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Does Brain Research Support the Hope for Musical Transfer Effects?

Introduction: Divergent concepts of intelligence

When talking about brain research and transfer effects in music we necessarily touch the issue of intelligence. For the hidden assumption (and the educational hope) beyond musical transfer effects very often is articulated in terms of if and how and to what extent music is apt to make individuals smarter. Therefore, I first would like to very briefly glance at the meanings of intelligence.

Very often - or even mostly - intelligence is associated with cognitive and intellectual capacity. In a very broad sense Intelligence can be defined as the psychobiological potential to solve problems. However, there is a still ongoing debate on two conflicting theories: the global g-factor theory versus the theory of multiple intelligences. The question is whether intelligence can or must be seen as one global property corresponding to a hierarchical model with the g-factor on top that influences many domains, or whether it reflects a community of separable intelligences which humans develop in distinct ways for which Howard Gardner(1985) has defined clear criteria. From that, personal *intelligence profiles* with different peaks and depth develop rather than *one general intelligence*.

In general, it can be shown that intelligence or intelligent cognitive achievement has neurobiological correlates such as

- higher speed in neuronal signal transmission and signal processing,
- stronger and more efficient neuronal interconnectivity,
- high correlation between IQ and neuronal activity (r = .50 - .70).

For our reflection, it will be reasonable to examine whether brain research supports the growth of particular abilities independently from other cognitive domains.

- Does music stimulate other brain areas than primary, secondary and tertiary auditory cortices so that other cognitive areas are infected?
- Is there an objectively measurable correlation between other skills and music?
- Are there observable combinations of music with another intelligence above chance level?

Effects of music on the brain

We know from episodic experience and personal observations that sometimes high music aptitude goes along with other aptitudes, but that is not consistent. Research studies, however, have demonstrated significant cerebral effects of enriched versus impoverished environmental experience (Kempermann et al. 1997; Martinez & Kesner 1998). Generally, one can state that music actually has a strong effect on the brain in manifold ways. But that does not automatically include a constant correlation with other intellectual or behavioural abilities.

- It has been proved that the corpus callosum is stronger in musicians compared with non-musicians (Schlaug et al. 1995 a).
- Musicians with perfect pitch develop a larger left planum temporale where local processing takes place (Schlaug et al 1995 b).
- In general, highly trained musicians exhibit an enlarged tonotopic map (Pantev et al. 1998).
- Furthermore, string players develop an increased cortical representation of the fingers of their left hand (Elbert et al. 1995).
- With respect to learning in general, just recently neuroscientists from Geneva university demonstrated a new physical phenomenon on electron microscope images. Researchers have long believed that learning correlates with synaptic connections. Neuroelectric and neurochemical changes were seen as causing that change. Now, a physiological change was found for the first time: when neurons produce a long-term-potential, which triggers a duplication of the active synapse. In 20% of those neurons researchers found double spines (Barinaga 1999).
- Finally, a recent study documents that temporal patterns of activity recorded over particular brain regions track the pitch contour of a melodic tone sequence. The synchronisation between the left posterior hemisphere and the rest of the brain is best when sequences have melody-like statistical properties (Patel & Balaban 2000).

All of these findings confirm a relevant impact of music and music learning on the brain. Beyond that, the large body of research on patients with brain disorders (especially with Alzheimer's disease and Williams syndrome) documents that music has a very special therapeutic effect on the behaviour of those patients. Furthermore, Williams syndrome patients reveal a very strong affinity to music and achieve in music conservation tasks whereas she fail cognitive conservation tasks.

Transfer effects

In recent years several long-term studies have been conducted (Spychiger 1988 - 1991; Bastian 1993 - 1998) to demonstrate that enhanced music lessons at school have an effect on social behaviour, creativity, openness, readiness for co-operation and even intellectual growth. The outcome of these studies was relatively poor and limited. Nevertheless, music educators are tempted to use those arguments for justification of music education in school curriculum in a political debate.

The most spectacular effect has become well known as the so-called "Mozart effect". Here, it was demonstrated that listening to a Mozart sonata caused better results in a spatial-temporal reasoning task measured by an IQ test (Stanford Binet Intelligence Test) than other acoustic stimulation (Rauscher et al. 1995). This effect came under debate just recently because the results could not been replicated (Chabris 1999; Steele et al. 1999). On the other hand, there are reports on clinical case studies that show a therapeutic effect of Mozart's sonata on patients with Alzheimer's disease (Johnson et al. 1998) and Lennox-Gastaux syndrome (Hughes et al. 1999). Moreover, keyboard training studies (Rauscher 1997; Costa-Giomi 1997, Eastlund Gromko 1999) revealed a significant effect on spatial-temporal reasoning tasks. Moreover, rats that were exposed to the above mentioned Mozart sonata 30 days in utero and 60 days post-partum, were faster and did fewer mistakes in a maze experiment than controls (Rau-scher et a. 1998). However, what remains open is to identify the musical parameter that causes the effect: e.g. the rhythmic structure, the frequency of pitches, the harmonic tension, or the balanced interplay of unexpected and redundant information, or a combination of some those.

Another possible transfer effect was discovered at the Chinese University of Hong Kong where researchers have found that music training improves verbal memory (Chan et al. 1998). Although that effect appears to present music as an agent for memory training, we must take into consideration that in Hong Kong the most commonly spoken Chinese dialect is Cantonese which, in fact, is a tonal language where verbal memory is very much equivalent to tonal memory. Therefore, music is supposed to have an effect on verbal memory.

Most of the mentioned experiments indicate an immediate interaction between brain areas within the cortex and between cerebellum and cortex as well. The stimulation of neuronal tracks by music obviously functions as a trainer for the transmission of signals which are used for the activation of other brain functions.

When talking about transfer effects we must carefully differentiate between *internal brain effects,* which are due to a stronger interaction between different brain areas and correlate various brain functions (like higher speed of signal transmission, stronger neuronal connection, co-activation of different cortical areas), and *external effects* that supposedly stimulate or strengthen skills in other than musical domains (as cognitive or behavioural skills like math or language, social sensitivity or readiness for collaboration etc.). There is, however, little evidence for the latter, but good reason for much more complex interaction between different brain areas - within the cortex and between cortical and subcortical layers - than we still know. Further research will discover and present more details.

As to now, I would like to refer to two studies which demonstrate that kind of internal interaction very clearly .

(1) In a long-term experiment (Bangert et al. 1999), subjects (novice piano students and professional pianists) were trained for 5 weeks to reproduce a short melody on a keyboard after aural presentation without any visual or verbal cues. Whereas one novice group were not given the opportunity to establish an internal map between motor events and auditory targets by a shuffled relation between keys and pitches after each training session, the other group developed a robust link between auditory and motor tasks. During the experiment, all subjects were repeatedly measured by EEG in a *passive auditory* and *mute*

motor task. DC-EEGs record the excitatory post-synaptic potentials on the lowest frequency range caused by afferent inflow.

Very soon - first effects appeared even after 20 minutes - the novices who had developed an internal map of aural and motor activities showed a co-activation of the left primary sensorimotor cortex in the auditory task, and a co-activation of bilateral frontolateral and temporal cortex in the motor task. Moreover, professional pianists, of course, have developed a robust link between internal representations of the musical ear and their musical hand, of motor and aural skills. On the contrary, controls did not show any co-activation effect

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If we agree that these results also can be addressed as a transfer effect, then, it is obvious that a special training effect is likely to be seen as an operant conditioning. The task establishes a synaptic link between synchronically stimulated areas which is efficient even if only one neuronal track is activated. Learning, then, tends to establish those links, or in other words: to develop a dense neuronal network of connections that enables co-representations.

(2) In a long-term investigation on young children's music learning (Gruhn 2000) we collected data from 13 children age 1 to 2 (distribution from 8 to 27 months, mean 19 months) over a period of 15 months. 58 criteria were selected for observation relevant to attention, movement, audiation, voice production (imitation, improvisation, creativity), and listening. Each section was analysed separately, individually and as a group means. Then, we correlated the data of each criterion with any other. Significant correlation was found only between accuracy in voice production and the coordination and synchronisation of movement.

voice	rhythm patterns		tonal patterns		songs
movement	consist.tempo	accuracy	intonation	pitch	rhythm
flow	.77*	.74*	.86**	.84**	.83**
coordination	.80**	.74*	.81**	.70*	.70*
synchronization	.82**	.80**	.91**	.81**	.81**

Fig. 2
Signifikant correlations between voice and movement after 6 months (© W.Gruhn 1999)

The better the children performed continuous flow and coordinated movements, the more accurately and precisely they imitated tonal and rhythm patterns and songs or chants. For that, what educators and artists like Rudolf von Laban, Emile Jacques-Dalcroze, Heinrich Jacoby or Edwin Gordon have intuitively stated or empirically observed, we now have the data: there must be a neurophysiological link between fine motor control in movement and in muscles engaged in the vocal apparatus. It is not a co-activation like in the auditory and motor task, rather it must be seen as a transfer effect within the neuronal transmission tracks.

In view of these results of brain research, the answer to our initially raised question, whether brain research supports the hope for transfer effects, is not easily to be answered. Although some indications occur, 'hard-core data' confirming transfer-effects of musical ablities on other cognitive domains are rare or even missing (Altenmüller et al. 1999). As to now, we must accept that there is little evidence for an inevitable external transfer effect from one intelligence to another; but there is strong evidence for internal correlation between different brain functions and brain activation areas that tempt us to believe in or hope for external transfer effects as well.

Conclusions and considerations

Results from brain research and neurobiological findings can hardly induce immediate applications and recommendations for music education and music learning. Empirical data cannot be directly transferred to educational practice because scientific descriptions are essentially different from educational prescriptions. Empirical data are based upon objective facts and verifiable procedures; scientific research is committed to objectivity, reliability and validity. Judgements in education, however, are value judgements to a large degree. Normative decisions on values can never deduced objectively from empirical descriptions. As Howard Gardner puts it: "We could know what every neuron does and we would not be one step closer to knowing how to educate our children," because "the chasm between 'is' and 'ought' is unbridgeable" (1999, 60, 79).

No doubt, mental representation has become a key notion of the cognitive revolution during the decade of brain (Gardner 1999). Therefore, a possible application to music education necessarily refers to mental representations. However, as already mentioned, education is based on decisions that are grounded on underlying value judgements which deal with "what" and "why" to teach; but findings in neurobiology may indicate new ways of "how" to teach. Rather, teaching interacts with dispositions and potentials given to each individual. Although neurobiological findings cannot tell us why to teach music of a particular culture and what to select from the broad variety of musical traditions, empirical findings can advise us of how and when to teach so that mind and memory, perception and cognition can be developed most efficiently. From that perspective, we may conclude from neurobiology of cognition and learning:

(1) Learning is the process by which one develops and incrementally differentiates mental representations. Therefore, music learning focuses on the development of genuine musical representations.

(2) Procedural knowledge (knowing how) is more appropriate in music cognition than formal declarative knowledge (knowing about). Immanent musical properties (pulse, meter,

tonality, intervals, motifs, contours etc.) are represented by neuronal connections that are activated through aural stimulation. And the other way around, these musical entities can only be articulated in singing or playing if developed as mental representations. Conscious activation in mind is called "audiation" (Gordon 1980). It takes place when neuronal representations are activated in thinking, listening or "musicing" (Elliott 1995).

(3) This calls for the idea of teaching music musically (Gruhn 1997, Swanwick 1999), i.e. to advance those teaching strategies and learning modes that promote the development of genuine musical representations by priming an aural-oral loop.

(4) Genuine musical representations appear to be contradictory to transfer effects. As demonstrated, music has a strong effect on the brain, but there is little evidence that music learning automatically affects other cognitive skills.

(5) The same reluctance is well suited for simple lateralization effects in music. Music is always processed in both hemispheres, but performs an asymmetric predominance depending on the applied cognitive strategy (global versus local, verbal versus procedural). Therefore, music teaching and learning should take into consideration that different strategies engage different brain areas and develop stronger connections. The more interconnected these areas are, the more stable representations can be attained.

(6) Research on patients with mental (brain) disorders clearly demonstrates that musical abilities are uncorrelated to other domains of cognitive development. Individuals rather form a domain specific intelligence profile. Music education should stress on those domain specific potentials instead of hoping for transfer effects which reasonably may be applied in therapy. Music education should rather develop the given musical aptitude to the highest possible level.

The tremendous progress in brain research gives rise to investigating more aspects of music learning in a more sophisticated way and, therefore, we may expect new insights into neuronal developments and cognitive effects related to music learning.

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