Daisy Bui
PSYC 0206
I have neither given nor received unauthorized aid on this assignment. DB

Memory Project
(Piano Practicing on 'Can You Hear the Music'
by Ludwig Göransson - recomposed by Patrick Pietschmann)

Stage 1 - Getting Started (The Initial Structure of Learning)

During my initial practice sessions, I choose to focus on a single hand first to fully engage my working memory. According to Cowan (2008), efficient working memory storage is closely linked to attention-related processes. By starting with just my right hand, I can maintain focused attention on the treble clef, allowing for deeper engagement and more effective learning. Attempting to practice with both hands simultaneously requires dividing my cognitive resources between the treble and bass clefs (using right and left hand), which demands greater attentional capacity and coordination across both sides of the body. This division of attention can easily disrupt the rehearsal process within working memory, making it harder to achieve proficiency. Furthermore, research has shown that neurons in the hippocampus—a brain region crucial for memory formation and consolidation—remain persistently active during the sustained maintenance of working memory (Boran et al., 2019). Consequently, by concentrating on practicing with my right hand and left hand separately, I was able to engage these hippocampal neurons continuously without much interference. This persistent focus allowed me to become proficient in playing the notes with a significantly reduced error rate.

An intriguing aspect I observed during my practice is the shift from visually dependent practice to relying purely on auditory cues. Unlike those gifted musicians who can play a piece after hearing it once or twice, as showcased on many social media platforms, I need to have the sheet music in front of me while practicing. My past music theory knowledge allows me to associate the notations on the page with the corresponding piano keys (thanks to long-term memory recall). This enables me to detect errors when the played keys do not match the written notes.

As discussed in class, after receiving sensory stimuli from the external world (e.g., reading musical notations), the hippocampus triggers neural activity through recurrent connections to restore the memory representation of these notations, including how each note sounds. This process is referred to as pattern completion, which involves the reactivation of an engram to bring about memory. Simultaneously, pattern separation involves transforming sensory information into distinct, vivid neural representations for long-term storage. During piano practice, visual stimuli (sheet music) activate the auditory memory of the notes being played, both of which are part of a stabilized, distributed representation. As a result, visual cues from the sheet music help reconstruct the auditory memory of the piece, aiding in accurate recall and performance.

Stage 2 - Memory Interference (The Problem of Distributed Representation)

Prior to this memory project, I have been practicing two other piano compositions, namely "Heart of Courage" (HOC) and "Protector of the Earth" (POTE) by Two Steps from Hell. A notable distinction between these pieces and the one I learned for this memory project lies in their chord progressions and the

energy that they bring. Two Steps from Hell's compositions usually exude a profound sense of turmoil and bravery, characterized by their bold chord choices. Meanwhile, "Can You Hear the Music" by Ludwig Göransson captivates the suspenseful progression and brisk tempo, instilling a sense of urgency and anticipation.

When learning various musical compositions, the process engages brain regions linked to music interpretation and performance. Distributed representations play a key role in pattern completion, where even partial or degraded external input can activate the associated memory (Hinton et al., 1986). This capability facilitates memory generalization, allowing us to recognize common features shared among related memories. For instance, if we encounter only a subset of cues, such as the presence of B-flat and E-flat in chords, we can still retrieve the complete memory of playing a B-flat major music piece through the reinstatement of the entire distributed pattern of activation.

However, the distributed representation of rhythm, notes, and chords across different pieces presents a challenge. The interconnections among networks of neurons can blur the specific distinctions between compositions, leading to frequent errors during practice. This is particularly evident in my experience with pieces from Two Steps from Hell. Although not referring to the specific piece for this project, the other pieces, "Heart of Courage" and "Protector of the Earth," involve overlapping chords (e.g., B-flat major in POTE and D-flat major in HOC both contain B-flat and E-flat keys). Therefore, having to remember the different rules for sign and time signatures in each piece makes practicing more challenging as it is easier to confuse them. This confusion often results in playing incorrect notes and rhythms, detracting from the overall accuracy and flow of the performance.

Stage 3: The Hand Shake

Once I am able to play my right hand without looking at the music sheets, I shift my focus to integrating the left hand with the right. Rather than practicing my left hand separately, I synchronize it with the flow of my right hand. This process necessitates cross-hemispheric communication, enabling coordination between both sides of the body.

The ability of the two hemispheres to effectively communicate relies heavily on functional plasticity, which is the brain's ability to adapt and rewire itself in response to new learning experiences. This enhanced connectivity facilitates better coordination and integration of motor skills, allowing both hands to work together in synchrony. Furthermore, enhanced structural connectivity allows for more efficient and rapid transmission of information between the hemispheres. In the context of piano practice, this means that the brain can better coordinate the movements of both hands. As I practice playing with both hands together, the repeated, synchronized activity promotes the development of these structural connections. This, in turn, leads to smoother and more precise bilateral coordination.

Groussard et al. (2014) conducted a study indicating a strong positive relationship between gray matter volume, particularly in the hippocampus and temporal cortex, and the duration of musical practice. Thus, it can be inferred that practicing piano can induce structural alterations in the brain. Previous research has also illuminated the impact of musical training on brain function. Herdener et al. (2010) also suggested a strong correlation between hippocampal sensitivity to novelty and musical abilities. This finding is supported by Li et al. (2018), who suggest that increased time in musical training enhances functional connectivity within the sensorimotor network and boosts both functional and structural connectivity of the auditory-motor network. These studies thereby underline the importance of functional

and structural plasticity in mastering complex musical pieces, as it contributes to connectivity in auditory and sensorimotor networks as well as enhances coordination between both hands.

Stage 4: The Continuous Struggle with Tempo

Musical expression encompasses varying tempo, dynamics, and articulation to convey emotion and character. While musical notations provide guidelines for how certain parts should be played, these indications are not as rigidly followed as key signatures. Thus, the beauty of music lies in its interpretative nature.

As I became more comfortable practicing with both hands, it was time to match up the tempo. This phase is arguably the most challenging of all. Playing the correct notes is one aspect, but infusing the music with emotion and expression requires a balance of stability and flexibility. Stability involves the precision of playing the correct notes consistently. Flexibility, on the other hand, pertains to the ability to introduce variations and nuances without disrupting the overall structure of the piece.

It is important to note that “Can You Hear the Music” is particularly challenging not because of its speed but due to its constantly shifting tempo, which changes every four bars; and so the metronome would not even be much helpful. This is where short-term plasticity becomes crucial. As I repeatedly practiced at the initial tempo of 50 BPM, my neural connections adapted, allowing me to perform the piece more automatically and with less conscious effort devoted to timing. This adaptation involves short-term facilitation of synapses, where clusters of inputs consistently activate new neuronal patterns, thereby modifying connections to produce appropriate responses.

However, the piece’s ever-changing tempo—transitioning from 50 BPM to 65 BPM, then to 60, 80, 70, 90, 75, 95, 80, and so on—requires more than just short-term facilitation. Short-term depression also plays a key role in dissociating typical input patterns, facilitating the formation of new connections in response to the varying auditory stimuli and ensuring the correct timing response. When reaching a new four-bar segment with a different tempo, previously activated synaptic connections are weakened, allowing new, faster, or slower motor responses to emerge. As a result of the dynamic interplay between short-term facilitation and short-term depression, combined with the application of both stability and flexibility mechanisms of plasticity, I am able to improve my tempo proficiency and thus adding more dynamics into the performance.

Stage 5: The Final Performance

Can You Hear The Music?...[1]

Overall, practicing piano with a neuroscientist mindset focused on brain plasticity has been an enlightening and transformative experience. Understanding how my brain adapts and rewires itself through repeated practice has not only deepened my appreciation for the complexities of musical training but also significantly enhanced my performance over time. By leveraging the concepts of short-term facilitation and depression, as well as stability and flexibility mechanisms, I was able to refine my tempo, coordination, and expressive capabilities. Additionally, the distributed representation of memory played a crucial role, both aiding and interfering with my practice. While it helped in recognizing and generalizing

[1] The final performance was not mine but was from Pietschmann, the original artist who rearranged the piece. Surprise! I have included the finalized version by the original artist because I want you to enjoy a fulfilling experience with some dopamine boosts while evaluating my essay. This is why I did not put the date for that stage. Please don't flag me for copyright violation—I'm not asserting any ownership over this "Final Performance."

patterns, it also occasionally led to confusion between similar musical pieces. Integrating this knowledge into my routine allowed me to observe firsthand the remarkable capacity of the brain to evolve and improve with persistent effort, ultimately breathing life into each piece I played.

Works Cited

Boran, E., Fedele, T., Klaver, P., Hilfiker, P., Stieglitz, L., Grunwald, T., & Sarnthein, J. (2019). Persistent hippocampal neural firing and hippocampal-cortical coupling predict verbal working memory load. Science advances, 5(3), eaav3687. https://doi.org/10.1126/sciadv.aav3687

Cowan, N. (2008). Chapter 20 What are the differences between long-term, short-term, and working memory? In *Progress in brain research* (pp. 323–338). https://doi.org/10.1016/s0079-6123(07)00020-9

Groussard, M., Viader, F., Landeau, B., Desgranges, B., Eustache, F., & Platel, H. (2014). The effects of musical practice on structural plasticity: The dynamics of grey matter changes. *Brain and Cognition*, *90*, 174–180. https://doi.org/10.1016/j.bandc.2014.06.013

Herdener, M., Esposito, F., Di Salle, F., Boller, C., Hilti, C. C., Habermeyer, B., Scheffler, K., Wetzel, S., Seifritz, E., & Cattapan-Ludewig, K. (2010). Musical training induces functional plasticity in human hippocampus. ˜*the* œ*Journal of Neuroscience*/˜ *the* œ*Journal of Neuroscience*, *30*(4), 1377–1384. https://doi.org/10.1523/jneurosci.4513-09.2010

Li, Q., Wang, X., Wang, S., Xie, Y., Li, X., Xie, Y., & Li, S. (2018). Musical training induces functional and structural auditory‐motor network plasticity in young adults. *Human Brain Mapping*, *39*(5), 2098–2110. https://doi.org/10.1002/hbm.23989