers need to study both the **creators** of the art and the **consumers** (enjoyers) of the artistic products. That is, a focus on one aspect of the process alone is incomplete because art is fundamentally a communicative medium. Creators intend their art to be experienced by other people, and consumers of art expect to have an emotional reaction to the art based on what the artist was feeling and/or trying to communicate. For meaningful research, it is critical that both aspects of the communication channel be taken into account. In metaphorical terms, a horse without a cart has no defined function, while a cart without a horse has no form of motivation. In the same way, an audience without the artist has no material inspire them, while an artist without an audience is ‘whistling in the dark’. An adequate theory of emotional and aesthetic responses to art must account for both the holistic and componential factors that contribute to artistic objects. This **dual focus** is fundamental to informing theories of how we learn to create and appreciate art.
- In considering the enhancement of learning, a key need is to identify the core factors of the optimal learning environment. One outcome of the Workshop was to identify **inspiration** as a key factor in effective learning. Without inspiration, learning is a dull and insipid affair. When taught by an inspiring teacher, on the other hand, the same facts are brought into play in relation to the students’ lives, their power and beauty is captured in metaphor and nuance. Ironically, it seems that the more relationships are attached to individual facts, the easier the whole is to learn

- There is a compelling need of research to identify not just the range of **motivational styles** but the dimensionality of the domain of motivational inspiration, as well as to reveal the underlying neural mechanisms of motivation in order to expand the repertoire of strategies for learning enhancement.
- A key factor in the **long-term learning** effects or plasticity of permanent change as a result of the learning exposure is the consolidation of learning as a result of appropriate levels of **attention** to the material and **incorporating** it into our array of accessible mental resources. In the Book of Common Prayer, Thomas Cranmer (1549) instructed his congregation that full learning of the scriptures required them to "read, mark, learn and inwardly digest" the material. These correspond to four significant levels of long-term learning:
    - Exposure to the material
    - Attention to its meaning
    - Committing it to memory
    - Understanding its significance in relation to other knowledge

- Mere undisciplined exposure to art materials with subjective, idiosyncratic goals may not prove to provide a productive contribution to either creativity or general learning behavior. More focused forms of **sensory learning** content and activities should be tested in real world educational environments aiming for measurable as well as qualitatively superior visual/auditory outcomes.

- **Creativity** should be another key factor addressed in future research. It is not a separate arena distinct from the business of learning, but is in many respects an integral aspect of both the learning experience and the implementation of enhanced learning. It is the flexible use of fully comprehended material that is the hallmark of intelligent behavior, carrying the inherent implication of an ability for creative re-expression of the original material.

- However, as reported at the workshop, creativity has been found to be especially effective in the **group setting** with effective interaction among the participants. That is, when a group is operating as an interactive team, both learning and innovation operate at their most effective level. There are many factors involved in this group success, including the expansion of the propensity to generate alternative solutions that are then digested by each member of the group, but also the motivation to continue focusing on the material due to the cooperative and competitive interactions among group members, when attention might flag if each member was alone. The complex interplay of group dynamics that tends to enhance the learning capability and efficiency is again poorly understood from a scientific perspective. Thus, an important component of further research strategy should be to both understand the mechanisms, and to develop the methodology for properly incorporating group dynamics into the learning experience.

- **Long-range projects in collaboration** with professional arts educators should build a strong integrated understanding of arts role in increasing learning and creativity within the educational community. In both basic neuroscience and applied educational research, the agenda should capitalize on these beginnings and systematically explore how specific, well-defined thinking skills contribute to growth within the visual arts discipline and support for learning generally.

Methodological Recommendations

• To better understand both the cross-modal effects of art training and the nature of the response in the aesthetic experiences when people appreciate art, it is necessary to understand **basic perceptual processing** of the artistic objects that give rise to these experiences. The extent to which different key parameters play a role in the artistic experience should be investigated **parametrically**. For example, color in paintings can be manipulated by altering hue, saturation and lightness in computer displays. Timing and amplitude in music can be manipulated in electronic MIDI or live performance. Researchers need to understand the extent to which people can detect changes in these parameters and how they impact on the artistic experience. What are the thresholds for detection and for appreciation? How do such manipulations affect the subjective impressions of the artistic experience? Finally, how do these functions map onto the spectrum of artistic expertise?

• **Non-invasive neuroimaging techniques**, such as functional magnetic resonance imaging (fMRI) of local metabolic activity, combined with electro- and magneto-encephalogram (EEG and MEG) of neural population responses, high-resolution diffusion tensor imaging (DTI) of the fiber pathways connecting cortical regions, and transcranial magnetic stimulation (TMS) to generate a reversible blockage of neural activation, should be used to answer the questions of learning transfer, enhanced creativity and enriched aesthetic experience.

• All these forms of investigating brain organization can be fed into the approach of **causal network modeling** of the information flow amongst cortical regions. Such methodology provide a powerful resource that should be further employed to provide new insights into the neural mechanisms of brain plasticity, which are of major importance for the future development of cognitive training strategies and techniques. The knowledge gained from such techniques can, in turn, influence the development of new educational strategies and programs.

• Integration of advanced **psychobiological and psychophysiological** methods is an effective strategy for **measuring** reactions to the artistic experience. These methods may include galvanic skin response, heart rate, respiration, pulse, blood pressure, core body temperature, etc. Correlating these measures with attributes of the artistic object itself will help us to better understand what people respond to when they appreciate art and have subjective aesthetic experiences, and will help to obtain improved objective measures of such experiences. This approach opens the opportunity for converging approaches using objective (rather than the traditional subjective) measures. Additional possibilities that are only now available arise from the new methods of measuring **psychobiological markers**.

• Moreover, the field needs to develop an appropriate set of operational definitions, **standardized measures and vocabulary** for studying how non-professionals talk about and describe different arts. For instance, the majority of music listeners lack the specialized vocabulary of academics and theorists, yet possess strong and stable intuitions about their likes and dislikes. Formalization of such aesthetic categorization is fundamental to any meaningful integrative work that might subsequently be performed.

• Future investigations should recognize that **art is a dynamic cognitive process** in which artists engage the most perplexing issues in present experience and try to find a way of symbolizing them visually so that they can bring coherence to their experience. Consequently the definition of art is constantly changing in relation to its time. In particular, the biological and anatomical approaches currently in use still rely on too static a model of development and function. Thus a **more comprehensive approach** should be used to explore the hypothesis that physiological characteristics and learning functions are inherently chaotic, continuously evolving into unpredictable states. The future analysis of such systems requires a structural approach in which the parts are constantly undergoing **dynamic modification**, and redefinition of the research strategies to incorporate such unpredictable bases should lead us in productive directions.

SPECIFIC BREAKOUT GROUP RECOMMENDATIONS

Visual Breakout Group:
Christopher Tyler (chair), Jonathan Fineberg, Lora Likova, Margaret Livingstone, Bulent Atalay, Dahlia Zaidel, Alessandra di Croce

Learning in any visual art – painting, drawing, sculpture, etc., engages a complex system of perceptual, higher cognitive and motor functions. This suggests a great potential for cross-cognitive transfer for enhanced learning and creativity. Moreover, as art is a form of communication deeply imprinted in the human nature, the act of art experience and appreciation in the “receiver” also has the power of cross-cognitive effect during any time point of the individual development. Finally, works of art may be considered both on the level of the individual (precognitive) empathetic response and the level of cognitive analysis that is dependent on cultural context. To achieve full understanding, the investigation of art and art learning in the terms of cross-cognitive transfer effect should not be restricted within one level, but include consideration of the whole complex of interactions between the levels.

The main suggestions of the Visual Break-Out Group are structured in three general categories of open questions:

1. What are the changes in the brain as one goes through the artistic trajectory, as the doer?

- What is the underlying neurobiology of the learning process in the visual arts? What are the specificities of the responsive brain networks for different visual arts? What processing “modules” are shared with other cognitive functions, in particular those known to be involved in learning and creativity in non-artistic domains?
- The processes of art production can be broken down into roughly isolatable components. How can the relative importance of these components in the learning process be quantified and understood in terms of the neurobiological underpinnings?
- What is it that children are learning when they produce art? What can their art tell us about the development of the underlying neural mechanisms? Is the distortion typical in children’s drawings due to a distortion in the retinotopic maps of the early stage of visual coding, or in the attentional mapping regions of parietal cortex that is too focused on the central region of space? Or do the distortions derive from a process of representational recognition by cells in the temporal lobe, in which by trial and error the drawing evolves to match the distortion in this representation?
- Does learning to draw or paint improve the spatial skills, imagery, perceptual memory and attention, the capability of reading maps, technical diagrams or solve geometrical problems? What is the relative weight of such potential transfer for to different cognitive modalities? Why does art production seem to be an internal necessity in most children?
- Can controlled attention to different aspects of the visual scene being depicted enhance the capability of drawing and painting? (Many art schools recommend attending to ’negative space’ as a way of rebalancing habitual modes of attention in order to identify

the true spatial configurations of the objects in a scene. Applying TMS to the anterior lobe has been reported to make people able to draw better because it deactivates the higher-level representation and 3D interpretation that is distorting the 2D perceptual space.)

- Does learning in the visual arts provide enhanced performance on psychological tests of creativity?

2. What are the changes in the brain as one perceives the art, as the receiver?

- As any art, visual art is a powerful way of interaction between the “doer” and the “receiver”. How can we understand emotional reactions to experiencing works of art? What is the relationship between the kinds of emotions we feel in response to the fictional, imaginary worlds of the arts and those in response to “real life” events? Is there an “aesthetic emotion” evoked by works of art that differs in any measurable way from other kinds of emotions?
- At what processing level does a painting draw the viewer into it to evoke an aesthetic experience? What are the relative roles of the perspective space, the color combinations, the dynamics, the empathic/social interpretation?
- What can the science of perception contribute to the artistic process? Are there parameters of both presentation and viewing conditions that affect the strength of the intended artistic effect? A good example is the relative impact of a visual artwork as viewed in its original gallery or public setting, as a reproduction in a book, or via a self-illuminated digital medium. How can the relative viewing conditions be controlled and evaluated? For example, is it important to view a perspective construction from its center of projection in order to experience the impact of the spatial composition?
- What are the main components of the analytic discipline of art? The analysis of a painting is a thought process that may reorganize one’s experience of reality in a way that is really fresh in a great work of art. How can the transformative process of the art experience be studied?
- How can the dimensionality of the aesthetic domain be defined? One empirical approach is to have an articulate group to propose dimensions of the aesthetic experience and have people rate them as individual responses to examples on each dimension, thus refining the dimensions of the domain.
- To what extent are the components of the underlying neural activity mutable and content-defined, versus being fixed elements that are recombined in multiple complex ways to form the variety of experience?
- How can comparative neuroimaging studies be designed to study differences in the brain responses of amateurs vs art historians to works of art? What are the neural effects of training on artistic competence and skill?
- How does the visual exploration strategy of the artistic professional differ from that of the casual viewer? The eye movement exploration strategy of art professionals has been reported to be very different from that of an amateur (professionals make brief

regular looks of about 12 times/minute, while the amateurs are irregular). How does this strategy help the professionals, and what aspects of the learning mechanism shape it?

3. Is art a universal language?

- If an art work has an effect on the viewer, it has had a worthwhile neural influence that could be applied to enhance learning. If one considers the experience of the beholder of art, something resonates between the viewer and the artwork. Can the positive or negative valence of this form of empathy be harnessed to enhance learning in related fields of endeavor?
- The concept of the appreciation of artworks through "embodied cognition" suggests that they affect the viewer by mirroring the feeling portrayed in the painting through neural mechanisms such as motor potential and preparedness to extrapolate the motion implied in the work. A classic example is of paintings of wrestlers evoking physical empathy of muscular activation in the viewer. Can these important experiential aspects of paintings be used to enhance their learning impact on the viewer?
- Neuroscience studies report a class of "mirror neurons" that form a mirror-matching system that responds similarly when an act is performed by the individual studied or by observation of a separate person performing the same act. Does the mirror neural system form the neural substrate of the embodied cognition experienced when viewing a work of art?
- The driving force for art is cultural, based on a need to communicate. Works of art have the capacity to convey concepts that cannot be articulated in language, and to integrate the tensions specific to the individual experience with the external culture. The same work may appear derivative in itself but may be inspirational when its cultural context reveals, for example, the creative effort involved in its implementation. Can behavioral paradigms be developed to study the impact of the artwork before and after it has been placed in its cultural context?

Auditory Break-Out Group:
Daniel Levitin (Chair), Nina Kraus, Stefan Koelsch, Steven Brown, Michael Kubovy, Mike Shutz, Alexandra Parbery-Clark

We propose the study of three initiatives.

I. How is music experienced?
We feel that it is imperative to develop standardized measures and vocabulary for how naive listeners talk about and describe music. In particular, these would refer to genres, moods, and descriptors for the piece-as-a-whole. Then, at the level of the song, we would ask how do people perceive its sections and their emotional content? The group reached consensus on a sample research design. Experimental participants would listen to music and indicate the smallest units of grouping in the piece, then the next highest level, then the next. They would apply emotional labels to the piece-as-a-whole as well as to each unit. One would end up with a hierarchical representation of the musical selection and could then study individual differences in ratings, group consistency for ratings, and develop a kind of taxonomy or

genetics of musical structure. This work is fundamental to any future work in art and learning because it establishes both a vocabulary and a mathematical structure within which to pursue further study on music perception, cognition, creativity and learning. Future studies could look at the extent to which such representations can be learned.

2. Identifying orthogonal component musical skills.

The field currently has no reliable or valid instruments with which to assessment musical background, ability, or aptitude. We recognize that musicality manifests itself in a variety of ways, typically non-overlapping. Any assessment instrument must be able to account for those who become successful (commercially, artistically) without having necessarily learned the standard nomenclature. Included in this initiative is the study of how people learn to understand nuance in expression of timing, phrasing, etc. A particular question is "what counts as success at the end of a year of musical training?"

Implicit in this initiative is the recognition that one can (and should) attempt a decomposition of musical skills in terms of its operational dimensionality. A provisional 8 x 4 factorial model of musical skills can be proposed:

Eight ways in which musical skill can be manifested:

- composing the score
- playing an instrument
- directing a performance (conductors, record producers, theater directors)
- talent scouting
- programming a musical experience (disc jockeys, film music supervisors)
- performing
- arranging/orchestrating
- engineering the sound

And 4 musical attributes at which one can excel:

- rhythmic ability
- pitch ability for rendering the tune
- intonation
- harmony

3. Implicit benefits of musical experience. Transfer effects.

What factors are learned with musical experience? How are they malleable across the lifespan? What is the vehicle or learning strategy or stimulus to be tested? (e.g., comparing the Suzuki method vs alternative training; computer-based instruction vs. individual instruction; etc). What are the biological underpinnings?

4. A grab bag of methodological suggestions.

- Longitudinal studies to look at effect of musical experience (assessing it either behaviorally or neurally) with well-matched groups. How can this approach be applied to many of the previously published studies?
- Lack of ecological validity of perceptual experiments using pure tones. Maybe the entire literature needs to be redone with music. The implication is not simply that humans did not evolve in a world without pure tones, but that they are missing the

structure of sounds in the natural world. Thus, experiments with pure or synthesized tones may come out very differently from those with naturally-produced musical sounds.

- Literacy and the intersection between reading and music. Can reading be taught through music? Do phonics help in reading? Measurement of before and after outcomes, behaviorally and neurally, within and across domains. What is the underlying biology? What is the nervous system doing? What distinguishes good learners from poor learners?
- Cross-cultural differences. There are different approaches to how music is experienced and taught in different cultures or subcultures within the same ethnic group.
- Most work has looked at individuals rather than groups. Group learning and group performance should be also studied.
- Teaching creativity. Creativity taught in music to see if there is transfer to intelligence tests.
- Development of singing ability (Tone deafness, how people sing in or out of key). Perception does not predict singing. Developmentally, age effects, sensitive periods. Timeline for the acquisition of pitch-matching skills. Cross cultural studies of pitch categories.
- What is a suitable control for musical emotion?
- Can music education in pre-school children prevent specific language impairment (SLI)? Move from the correlational evidence to controlled studies combined with fMRI and EEG cortical responses. Ask the same question for dyslexia, dyscalculia, and other impairments.
- How do we break down musical ability into components? Experts in various sub-domains of music: composition, instrumental ability, listening ability, coaching ability.
- Plasticity/malleability across the lifespan of the component abilities. What is it about musical training that helps people become better musicians? What is it that the learner is actually learning? What factors does musical training impart? What is the link between this and outcomes in the language, social, and cognitive domains?

Education Breakout Group:

Ellen Winner (chair), Dennis Dake, Keith Sawyer, Andrea Shindler, Thalia Goldstein, Trent Grover, Echo Wu

1. Links between Cognition/Learning in the Arts and the Sciences

- What are the measurable cognitive and biological underpinnings/outcomes associated with learning in specific art forms (visual arts, music, theater, dance)?
- Does learning in an art form “transfer” to learning in science? (e.g., does the learning of music foster the ability to learn mathematics?)

- Are scientists particularly drawn to the arts and if so can we predict specific kinds of affinities? Thus do scientists working in areas where visual thinking is important show heightened interests and abilities in the visual arts? Do mathematicians show heightened interests and abilities in music?
- Are artists drawn to the study of science, and how does science influence and inspire artists?

2. Learning through the Arts

- When the arts are integrated with other related disciplines in schools, is there evidence that learning in these other disciplines enhanced? For example, can we enhance the learning of mathematics by integrating math with music?
- Does the answer to this question depend upon the type of learner (e.g., learning disabled; typical)?

3. Developmental Trajectories of Creativity and the Arts in Typical Children, Prodigies, and Savants

- How do skills in creating and responding to/understanding the arts, and in creativity, develop in each of these populations?
- Does development in these areas always increase with age, or are there aspects that decline after the preschool years?
- How does gaining expertise in an art form alter one's reactions to art?
- Can we identify brain differences, either anatomically or functionally, across these populations associated with artistic/creative behaviors?
- What factors in child prodigies predict the ability to make the transition from prodigy to adult creator?
- How heritable are artistic and creative abilities?
- What is the ideal age of exposure to an art form to foster talent?
- How can creativity and the arts be best fostered in childhood? What is the role of the family, mentors, and role models? What is the role of flow and of play? What is the role of participation in virtual worlds? What is the role of rote learning? What is the role of constructed architectural environments?
- How does the act of creating art affect emotional functioning in typical and atypical populations?

DISSEMINATION OF THE RESULTS OF THE WORKSHOP

Bringing the group of scientists and educational experts together for the workshop in this sparsely studied cross-disciplinary field will itself provide an impetus for enhanced research in the area. The participants will be encouraged to develop courses and projects exploring various aspects of this novel area. It is expected that the student participants will be inspired to conduct research studies in the ensuing topics. The workshop culminated in a Final Report, together with a White Paper focusing on the recommendations for the most productive areas in which to conduct research in the field of the enhancement of cognitive learning skills and education strategies by experience with creative pursuits in the arts. Reports of the meeting will be disseminated by its publication in Neuron, Nature Neuroscience or Science Magazine, based on the White Paper. The recommendations will be provided to NSF for inclusion as an RFA for future research funding.

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APPENDIX I

Abstracts of the Talks (in order of presentation)

Inspiration in art and neuroscience

Christopher Tyler, Smith-Kettlewell Institute, San Francisco

Art has had numerous functions through the ages, but the underlying role in many of them has been as a source of inspiration toward domains of endeavor beyond everyday concerns. What makes a picture 'art' is its ability to go beyond mere representation to express the subtleties and contradictions of the human exploration of domains of cognitive and experiental creativity. Much of the impact of art is mediated by the flow of activation in the inner core of the brain – the limbic system, but the study of limbic system activation in artistic activities is still in its infancy. It is therefore of paramount importance to explore the role of both limbic activation and it is interactions with cortical centers in the human activities of art, creativity and learning.

Musical structure and the frontal lobes: implications for creativity

Daniel Levitin, McGill U, Montreal

Abstract: I argue that the act of music listening is itself a creative act, involving prediction processes on the part of the listener. We used functional neuroimaging (fMRI) as participants listened to music and musically random foils to identify regions in the brain associated with the tracking of musical structure (or syntax). We identified a network in pre-frontal cortex, particularly in Brodmann Area 47 and a portion of Broca's area that is associated with ordinary music listening processes. The implications of this work for theories of brain function, music processing, and creativity are discussed.

Some empirical observations about art, childhood, and the brain

Jonathan Fineberg, U of Illinois, Urbana-Champaign

What can children's drawings teach us about the work of major masters of modern art and how a work of art has the claim on our emotions that it has. Can we use psychoanalytic models as empirical tools to describe this relation? And does a structural approach to the functioning of the brain in making art give us a fresh perspective to understanding the neurophysiology of cognitive development?

Vision and Art: a hands-on inter-disciplinary approach to teaching both

Margaret Livingstone, Harvard Medical School and Bevil Conway, Wellesley College

We will introduce some of the principles of visual neuroscience and show how artists have implicitly (and occasionally explicitly) taken advantage of these in developing works of art. We will then present a sample syllabus hi-lighting how these issues can be approached in the undergraduate classroom setting, with hands-on laboratory exercises and self-directed learning projects. The goal of such a syllabus is not only to advance an understanding of the neural systems that underlie vision but also to cultivate observational skills and critical thinking.

What are we trying to explain: The phenomenology of aesthetic pleasure
Michael Kubovy, University of Virginia

I am often concerned that cognitive scientists and neuroscientists who write about assume that there is consensus on what were talking about in this workshop. I submit that we need a theory of the pleasurability of episodes. An experienced life consists of experienced *strands* relatively impermeable realms of experience a concept that draws upon two diverse ideas of about the nature of frames in experience (Goman, 1974; Subirana-Vilanova & Richards, 1996). Strands are experienced as consisting of *episodes*. An episode is a totally ordered set of experienced events, bracketed by the first event, which is experienced as *the beginning event,* and the last event, which is experienced as *the ending event*. Certain characteristics of pleasurable episodes, are related to narrative(s) they might engender, which allows one to consider not only the pleasurability of temporally extended aesthetic experiences, but also of putatively static works of art, such as paintings and sculptures.

Art and neuroscience through the lens of perceptual organization
Lora Likova, Smith-Kettlewell Institute, San Francisco

Perceptual organization is so effortless that we take it for granted; science first posed the problem of perceptual organization only about a century ago. Artists, however, were fully utilizing most of the underlying laws long before the Gestalt psychologists revealed them. The significance of some of these laws (e.g., Prägnanz), extends beyond perception into higher cognitive domains, such as learning and decision making.

My focus will be on the figure/ground relationship, which play a major role in both perceptual organization and artistic composition. What neural architecture allows local and global information to be combined rapidly, as it is necessary for figure/ground? Using fMRI and a temporal-asynchrony paradigm, we reveal that figure/ground categorization operates through a top-down suppression of the retinotopic representation of the less relevant background. The figure/ground network is widely distributed, going beyond the occipital cortex to reach to higher areas in the frontal cortex.

Interestingly, visual art analysis shows that the artists had the right intuition, in understanding the importance of *suppressing* the background in order to allow the figure to ‘stand out’ and form the focus of attention.

Shared neural resources for music and reading: Implications for learning
Nina Kraus, Northwestern U, Chicago

The effects of musical experience on the nervous system’s response to sound are pervasive and extend beyond music to the language domain (Musacchia et al., 2007; Basso et al., 2007). Music and speech sounds consist of three fundamental components: pitch, harmonics and timing, and the neural transcription of these elements can be assessed objectively, noninvasively and with great fidelity with scalp electrodes in humans. Musical experience and short-term auditory training can enhance subcortical representation of the acoustic elements known to be important for reading (Banai et al., 2005; Song et al., 2008; Russo et al., 2005). The shared biological resources underlying the neural processing of music and language can be used to improve the learning of literacy and literacy-related skills. Learning outcomes can be objectively assessed. (Supported by National Institutes of Health (R01DC001510) and National Science Foundation (NSF 0544846).

Dance and the brain

Steven Brown, Simon Fraser U, Vancouver

We can think of dance as a marriage of the rhythmicity of music and the representational capacity of language. The first neuroimaging studies of dance have recently been published, and have examined brain areas involved in both the production and perception of dance. Production studies have focused on two key issues, namely spatial navigation of the body, and rhythmic entrainment of movement to an external timekeeper, such as a musical beat. Perception studies have looked at neural “expertise effects”, demonstrating brain activations that occur preferentially in people who are competent to perform the dance movements being observed.

Functional neuroanatomy of music perception in children

Stefan Koelsch, U of Sussex, Brighton

This talk presents studies using chord sequence paradigms to investigate brain responses to music-syntactically regular and irregular chords. In 10-year-old children, irregular chords activate the inferior frontal gyrus and ventrolateral premotor cortex, orbital frontolateral cortex, the anterior insula, anterior and posterior areas of the superior temporal gyrus, and the superior temporal sulcus. These structures presumably form different networks mediating cognitive aspects of music processing (such as processing of musical syntax and musical meaning, as well as auditory working memory), and possibly emotional aspects of music processing. Musical training was correlated with stronger activations in the frontal operculum and the anterior portion of the superior temporal gyrus. With regards to brain electric responses to regular and irregular chords, we observed an early right anterior negativity (ERAN) in response to irregular chords in 2.5 year-old children (30 months). In this age group, the ERAN was quite small, suggesting that the development of the neural mechanisms underlying the generation of the ERAN commence around, or not long before this age. Children at the age of 5 years show a clear ERAN, although with longer latency than adults (around 230-240 ms). Interestingly, children with specific language impairment (SLI) do not show an ERAN in response to syntactically irregular chords, providing evidence for a strong interrelation between the language and the music processing system. As in 9-year-olds, 11 year-old children with musical training show a larger ERAN than children without musical training. Importantly, children with musical training also show a superior processing of linguistic syntax: In these children, the early *left* anterior negativity (ELAN) – a neurophysiological marker of linguistic syntax processing – was established two years earlier than in control children. These results indicate that musical training can improve the processing of musical as well as of linguistic syntax, and the data corroborate the notion of a strong overlap of the neural resources underlying music and language processing.

Neuropsychology of visual art & music: Lessons from brain damage, biology, and beauty

Dahlia Zaidel, UCLA, Los Angeles

The neuroanatomical underpinning of art production has been a source of fascination and interest. Defining art as a communicative system that conveys ideas and concepts explains why it is possible for the same brain that supports human language to support other communicative systems, art being one of them. This would presuppose millions of years of brain evolution and biological adaptive strategies. I will describe what we can surmise regarding the neuroanatomical underpinning of art production and appreciation from observations of brain damage in established artists, the relationship between art and other communicative displays by biological organisms, and explain the role that beauty plays in art.

Leonardo's model

Bulent Atalay, Institute for Advanced Study, Princeton U

Leonardo was a passionate artist, scientist and engineer — his endeavors driven by a relentless curiosity. He observed in the manner of the scientist, savored in the manner of the artist. It was important to be curious, and important to explore different intellectual worlds, but it was crucial to seek connections. He admonished others to learn from nature, not from each other; to carry a small pad and describe and sketch their observations — invariably honing their observational skills. The model that worked magnificently for him will never make anyone else another Leonardo, but it cannot fail to make everyone more creative, and more effective practitioners in whatever intellectual world they inhabit.

Applied Research Projects in Brain Compatible Visual Education

Dennis M. Dake, Iowa State University

This presentation will survey three applied research projects in the scholarship of teaching and learning that have attempted to create a new systematic curricular frame for brain compatible visual education.

These projects are (1) a junior level undergraduate studio arts course, Sources of Visual Design, based on the neurobiology and psychology of visual artistic thought and graphic ideation, (2) a successful twenty-three year effort, called New Art Basics, to create an interactive WWW database “Living Curriculum” of teacher-designed and classroom-tested learning activities, and (3) the DaVinci Project which engaged a number of New Art Basics teacher/researchers (each with a science educator partner) in creating a K-12 Art and Chemistry curriculum.

Utilizing knowledge from neuroscience to focus curricular activities and modify pedagogy, these three extended educational research projects have successfully sought to simultaneously improve visual arts education and emphasize its importance as basic to general learning.

Improvisation and learning
Keith Sawyer, Washington U, St Louis

My own research focuses on the performing arts—more specifically, performances that involve collaborative improvisation, including jazz, improv theater, and improv dance. In will begin my talk by summarizing research in the learning sciences that reveals the sorts of learning environments that foster deeper conceptual understanding, thinking ability, and problem solving ability. I then describe how improvisational collaborations among students can contribute to these learning outcomes. My concluding message is that collaborative improvisation should play a central role in classrooms that are designed according to learning sciences principles.

Emotional intelligence, education and the brain
Andrea Shindler, The Foundation for Human Potential, Chicago

A brief summary of the symposium of The Foundation for Human Potential, entitled 'Emotional Intelligence, Education and the Brain' and presented at the Art Institute of Chicago, will be shared. The focus will be on the work of the following presenters: neurologists, Antonio Damasio and Joseph LeDoux; psychologists/educators, Mihaly Csikszentmihalyi, Howard Gardner and Kay Redfield Jamison and New York City Ballet's former lead principal dancer/now esteemed arts educator, Jacques D'Amboise.

Thinking in and outside of the arts
Ellen Winner, Boston College, Chestnut Hill

Through an intensive qualitative study of 5 visual arts teachers, we identified six habits of mind taught in visual arts classes: observe, envision, express, reflect, engage/persist, stretch/explore. We next developed hypotheses about transfer of learning from the arts. The first hypothesis we are testing is that students trained in the visual arts should show superior ability to reason about geometry. We are embarking on a quasi-experimental two-year longitudinal study testing this hypothesis. I will also discuss a second ongoing 5-year longitudinal study, conducted with Gottfried Schlaug, investigating the effects of instrumental music training on brain and cognitive development. Recent analyses show enhanced corpus callosum growth after instrumental music training.

Art-science interplay: the future of creativity
Jacques d'Amboise, National Dance Institute, New York

The presentation will touch on a wide range of topics in the role of creativity in developing interactions between the arts and the sciences. Why are the arts considered separate from the sciences? How did the scientific enquiring mind arise? Learning should not be driven by fear but by desire. How can we envisage suggestions for techniques in learning to engage the emotions?

APPENDIX II

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APPENDIX III

Individual Speaker Recommendations for Future Research Directions

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Directions for Dance Research

Steven Brown, McMaster University

1) Development of motor skills and body schema. Dance represents one of the most complex motor activities that human beings engage in, both spatially and temporally. The psychology of spatial cognition contrasts two frames of reference: egocentric (body centered) and allocentric (object centered).Some basic questions related to this are: How do people learn dance movements? How does dance learning carry over to other motor skills, such as athletic skill or musical-instrument learning? How does dance learning impact on an individual's movement style, coordination, balance, posture, agility, and strength?
2) Sharing of rhythm between music and dance. The ability of humans to synchronize their movements to timekeepers like musical beats is considered to be an evolutionary novelty of our species. Dance reinforces the development of neural circuits for rhythmic entrainment. Does the learning of dance rhythm carry over to musical rhythm and vice versa? Does it carry to other motor skills requiring precise timing, such as athletic skills? Do improvements in timing production through dance training lead to improvements in timing perception, and vice versa?
3) Neuroscience of dance movement and timing. The issues raised in points 1 and 2 can be studied using neuroimaging techniques, not least in a longitudinal fashion during the course of learning a dance sequence.
4) Action perception and mental simulability. There is good neural evidence that learning a dance sequence activates premotor circuits involved in mental simulation of action. This is one type of expertise effect seen in dancers. Hence, action perception and mental simulation of action seem to be highly linked. How does expertise in dance modify neural circuits for action perception in general? Does this carry over to the perception of non-dance actions?
5) Emotional and body expression. Dance is a kind of body language. As such, dancing often helps people increase the expressiveness of their body movements, including their facial expressions. In addition, it can be quite cathartic. In what way does involvement in dance influence a person's ability to express their emotions? In what ways does it influence their ability to interact with other individuals in a cooperative manner?
6) Choreography, improvisation and creativity in dance. While some dances are based on invariant sequences of movements, others – especially couple dances – allow people the freedom to recombine elements from a repertoire of basic movement patterns. In such dances, a certain amount of improvisation is involved. Does improvisation in dance carry over to other aspects of creativity in life?
7) Social learning through dance. In many traditional cultures (but not so much our own), dance is an important means of enculturating people and teaching them about significant figures and key events in the history of their group. In this way, dance has an important historiographic function. Anthropological research in traditional cultures could look at how children learn about the identity and history of their social group through dance narratives.

Teaching Vision and Art: an Empirical Approach

Bevil Conway, Wellesley College
and Margaret Livingstone, Harvard Medical School

Undergraduate students, as well as the general public, are more likely to engage in scientific discussions when the content can be made relevant to their other interests. Visual art has broad appeal, and therefore serves as a valuable jumping off point for investigating how the visual system functions; in addition, an understanding of the function of the visual system enhances critical, formal analysis and opens the way for scientific investigations into visual discoveries made by artists. We have developed a syllabus that aims to introduce some of the principles of visual neuroscience and show how artists have implicitly (and occasionally explicitly) taken advantage of these in developing works of art. The sample syllabus hi-lights how these issues can be approached in the undergraduate classroom setting, with hands-on laboratory exercises and self-directed learning projects. The goal of such a syllabus is not only to advance an understanding of the neural systems that underlie vision but also to cultivate observational skills and critical thinking. The syllabus is a work-in-progress and will be modified following each semester it is taught. One of us (BRC) taught a 3-day workshop on Vision and Art ("Seeing seeing differently") at Lyme College of Fine Art to visual artists. This experience, along with extensive discussions between the co-authors, resulted in a full-semester course in the spring of 2008 for a group of 10 Wellesley undergraduate students. The students were selected from a diverse set of backgrounds including Economics, Film, Cognitive Science, Neuroscience, Physics and Chemistry.

Here we present two observations following this course. First, we consider whether such a course is productive for students with little or no prior neuroscience training. Second, we discuss the efficacy of hands-on laboratory exercises as teaching tools, and describe some practical ideas for laboratory exercises that bridge the gap between works of art and visual neuroscience. Following the course, students were asked: Do you think the study of art is enhanced by an understanding of the visual system and visual processing? Do you think studying art can tell us anything about how the brain works? Develop a cogent argument, with evidence to support your claims, for or against.

The responses were generally positive, and illustrate both the successes and failures of such a curriculum. It is clear that students rapidly develop a solid understanding of some concepts, but struggle with others. Other students related their learning experiences to their daily lives. What seems most clear from the first version of this course is that students benefit most from hands-on laboratory exercises, even in developing what seem to be the most basic visual neuroscience concepts. We conclude that concepts in visual neuroscience can be motivated by studying visual art, and can plausibly be communicated with simple laboratory exercises.

A sample lesson plan is included as Appendix V

Projection of Research Directions

Dennis M. Dake, Iowa State University

This paper will suggest several areas of emphasis in which future research agendas might be focused to explore the impacts visual arts education could make on creativity, learning and general cognitive abilities.

I. Does brain compatible visual education create a differential use of specific aspects of the visual perception system in the brain?

A number of scientific studies have provided evidence that illustrate significant differences between the way artists use their brains to collect and transform information from the visual world and the way other disciplines train the brain. Starting from these beginnings it is important to understand how these thinking abilities might support improved artistic ability and be integrated into an improvement of learning and creative skills for education generally.

EXAMPLE 1: Numerous studies have examined Eye Scans and Scan Paths both in visual artists and non-artists. Zangmeister, Sherman, and Stark (1995) found large differences between naïve subjects (bioengineering graduate students), and two groups of subjects, (Sophisticated art collectors and professional artists) in both reliance on global scanpaths and rate of eye blink. Given that Scanpath theory hypothesizes that internalized cognitive models drive eye movements could visual arts education make a contribution to learning by externalizing internal cognitive models for examination?

Zangmeister, W.H. and Sherman K., and Stark L. (1995) Evidence for a Global Scanpath Strategy in Viewing Abstract Compared with Realistic Images, Neuropsychologia, Vol. 33, No. 8, pp 1009 – 1025

EXAMPLE 2: Creativity requires a natural fluency of ideation. The sketchbooks of professional artists demonstrate such natural structural fluency. Jones-Gottman and Milner (1977) found that patients with right frontal and right fronto-central lesions were severely impaired in fluency. Does brain compatible visual education increate effective use of fluency in the brain?

Jones-Gotman, M. and Milner, B. (1977) Design Fluency: The Invention of Nonsense Drawings after Focal Cortical Lesions, Neuropsychologia, Vol. 15, pp. 653 - 674

II. Can we identify neural correlates of established visual processes that are demonstratively basic to discipline of artistic thinking?

The challenge here would be to specify thinking skills that are basic to the discipline of art making and explore them in depth along with their applicability to learning across a variety of non-art disciplines. This would need to be done not only with empirical methodology but also in light of the ideas of professional artists and the visual record of the generative practices embodied in their preparatory work.

EXAMPLE 3: The ability to perceive physiognomic characteristics of the visual world has been identified as a cognitive control principle that correlates significantly with measures of art aptitude and ability. It is the significant ability to see the world in other than literal meaning alone. Standardized tests of physiognomic perception exist and could be used to show its usefulness both in art and non-art disciplines.

Seitz, J. and Beilin, H. (1987) The Development of Comprehension of Physiognomic Metaphor in Photographs, British Journal of Developmental Psychology, Vol 5, pp. 321-331, 1987

Stein, M.I. (1975) Physiognomic Cue Test Manual, New York, Behavioral Publications, Inc.

Rosett L., Robbins H. and Watson W. (1968) Physiognomic Perception as a Cognitive Control Principle, Perceptual and Motor Skills, Vol 26, pp. 707 - 719

Takahashi, S. (1995) Aesthetic Properties of Pictorial Perception, Psychological Review, Vol. 102, No. 4, pp. 671-683

EXAMPLE 4: The ability to tolerate ambiguity and uncertainty during the creative process is an important mental trait. Allusive thinking by appearance alone lends intuitive judgment to overly rational thought and can lead to the discovery of meaningful metaphors. This type of thinking could be developed with focused visual education methods and its applicability shown in a variety of academic disciplines.

Tucker P., Rothwell S., Armstrong M., and McConaghy N. (1982) Creativity, divergent, and allusive thinking in students and visual artists. Psychological Medicine, Vol 12, pp 835-841

Peterson M.A. (1993) The Ambiguity of Mental Images: Insights Regarding the Structure of Shape Memory and its Function in Creativity, in Imagery, Creativity, and Discovery: A Cognitive Perspective, Amsterdam, Roskos-Ewoldsen B., Itons-Peterson M.J., Anderson R. eds., The Netherlands, North-Holland

Levy J., Trevarthen C. (1976) Metacontrol of Hemispheric Function in Human Split-Brain Patients, Journal of Experimental Psychology: Human Perception and Performance, Vol 2, No. 3, pp. 299-312

Smolucha L. and Smolucha F. (1985) A Fifth Piagetian Stage: The Collaboration Between Analogical and Logical Thinking in Artistic Creativity. Visual Arts Research, Vol. 11, No. 2. pp. 91-99

EXAMPLE 5: The ability to perceive implicit open and closed forms within a complex visual field can be developed. (Liu, 1995) The ability to see hidden relationships within the world is certainly a prime component of creative thought and could be an important mental skill when productive, independent thought is the goal in education.

Liu, Y. (1995) Some Phenomena of Seeing Shapes in Design, Design Studies, Vol. 16, pp. 367-385

Mazrsolek, C.J., Squire, L, Kosslyn S.M., and Lulenski, M.E. (1994) Form-Specific Explicit and Implicit Memory in the Right Cerebral Hemisphere, Neuropsychology, Vol 8, No 4, pp. 588-597

III. Can greater understanding of arts role in education be obtained through applied research within heterogeneous schooling environments at a variety of age levels?

This authors experience is that professionals trained in a visual discipline require evidence of qualitatively superior visual outcomes for validation. What seems to be needed, in conjunction with basic empirical research, is a body of applied research in shaping pedagogy and content based on neurological findings and subsequently assessing the effect on creativity and learning by both measurable quantitative and triangulated qualitative means. Arts professionals must see that brain compatible education is a discipline worthy of emulation and not only as activity that is useful in amplifying traditional logo-centric educational goals.

EXAMPLE 6: Mere undisciplined exposure to art materials with subjective, idiosyncratic goals may not prove to provide a productive contribution to either creativity or general learning behavior. More focused forms of sensory learning content and activities should be tested in real world educational environments aiming for measurable as well as qualitatively superior visual outcomes. Long-range projects in collaboration with professional arts educators can build a strong integrated understanding of arts role in increasing learning and creativity within the educational community.

Dake, D. (2000) Brain Compatible Visual Education: Part 1: A Knowledge Base for Improving Art Education, Reston VA, National Art Education Association

Dake, D. (2000) Brain compatible Visual Education: Part 2: Some Promising Art/Science Connections, Reston VA, National Art Education Association

Dake, D. (2000) A Natural Visual Mind: The Art and Science of Visual Literacy. book of readings, Natural Vistas in Visual Literacy & The World Around Us, International Visual Literacy Association

There already exists a body of published research that suggests that contributions from the visual arts to learning and creativity exist but there needs to be more sustained and coordinated research attention given to the elaboration, amplification, or replication of promising beginnings. In both basic neuroscience and applied educational research a future research agenda should capitalize on these beginnings and systematically explore how specific, well-defined thinking skills contribute to growth within the visual arts discipline and support for learning generally.

Research Directions

Jonathan Fineberg, University of Illinois

I would like to see us use a more sophisticated and contemporary model of what art is and in retrospect I wish I had undertaken to explain to my colleagues in the sciences that art is a cognitive process in which artists engage the most perplexing issues in present experience and try to find a way of symbolizing them visually so that they can bring coherence to their experience. In consequence the definition of art is constantly changing in relation to its time and for us to be using models from the Renaissance five hundred years ago is not as useful as dealing with the work of living artists.

I would like to use the powerful tools of observation afforded by psychoanalysis as a basis for describing the products of the brain and in particular art, which is a complex product of the brain that seems to range across a number of functions. On the basis of a broader empirical approach to what the brain produces and how it functions in making art I would like to reexamine the physiology. My feeling is that the biological and anatomical approaches we have been using still rely on too static a model (a modernist model) of development and function and I would like to see us look at physiology with the hypothesis that physical characteristics and functions are inherently unstable (a postmodern model) and that a structural approach in which the parts are constantly undergoing dynamic modification and redefinition on an unpredictable basis might lead us in fresh directions.

Understanding how we symbolize our experience, how we use symbolic form to organize our psyches, and what the neuroanatomical corollaries to these processes are will have obvious implications for learning.

However, this is too ambitious an agenda for the tools we have now. We first need to solve some hardware problems, starting with a more mobile technology for the MRI of the brain so we can scan the brain while people engage in more active tasks.

Research directions for exploring the effects of the arts on the enhancement of learning and cognitive abilities

Nina Kraus, Northwestern University

What we know:
Both long- and short-term musical experience engenders profound effects on the nervous system at both central and peripheral levels. It affects the neural transcription of sound not just for music but also for speech and other environmental sounds.

Musical experience also impacts the neural correlates of higher-level cognitive processes such as mathematics and language. Advantages in these domains have been attributed to musical training's effects on auditory working memory performance and abstract representation abilities.

Complex auditory experience strengthens corticofugal feedback loops in the auditory system, enhancing the frequency and duration tuning of subcortical auditory nuclei. Concurrent non-auditory sensory stimulation augments these enhancements. The multisensory nature of music engages multiple sensory systems (visual, tactile and auditory) and appears to have profound influences on corticofugal mechanisms engendering auditory plasticity.

Reading requires accurate neural transcription of key acoustic elements common to both speech and music. Additionally, both reading and music are inherently multisensory. The common pathways in speech and music processing, the ubiquitous human appeal for music and its inherent emotional and social functions make it an attractive avenue for the pursuit teaching reading and for remedial treatments.

Use of music to facilitate learning:
Pairing music with other learning strategies has proven enormously successful for teaching phonics (e.g. Sesame Street), math and other sciences (School House Rock). Musical training enhances the auditory working memory, which may account for its successful application in general education.

Cognitive effects of musical experience are of interest to musicians, educators and scientists alike. Related investigation necessitates a platform for interdisciplinary conversations with representatives from all three fields.

Through such conversations, entire educational curricula (e.g. reading) could be developed systematically and outcomes (both neural and educational) objectively measured. Potential outcomes include the development of classroom, web-based and computer-based (standardized) components of music-based learning.

Understand how musical experience impacts learning throughout the lifespan:
Musical experience influences neural development in various domains, even when children have had only one year of training. Long-term musical experience on development is known to last for years and it is possible that such experience may provide protective effects against aging and the disruptive effects of hearing loss.

Longitudinal studies are currently lacking yet needed to disentangle the roles of a) biological predisposition and experience, b) permanence of neural influences of musical experience and c) optimal periods in musical development.

Neural bases of successful music-driven learning:

With the ability to identify the putative neural factors associated with successful learning-through-music and locate them in the nervous system will come the promise of more focused and effective strategies for learning.
Rather than focusing on whether there are effects of musical experience on the nervous system, the better question is: in which individuals/cases are measurably changes associated with musically-driven learning? Therefore, focusing efforts on ways to look for factors contributing to successful learning outcomes is necessary.

Super-learners:
How can we explain super-performers? Through looking at extreme cases (e.g. cochlear implant users who can discriminate pitch/melody far beyond the technical limits of the prosthesis) will enable us to identify factors that underlie success. The logical next question becomes: how can we design training strategies to promote development of these factors?

Objective and individual-subject measures of neural function:
The behavioral nature of the task can influence results. This underscores the need for objective physiological measure of auditory learning that do not rely on the cognitive and attentional state of the listener or a behavioral response.

Objective neural measures of neural function (combined with behavioral metrics) are needed to assess outcomes.

The heterogeneity of learning strategies necessitates use of measures of neural function which can assess these factors in individual subjects.

The Effect of the Arts on Learning and Cognition

Michael Kubovy, University of Virginia

Art & pathology

- Do the pathologies of artists (e.g., bipolar disorder) enhance their creativity or is a person's engagement in art a risk factor?
- The healing effects of creating and consuming art (to be considered against the backdrop of the widespread gullibility mentioned below).
- The effect of pathology on our ability to perceive and appreciate art (e.g., amusias).
- Abnormalities that may produce extraordinary artistic abilities (e.g., autism) and whether they may represent a disinhibition of a widespread potential.

Art & human potential

- The capacity of art to enhance our
  - perceptual and cognitive abilities (e.g., using art appreciation to sharpen medical diagnostic skills).
  - empathic and moral sensitivity (enhancing tolerance).
- The etiology of gullibility regarding the benefits of art (e.g., the probably nonexistent Mozart effect).
- The relation between what Kahneman (http://www.nih.gov/news/NIH-Record/04_13_2004/story02.htm) calls system 1 and system 2 in the creation and appreciation of art.
- Evolutionary theories on the biological functions of art.

Art & culture

- Art as a mirror of a culture's views on
  - pathology, etiology, and healing (e.g., images of amnesia in film).
  - the challenges it faces (e.g., the film Independence Day as a representation of an implacable alien culture non-negotiably bent on our destruction)
- Etiology of societal resistance to art from Plato to the present (mostly ethical & economic).
- Art & cultural pathology: are they orthogonal? Could a culture's
  - refined appreciation of art contribute to the rise of societal pathology (e.g., Germany, Japan)?
  - rejection of high art contribute to the rise of societal pathology (e.g., Third Reich)?

Arts, Creativity, and Learning

Future Research Directions

R. Keith Sawyer, Washington University

It has been difficult to prove that arts education enhances learning in non-arts content areas, such as math, science, literacy, or social studies. Since the 1970s, arts education scholars have argued for weaving the arts throughout the curriculum; a key word associated with this approach has been "interdisciplinarity." A second line of argument appeals to learning styles, arguing that some learners may learn even "hard" subjects like math or science more effectively with arts-based approaches. (Gardner's MI theory has often been used in this way, in spite of protests by Gardner himself.) However, recent meta-analyses (such as by Ellen Winner) have not found solid evidence that arts education enhances learning across the content areas.

Very little of this research has focused on performing arts. Perhaps the key distinguishing feature of the performing arts, in contrast to other arts, is that they are deeply collaborative. In contrast, painting or poetry are often taught as solitary pursuits. My own research suggests that improvisational forms of ensemble performance can enhance students' ability to learn and to function in collaborative groups. And a broad range of learning sciences research suggests that collaboration contributes to particular learning outcomes: deeper conceptual understanding, thinking, and problem solving in real-world domains.

So I would like to see research studies that focus on collaborative arts, which would probably focus primarily on performance (although even painting and writing can be taught in collaborative ways). I wonder if we could identify differential effects of collaborative performance arts, and solitary "plastic" arts?

A second line of research could focus on introducing creativity into the content areas. Most arts education scholars have focused specifically on the arts, rather than on creativity more generally. The actual practice of professional science is deeply creative, but K-12 science instruction rarely teaches it this way. Instead we usually see a transmission-and-acquisition style of instruction that results in memorization of facts and procedures.

A huge need is for a new form of outcome assessment that would reflect the deeper conceptual understanding, and the greater creative facility, that are expected to result from transformed learning environments. I would like to see a research project directed at development of new assessments, for example that could replace the SAT subject area exams or the AP exams, as well as national assessments used in connection with NCLB.

Research Direction for Exploration of the Effect of the Arts on Enhancement of Learning and Cognitive Abilities

Andrea Shindler, The Foundation for Human Potential

In this age of standardized testing, it is most important to regard the arts as a unique influence on learning, rather than to attempt , as has been done in testing-focused education circles, to create a relationship between the arts and specific aspects of academic learning, i.e. standardized test scores.

Learning about arts abilities, following or in the context of brain damage , is most instructive. While this work is often done with adults, post-stroke, post- traumatic head injury, progression of Alzheimer's Disease, fascinating work has been done with autistic children in both art and music. The goal of furthering this work will benefit education policy worldwide. Unique talent is evidenced in brain damaged patients, as per the observations of Oliver Sacks and others.
Emerging Scientific Picture of Creativity (Taken from Contemplating Creativity by Andrea Gellin Shindler) www.fhpoline.org please go to home page, bottom right, ADDITIONAL READING, and click on Contemplating Creativity.

1. A creative person regularly solves problems or fashions products in one or more domains.
2. Beyond a certain point, there is rarely a correlation between measured IQ and creativity.
3. Creative output is a predictable occurrence, not a on-time "accident".
4. A creative tendency in one field does not predict similar tendencies in other fields.
5. Most creative insights come about gradually, not with a burst of insight (Charles Darwin's theory of evolution and Alver Einstein's theory of relativity emerged over years of observation and thought).
6. Personality traits of creative people include independence, self-confidence, unconventionality, alertness, ambition, commitment to work, willingness to confront hostility, inquisitiveness, a high degree of self-organization, and the ability to work effectively or long periods without sleep.
7. Creative individuals are risk-takers who confront problems with an unusual combination of intellectual strengths that allows them to investigate an area in a new way or to define a new area of study.
8. Cognitive style, the way one thinks, rather than native intelligence seems to set creative individuals apart from their peers.
9. Intrinsic factors (the passion for pursuing a particular activity for the sake of the activity itself) rather than extrinsic factors (reward such as fame, fortune, status, or prizes) motivate creative individuals.
10. Parental support of creative young people in their formative years tend to be either very strong or lacking.
11. Creative people often have special mentors
12. Creative people have an aesthetic sensibility that distinguished "good" problems (those to be pursued with vigor) from "unimportant" problems (ones that can be ignored).

Among others, important individuals influencing creativity and learning:

Amabile. Teresa M.
Arnheim, Rudolph
Csikszentmihalyi, Mihaly
D'Amboise, Jacques
Gardner, Howard
Sternberg, Robert
Winner, Ellen

Authors and work on Creativity and Learning:
The goal of developing and implementing arts programs designed for brain damaged adults and children could shed informative light on the abilities of the affected populations, ultimately useful to all aspects of education/learning, identifying remarkably improved potential for the process of education. The goal of improved measurement of education, via, assessment in context, i.e. in the process of learning, rather than with pencil and paper tests, will provide a meaningful measurement of learning.

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Thinking In and Outside of the Arts

Ellen Winner, Boston College

All too often, the arts are marginalized in our schools. In response to this marginalization, educators have sought to justify the arts in terms of their instrumental value in promoting thinking in non-arts subjects considered more important, such as reading or mathematics. There is little convincing empirical evidence that the study of the arts promotes academic performance or elevates standardized test scores, as demonstrated by a series of meta-analyses conducted by Winner and Hetland (2000), which I will discuss.

The existing studies included in our meta-analyses investigating whether arts learning transfers to academic performance had two fundamental flaws: they failed to assess what was actually learned in the arts; and they failed to specify any plausible mechanisms that might motivate a transfer hypothesis.

We therefore undertook a qualitative, ethnographic study of the kinds of cognitive skills actually taught in the arts classroom, choosing the visual arts as our point of departure (Hetland, Winner, Veenema, & Sheridan, 2007). Our goal was to understand what is taught, in order to be able to develop a plausible theoretical transfer hypothesis.

We identified six “Studio Habits of Mind” that we saw being taught in these visual arts classes. Students are taught to observe -- to see with acuity; to envision -- to generate mental images and imagine; to express – to find their personal voice; to reflect -- to think meta-cognively about their decisions, make critical and evaluative judgments and justify them; to engage & pPersist – to work through frustration; and to stretch & explore –to take risks, “muck around,” and profit from mistakes. Our work is the first to demonstrate objectively the kinds of thinking skills and working styles taught in arts classes.

After having identified the skills taught in the visual arts classroom, we developed a hypothesis about potential transfer of learning from the arts to a non-arts domain. Because training in the visual arts stimulates the ability to envision, we predicted that students trained in the visual arts will show superior ability to reason about geometry. We are now embarking on a quasi-experimental two year longitudinal study investigating this hypothesis.

In parallel with this investigation into the potential transfer of learning from visual arts to geometry, we are investigating two other transfer questions: (1) Does training in theater lead to enhanced social cognitive skills (i.e., the ability to understand and empathize with others and regulate ones own emotions)? (2) Does learning an instrument lead to learning that transfers to mathematics, verbal ability, and/or spatial skill, and does instrumental music learning affect brain development. The motivation underlying all three of these programs of research is to understand the relationship between the kinds of cognitive skills learned by training in an art form, and cognition used in areas outside of the arts.

Projections for productive research: Neuroscience underpinning of art, and beauty in art

Dahlia Zaidel, UCLA

The neuroanatomical and biological underpinnings of the arts hold great fascination to students and scholars alike. Even those not in the neuroscience or biological fields are intrigued by such topics. In my experience, university students majoring in chemistry, physics, mathematics, or economics, switch their majors to neuroscience after learning about the neuroanatomical and brain underpinnings of the arts in an interdisciplinary brain-art course. The arts become the magnet to the intense interest in the brain. Their goal becomes learning how the brain supports a mind that gives rise to such diversity and types of arts, even when ultimately they become medical students or graduate students in non-art fields. But the reverse is also true: Combining art and neuroscience in the same course attracts non-art students to the arts. Future Research: More funding to interdisciplinary courses emphasizing neuroscience of the arts and measuring interest in the neurosciences before and after, as well as measuring interest in the arts before and after.

Beauty in the arts also provides a fascinating platform for learning. In general, beauty and its myriad of mysteries play a prominent role in attraction to a broad spectrum of experiences be they art works, faces, objects, foods, ideas, concepts, or cognitive problems. Beauty arouses interest, emotions, commitment, and, importantly, leads to attachment. It is a major attractant with biological underpinnings. The arts provide an ideal platform for learning about the nature of beauty; the art-beauty interplay introduces a source of non-traditional learning perspective. It teaches the relationship between beauty and the pleasure of knowing, as in knowing something not known previously, be it an idea, a concept, or a fact. This in turn provides motivation to explore further, analyze and synthesize, and indulge in convergent and divergent thinking. Future Research: More funding for empirical research into the differential reactions of multi-forms (expressions) of beauty (e.g., paintings vs faces vs objects vs cognitive problems vs ideas vs concepts, etc.).

APPENDIX IV
Individual Student Recommendations for Future Research Directions

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Alessandra di Croce

Research Recommendations

I should confess that, being an art historian and not a psychologist or an educator, I have never considered the beneficial effects of arts training on the learning process. Indeed, my interest in Neuroscience comes from the conviction that recent neurological findings namely the discovery of mirror neurons and their implications, may help answer several questions traditionally raised in the history of art; and above all, the question concerning our responses to art works and images in general.[1] Therefore, I am afraid that I might not present here very relevant observations concerning the enhancement of learning through arts; nor can I certainly suggest any scientific experiments. I can only propose to consider the question of corporeal and psychological responses to what one sees a topic that is critical to art historical studies, as Professor David Freedberg has pointed out several times from a multidisciplinary approach that, while using neurological results provided by others, may suggest a new way of addressing the problem.

The other reason for which I have never considered whether there are cognitive differences between art-trained and non art-trained students, is that I am interested in "automatic responses" to art rather than in "cognitive responses". With "automatic responses" I refer to those immediate and pre-reflexive responses, or "bottom-up responses", which do not depend on context but are rather based on neurological mechanisms. Of course, it is not my intention to deny the role of context culture, personal education, or social constraints in our response to art works. Nevertheless, I believe that what we define as "cognitive responses" represent only a second step, so to speak, in the process of the reception of an image, be it an image from our daily lives or an art work, anticipated by a corporeal and bodily response to it. We are presented here with the longstanding question of empathy as "inner simulation", physical involvement of the beholders in what they see that is to be found throughout the history of Western culture, and became largely debated towards the end of the 19th century Vischer, Wolfflin, Lipps. The issue is here twofold: how the beholder becomes involved with what he sees, and how and to what extent movements and gestures may convey emotions.[2]

While artists and theorists of the past only had an intuitive knowledge of the mechanisms that allow viewers to be physically engaged with a picture, we are now in a better position to understand such mechanisms due to the discovery of mirror neurons. As it is known, these neurons fire during both the execution of one's own actions and the observation of the actions of others they constitute a "mirror matching mechanism", and seem to represent the neurological basis for our ability to establish meaningful relationships with others, without the necessity of any particular cognitive operation. According to the "mirror-matching theory", action observation is action simulation, which in turn allows an implicit form of action understanding[3] beginning with the inner simulation of the given action (⇒ embodied simulation / physical empathy).

Furthermore, mirror neurons may hold the key to understanding several other aspects of the human mind, including imitation - *"to imitate someone is to translate an external perspective into my own personal body perspective" (*Gallese) - imitation learning, and also language since the human MNS includes

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[1] My interest in these questions was stimulated by Professor David Freedberg, whom I first met in Rome in 2006. Having read his book " *The power of images"* I became further interested in the problem of emotions and responses to art works, issues of the utmost importance to studies in art history. Along with Professor Freedberg, I am convinced

that an interdisciplinary approach, as difficult and challenging as it might be, offers the most fruitful and creative way to think about such problems.

Broca's area, typically considered the area of language[4]. The importance of imitation learning is obviously clear from both an evolutionary point of view and a social point of view imitation learning as the origin of the "big bang" of human evolution as Ramachandran suggests and a form of learning that avoids time-consuming trial and error learning. Moreover, imitation is a fundamental form of social communication, identification and interaction among conspecifics. It is important to recall here that, according to fMRI experiments, imitation of actions both actions that belong and do not belong to the motor repertoire of the observer involves the same neurological network involved in observation and simulation of actions (Iacoboni, 2005). To conclude, a lot of neurological data suggests the presence of a matching mirror system that accounts for a common mechanism of embodied simulation; an automatic, precognitive, and unconscious mechanism that represents the basic level of the link we establish with the others intersubjectivity, and with the external world around us.

As mentioned above, mirror neurons with their implications of inward simulation, imitation, and physical empathy may help explain the effects of images on the viewers, their capacity to arouse emotional responses through bodily movements, and to provoke a sense of physical engagement and inward imitation. In this light, the question of gestural language is particularly interesting inasmuch as it is directly related to the perception of the body in motion, the inner simulation of observed movements and gestures, their emotional effects on beholders, and the relationship between movement and emotion. Moreover, it is related to the fascinating theory that language evolved from gestures rather than from vocal calls; a theory that could substantiate the dream of a universal and primigenial language shared by all human beings before the tower of Babel. [5]

As for the relationship between art training and learning process, I would like to stress two aspects which may perhaps be interesting and worth exploring. Perhaps, not only an education to creative or performing arts may determine cognitive differences but also the observation of art works, the ability to "look at" images may affect the learning process focusing attention and encouraging empathetic responses.

1. Let us assume that there is indeed a first, immediate, and precognitive response to images based on embodied simulation, followed by a cognitive response. We could then consider the relationship between bottom up and top down processing, that is, how automatic and precognitive perception of movements and gestures may direct our visual attention, and modulate our cognitive reception of the image at hand for instance, a selective vision of the different elements depicted; what capture our attention and why;

2. If embodied simulation and empathetic engagement are part of our response to images, it follows that observation of images and art works may sharpen our empathetic responses to the world around us. And in doing so, reevaluate the role often neglected of emotions in cognitive processes: emotions are one of the ways available to us to acquire knowledge about ourselves, and in relation with other individuals role of emotions in the building of our experience of the world process of decision making accomplished by a "covert mechanism" directly responding to "somatic markers". Physical basis of emotions: " *as if body loop",* (Damasio.) N. Goodman: " *emotions function cognitively".* Embodied mind: beyond the traditional Aristotelian dualism of emotions/reason and body/mind;

3. Given the physical engagement and inward simulation provoked by images, looking at art works involving movements may enhance our sense of muscular possibility, and the motor potential of the same muscles than those observed see B. Berenson, "life-enhancing" effects; Battaglia-Freedberg: " *sight of depicted actions enhanced the movement evoked potential of the muscle concerned".* And it might be worth investigating the educative and therapeutic possibilities here implied.

[2] In his Trattato della Pittura ... Leonardo writes: " *if the narrative painting represents terror, fear, sorrow or pleasure, joy and similar conditions, the mind of those ... who view it ought to move their limbs so that they seem to find themselves in the same situation the figures in the narrative painting represents ".* L.B. Alberti states that paintings should " *move the soul of the beholder when the people painted there clearly show the movement of their own souls ".* See also Aby Warburg and his pathosformel, that is the ways in which the movements and gestures of the body represent and express emotions and were used in art to convey specific emotional meanings i.e. Maenads.

[3] Gallese *et alii* 1996; Rizzolatti *et alii* 2001; Gallese 2003;

4 On imitation and imitation learning, see Iacoboni *et al.,* 1999; Iacoboni *et alii* 2001; Iacoboni 2000.
5 See Rizzolatti Arbib 1998; Bernardis Gentilucci 2005; Corballis 2002; Corballis 2006; Montgomery *et alii* 2007.

Thalia R. Goldstein

Future Work Statement

Most people today are somehow involved in the world of acting, typically as audience members. Yet psychologists know little about the psychological components of acting - the prerequisite skills required, the developmental course of acting talent, and the cognitive and affective consequences of engaging in acting. This stands in contrast to how much psychologists have learned about the cognitive components of visual arts (e.g., Arnheim, 1974; Freeman, 1980; Gardner, 1980; Golomb, 2004; Hagen, 1980; Zeki, 1999; for a review see Winner, 2006) and music (e.g., Bamberger, 1991; Deutsch, 1982; Sloboda, 1986; Trehub, 2003; for a review see Winner, 2006).

I believe an important direction for future work in the arts and learning is how acting training and involvement in theatre can help children learn various social cognitive skills. Particularly, I believe acting can teach important lessons about theory of mind, empathy, and adaptive emotion regulation. There has been some previous work in the area of learning and acting, notably Noice & Noice's (2006) work on verbal memory in adults and older adults, and Podzlony's (2000) meta-analysis of studies of transfer from creative drama to verbal skills. However, apart from two studies linking role playing and perspective taking (Chandler et al. 1973, 1974), and one study (Schellenberg, 2000) that showed and increase in social skills after a drama intervention, there has been no systematic program of research that looks at the power of acting training to foster social cognitive skills. I have begun such a program of research and currently have several papers under review. In one study, I show that adolescents involved in acting training have higher levels of social-perceptual theory of mind, but not empathy. In another study, I show that adult actors use more acceptance and less avoidance in order to regulate their emotions. Currently, I have a study underway showing that 8-10 year old children involved in acting have higher levels of social- perceptual theory of mind, but not empathy, with some evidence to also show advantages in social-cognitive theory of mind, when compared to children involved in dance or not involved in an art form.

The major question that must be addressed is the direction of causality. Are individuals drawn to seek theatre training because they have high social-cognitive skills, and/or does theatre training foster such skills? If the latter, we need to investigate the dimensions of theatre training that are linked to social-cognitive development. In my dissertation to be conducted in the next two years, I plan to try to answer both of these questions. These questions are of theoretical significance and also have both educational and clinical implications. Individuals with Asperger's and autism spectrum disorder have poor theory of mind skills, and maladaptive emotion regulation techniques may be associated with depression. Thus it might be possible to use theatre as an intervention.

Trent Grover

Potential Research Directions for Learning Enhancement: Video Games

Well-designed educational video games have the potential to engage students more wholly and effectively in the learning process in a variety of ways. As such, the design, implementation, dissemination, and evaluation of educational video games provide an expansive and worthwhile arena for future academic research.

Effective classroom instruction typically begins with concrete representations and then moves towards abstractions. In almost every classroom, you begin teaching/learning with the things you can see and interact with. You first learn about gravity by dropping things. Only when you've attained firm ground within this experiential setting can you begin to imagine the theoretical or ephemeral underpinnings that lie beyond.

Unfortunately, many fields of study cannot provide a convenient experiential starting point. For example, the understanding of cellular function is challenging because everything occurs at a scale that we cannot perceive. Instead we are forced to rely almost entirely on static textbook diagrams that frequently distort relative sizes, lack three-dimensional spatial representation, have no interactive components, and cannot fully illustrate dynamic processes. The computer generated virtual environments of video games can address these shortfalls by providing an experiential platform for teaching even the most abstract of concepts.

Video game players display a remarkable, and often voracious, capacity for absorption of the geography, interaction methods, and rules of action that govern complex game environments. This often unconscious ability seems to apply equally to well designed games, regardless of genre, across the immense array of unique and fantastical environments available. If students can so readily absorb fictitious, imagined worlds, why not represent the seemingly fantastical worlds of biology or mathematics in a similar manner?

The presentation of educational material within a well designed, emotionally engaging, storyline provides students with constant motivation to engage with and absorb that knowledge. In addition, video games provide an intermix of instruction, demonstration, experimentation, and performance that is quite effective. In particular, video games provide an environment in which students can learn by experimentation and discovery rather than by presentation, ultimately encouraging more understanding and less memorization.

Key research questions relating to the creation and use of educational video games would include:

- How effective are educational video games in comparison to conventional instruction?
- What design elements are most effective in educational video games (artwork, music, animation, puzzles, etc)?
- What fields of study are most conducive to video game representation?
- Are video games a more effective teaching aid for students of certain demographics?
- Does the use of an educational video game enhance later consumption of related educational materials?
- What are the most efficient tools available to educators for the design and creation of educational video games?

Michael Schutz

Listening to the Music: Using art to understand science

We live in a noisy world filled with incredibly diverse sounds. In order to make sense of the complex auditory scene, we have evolved a flexible and powerful perceptual system reflecting important characteristics of our environment. In a sense, music has followed a similar path of incremental evolution. However, as a man-made sound designed for the listener's experience, it has been shaped by psychological – rather than ecological – pressures. Music has evolved from monophonic chants and simple single-line melodies to the harmonically complex, polyphonic compositions we have come to expect and appreciate. In essence, music reflects the structure of the mind as much as the mind reflects the structure of our environment. Accordingly, we can learn a great deal about ourselves by studying artistic expressions such as music which have been shaped by our biases, limitations, constraints, and preferences.

Its considerable aesthetic value aside, from a purely from a cognitive perspective music represents a phenomenal human achievement. Music is essentially an auditory playground, fascinating centuries of the worlds best composers, performers, and enthusiastic listeners (all experts in different aspects of perception and cognition). Given the incredible human investment in time and energy devoted to its practice, music represents the ultimate "free market system" for exploring the boundaries of perception and cognition. Consequently, the comparatively younger fields of experimental psychology and cognitive science can benefit tremendously from examining what expert musicians have already discovered.

Through trial and error, composers have learned to sculpt sound so as to achieve particular results, and as such music is reflective of psychology more-so than acoustics. Consequently, musicians are masters at knowing what does and does not "work" with respect to our psychological capacities. Composers implicitly understand the constraints on our processing capabilities, restricting their compositions to the types of patterns and structures that we can reasonably process. Performers are masters of motor control and the memorization of complex yet flexible hierarchical structures, capable of quickly learn and executing compositions with tens of thousands of notes. Professional aside, even casual listeners without musical training are generally able to recognize a vast array of popular music, often along with relevant information regarding song title, artist background, period of popularity, etc. Given these observations, I believe all facets and aspects of music hold incredible potential to inform our understanding of the mind.

To give one example from my own research, I have found that percussionists use gestures to alter musical note duration, contradicting long-standing assumptions regarding the nature of auditory-visual integration. Even though it is not possible to use changes in physical gesture length to alter acoustic note length, expert performers have "learned" to use changes in gesture to alter the perception of acoustic note length. In other words, even though gestures cannot change the sound of a note, they can (and do) change the way notes sound. Curiously, it has been psychologists even more than musicians who are surprised by this finding, as they previously believed this particular pattern of audio-visual integration to be impossible. The reason for this misunderstanding is that the natural sounds used by musicians are processed categorically differently from the artificial (but convenient) sounds generally favored by experimental psychologists. Therefore even though this line of research started with a purely musical question, it has helped to inform our understanding of the way the mind works within the constraints of our natural environment.

While I feel fortunate to have stumbled somewhat accidentally upon such an interesting phenomenon, the concept of music informing our understanding of psychology is by no means new. For example, although Bregman, Deutsch, and van Noorden receive the lion's share of credit for exploring auditory stream segregation (and rightly so), they fully admit that Bach, Telemann, and Tchaikovsky discovered and exploited similar principles to great effect hundreds of years earlier! These are but a few instances of what I believe to be many ways in which a careful study of standard musical practice can inform our understanding of cognitive science. It's difficult to envision precisely what science will learn next from a careful study of music, but I have no doubt it will be fascinating, informative, and far easier than "starting from scratch" by attempting to rediscover through laboratory experiments the principles of auditory perception and cognition already explored thoroughly by generations of musicians.

Echo H. Wu

Proposed Research Questions and Rationales

(1) Is creativity an innate ability? Can creativity be nurtured?

Rationale:
Similar to "Giftedness," creativity is such a controversial issue that not a single definition could explain it thoroughly. How can we measure creativity at an early stage of life? How do people come out with creative ideas, innovations, and make differences to the world? Can those unique processes of thinking be trained and nurtured over time? If the answer is no, should we leave the children to develop by themselves? If the answer is yes, what should educators and researchers do?

(2) What are the parenting and family roles in nurturing creativity among children, especially pre-school children?

Rationale: Family and parents can be seen as the most significant ones to children, especially those younger ones before starting primary school. Talented performance in many areas, e.g., arts, music, or dancing, can be fostered by parents, or at least the parents or other family members can provide the opportunities for children to participate in various activities, which may lead to a life-long involvement or commitment. Research studies are needed to examine the roles of parents and families so as to provide valuable implications to the society for better nurturance of creativity among the younger ones.

(3) How does the concept of creativity vary among different cultures? What are the crucial aspects of creativity that we need to pay attention to when promoting creativity in countries with different cultural backgrounds?

Rationale: As can been seen from the literature, the concept of creativity varies from one culture to another. Not only people have different beliefs over the nature of creativity, but they may also behave differently in their endeavors to promote and nurture creativity among children. For instance, in China, with the influence of Confucian philosophy on learning and achieving, which puts much attention on effort rather on innate ability, creativity is seen as an asset that could be nurtured and developed through hard work, good will, and training and practice. It is important for researchers to investigate what the impact of such cultural differences can make, and what indeed creativity can be better nurture combining the strengths of thinking among different cultures.

Appendix V

Sample lesson plan for "Teaching Vision and Art: An Empirical Approach"

Bevil R. Conway (Wellesley College), Margaret S. Livingstone (Harvard Medical School)

Undergraduate students, as well as the general public, are more likely to engage in scientific discussions when the content can be made relevant to their other interests. Visual art has broad appeal, and therefore serves as a valuable jumping off point for investigating how the visual system functions; in addition, an understanding of the function of the visual system enhances critical, formal analysis and opens the way for scientific investigations into visual discoveries made by artists. We have developed a syllabus that aims to introduce some of the principles of visual neuroscience and show how artists have implicitly (and occasionally explicitly) taken advantage of these in developing works of art. The sample syllabus hi-lights how these issues can be approached in the undergraduate classroom setting, with hands-on laboratory exercises and self-directed learning projects. The goal of such a syllabus is not only to advance an understanding of the neural systems that underlie vision but also to cultivate observational skills and critical thinking. The syllabus is a work-in-progress and will be modified following each semester it is taught. One of us (BRC) taught a 3-day workshop on Vision and Art ("Seeing seeing differently") at Lyme College of Fine Art to visual artists. This experience, along with extensive discussions between the co-authors, resulted in a full-semester course in the spring of 2008 for a group of 10 Wellesley undergraduate students. The students were selected from a diverse set of backgrounds including Economics, Film, Cognitive Science, Neuroscience, Physics and Chemistry. Here we present two observations following this course. First, we consider whether such a course is productive for students with little or no prior neuroscience training. Second, we discuss the efficacy of hands-on laboratory exercises as teaching tools, and describe some practical ideas for laboratory exercises that bridge the gap between works of art and visual neuroscience.

I. Is a course on Vision and Art productive?
To address this question, following the course, students were asked:

Do you think the study of art is enhanced by an understanding of the visual system and visual processing? Do you think studying art can tell us anything about how the brain works? Develop a cogent argument, with evidence to support your claims, for or against (1-2 pages, single spaced).

The responses were generally positive (5 samples are included below), and illustrate both the successes and failures of such a curriculum. It is clear that students rapidly develop a solid understanding of some concepts, but struggle with others. Example essay # 5 persists in the popular misconception that rods encode black and white while cones encode color. She writes that:

> "cones are activated by color and the precision of line whereas rods have black and white, blurry receptive fields, or rather are stimulated by luminance and out of focus visual fields. It is thought that the lack of line and emphasis on movement of impressionist paintings increases rod activation. Perhaps there is a stronger connection between rods and areas such as the amygdala, stirring the emotional response of viewers." The student has grasped the concept that different aspects of a visual scene can be communicated by segregated parallel pathways, but the specifics of these pathways remains poorly understood and fraught with popular misconceptions.

Other students related their learning experiences to their daily lives. Example essay #1 describes the way in which her conception of color constancy applies directly to her daily life. She writes:

> "last week I was feeling a bit too white-blonde so I decided to get low-lights to contrast the white-blonde. But the result ended up being a silver-grey-green drab mess. My colorist assured me it was because of the contrast. Immediately my knowledge of color and visual processing came to the forefront of my thoughts: But how could this be, doesn't local color contrast brighten the white? Why was my hair appearing so drab? All it seemed to be doing was casting a silver grey shadow that did not appeal to my eye, and I couldn't figure out exactly why. I wanted my hair to look warmer, so she toned it with gold. But this dulled it even more by getting rid of all the contrast together. My hair was a color disaster. So yesterday, I went to my expert colorist in Minnesota to correct the job. We looked at photos (though as pointed out in the previous question, matching color from a scene could be quite a feat), and I described in detailed what I wanted. I used language such as "warm, bright, golden, honey, contrast." We got so into it, I started telling her about this great class I was taking on Vision and Art. We talked about coloring hair as a true art form. I told her I noticed that in this salon the lighting was much more conducive for happy costumers because it made any hair color warmer. Even the color of the walls helped with the hair's warmness. So we had a two step plan.1. to re-tone my hair with gold 2.Add back in white-blonde and a warm brown to bring back that brightness that makes my hair pop. It was a fun moment yesterday, as I shared what I learned in class but also synthesized and applied my knowledge to the real world. On top of that, I got exactly the hair color I wanted. Therefore I truly believe that the knowledge of the visual system enhances the study of art (and art in any context—including hair coloring!)."

The complete responses from 5 students are given in Appendix 1.

<u>II. From art to visual neuroscience: laboratory exercises</u>

What seems most clear from the first version of this course is that students benefit most from hands-on laboratory exercises, even in developing what seem to be the most basic visual neuroscience concepts. We will describe two examples, the first deals with the concept of the V□function; the second deals with the concepts of additive and subtractive color.

Blues in paintings are almost always darker than the other colors in a painting, and as a result usually involve less volumetric development. This observation, once made, becomes difficult to ignore when looking at visual art. How can we account for this observation? The students easily grasp the concept of the V□ function, but when asked to apply it to explain the relative brightness of colors across the spectrum (why blue looks dark and yellow looks bright), the students are at a loss. By providing the students with an afternoon hands-on laboratory exercise in which they can directly measure the luminance (using a simple hand-held photometer) of the light emitted from different colored lights (powered by a variable power supply), the students can empirically establish the correlation between brightness and wavelength, bringing their understanding full circle.

Pointillist artists (Seurat, Signac et al) employ small dabs of many different colors to develop an impression of a scene, often a landscape. The technique results in a consistent texture across the canvas surface and produces a pearly multicolored effect. The effect captivates even the uncultivated viewer; many theories have been developed to account for the visual effects of pointillism, and most play upon a false understanding of additive and subtractive color (usually described as "optical mixing"). Students confronted with accounting for pointillist pictures were asked to do a straightforward laboratory exercise. Using oil paints, the students prepared a simple pointillist image from small alternating dabs of blue and yellow paint. They were asked to view the picture from several viewing distances and to record the (perceived) color. Then they were asked to smear the dabs of color to create a homogenous surface; and to repeat the observations. A sample report that discusses the observations in terms of principles of vision is given in Appendix II.

Concepts in visual neuroscience can be motivated by studying visual art, and can plausibly be communicated with simple laboratory exercises, as outlined in the table below. We hope this table forms a springboard for discussion and development (more rows could be generated during discussion).

Concept	Example from Visual Art	Laboratory exercise
Pattern of light on the retina is a flat projection of the real world	Ingres, Vermeer	Make and use a camera lucida
Pigments reflect the wavelengths of light they do not absorb	Pointillism	Compare the apparent colors of two pigments mixed optically or physically, compare additive (light) and subtractive (pigments) color mixing.
The first and most fundamental computation in the visual system is center/surround	Countersh ading	Make examples of simultaneous contrast; Make layers of gray washes to see how linear changes in density convert to logarithmic grayscale; do the same experiment with Photoshop; Generate Mach Bands
The second step in visual information processing is contour	Picasso Egon Schiele	Life drawing. Use of negative space, mirror, looking upside down in order to see contours
Luminance is encoded by summing the 3 cone types; color by subtracting	Monet	Estimating luminance of different colors; Adobe Photoshop's grayscale
Depth and motion are processed by the largely colorblind dorsal stream	Op art	Exercises in generating effects with equiluminance
Vision is information processing; higher visual areas must code distinctive features of objects, not Cartesian reflections.	Caricature , abstractio n	Generate or analyze caricatures
Object representations are position and scale invariant	Cubism	Analysis of drawings made by patients with parietal and temporal lobe strokes
Objects at different depths produce retinal disparities. Mismatching two retinal images can generate false depth.	Impressio nism, Klimt	Make autostereograms or depth illusions
Lower contrasts are processed more slowly than high contrasts. Equiluminance can generate illusions of jittery motion.	Op art	Generate motion illusions with contrast and equiluminance
Central vision and peripheral vision have different optimum spatial frequency ranges	Leonardo, Chuck Close	Make photomosaics, mimic the Mona Lisa effect
Color perception is lower resolution than luminance contrast.	Watercolo r, pastels	Exercises in color bleeding/spreading

Sample Student Responses

Do you think the study of art is enhanced by an understanding of the visual system and visual processing? Do you think studying art can tell us anything about how the brain works? Develop a cogent argument, with evidence to support your claims, for or against (1-2 pages, single spaced).

Student Essay #1

Libby MacFarlane
Wellesley College, Spring Term 2008
Neur320, Vision and Art: physics, physiology, perception and practice
Prof. Conway

I believe the study of art is enhanced by understanding the visual system and visual processing, however I hope as information is revealed it is used only as a tool to open doors and not close them. I would be hesitant as an artist to know *too* much, for it might become a road block to my creativity. Just as you said in our Life Art Drawing Class, "there is no such thing as multiple-choice drawing". If people/artists are too rigid about the outcome and are too invested in how our visual system reacts to the art, then perhaps we have let our knowledge close a door. Just like a musician who fixates on off-pitch note at a concert may fail to enjoy the concert for its true musical experience, an artist knowing too much science, might do the same thing while walking around a museum and visually dissecting the art. I think sometimes when we deconstruct and unpack things too much we are at the risk of losing and enjoying the big, whole picture why? I am not aware of any case where this is so… I take the opposite position: the more you know about something, the more you enjoy it; and the more captivating its mysteries becomes (like wine!). Don't get me wrong, I am an advocate for learning and knowledge, and that it does open doors if that's where we direct it. Awareness is the key to evolution and transformation of our self and our world. And if we want it to, the study of art is enhanced by understanding the visual system. I will tell a quick story to illustrate my point: Just yesterday, I was getting my hair color corrected. Last week I was feeling a bit too white-blonde so I decided to get low-lights to contrast the white-blonde. But the result ended up being a silver-grey-green drab mess. My colorist assured me it was because of the contrast. Immediately my knowledge of color and visual processing came to the forefront of my thoughts: But how could this be, doesn't local color contrast brighten the white? Why was my hair appearing so drab? All it seemed to be doing was casting a silver grey shadow that did not appeal to my eye, and I couldn't figure out exactly why. I wanted my hair to look warmer, so she toned it with gold. But this dulled it even more by getting rid of all the contrast together. My hair was a color disaster. So yesterday, I went to my expert colorist in Minnesota to correct the job. We looked at photos (though as pointed out in the previous question, matching color from a scene could be quite a feat), and I described in detailed what I wanted. I used language such as "warm, bright, golden, honey, contrast." We got so into it, I started telling her about this great class I was taking on Vision and Art. We talked about coloring hair as a true art form. I told her I noticed that in this salon the lighting was much more conducive for happy costumers because it made any hair color warmer. Even the color of the walls helped with the hair's warmness. So we had a two step plan.1. to re-tone my hair with gold 2.Add back in white-blonde and a warm brown to bring back that brightness that makes my hair pop. It was a fun moment yesterday, as I shared what I learned in class but also synthesized and applied my knowledge to the real world. On top of that, I got exactly the hair color I wanted. Therefore I truly believe that the knowledge of the visual system enhances the study of art (and art in any context—including hair coloring!).

I also believe that the study of art can tell us something about how the brain works. When we look at multiple pieces of artwork we can start to detect patterns in what we like and how our brain responds. This correlation can help set up studies/research to test certain functions of the brain. In our two most recent articles that we read for class, neuroscientists used artwork to study phenomena such as "why does our eye not notice incorrect shadows?" Art, in this case, acts as a tool to unpack how the brain works.

Student Essay #2

Rosa Lafer-Sousa
Wellesley College, Spring Term 2008
Neur320, Vision and Art: physics, physiology, perception and practice
Prof. Conway

E. O. Wilson theorized on a concept he calls consilience, a unification of knowledge, “Literally a jumping together of knowledge by the linking of facts and fact-based theory across disciplines to create a common groundwork for explanation.” In his book on the subject he argues for a neurobiology of aesthetic, suggesting that the subjective experience communicated and explored by art can be understood at a neurobiological level. In a universe governed by a set of physical laws, with no one thing being separate, the pursuit of knowledge in any one field inherently lends insights to another. In fact, this pursuit of knowledge from the point of view of multiple disciplines allows the questioner to ask questions he previously was not set up to ask. It is a matter of shifting one’s perspective, not the ultimate subject matter at hand. We are all pursuing the same basic themes—some might call them ultimate truths. It is our starting points that lie far apart.

Consider a given problem to be a spherical body in which you can begin anywhere on the surface and travel inward in pursuit of the answer. The path one follows is defined by the language, scale, method of description, and organization of knowledge unique to that constructed field of questioning. The ultimate destination is one and the same for any path taken. What one can see and ask of the problem at hand is limited by the perspective inherent in his path of choice, as is the presentation of the answer. Increasing the number of paths traveled liberates the questioner of this single-track perspective and pushes him to develop a more profound understanding of any and all knowledge encountered. When the achieved answer can be described in a diversity of languages and media, it is made increasingly accessible. So yes, the study of art can be enhanced by the study of vision and vice versa.

When we study art we talk about the way in which it is constructed and received, as well as the context of the creator, the viewer, and the piece. Understanding the components of how our visual system functions provides a useful framework for these conversations. For example, I can talk about the experience of my eye being drawn to a certain point in a composition, but I may not be able to say *why* this occurs without understanding that our visual system is set up to identify regions of high local contrast and discontinuities in form. And without studying art, I may not have ever been made aware of the fact that my eyes’ focus and movement can be guided by elements of visual composition, and so would never have pursued a neurobiological explanation of the phenomenon.

Figuring out how something works is all about asking the right questions. We are not always in the position to ask the right question. The more we learn, the more questions we can ask. Arthur Kornberg addressed this phenomenon in his book *For the Love of Enzymes,* where he described “the perimeter of our ignorance.” Imagine a circle, inside of which is what we know and outside is what we don’t know (which is infinite), as we learn more, the perimeter increases. This perimeter is the interface of our interaction with the unknown, so as the perimeter increases so too does the area of questioning.

A background in evolutionary theory helps one to look at the problem of processing visual information in terms of the identification of biologically useful information and rendering of it to the organism. With this perspective one can understand that our perceptions are not simply the product of a camera-like organ, but rather a filtered, distorted, translation of external information. Studying art provides the same insight. Artists talk about ‘tricking’ the eye into seeing one thing or another. For example, when trying to achieve a sense of depth on a two dimensional surface, an artist may exercise a knowledge that certain colors recede while others advance. He may have discovered that the placement of a patch of color on neutral background makes the color really pop, so to speak, and so makes use of this ‘trick’ throughout his works. The study of vision addresses the neurobiology behind these and like phenomena, but pursuing and understanding such explanations may not have been so obvious without the experience of having painted with color. But why is such a neurobiological explanation even useful to the artist? Or viewer of art?

Yet another example of this interplay of observed phenomena in art and the quantitative pursuit in science relates to the way in which our brain integrates abstract knowledge with incoming visual information to produce the visual experience. The artist knows that the visual presentation of information has the ability to evoke emotional and intellectual responses—from the feeling of being sick to one's stomach to the recognition of an abstracted object. Kandinsky developed a powerful ability to compose abstract assemblies that generate astonishing emotional responses. This arose out of his personal artistic experience, and it demonstrates the cultivation of an intuitive understanding of how our visual system functions. Artists who put very little down on the canvas but communicate immense amounts of information demonstrate an intuitive knowledge of how object templates are encoded in the cortex nice point. Studying such artwork helps researchers identify which elements in an image are necessary to object recognition, and how the underlying neural circuitry encodes said templates. While these are just a few examples from a growing field of vision and art research, they clearly demonstrate the key benefits of this inter-disciplinary field.

The study of vision cannot teach one how to make art. But it certainly can enhance our study of it. And when it comes to understanding the brain and our subjective experiences, we find ourselves in the funny spot of trying to study the exact thing we are using to study it yes! Isn't it troubling?!. The only way to make real advances in this pursuit is to add dimension to the problem solving. The study of art does exactly this.

<u>Student Essay #3</u>

Colleen Kirkhart
Wellesley College, Spring Term 2008
Neur320, Vision and Art: physics, physiology, perception and practice
Prof. Conway

For many, art and science seem to be diametrically opposed. Science is concerned with the objective, with method and results, while art seems to be mostly about the subjective, about feeling and emotion and stretching the boundaries of convention. When the two start to interact with each other, philosophical questions are raised. What can something as personal and subjective as art tell us about the biology of vision? What can cold, rule-driven science tell us about art? What effect will a science of art have on art itself? Will this interaction be beneficial or harmful to the two fields involved? Because the scientific study of art on the neurological level is still in its infancy, we, as neuroscientists, have a moral obligation to address these questions before we dive headfirst into the study of something as fundamental to the human condition as art. I believe that the interaction of science and art will ultimately be beneficial to both fields.

Studying art as a means of furthering the study of visual perception is extremely valuable. In many respects artists themselves have spent the last two thousand years doing the fieldwork that is necessary to begin understanding the visual system. They have pushed the boundaries of color, shape and line, finding what works and what doesn't work. They know what shortcuts can be taken to depict a realistic scene without having to employ the psychotic attention to detail of the Northern renaissance artists. These shortcuts can provide neuroscientists with clues as to which aspects of the world are fundamental to our visual understanding and which are not. We know from the biology of the eye and brain that our eyes are not like cameras. They do not simply record every detail of a scene as it is but instead pick and choose key features. We can use art to figure out what those key features are. Take shadows, for example. Artists have a tremendous amount of flexibility when depicting shadows. The shadow doesn't have to be pointing in the same direction as other shadows or even really correspond to the visible light source. As long as it is darker than the object creating it and doesn't appear to have volume of its own, it will be read by the visual system as a shadow. This provides many questions that the neuroscientist can begin to answer, most fundamentally, why do these types of tricks work? What are the evolutionary and biological reasons that we don't pick up on sometimes glaring discrepancies between what and what?? Questions of this nature have even further highlighted the importance of local computation of differences in the visual system. The study of art has the potential to open up a new world of questions and discoveries for the vision researcher.

What about the other side of the coin? What effect will scientific study have on art, or the appreciation of art? Some people are afraid that the objective, impersonal power of science will transform art into a rulebook. People could use their detailed knowledge of the visual system to arrange elements in a way that activates the visual system correctly, and tada, they have made art. But is this a serious concern? One important consideration is that most artists already know, on some level, much of what will be explained in the neuroscience of art. Sure they don't have any idea of the computational process that underlies color constancy in the visual system, but they know from the experiences of themselves and their predecessors that the perception of a pigment changes based on the colors surrounding it. They don't know the evolutionary reason for why a line drawing works, but they know that a few well-placed contours have the ability to communicate a whole. They don't know why we tend to overestimate the circularity of the top of a vase, but they know that we do and have developed methods to overcome it. This knowledge has not trapped artists, forcing them to use a template for "correct" art. It has simply broadened their repertoire, giving them a larger set of ways to communicate their vision. All artists know that they cannot simply follow some set of pre-determined rules to create art, so a deeper understanding of these rules should not damage art in the least.

Going one step further, I believe that not only will science not damage or limit art, but it will actually enhance it. For an artist who is interested in the neuroscience of vision, and has taken the time and effort to understand the neural mechanisms behind vision, the scope of possibilities for him or her as an artist will broaden. She or he even can now rely on her knowledge of vision to manipulate the viewer in ways that may have not been possible before. She has, in essence, increased the size of her palette, giving herself more techniques which she can use to express herself. On the flip side, she could also use this knowledge to rebel against the "rules" of visual perception. In the past century, the art world has seen this type of rebellion in most of the modern and contemporary movements. I believe that the understanding of the biology of vision will increase our respect for artists that are able to create art while rebelling against these standards. How can they disobey the rules of visual perception and still spark a reaction in the viewer? This of course will open up new questions for neuroscience, again challenging our previous conception of visual perception, resulting in a circular, continuous, symbiotic relationship that will ultimately strengthen both fields.

Student Essay #4

Hillary Chu
Wellesley College, Spring Term 2008
Neur320, Vision and Art: physics, physiology, perception and practice
Prof. Conway

I do think that studying art can tell us about how the brain works because it is not only a resource that feeds the visual system, it is a product of the visual system. Analyzing art is an effective way to investigate how the brain processes and interprets visual stimuli. As Cavanaugh (2005) and Conway & Livingstone (2007) describe, examining paintings that "trick" our visual system help us understand the "rules" with which we view works of art. Cavanaugh used the example of an impossible reflection to illustrate his point. The painting used to support his argument is of a nude facing away from us and a mirror presumably containing her reflection. The assumption that the mirror reflects the figure is problematic for several reasons: the figure and the mirror are angled in such a way that it would be impossible for the viewer to see such a centralized face in the mirror, and the sizes of the figure and her supposed reflection are not consistent (her reflection is bigger than her head). Yet, we do not have a problem with understanding the image, nor do we feel uncomfortable with its inconsistencies. Enough cues are present such that we understand what is being represented in the painting. This observation tells us that reflections, like shadows and transparencies, are defined locally, not by context. In terms of describing how the brain works, this finding shows that the visual system builds our perception of the world by making local comparisons and piecing together relative information. Another good example of art informing neuroscience is Milton Avery's painting of a girl and a dog.

Although both figures lack any facial features, they are both immediately recognizable as a girl and a dog. This observation tells us that the brain relies on very little visual information to understand the world.

Art can also be used to study cognition in animals. In Psychology of Memory, we saw an experiment in which pigeons were taught to recognize and differentiate paintings by two Impressionist artists, Van Gogh and Monet. Although this task is effortlessly accomplished by most museum-goers and art students, not absolutely all people can tell the difference between works by the two artists. The fact that the pigeons were able to identify which artist completed a particular painting, even one that the pigeons had never seen, suggested that recognizing and evaluating art is a sensory process that requires little higher-level brain functions. In terms of what it tells us about how the brain, specifically the visual system, works, the results of this study suggested that visual processing is not necessarily terribly complicated—even a pigeon could do it. Can you get me a reference for this study?

I enjoy studying art because of what it can tell us about cultural attitudes, political moods, and social landscapes of different countries, cultures, and time periods. While understanding these concepts does not depend on knowledge of the visual system or visual processing, I certainly think that understanding how the brain works does enhance the study of art. Art historians who study imperial Chinese painting have shown how landscape paintings were used to convey political hierarchies (Scarlett Jang, Ping Foong, etc., dates completely forgotten). Although they based their arguments on knowledge about the political attitudes of the imperial courts at the time as well as primary literature, some primary sources suggest that visual processing of the images mattered too. Guo Xi, undeniably among the most well-known imperial court painters, wrote a thesis on landscape painting in which one of his arguments was that creating the impression of political glory and power involved the illusion that mountains, trees, mist, and fog extended beyond the boundaries of the image. His argument was straight-forward and easy to follow: if you show the whole mountain, it looks small because it is contained within the surface of the supporting material. His technique was to enshroud mountains in mist so as not to show the mountain in its entirety; the human imagination not only fills in the missing parts, it extends the mountain beyond the painting. I think that understanding the visual system enhances the reading of Guo's works because things we know about psychophysics and how we view paintings tell us how and why the brain fills in the missing parts of the mountain. What a great example and argument. Can I use this in my book? In his article, Cavanaugh explains that when an image is fragmented, the brain relies on residual elements and visual memories to construct the missing parts. Thus Guo's argument is correct: the artist does not have to show the whole mountain for its entire presence to be appreciated. Although knowing this bit of information does not drastically alter the beauty or significance of Guo's works, I think that it enriches the perception and understanding of his art.

<u>Student Essay #5</u>

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Neur320, Vision and Art: physics, physiology, perception and practice
Prof. Conway

There exists a mutual-gaining-of-insight relationship between neuroscience and what is considered art by which both an understanding of the visual system and visual processing enhances the study of art and, reciprocally, studying art can tell us about how the brain works. Firstly, I believe that an understanding of almost anything is enhanced by a collection of different types of knowledge or experience of it. Just as we cut the brain in sagittal, horizontal, and coronal sections to build an image of its structure into our capacity of knowledge, seeing an alien, for example, in different dimensions with varied perspectives, looking at its structure, how it moves and how it behaves allows a holistic understanding of it. In this case a simultaneous learning of art and of how the brain works is enhanced by the approaches of experiencing and cognitively comprehending, which function as complements in methods of study.

An artwork is understood differently when it is experienced, without being processed intellectually, and more specifically, scientifically, compared to when it is analyzed in terms of neural functioning. The same is true with the brain. The study or production of an artwork is analogous to the former case: it is the experiencing of the brain. An analogy for the latter case is obvious: visual neuroscience. These approaches to understanding can be considered as each giving equal and opposite insight into the other. What is reduced out of one approach can be made up for by its complement.

Studying art can tell us about how the brain works because the process [of art or of brain function?] is reflected in the product [of art or brain function?]. When we look at an object we are drawing, the amount of graphite reflects how much time and focus we had on a particular area of the object. In this way, the lines on the paper work similarly to an eye tracker. By looking at the marks on the paper we gain insight into what attracted our attention. The very fact that we intuitively draw lines to represent objects suggests that a major function of the visual system is edge detection by contrast, as we have seen represented in the on/off-center cells. These are a couple examples of how what we draw reveals the function of our visual system.

By studying art we can not only learn about what we look at but we can also get hints about how we look at it. The painting is the painter’s output and the viewer’s input. What the viewer sees is that which the painter sees one-step-removed as if looking at a painting as an image of the inside of the painter’s head. Let us take impressionist painting as an example, a style that has been described as having a strong emotional component. By looking at trends in impressionist paintings we can understand how scenes are processed by the visual system and why this causes them to have this emotive quality. Although it is a generalization, many impressionist paintings use a wide mixture of colors, thick oil paints, and heavy brush strokes, leaving the print of the movement painting on the medium. There is an emphasis on color over line and movement over detail. In this way it could be said that impressionist painters include more than what is tangible and scrutable.

So what is it that impressionist painters are looking at? Attention to movement instead of detail. Detail is made up of specific marks whereas movement is continuous. The neuronal makeup of the visual system offers an interesting perspective to this question. It is thought that impressionist paintings have the affect they do because they are more apt to activate parts of the brain having to do with emotional response, such as the amygdala, the hippocampus and the thalamus. This relates back to the difference between realistic and symbolic in that, whereas detail is analyzed rationally, as pieces of language, movement is processed by a different part of the brain. As if this character of color and movement, and attention to non-detail and non-fixed components signals the brain to send the visual information in the direction of emotional processing as opposed to rational processing. As it turns out, the response people have seems to be related to cone and rod activation. Cones are activated by color and the precision of line whereas rods have black and white, blurry receptive fields, or rather are stimulated by luminance and out of focus visual fields. It is thought that the lack of line and emphasis on movement of impressionist paintings increases rod activation. Perhaps there is a stonger connection between rods and areas such as the amygdala, stirring the emotional response of viewers. Or perhaps it is the other way around and that cells in the emotion centers of the brain are sensitive to color and movement and therefore “monopolize” on the image with their language of processing. This could mean that there is a larger group of magnocellular-like (as contrasted with parvocellular-like) cells in the amygdala that respond to movement. It is guesses such as these that can be made by studying art and then later tested as hypotheses in scientific experimentation providing complementary insights into both the study of art and the study of how the brain works.

Both disciplines study the visual system; art uses it as experience while neuroscientists look at electrochemical relationships in the brain, both offering us with its projection of visual processing each in its respective language. It is interesting to think of these two methods of study in terms of an analogy to the visual system itself. In a way, studying the visual system only by means of science is like looking at it only with our cones; studying the visual system only by means of drawing is like looking at it only with our rods. Of course there is some overlap, and this argument may not even be valid, but for arguments sake let us say it is.OK To use the example of studying artwork, a drawing of objects or scenes detects them and what is taking place during our (the artist and the viewer) looking at them, asking questions about and challenging how our looking at them works. As discussed above, cones tend to detect the specifics of line and detail with center of acuity while rods function outside the fovea, responding to unclear information and are more sensitive to low spatial frequencies. Each class of photoreceptors sees something the other class does not. The input information from both cones and rods is sent to the LGN where they remain distinct. It has been recorded that more of the cortex is dedicated to the fovea. There is most likely another part of the brain that is equally dedicated to the rods, as suggested earlier perhaps it is the amygdala. When looking with our cones we know "exactly" what's happening, that is, all the information that is in focus and precise in the center of acuity. When looking with our rods we get "a feeling" for what's happening. Its significance is seen by the periphery, not looked at directly and not analyzed too closely. Its detail is not translated into a verbal language but rather its phenomena are detected as present. By this analogy, the rods send information to centers of emotion and the unconscious, producing a painting, while the cones talk to cognition in order to write up a theory of scientific evidence. The point of this argument is that both the rods and the cones are important for seeing just as both studying art and studying how the brain works function mutually to provide an understanding of one another.

Sample Lab Report

Assignment: Determine the color appearance of a card painted with alternating blue and yellow dots, viewed from different distances. Indicate viewing distance; scale of dots; & color appearance. Repeat, but after mixing the dots so that the surface is homogenous. Write a brief scientific report with a 100-150 word abstract; concise description of the experiment outlining the methods and results; and a brief discussion (what you found, whether it was surprising or not, and how you can account for the findings).

Yellow + Blue = Green?
The Counterintuitive Rules of Optical Mixing

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Abstract

Optical mixing occurs when wavelengths of light from distinct patches of color combine together because the patches are either too small or too far enough away to be resolvable by the visual system. In this experiment, small yellow and blue dots were added in a checkerboard pattern to a card and viewed at a variety of distances. The colors where then mixed and also viewed at various distances. Before mixing, colors appeared separate until a distance of 15 feet where they appeared as grey due to additive color mixing. The physically mixed paint appeared green at all distances due to subtractive color mixing.

Method

Using the end of a paint brush, yellow and green oil paint was dotted onto a plain, white index card. The dots were about 5mm in diameter and two colors were arranged in a grid creating a checkerboard pattern. The pattern was then viewed by two different observes at distances of one foot, five feet, ten feet, fifteen feet and twenty-five feet. In each case observers were asked to report how much green appeared in the grid. Once this task was complete, the painted dots were then mixed together on the card and again the amount of green was recorded.

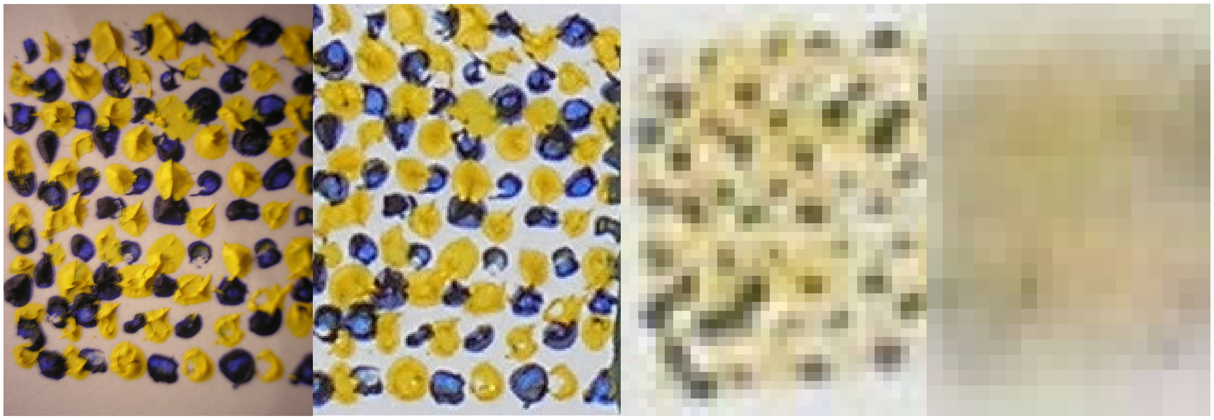

Figure 1. Appearance of the grid of blue and yellow dots at a distance of one inch, one foot, five feet and ten feet respectively. All images were taken with a digital camera at the same zoom and then enlarged digitally to make then equal sizes.

Results

For the first test, both subjects identified the separate yellow and blue dots at distances of one, five and ten feet. When the card was moved to the further distances, however, the individual dots could no longer clearly be seen and instead the patch appeared a grey color (Fig 1). When the individual dots of paint were mixed together thoroughly, however, the patch turned a vibrant green color and appeared green to both subjects at all distances.

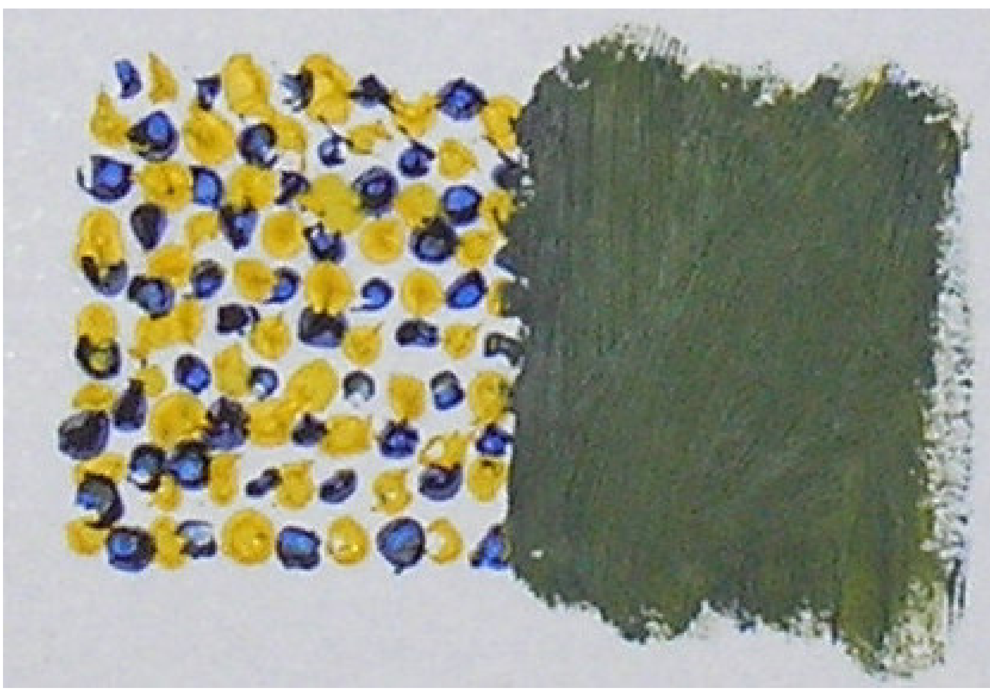

Figure 2. Mixing the right side of the grid of yellow and blue dots produced a distinctly green color patch.

Discussion

At first the result may seem surprising. One might assume that when the yellow and blue dots are too distant to resolve, the eye would mix them together and produce green, not grey. This is because normally we are used to thinking about subtractive mixing of colors, not additive mixing. The second part of the experiment, when the paint was physically mixed together, is an example of subtractive mixing. Both paints absorb a certain range of visible light wavelengths, and the color that we see is a result of the wavelengths that are reflected. When we mix two different colors of paint together, we increase the range of wavelengths absorbed by the paint, restricting what can be reflected, and hence, what can be seen. Additive mixing, on the other hand, can explain why grey and not green is seen when the grid of dots is too distant to be resolved. As already explained, both the yellow and blue paints have a specific range of wavelengths they absorb, while reflecting the rest. This is true at any distance. When the card is close enough for the subject to see the individual dots, the reflected wavelengths hit the eye and the paint is observed as separate patches of yellow and blue. When the card is far away, however, the same range of wavelengths are hitting the eyes, but patches no longer appear separate because the size of the receptive field is bigger than the space taken up by the dot in the visual field. Because the range of wavelengths has increased, the light activates the photoreceptors more evenly and we see an achromatic patch of paint.