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Exploring the Musical Mind-Brain
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Before describing examples of my recent research on mind and brain studies, I first need to explain the "mind-brain" phrase. My background is in cognitive psychology, which is the study of higher mental processes, largely in humans. My particular interest is in human memory. The subject matter of cognitive psychology is mind: the mental operations whose results we can see but which we cannot directly observe. Mind is, if you will, the software that runs on the hardware of the brain. Since we cannot observe mind directly, we infer mental operations by the results of behavioral tests. For instance, if people take longer to answer one type of question than another, we infer that the longer latencies reflect a processing difficulty. Judicious choice of question type can give us a good picture of how the mind handles certain problems or memory challenges.

Brain, on the other hand, refers to the physical substrate that carries out these operations. We can observe the machinery of the brain using modern neuroimaging techniques such as magnetic resonance imaging, and we can observe the metabolic activity level of this machinery by functional magnetic resonance imaging (fMRI). This relatively new tool tracks the oxygenation level of blood in neural tissues. Assuming that more use of oxygen equates to more neural activity, we can look at functional activity of brain areas as small as a few mm 3. Sensitivity of this technique is improving rapidly. Using neuroimaging during performance of carefully designed cognitive tasks allows us to correlate mind and brain; the province of "cognitive neuroscience".

The other part of my title refers to music. I have spent much of my career studying how people process music. I do so for several reasons. First, music is a ubiquitous and sometimes very important part of many people's lives. I, and my research participants, find musical tasks intrinsically interesting. More scientific reasons for studying this include the fact that music presents some interesting research questions, such as how one can rehearse and retain nonverbal information. Finally, the musical domain allows one to ask questions about the effect of training in a specific field on both the mind and brain. Fortunately the college population contains people from many backgrounds who study music to varying extents (this is in contrast to other areas of expertise such as chess mastery or piloting an airplane which would be confined to a small, mostly male, segment of the population).

I would like to first describe a study conducted with a senior honors student from Bucknell, Jill Warker, currently a graduate student at the University of Illinois. It is called *Musical Stem Completion: Humming That Note.* (Warker & Halpern, submitted). In this study, we explored the operation of implicit memory for music. Memory for almost any time of information can be tested in two ways. Explicit memory tasks are ones in which the rememberer knows consciously that he or she is trying to remember something. An example from everyday life would be trying to recall the name of an actor from an old movie. An example from the laboratory would be showing people a list of 20 words, distracting them for a while, then presenting a list of 20 old and 20 new words from which they needed to pick out the old words. In contrast, in implicit memory tasks, people show that they have remembered some information just by a change in their b ehavior. An example from everyday life is finding yourself improving on a skill without explicitly recalling coaching tips or other verbal instructions. An example from the laboratory is "stem completion". In this popular memory paradigm, a list of words is presented under the guise of gathering ratings of some aspect of the words. No mention is made of remembering them. Sometime later, an alleged Part 2 of the experiments presents the first few letters of words (the stem) and the participant is asked to complete the stems with "whatever word comes to mind". The earlier-presented words show up as completions at higher-than-baseline rates, even when people fail to recall them in a later trial.

These two forms of memory retrieval appear to differ both with respect to mind and brain. A number of factors such as circumstances of learning, and the physical form of the material, affect the two tasks differently, and the two tasks are mediated by at least partly nonoverlapping brain circuits. Most knowledge we have of implicit memory procedures comes from verbal tasks. But clearly people remember music both explicitly (what was the theme music to *Star Wars?*) and implicitly (humming along with *Star Wars* even if you failed the first task). In her thesis work, Jill refined a measure of musical implicit memory that we called musical stem completion, and began exploring what factors might influence its operation.

The task involved presentation of novel but musically coherent phrases. Listeners either rated the tunes for pleasantness or rhythmic regularity; we assumed the former task would require more elaborate thought to complete. After a short time, the openings, or stems, of a second set of tunes was presented; half were old and half had never been heard (see Figure 1). In the explicit task, participants were asked to sing or hum the note they remembered as coming after the stem, consciously retrieving what we called the completion note. In the implicit task, they had to sing or hum the note they thought would come next musically, or displaying an implicit retrieval of the completion note. Different tunes were used in the explicit and implicit task, and the implicit task always came first in the session, so as not to give away the surprise of the memory retrieval. Finally, some tunes were presented in the same timbre at presentation and test (flugelhorn or steel guitar), and some were presented in different timbres. If musical stem completion acts like other verbal stem completion tasks, then the type of encoding task should have affected explicit but not implicit memory, with the pleasantness task engendering better performance. And a timbre switch at test should have impaired implicit but not explicit memory.

Both tasks reflected preserved memory: the correct tone was produced more often to the old than new stems. In that respect we think we have captured musical implicit memory. Also, performance in the two tasks was not correlated, reflecting the independence of the memory systems. However, neither the conditions of encoding nor the timbre match or mismatch affected memory in either the implicit or explicit task. The one thing that did affect memory was timbre preference, and this indeed affected the two kinds of memory differently. It turns out that people preferred the flugelhorn timbre to the steel guitar sound. We found that in explicit, but not implicit, memory retrieval, memory was best for presentation and test sequences in both heard in flugelhorn, next best for mixed timbres, and worst for the steel guitar timbre at presentation and test. I am currently following up the relationship between how much someone likes to-be-remembered material, and memory for that material.

Turning now to brain, I would like to describe a study recently published by myself and several colleagues, including Jennifer Johnson. She was an undergraduate with me and is currently a graduate student with my longtime collaborator Robert Zatorre at McGill University. She participated in this project as a recently arrived graduate student at McGill. The title is *Behavioral and Neural Correlates of Perceived and Imagined Musical Timbre* (Halpern, Zatorre, Bouffard & Johnson, 2004). Zatorre and I have long been interested in the experience of hearing a song in one's head. Most people can call up a tune from their memory (try this now with a tune of your choice), and we have explored the neural activity that occurs when this happens. In our previous work we asked people to make pitch judgments in imagined tunes, or to simply imagine phrases of various lengths, and used Positron Emission Tomography as our neuroimaging technique. We showed that during tune imagery, neural activity was observed in a secondary auditory area. By this we mean not the first place that real sounds are processed in the cerebral cortex (primary auditory cortex), but the surrounding tissue that processes auditory signals after initial reception. We also found activity in an area usually used for motor planning, the supplementary motor area (SMA). The fact that both of these areas were active is interesting because no sounds were actually being played, and participants were not actually moving during our experiments.

We decided to use timbre judgments in this latest study, to reduce the motor component of the task. Although you are able to imagine the sounds of violins and bassoons, very few of us could produce the sounds of these. We used fMRI as our neuroimaging technique, and in the perception condition simply asked people to rate the similarity of pairs of sounded musical instruments on a 1 to 5 scale. For the imagery part, we just turned off the sound, and people had to make those same ratings after simply seeing the words "violin" and "oboe". We also had a visual imagery control task (compare the shapes of imagined objects), as we thought that people would likely imagine shapes as well as the sounds of the instruments, so we wanted to remove that effect.

When we looked at the behavioral data, we found a high correlation between the similarity ratings in the imagery and perception conditions. This suggests that people were using a similar strategy to compare the sounds of instruments whether heard or imagined. We then looked at the activation patterns of the imagery and perception tasks, minus the activation engendered by our visual imagery task. In the perception task, we found as expected activation of both primary and secondary auditory areas, with somewhat more extensive activation on the right than the left side of the brain. This right-sided asymmetry is often found in some kinds of musical tasks. In the imagery task, we saw no activation of primary, but did find activation of secondary auditory areas, again with a right-sided asymmetry.

Figure 1

What about the SMA? We did find SMA activation, but just under the stringent statistical threshold we had selected. Therefore we think that this motor planning area was still involved, albeit to a somewhat lesser extent, in this timbre comparison task. It may be the case that all auditory imagery has some motor component to it, although we are now searching for a task that reduced the motor component even further than the task just described. We would also like to explore expert-nonexpert differences in musical imagery, and also extend our studies to imagery for other nonverbal sounds, such as environmental noises.

In both of these studies, as well as all my other work, undergraduates have played a vital role as research assistants or co-investigators. At about the same time that I received word of having won the CUR Fellows Award, our department hired one of the students who had written a letter of support for my candidacy. This is for a two-year replacement position; the second year of the term is to replace me while I am on sabbatical. This search outcome was a gratifying addition to the honor already conveyed by the award. I hope she in turn will have the pleasure of mentoring her successors for many years to come.

References

Halpern, A. R., Zatorre, R. J., Bouffard, M. & Johnson, J. (2004). Behavioral and neural correlates of perceived and imagined musical timbre. *Neuropsychologia, 42,* 1281-1292.

Warker, J. A., & Halpern, A. R. (submitted). Musical stem completion: Humming that note.