**Introduction**

Evidence shows that memory for music is maintained even when other semantic memories have been forgotten in individuals with neurodegenerative disorders such as Alzheimer’s disease (Baird & Samson, 2009; Cuddy et al., 2012; Cuddy & Duffin, 2005; Vanstone & Cuddy, 2010). The mechanism through which this separation of memories occurs is yet unclear, but some studies suggest that this may have to do with the way memories of music are stored in the brain. Peretz and Coltheart (2003) proposed that humans have a ‘musical lexicon’ containing representations of all the musical phrases one has ever heard, and that this musical lexicon is separate from the verbal lexicon, where representations of phonological sounds are stored.

Neuroimaging techniques have allowed researchers to uncover the neural basis for the separate musical lexicon described by Peretz and Coltheart. Using PET, Groussard et al. (2009) showed that the musical lexicon, and musical semantic memory in general, is sustained by a temporo-prefrontal cortical network. This network showed greater activity during a task where participants rated their level of familiarity with a series of melodies than in a task where participants determined whether two unknown melodies were the same or different. Groussard et al. (2009) hypothesized that the right-sided regions within this network are mainly responsible for holding the melodic traces of familiar tunes, whereas the left-sided regions are responsible for the semantic and associative memories involved in recognizing a musical piece as familiar. The left-sided activation occurred in areas common to those classically shown to be involved in verbal semantic memory (Groussard et al., 2009). In 2010, Groussard et al., conducted a follow-up study using fMRI and showed a clear dissociation between the neural patterns elicited by musical and verbal stimuli. These neuroimaging results supported the theory of Baird and Samson (2009) who suggested that musical memory in Alzheimer’s patients is spared because of the intact functioning of the necessary and specific brain regions that are relatively unaffected by the disease. They suggest that explicit musical memory, that relies on the temporal lobes, is affected by Alzheimer’s disease, but other types of musical memory such as procedural musical memory rely on frontal areas and therefore are relatively preserved in Alzheimer’s. In 2015, Jacobsen, Fritz, Stelzer, & Turner showed that the caudal anterior cingulate and the ventral pre-supplementary motor areas are involved in the processing of both unknown and known music and that these areas, responsible for encoding musical memory, were relatively spared in a sample of patients with Alzheimer’s disease. Together, these results indicate that not only is memory for music separate from other types of memory, but this dissociation can be seen with neuroimaging techniques.

Studies that have explored musical memories have compared differences in brain activation between unknown songs and long-known music. The long-known music is generally deemed to be familiar to participants through separate pilot studies (e.g. Groussard et al., 2009; Jacobsen et al., 2015). The difficulty in such a comparison is that there may be many differences between the unknown and the long-known music beyond just the memory for the stimulus. For example, auditory characteristics of the music such as genre, or instrumentation may differ. It is also nearly impossible to control the degree of familiarity across people. Finally, a key aspect to much of the music used in these studies are the lyrics. Research has shown mixed results regarding music’s effect on remembering words, but whether the presence of language affects memory for music is yet unknown. Previous studies exploring the effects of musical memory have controlled for language (e.g. choosing all stimuli with or without lyrics) , but have not systematically studied whether language changes how music is remembered.

In this experiment we use a strict training paradigm to control for the degree of exposure to the stimulus. In this way, we not only have a concrete measure of familiarity, but are also able to compare identical stimuli in the unknown and familiar conditions controlling for acoustic characteristics between memory categories.

Traditionally, the method for investigating memory for music using neuroimaging has involved a comparison between the blood-oxygen level dependent (BOLD) activation during unknown and well-known music (). One downside to this approach is that it collapses over the time dimension over which music unfolds. In order to better understand how memories for music are stored in the brain, an analysis that takes the time domain into consideration may be more informative. One such multivariate approach is a representational similarity analysis (RSA) (). At its core, an RSA analysis looks for differences in the patterns of brain activations between stimulus categories. The aim of this experiment is to better understand how brain activation patterns differ for familiar and unfamiliar music and how the presence of language interacts with these patterns.

**Methods**

**Participants**

*Twenty-six* neurologically healthy participants (14 female) aged 18-39 (mean=24) were recruited via posters and word of mouth at The University of Western Ontario. *Include relevant musical demographic information based on what goes into the analysis.*

**Testing procedure**

Participants completed two functional MRI scans that were separated by a stimulus training period (14-29 days; mean = 19 days). During both scans, participants passively listened to the stimuli (described below). During the training period, participants listened to the stimuli via an online player (designed in-lab) that tracked the number of times each stimulus was played. To ensure participants were listening, the player presented a simple question about the stimulus (e.g. “*were there lyrics present in the previous song?”*) at random between stimuli. Participants also came to the lab between for four sessions between scans. In each of these sessions, participants listened to the stimuli in lab and completed a series of behavioural tasks (described below).

**Stimuli.** Eight different auditory stimuli were created from songs written and recorded by a lab member between *year1-year2* in Cambridge, UK. These songs were chosen to lower the likelihood of participants being familiar with the stimuli. Two songs were kept whole (vocals & instruments), two songs had the vocals removed leaving just the instruments, two songs had the instruments removed leaving a single a capella voice, and the lyrics of two songs were recorded in-lab as spoken word (no music). The voice in all stimuli was the same. During the training period, participants listened to half of the stimuli via the online player (4 songs, one of each type). The training sets of stimuli were counterbalanced across participants.

**Behavioural tasks.** During the training period, participants came into the lab four times. Each session lasted less than one hour. Participants listened to the stimuli in-lab and completed 2-3 of the following behavioural tasks in each session.

To test whether participants were learning their training stimuli, two tests designed in-lab were used. The first, was a lyric modification task that presented participants with pairs of lyrics. Each pair consisted of a lyric taken directly from their stimuli training group and a modified version of the same lyric. Participants indicated which lyric was the correct lyric. The lyric pairs were tested for their validity before being included in this study. Before the first scan session, participants were presented with the entire set of 25 lyric pairs to obtain a baseline measurement. As participants were not familiar with the stimuli these lyrics were taken from, they were asked to indicate which lyric they believed was most likely to come from a song. In each behavioural session, participants responded to a subset of 10 lyric pairs to track learning progress. After the second scan session participants completed the full set of 25 lyric pairs again.

The second test of familiarity was a melody recognition task. After the second scan only, participants heard pairs of 2 sec clips taken from the stimuli. These clips did not contain any lyrics. One clip was taken from the stimuli training set, the other clip was from a stimulus the participant did not train on. Participants were asked to indicate which clip was most familiar to them.

Participants completed a questionnaire regarding musical abilities and training as well as a test of melodic memory and a test of beat perception taken from the Goldsmith’s Musical Sophistication Index (CITE). Finally, participants completed a musical association form where they described what each of the trained stimuli reminded them of (memories, other songs, etc.) and a lyric orientation questionnaire that measured to what degree the participant focuses on the lyrics in a song over the melodic content (D. VUVAN).

**Preference ratings.** In each lab session and after the second scan, participants rated on a scale of 1-7 how much the liked the songs in their stimulus training group allowing us to track how preference changed as familiarity increased.

**fMRI acquisition and analyses**

Imaging was conducted at the Robarts Research Institute on a Siemens Magnetom 7 Tesla scanner with a 32-channel head coil. Functional scans were acquired with 54 slices per volume (TR = 1.25 s; TE = 20 ms; flip angle = 35°; FOV = 220 x 220 mm; voxel size = 2.5 mm3). Between functional runs within the first session only, a whole-head anatomical scan was acquired (TR = 6s; TE = 2.69 ms; FOV = 240 x 240 mm; voxel size = 0.75 mm3; 208 slices). Two functional runs, each lasting twelve minutes were collected in both the first and second scans. During the scans, participants heard ten 10sec clips from each of the 8 stimuli (80 clips total) that were randomized across two runs (40 clips in each run). The clips were equally distributed across the beginning, middle, and end of the stimuli.

Data were processed using SPM12. Data were corrected for motion and coregistered to the participant’s structural image. Images were normalized to MNI space and smoothing was done with a Gaussian kernel of 8 mm FWHM (Peigneux et al., 2006).

**Results**

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