Understanding Practice Stages for a Proficient Piano Player to Complete a Piece: Focusing on the Interplay Between Conscious and Unconscious Processes

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Abstract— **Research into instrumental music performance has garnered significant attention, particularly regarding the intricate interplay of perceptual-cognitive-motor interactions, knowledge application, and the cognitive representation of musical structure. Understanding these dynamics holds promise for enhancing instruction and aiding learners in their journey towards mastering instrumental performance and practice. However, grasping the learning process necessitates more than just comprehending the individual cognitive mechanisms at play; it requires a holistic approach that considers the cognitive architecture enabling the integration of these processes. In this paper, based on the MHP/RT framework proposed by Kitajima and CCE research method which based on the MHP/RT principles, we attempt to understand the process of proficiency in music performance by proficient piano players as a brain model based on the coordination of perception, cognition, and movement, and the concept of Two Mind. Initially, we modeled the cognitive process of piano performance proficiency, and ethnographically described the process of proficiency in music performance for selected elite monitors. The descriptions are analyzed and compared with the model of cognitive processes and actual behaviors in performance proficiency. The description of which perspectives can/cannot be interpreted by the model based on MHP/RT were considered. Finally, a series of piano playing exercises and lessons are analyzed from the perspectives of the Two Minds process, and the knowledge system (implicit/explicit) utilized. Through the analysis, the relationship between acquired knowledge and cognitive ability and Two Minds is considered. The findings suggest that the proficiency process of instrumental music performance exhibits a kind of phase transition. It involves not only a gradual shift from prolonged, System 2-driven mechanical training towards an intuitive, System 1-driven unconscious expression but also deviations from this pattern. Therefore, it is imperative for players to thoroughly comprehend their perception of the entire piece (System 2) while also fostering a sense of ease and naturalness in performance akin to unconscious expression (System 1) for the listener.**

Keywords— Proficient Piano Player; Cognitive Process; Two Minds; MHP/RT; Ethnological Study.

I. Introduction

This paper is based on the previous work originally presented in COGNITIVE2024 [1]. A review of MHP/RT and the fundamentals needed to understand the process of training and performance of proficient piano player in preparation for competition were added in Section II.

Instrumental performance has attracted attention as a result of the interaction of perceptual/cognitive and motor abilities. Numerous studies focus on the process of instrumental performance proficiency. The goal of this study is to understand the proficiency process of instrumental performance, which has the possibility of providing better instruction to a performance learner.

Palmer [2] summarizes empirical research on instrumental performance in terms of conceptual interpretation formation, control over motor actions, interpretive transfer as perception, and structural disambiguation. Lehmann and Ericsson [3] focus on the development of instrumental performance skills at the level reached by high school students and amateurs. In their study, they posit that the method of practice is particularly important in improving the level of instrumental performance. A study that focused on the subjectivity factor of instrumental performance practice itself, shares a different perspective; Araújo [4] conducted an online questionnaire survey of self-regulated practice behaviors pertaining to advanced musicians, from which he indicates that practice organization, personal resources, and external resources are important factors. For understanding proficiency in instrumental performance, Chaffin et al. [5][6] applied the protocol analysis method, investigating the characteristics of a concert pianist's performance of a piece of music, in addition to the characteristics of the music. They categorized elements of the instrumental performance in three basic dimensions (fingering, high difficulty, and familiarity with the note form), four interpretive dimensions (phrasing, dynamics, tempo, and pedal), and three expressive dimensions (basic, interpretative, and expressive). Through the categorization process, a possibility of the existence of image for desired representation of the music from the beginning, so-called a "*big picture*", was found.

Focusing on *how to practice* instrumental music performance, as Palmer [2] mentioned, an individual's cognitive representation of musical structure is important especially from the perspectives of specific errors and knowledge utilization in instrumental music performance. To understand this, it is not sufficient to understand the cognitive mechanisms for individual perceptual, cognitive, and motor processes, but research from the perspective of cognitive architecture is certainly needed, which enables these processes to be handled in an integrated manner.

There are several cognitive architectures concerning the interaction between perceptual/cognitive and motor abilities, however, we apply Model Human Processor with Realtime Constraints (MHP/RT) proposed by Kitajima et al. [7][8][9] for this study. MHP/RT is a cognitive architecture, which is constructed by extending the concept of Two Minds [10][11] to reproduce the perceptual, cognitive, and motor processes as well as memory processes at work in everyday action selection. MHP/RT has been applied to the comprehension of language utilization [12] and the process of creating ceramic artworks [13]. For the latter study, MHP/RT is applied with a companion field study methodology called Cognitive Chrono-Ethnography (CCE) [9][14]. CCE is a research methodology utilized to clarify the process of development concerning how a specific individual has acquired the behavior selection characteristics at the present time, and the development process of the behavior selection characteristics at the site where the behavior is executed based on the behavior selection mechanism on a time axis, which is specified by MHP/RT. The implementation of CCE requires appropriate research participants – elite monitors – who are ideal for the purpose of the particular research.

In this article, we attempt to understand the process of proficiency in music performance by applying CCE, underpinned by the MHP/RT's underlying concept of Two Minds, such as the interplay between the unconscious process of System 1 and conscious process of System 2. In Section II, starting from an outline of MHP/RT and its fundamentals, MHP/RT's basic processes constituting proficient performance are described. In Section III, the cognitive process in piano performance proficiency based on MHP/RT is modeled, which provides the basis of CCE. In Section IV, the process of proficiency in music performance for selected elite monitors is described. In Section V, the cognitive process model and actual behavior in performance proficiency is compared, and the points that can be interpreted by the model, the points that cannot be interpreted by the model, and the implications from the MHP/RT perspective are thoroughly discussed.

II. Interplay between System 1 and System 2 in Performance Development

The purpose of this study is to understand the stages of practice that a proficient piano player must follow when attempting to complete a piece. The basis for this understanding is provided by a cognitive architecture that allows for an integrated treatment of the perceptual, cognitive, and motor (PCM) processes that take place during practice, as well as the memory processes involved in knowledge use by the PCM processes and knowledge acquisition as the result of the PCM processes. In this section, we first look at MHP/RT, which is the cognitive architecture employed in this study, in Sections II-A and II-B. It then describes in Section II-C the characteristic patterns of execution of PCM and memory processes exhibited by proficient performers, as revealed by previous research [13], which provide a basis for understanding the practice stages of proficient piano players discussed in Sections III and IV.

A. MHP/RT as an Extension of Two Minds

1) Two Minds: Cognitive processes map perceptual information to motor information. Cognitive processes include intuitive and sensory unconscious feedforward control processes that directly map perceptual information to motor information. In addition, there is a conscious feedback control process where the information necessary for mapping, such as information directly connected with perceptual information, secondary information connected with that information, and so on, and finally connected with motor information, is sequentially and serially extracted from memory.

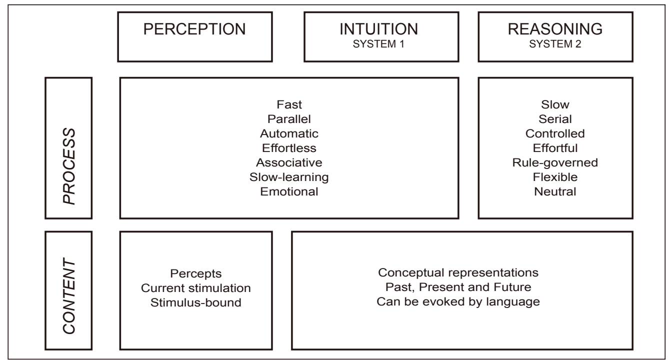

Figure 1. Two Minds [10, Figure 1].

Figure 1 shows the process of situational judgment and subsequent response selection (decision making) in more detail. This figure shows Two Minds proposed by Daniel Kahneman, who won the Nobel Prize in Economics in 2002. Two Minds is the idea that human decision making is carried out by two cognitive systems: System 1, which controls intuition, and System 2, which controls reasoning [11]. System 1 is a fast feedforward control process driven by the cerebellum and oriented toward immediate action. Experiential processing is experienced passively, outside of conscious awareness; one is seized by one's emotions. In contrast, System 2 is a slow feedback control process driven by the cerebrum and oriented toward future action. It is experienced actively and consciously; one intentionally follows the rules of inductive and deductive reasoning.

2) MHP/RT as Two Minds in the Real Dynamic Environment: Two Minds shows that the decision-making process involves conscious and unconscious processes, but it does not say much about the dynamic processes leading up to the decision or the cognitive activities involved in the outcome of the activities performed as a result of the decision. Also, although memory is involved in what is done by the Two Minds process, it says nothing about how memory is used for decision making and updated while reflecting on the outcome of decisions. Daily life can be viewed as a series of behavioral choices involving decision-making, but to understand it on the basis of Two Minds, we need a framework that can provide answers to the unspoken points mentioned above.

MHP/RT directly addresses these points by introducing the idea described below. Considering the human action selection process as a series of perceptual, cognitive, and motor subprocesses, one part of action selection with the processing flow of "perception ⇒ cognition by System 1 ⇒ action"

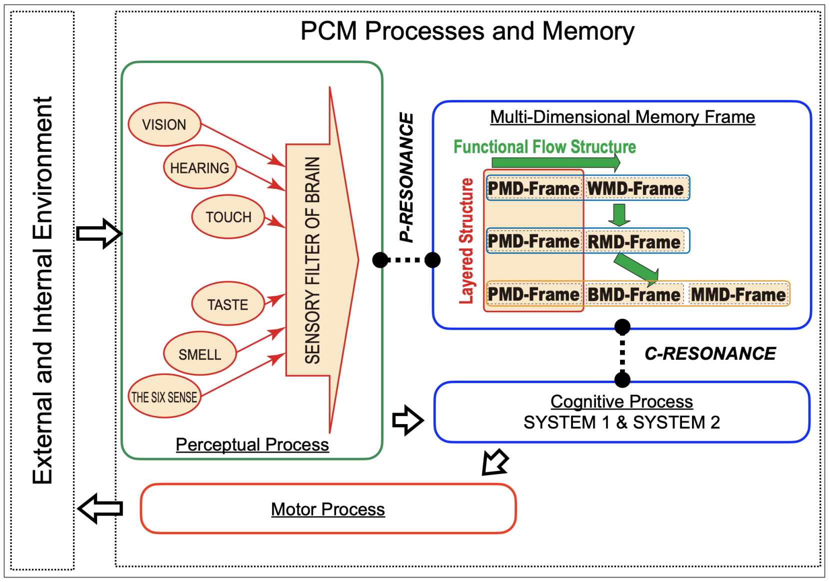

Figure 2. Information uptake by perceptual processes from the external and internal environment, memory activation and execution of cognitive and motor processes through resonance [15, Figure 1].

can be characterized as a *feedforward* control process, in which the unconscious association of perception and motion by intuition leads to action; another part with the processing flow of "perception ⇒ cognition by System 2 ⇒ action" is characterized as a *feedback* control process.

Feedforward control refers to doing things with momentum. In other words, it is a state in which things are done one after another without evaluating what has been done at each point in time (whether it went well or not as expected). On the other hand, feedback control is a state in which the behavior is evaluated each time, the deviation from what was expected is evaluated, and the behavior that reduces the degree of deviation and achieves the expected state is selected from among the actions that can be performed at that point in time, and the behavior is advanced.

Since feedforward control does not involve a cognitive process to evaluate the results of execution, it can link perception and action several times faster than feedback control. Feedback control requires cognitive processes such as understanding the state, evaluating deviations from expectations, and selecting actions that contribute to reducing deviations, e.g., application of the hill-climbing heuristic for solving a problem. Let N be the number of steps required to execute these cognitive processes, the time required is approximately $70 \times N$ msec, where 70 msec is the cycle time required for perming a simple cognitive task, e.g., comparison of two digits. If $N = 10$, it takes 700 msec. Assuming that perceptual unit cycle time is 100 msec and motion unit cycle time is 70 msec, in the case of feedforward control, perception, cognition, and motion can be executed in as little as $100 + 70 + 70 = 240$ msec, e.g., press a button when a circle appears on the display. On the other hand, if feedback control is included, the time required is $100 + 700 + 70 = 870$ msec, which is about three times longer, e.g., press a button when a next move is selected while solving a puzzle after mentally examining a number of alternative moves. Note that in these rough evaluations, the values for perceptual, cognitive, and motor unit times were those reported in the literature as the respective cycle times of the Model Human Processor [16].

MHP/RT is a real dynamic brain model with Two Minds at its core. System 1's unconscious processes with feedforward control and System 2's conscious processes with feedback control are autonomous systems and work together. *both* System 1 and System 2 receive input from the perceptual information processing system in one way, and from the memory system in another way. The cognitive system of Two Minds, System 1 and System 2, are connected with the perceptual and motor systems, and the memory system. These systems work autonomously without any superordinate-subordinate hierarchical relationships but interact with each other when necessary.

B. Fundamentals of MHP/RT

The key for understanding the human–environment interaction based on MHP/RT is the idea that the communication between the autonomous systems is achieved by a mechanism of *resonance* [17]. Both environmental systems and human systems are autonomous systems. The human systems as modeled by MHP/RT include the perceptual, cognitive (Two Minds), motor, and memory systems, all of which are autonomous systems. This section describes how the processing of System 1 and System 2 behind continuous the human–environment interaction is supported by resonance mechanisms that link between autonomous systems.

1) Interaction with the Environment Through Memory, Perception, Cognition, and Motor Processes Using Resonance: When interacting with the environment, humans respond to physical and chemical stimuli emitted from the external and internal environment by sensory nerves located at the interface with the environment and take in environmental information in the body. The brain acquires environmental information concerning the current activity of the self through the multiple sensory organs. Further, it generates bodily movements that are suitable for the current environment. The stable and sustainable relationship between the environment and the self is established through continuous coordination between the activity of the self and the resultant changes in the environment, which should affect the self's next action.

Figure 2 shows the process of MHP/RT [7][9], by which environmental information is taken into the body via sensory nerves as M-dimensional information, processed in the brain, and then acted upon by the external world via motor nerves as N-dimensional movement [15]. This process involves memory, which is modeled as Multi-Dimensional Memory Frame, and perceptual, cognitive (Two Minds), and motor processes. The cognitive process essentially converts the M-dimensional sensory input to the N-dimensional motor output, which is called $M \otimes N$ mapping, with the help of memory. The memory structure, Multi-Dimensional Memory Frame (MDMF), consists of Perceptual-, Behavior-, Motor-, Relation-, and Word-Multi-Dimensional Memory Frame (abbreviated hereafter as P-MDMF, B-MDMF, M-MDMF, R-MDMF, and W-MDMF, respectively). P-MDMF overlaps with B-, R-, and W-MDMF, for spreading activation from P-MDMF to M-MDMF in an attempt to establish $M \otimes N$ mappings.

Perceptual information taken in from the environment through sensory organs resonates with information in the memory network structured as MDMF, which is called *P-Resonance*. In Figure 2, this process is indicated by •—•. Resonance occurs first in the P-MDMF to activate the memory networks. After that, the activity propagates to the memory networks that overlap the P-MDMF, which are the B-, R-, and W-MDMF, and finally to the M-MDMF. In cognitive processing by Two Minds, conscious processing by System 2, which utilizes the W- and R-MDMF via C-Resonance (the upper and middle layers of MDMF), and unconscious processing by System 1, utilizing the B- and M-MDMF via C-Resonance (the bottom layer of MDMF), proceed in an interrelated manner. The motor sequences are expressed according to the M-MDMF, which is the result of cognitive processing. The memories involved in the production of a behavior are updated to reflect the traces of its use process and influence the future behavior selection process.

2) Four Operation Modes: In MHP/RT, the action selection process is controlled by System 1 and System 2 of Two Minds [11]. These systems cooperate to link perception and movement, and the degree of cooperation depends on the state of the external environment with which the MHP/RT interacts. Table I shows the Four Operation Modes characterized by the relationship between System 1 and System 2. There are synchronous and asynchronous modes. Since the activities addressed in this study are concentrated activities, they are performed primarily in the synchronous modes, which are System 1 driven mode (Mode 1) and System 2 driven mode (Mode 2).

TABLE I. FOUR OPERATION MODES OF MHP/RT AND THEIR RELATIONSHIP WITH THE FOUR BANDS IN THE TIME SCALE OF NEWELL'S HUMAN ACTION [18, FIGURE 3-3]; B-, C-, R-, S-BAND REFERS TO BIOLOGICAL, COGNITIVE, RATIONAL, AND SOCIAL-BAND, RESPECTIVELY, ASSOCIATED WITH THE CHARACTERISTIC TIMES, RAGING FROM 10^{-4} TO 10^{7} SECONDS.

Synchronous Modes	
Mode 1:	System 1 driven mode *A single set of perceptual stimuli initiate feedforward processes at the B- and C-bands to act with occasional feedback from an upper band, i.e., C-, R-, or S-bands.*
Mode 2:	System 2 driven mode *A single set of perceptual stimuli initiate a feedback process at the C-band, and upon completion of the conscious action selection, the unconscious automatic feedforward process is activated at the B- and C-bands for action.*
Asynchronous Modes	
Mode 3:	In-phase autonomous activity mode *A set of perceptual stimuli initiate feedforward processes at the B- and C-bands with one and another intertwined occasional feedback processes from an upper band, i.e., C-, R-, or S-bands.*
Mode 4:	Heterophasic autonomous activity mode *Multiple threads of perceptual stimuli initiate respective feedforward processes at the B- and C-bands, some with no feedback and others with feedback from the upper bands, i.e., C-, R-, or S-bands.*

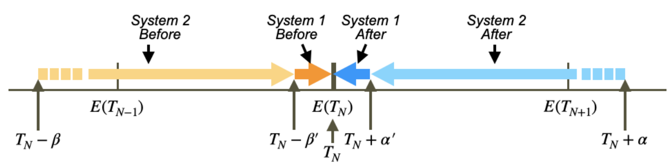

Figure 3. Four processing modes of MHP/RT [13, Figure 3].

3) Four Processing Modes: The experience associated with an individual's activity is characterized by a series of events that are consciously recognized serially. Let $E(T_N)$ denote the event that occurred at time T_N. The experience is then defined as a series of events along the timeline as follows:

$$\cdots \rightarrow E(T_{N-1}) \rightarrow E(T_N) \rightarrow E(T_{N+1}) \rightarrow \cdots$$

Considering the way System 1 and System 2 are involved in individual events, four processing modes can be defined as shown in Figure 3.

- **System-2-Before-Event-Mode**: In the time range of $T_N - \beta \leq t < T_N - \beta'$, MHP/RT plans for future events to occur. There is enough time to think carefully.
- **System-1-Before-Event-Mode**: In $T_N - \beta' \leq t < T_N$, the action selections smoothly generate the immediate event.

- **System-1-After-Event-Mode**: In $T_N < t \leq T_N + \alpha'$, to perform better for the same event in the future, the connection between the incoming perceptual information and the output motor content is adjusted unconsciously.
- **System-2-After-Event-Mode**: In $T_N + \alpha' < t \leq T_N + \alpha$, the event is reflected upon. The results are stored and used in the next System-2-Before-Event-Mode before a similar event occurs.

C. Basic Processes Constituting Proficient Performance

Proficient performance can be understood in terms of the combinations of the four operation modes and four processing modes of MHP/RT when attempting to find $M \otimes N$ mappings by utilizing MDMF. In the previous study [13], we identified the elemental processes that constitute the ceramic artist's skilled work by conducting a CCE study. CCE is a method for obtaining an ecological understanding of how action selection is performed in the domain under study. CCE identifies several parameters that characterize action selection by building a model that can simulate action selection at a coarse level on a cognitive mechanism. Experimental collaborators corresponding to the characteristic parameter value combinations are then selected as elite monitors to observe the action selection process and revise the model based on the results. The perceptual, cognitive, and motor processes, and the memory acquisition and utilization processes that characterize the processes of skilled performance are expected to be common to the piano performance activities discussed in this study. Therefore, in this section, we present the three elemental processes identified in the previous study [13] in a generalized, domain-independent form. They will be related to the specific examples described in the subsequent sections, Sections III and IV.

1) Master Planning in Mode 2: Skilled ceramic work included essentially a conscious decision-making process carried out by the System 2 driven mode (Mode 2 in Table I) for accomplishing the purpose of the ceramic steps such as forming the rough image of the work, selecting the material, and selecting the size. It starts with a respective initial idea followed by an evaluation-update cycle of the idea. It terminates when an idea is evaluated satisfactory.

(β —— β' $-*-$ α' —— α) *Repeat*

β: Consciously clarify the policy for updating the current idea.
β': Spread activation in the MDMF.
$*$: Decide on an update for the current idea.
α': Organize activation in the MDMF.
α: Consciously evaluate the updated idea.

Figure 4. Master Planning in Mode 2.

Any skilled activity includes its own set of essential conscious-decision steps for the work. Figure 4 schematically illustrates what is happening in each step in terms of the characteristic moments of the four processing modes, i.e., β, β', $*$, α', and α. At β, a conscious activity starts for the future event to be carried out at $*$ as a consciously recognizable event, i.e., a decision is made. At α, the event is consciously reflected. During the period of $(\beta',\ \alpha')$ of several hundred milliseconds, unconscious activities related with the event are carried out.

Each step starts at β for performing conscious reasoning to elaborate the current idea, which could be the initial idea for the step or the updated idea of the previous evaluate-update cycle. The spreading activation within the MDMF proceeds through a series of divergences starting at β' to extend unconsciously the possible paths for establishing $M \otimes N$ mappings, followed by the moment of decision on the updated idea at $*$, where the possible paths are narrowed down to those oriented to a same direction, and the period for convergences terminating at α' to organize them unconsciously along the decided one. Afterward, the decision is evaluated at α. This process is repeated until a satisfactory evaluation for the current idea is obtained. The result constitutes part of "master plan of the work." The decision concerning the master plan is consciously retrievable in the subsequent stages.

The content of the master plan of the work is affected by the extent to which activity is propagated within the MDMF during the period leading up to it. This process is characterized by the richness of the MDMF, or the amount of experience concerning the work. It is carried out by initially placing a seed that represents the image of initial idea *consciously* in the P-MDMF. It ultimately leads to the event concerning a final decision, which is a conscious representation in the W-MDMF referring to a rough image of the work represented in the P-MDMF. This is done by spreading activation in the MDMF, which has been constructed through extensive $M \otimes N$ mapping experience. The final decision for master plan, which is consciously accessible in the subsequent stages, is obtained as activated patterns of the network in the MDMF centered on the P-MDMF.

2) Two System 1-Driven Activities: There are two types of activities conducted under System 1 driven mode, which are conducted to implement the master plan specified in Section II-C1 represented as symbols in W-MDMF. The first one is characterized by extensive unconscious exploration of candidate $M \otimes N$ mappings at a detailed grain size to find the best one (see Section II-C2a), and the second is characterized by initiation of a long unconscious and non-interruptable activities in the real world, i.e., execution of a sequence of unconscious bodily movement represented in M-MDMF (see Section II-C2b).

a) Testing Ideas in Mode 1: In the skilled ceramic work, there is a step to create the modeling manually that will not break in the next firing process, which is an irreversible and uninterruptible firing process and finalizes the modeling as something permanent in the real world described in Section II-C2b. In any skilled activity, there are steps for concretely imagine body movements to implement the master plan. Figure 5 schematically illustrates the characteristic of these steps. It is a repetitive procedure, which is the same as

$(\beta - \beta'$ ——//——$*$——//—— $\alpha' - \alpha)$ *Repeat*

β: Consciously think of the final performance.
β': Spread activation in the MDMF.
$*$: Select a candidate bodily movement for the final performance.
α': Conduct a trial for the candidate bodily movement.
α: Test if the result of trial matches the final performance.

Figure 5. Testing ideas in Mode 1.

Figure 4; it is different in terms of the longer unconscious period carried out by System 1 before and after $*$.

At β, *perceptual* representation of a candidate for the complete form of performance is placed consciously in the P-MDMF as a seed. Then, $M \otimes N$ mapping is carried out during the period of $(\beta', *)$ to obtain a candidate motor movement of body parts in the M-MDMF at $*$ for producing the performance defined in the master plan; The event that occurred at $*$ is the event that a candidate for a consciously accessible motor action has been selected in the future. During the period of $(*, \alpha')$, the movement represented in the M-MDMF is used to generate *trial* movement. Its outcome is a perceptual representation in the P-MDMF, which is used to make a judgment at α whether it matches the final performance defined in the master plan of the work. If it fails, the outcome might be used as a next seed in the P-MDMF to spread activation in the MDMF. This updating process is repeated until a satisfactory one is obtained.

b) Embodiment of a Series of Actions in Mode 1: There is a step for embodying the trial movement obtained in the procedure described in Section II-C2a. Figure 6 schematically illustrates the procedure for this step. This is a one-time procedure; once it is initiated, it proceeds until it ends.

$\beta - \beta'$ $-*-$ α' ————-//————- α

β: Clarify the final performance and a candidate is placed in the P-MDMF.
β': Spread activation in the MDMF.
$*$: Make a decision with the performance and carry it out.
α': Organize activation in the MDMF.
α: Evaluate the decision consciously.

Figure 6. Embodiment of a series of actions in Mode 1.

At β, the final performance is consciously clarified in the MDMF specified in the master plan. Then, the perceptual representation for the trial performance for the master plan obtained in the preceding step is placed in the P-MDMF, followed by $M \otimes N$ mapping from there into the MDMF to have the M-MDMF get activated, which specifies candidate movements of body parts for performance. Unconscious $M \otimes N$ mapping is carried out during the period of $(\beta', *)$ for making decisions on the single sequence of bodily movements

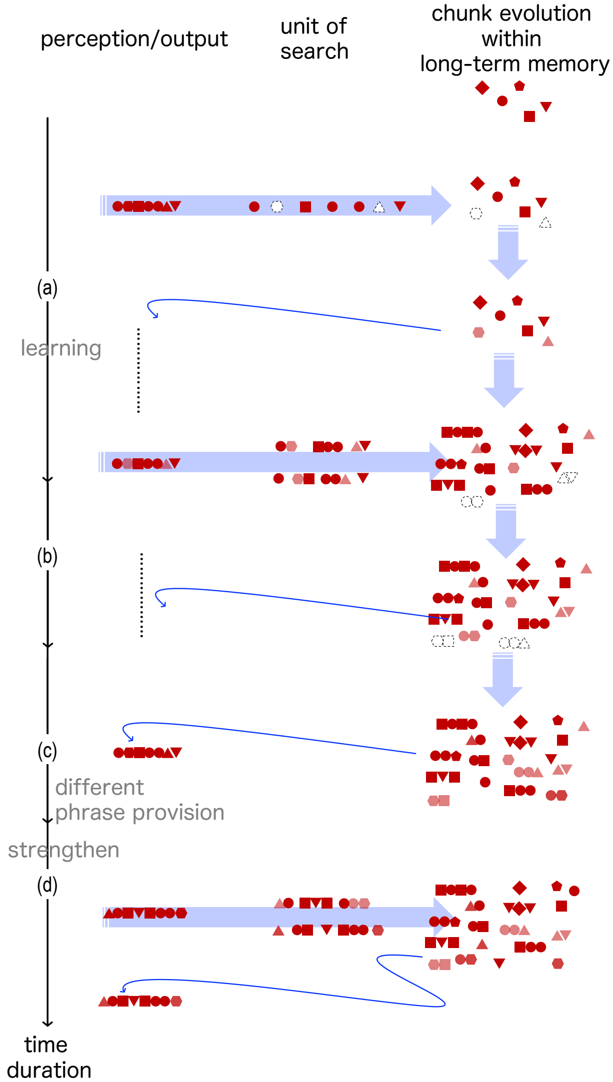

Figure 7. The relation between perception/output and chunk evolution within long-term memory.

in the real world for performance at $*$. This is the moment when the chain of body movements for the performance is established in M-MDMF and the performance is ready to carry out under unconscious feed-forward control by System 1 processing.

After a certain amount of period shown by —//— , the result of the performance will be evaluated at α by System 2. There might exist discrepancies between the final performance imagined at β and the resultant performance obtained at α. By integrating the traces of spreading activation from β to $*$ for performance and the evaluation result at α, the MDMF, which can be used in the $M \otimes N$ mapping for the future embodiment step, is updated.

III. Cognitive Processes Leading to Proficiency in Piano Performance

Playing piano involves processes such as reading the score and creating its mental representations and retrieving knowledge from long-term memory related to the representation, which comprise a variety of information necessary to establish links between the representation of visual information on the score and the concrete hand/finger movements to be conducted on the instrument. These links are used to carry out the $M \otimes N$ mappings introduced in Section II-B1. Long-term memory consists of chunks for establishing these links, which develop with practice from an initial configuration with inefficient linkage to an advanced one with effective linkage, corresponding to the state of proficiency. This section provides a theoretical description for the development process of the chunk structure.

A. Initial State: Initial Chunks in Long-Term Memory

The chunk structure, within long-term memory at the beginning of reading a score, is a set of chunks that have been acquired as knowledge and stored in long-term memory. Let C_{mus} be the chunk set that must be stored, the chunk set C_{LM} that exists in long-term memory at a certain time t is a subset of C_{mus}. C_{mus} is composed of the following, based on the smallest element c_i $(1 \leq i \leq n_c(t))$:

- Chunks composed of the minimum element $n_c(t)$ only,
- Larger chunks composed of $n_e(t)$ $(1 < n_e \leq n_c)$ minimum elements, without duplication, and
- Still larger chunks consisting of $n_{e'}(t)$ $(1 < n'_e \leq n_c)$ minimum elements, with duplication allowed.

In addition, C_{LM} consists of the relation:

$$C_{LM} \quad = \quad \{\boldsymbol{c} \mid c_i \in C_{mus},\ 1 \leq i \leq n_{LM}(t)\}$$

The internal structure of C_{LM} evolves as a learning and strengthening process as the number of chunks it contains increases with practice.

B. State (a): Recognition of Individual Notes or Short Phrases

When reading a new score of music, the perceived sequence of notes is divided into known notes or short phrases. When the learner encounters an unknown phrase, it is stored as a new chunk. The layer (a) in Figure 7 exhibits this state. A sequence of notes $S(t)$ perceived at t consists of n_p elements. When $S(t)$ is initially read, $S(t)$ is separated by n_p individual chunks c_j, and the score reading process commences. When an unknown element $c_{j'}$ appears, $c_{j'}$ is newly stored in long-term memory (black dashed line in the figure). As the score reading proceeds in this manner, the reading of each n_p element proceeds smoothly, and the newly stored $c_{j'}$ is additionally stored and fixed in memory. This is the timing that determines the size of the dimension that processes the perceptual information, referred to as M in II-B1. In this state, the learner plays these phrases with a pause – each c_j plays with intermittent, so that it can only be played with an awareness of partial cohesion. In other words, the memory network to link the input perceptual information to a series of N dimensional motor movements, i.e., the $M \otimes N$ mapping, has not been established yet.

C. State (b) and (c): Recognizing Multiple Chunks Simultaneously

When a sequence of notes can be recognized as individual notes or short phrases, the same $S(t)$ is perceived, but several c_j are lumped together and recognized as a novel chunk (phrase) in order to play the music significantly smoother. The layer (b) in Figure 7 exhibits this state. When the learner perceives this unknown combination of c_j's as a set, it is stored as a new chunk (black dashed line in the figure). At this time, the size of the chunk is larger than that of the state (a), enabling the learner to perform with an awareness of longer chunks. In order to be aware of the large phrases, training is also conducted to recognize $S(t)$ more reliably by separating the elements of $S(t)$, and c_j's, in various ways. When the learner perceives an unknown c_j combination, the combination is newly stored in the long-term memory (black dashed figure in Figure 7). Through repeated training, the number of chunks (phrases) formed by the combination of c_j that existed prior to the training increases in long-term memory, and the learner's chunk set structure incrementally approaches C_{mus}. Finally, the learner's chunk set structure in long-term memory is reached at the state (c), and the presented sequence of notes can be recognized as a single chunk. If the learner's condition reaches the state (c), the learner's skill is regarded as "acquiring the ability to perform $S(t)$ with proficiency." In other words, the construction of the memory network for $M \otimes N$ mapping at a basic level has been completed at this state. It could be augmented further in the next state.

D. State (d): Efforts toward more Reliable Chunking

When the structure of C_{LM} is saturated, even if a sequence of notes is novel to the user, it can be perceived as a known sequence of notes by devising alternative segmentations for c_j, which is equivalent to activating corresponding paths in the $M \otimes N$ mappings. Assuming that a new sequence of notes $S(t')$ consisting only of chunk groups in C_{LM} is perceived, in this regard, the recognition of $S(t')$ is divided by utilizing the chunk elements in long-term memory. Since all the chunks are known, reading will commence without much effort being required. The layer (d) in Figure 7 exhibits this state. In this case, the chunks in long-term memory are simply strengthened.

E. Summary

As the above state is repeated, more C_{LM} is accumulated in long-term memory, and even when it is presented with a complex piece of music, the user can be confident that "this musical piece can be performed". Therefore, as C_{LM} increases in the fusion described above, the more musical pieces the learner practices, the more proficient the learner becomes, and the more musical pieces the learner is able to perform. However, in actual performance, there are two types of practice: one is to perform without making mistakes even if it takes a longer time, i.e., a phase of musical score reading, and the other is to perform without stopping to have the audience experience a smooth performance. The former is carried out by following the process schematically illustrated by Figure 5 in Section II-C2a where the player tries to confirm a satisfactory performance; whereas the latter by Figure 6 in Section II-C2b where the player lets the motor movements develop without interruption. The process of utilizing chunks while carrying out the $M \otimes N$ mappings should be different in these cases. The next section describes an example of how the cognitive processes, leading to performance proficiency described above, appears in actual performance proficiency with referring to the basic processes included in proficient performance as presented in Section II-C.

IV. An Example of Proficiency Process of Music Performance by a Proficient Piano Player

In this section, we describe a CCE study focusing on a single elite monitor, following the study conducted by Kitajima et al. [13] to understand the skill of a traditional craft artist and how the skill is passed down from generation to generation, as well as how the process by which a proficient piano player reaches the expected performance level through practice of a given piece of music. We call the elite monitor, i.e., the proficient amateur piano performer, P^3, and consider the situation where P^3 tries to achieve a high level of performance perfection through practice. The characteristics of the score that P^3 is aiming for, i.e., the target score abbreviated as TS, with reference to P^3's performance skill level is elucidated. Subsequently, the study enumerates the elements included in the practice to be conducted to achieve TS, and elucidate the development of the practice over time and the content of the practice elements associated with it.

Here, the role of P^3 is taken by the first author. The core of the CCE analysis – describing P^3's experience – has operated as stated below. In order to avoid a biased analysis, when P^3 made an ethnographic analysis, P^3 asked the instructor the meaning of musical suggestion or cognitive meaning with regard to playing piano training method given by instructor. For representation of the CCE analysis, P^3 wrote down the experience series and the initial proposed model. Subsequently, the other two authors, who are professionals with the CCE, meticulously investigated the proposed model which P^3 proposed. Finally, the authors adopt the representation which all authors judged to be acceptable.

A. Main Objectives of a Skilled Piano Learner

In general, there are two main objectives when an adult learner attempts to acquire proficiency in musical performance.

1) Internal factor, such as genuinely wishing to become proficient for strong motives, e.g., favorite piece of music, wanting to perform it, and select a piece for a competition, etc.
2) External factor, i.e., a piece assigned for a competition or given for practice

It depends on which objective the learner set, but here we target the "to be made best performance at the competition" in 1). In this instance, P^3 can select a piece of his/her own will, but the target performance achievement is to pass at least the regional qualifying round of the piano competition (with a required score is 70/80 or higher), and preferably the regional finals (with a required score is 80/86 or higher).

B. Flow of Music Proficiency to Reach Competition Stage

Figure 8 represents the general proficiency process of a musical performance. Given that it takes a long time, anywhere from six months to one year, to become proficient in a music performance, the most important process is the selection of the music to be performed. Basically, there are two important perspectives of selection with regards to music and performing: whether or not the piece is appropriate for the player's performance skill level, and whether or not the player prefers the piece. However, in the case of P^3 who can participate in competitions, there is a lot of freedom in music selection, which means the performance skill level is not a constraint. Hence, P^3 asked her instructor for several candidate pieces that would be suitable for her own timbre and expressive characteristics. On top of that, P^3 herself selected the music to be performed through the following process :

- Give the score a once-over,
- Try out playing the initial few pages (where most of the music motifs are available), and confirming whether or not they can play the piece to the end, and
- Listen to a professional performance and determine if you can grasp the image of the piece.

This stage corresponds to "Master Planning" described in Section II-C1.

After the piece for competition is selected, the learner practices playing it to the end so that the framework of the piece can be imagined. This stage corresponds to "Testing Ideas" described in Section II-C2a. Then, the learner makes *Analise* with the outcome of practice. Post-completing the *Analise*, she fixes the image that expresses fluent performance, and additional interpretation as well as the necessary skills for performance expression. This stage corresponds to "Embodiment" described in Section II-C2b. Subsequently, she will go to the competition performance. Details of each process are described in the subsections to follow.

C. Details of the Processes and Mapping on Two Minds

1) Score Selection toward Practice: There are various ways to select a music piece for competition. In a competition which is not given a set piece of music and in which the goal is to perform well in the competition qualifying round and the finals, there are a number of points to consider in the selection of the music piece. In addition to selecting pieces and considering the level of difficulty, there are some other selection points. In the case of P^3, the following procedure was utilized to select pieces at an appropriate level.

1) Ask her instructor to list some candidate pieces: There are two reasons for this. One is to avoid selecting pieces of an inappropriate level for the competition. The other is to have an outsider recommend a piece

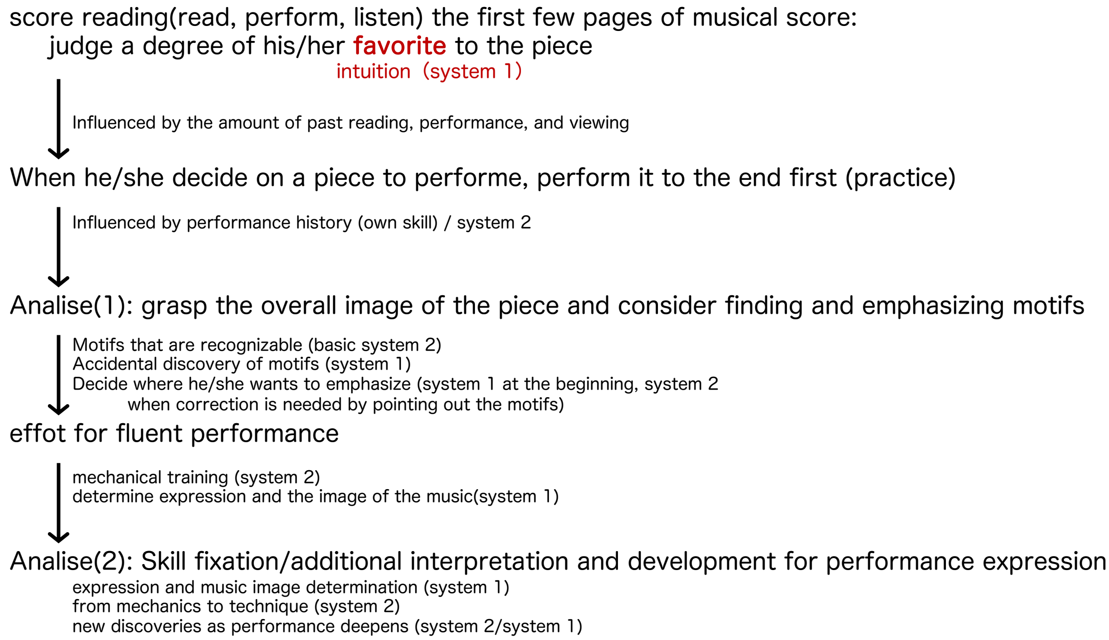

Figure 8. Flow to proficiency in music performance.

that is suitable for the color of P^3 from a third party's perspective.

2) Read the scores giving a once-over to the end to get an image of the music, and narrow down the candidate pieces to 2∼3:
In the case of P^3, the key points in narrowing down the candidate pieces are basically two points: whether the feeling of the music fits, and whether the image of the music can be grasped by reading the scores once-over.

3) Read and perform the initial few pages of the piece (up to the point where the initial and subsequent motifs appear):
There are cases where the mechanics utilized in the actual performance are quite different from the image. In addition, even if the instructor thinks "She can perform this," P^3 finds later that the motifs involves the mechanics "her cognitive or motor reaction rejects." This process is designed to prevent such mismatches.

4) Select a piece of music that she is convinced she could perform well.
In the case of P^3, the selection is made focusing on the music that immediately comes to mind concerning "what she wants to express" when the motifs are performed.

The goals of these steps are 1) listing the candidate pieces, 2) selecting pieces with graspable images, 3) selecting pieces involving mechanics her cognitive and motor reaction accept, and 4) selecting a piece she is confident that she can play. These goals are consciously set and accomplished after several iterations until satisfactory results are obtained as shown in Figure 4. The selected piece for the proficient piano player would correspond to the master plan for the ceramic artist. Both are associated with the images of finished performance via rich memory networks.

2) Transition of Instructional Contents: The process required to complete a musical performance can be divided into two main categories: musical score reading and compositional expression. The musical score reading is a practice stage in which mechanics – motor system – play a major role. This stage is carried out by the process shown by Figure 5. Compositional expression practice is the stage, where musical interpretation, i.e., the player's expression tailored to his/her sensitivity, and technique for the expression, plays a major role. This stage is carried out by the process shown by Figure 6. There are significant disparities between the two practices.

a) Practice 1 – Musical Score Reading: In the case of musical score reading to train mechanics, the main focus is to be able to strike keys accurately. Therefore, the main task of practice is to reproduce the exact note value, pitch, and interval for each note head. In simple words, the primary focus of practice is to count the lengths accurately, to check the details of pitches, and pitches described in the score, and to check accidentals, articulation marks, ornaments, pedal marks, etc. The utilization of knowledge in this process is basically centered on (a) and (b) in Figure 7, and is mainly a System 2 process for consciously evaluating the results of keystroke execution in terms of practicing to play the sequence of notes exactly as described in the score.

b) Practice 2 – Compositional Expression: Conversely, in the case of the musical score reading for compositional expression, a variety of control with regards to the fingers and cognition is required, such as how far to play a note sequence as a whole, how to add dynamics, and which notes to insist on. Simply put, it is a prerequisite that the player has already finished *Analise* the piece and that the player's image of the entire piece has been established. The two elements are not independent, which means the existence of accurate mechanics enables the player to confidently express music utilizing this technique.

c) Advanced Mechanics Learning for These Practices: It is also necessary to learn the mechanics required to make the technique more precise, for example, the dynamic technique and the techniques required to change timbre. In this sense, it is a cooperative activity between cognitive and motor processes. When teaching these cooperative activities, the instructor decides on the contents of instruction in the following manner with regards to listening to the player's performance.

- Understand what the player wants to emphasize and what kind of expression he/she wants to express from the performance.
- Imagine what the player wants to do but does not seem to be able to do.
- Point out obvious deviations from the interpretation of the performance as described in the score, and give a more natural interpretation.

Of course, if the player is sufficiently competent, these items can be improved in a self-regulating way by recording and watching his or her own performance. However, different from students who are beginners when it comes to performing, there is a limit to self-regulation improvement in the field where *advanced* performance is required. For this reason, suggestions from the instructor play an important role in the case that mastering of advanced mechanics is required for the player who has been already at the level of high proficiency.

The instructor suggests more exercises that would contribute to the formation of chunks as opposed to the movement. They essentially act to strengthen what was weak in the paths connecting perception and movement within the memory network. For instance, changing the playing speed between stressed and unstressed parts (contributes to the formation of chunks), practicing rhythm (contributes to the formation of fingering chunks), and giving more accent than necessary to notes that should be emphasized (contributes to the formation of chunks in the imagery of the music). The primary utilization of knowledge in such exercises is exhibited in Figure 7 (c), and primarily consists of combining the smallest elements c_j that may appear in a piece of music in as long a phrase as possible, in order to be aware of the motifs of the music piece.

d) Improvement through Alternation of These Practices: Given that this is an expression of how the player feels about the music, it is not necessarily a System 2 process, but is gradually shifted to a System 1 process. Repeat the performance expression in the System 1 process as trial and error until the player's intention is well conveyed. The player repeats the pattern that successfully shares the expression he/she wants to share in the System 2 process to fix the expression. In addition, although System 2 and System 1 repeatedly appear during practice, there will be situations where "System 2 $<$ System 1." This is a time when unconscious performances increase and dramatic improvements in performance expressions occur.

As player's technique improves, he/she gradually discovers new discoveries and desires for additional expression in the piece. As player's techniques improve, he/she can make new discoveries for motifs/notes significance, and grow his/her appetite regarding compositional expression. Some of these improvements can be made solely by P^3, while others can only be made with the advice of the instructor. In any case, the final regulation for the competition will be made by repeating such improvements. At this time, the utilization of knowledge increases in the System 1 process in order to challenge a variety of expressions. In addition, even without the System 2 process, the approach to the state known as "the body remembers" and enables various expressions to be challenged.

V. Discussion Based on Two Minds

A. Overview of Annual Lessons

The following is a summary of the practice sessions described in Section IV, contrasted with the duration of the lessons. In order to take lessons, the learner makes practices about one hour per practice. The number of practice sessions is generally two to three times per week, depending on the situation at the time. One to two weeks prior to the competition, practice sessions occurred almost every day.

- 11 months prior to the qualifiers of the competition (C_P): Selection of pieces
  Play a few pages of several music pieces and select the pieces that suit the player's favorite
- Six months prior to C_P post-selection of music pieces: score reading (T_{C1}).
  Basically, the students practice developing techniques in some parts while focusing on the mechanics. It takes about three months to reach the level of playing through the whole piece, and the playing speed is two to four times slower than the specified speed.
- Six to three months prior to C_P: Transition to the expression of musical ideas (T_{C2}).
  ** By this time, the mechanics are 80% complete, so the main focus is on practicing to develop the techniques necessary for compositional expression.
- Three months prior to C_P, completion of the compositional expression:
  Completion of the musical compositional expression · constructing the music image (T_{C3}).
- 1 month prior to $C_P \sim C_P$: final adjustment for the regional qualifying round. (T_{C4}).
- Post C_P to the primary line of the competition: if you pass the qualifying round, practice for the regional finals (T_{C5}).

A total of 25 lessons were given. Each lesson lasted approximately 1.5 hours.

TABLE II. PHASE CLASSIFICATION OF KNOWLEDGE/COGNITIVE PROCESSES AND DEGREE OF INFLUENCE.

		process		knowledge		environment
Phase	Subphase	System 1	System 2	tacit	explicit	outsider intervention
decide piece	offer candidate	*	*		*	**
	once-over	*	**	*	**	**
	playing trial	**	*	**	**	
	listning	***	*	**	*	*
	select piece	***	*	***	*	*
score reading	fingering		***		***	
	score reading		***		***	
analise(1)	recognize motif		***		***	*
	set enphasis		***		***	*
	find motif of serendipity	***	*	*	***	
expression	mechanic	*	***	**	***	***
	construct image	***	**	**	**	
	transfer expression	**	**	*	***	**
analise(2)	confirm expression	**	***	**	***	***
	confirm image	**	***	***	**	***
	Technic		***		***	***
	performance deepening/serendipity	***	***	*	***	
final stage	fragmentation and reintegration	**	**	**	***	

B. *Two Minds in the Flow Leading to the Completion of the Music*

Once a series of experiences had been performed, the second trial for attending the competition may be able to utilize the prior experience to finish the piece at a faster pace. The items from stage 2 (practice) analise(1) to the effort for fluent performance in Figure 8, or $T_{C1} \sim T_{C2}$ in terms of the lesson schedule, are basically affected by the experience. It is possible to reach the stage of mechanical performance as reproducing with midi, through an experience such as earlier through participating in competitions repeatedly, taking lessons for many years, and so on. These changes are continuous, i.e., the degree of improvement increases monotonically as a function of the number of performances.

However, additional interpretation and deepening of the performance beyond that point may not be successfully achieved by simply repeating the process. In P^3's participation in the competition, the performance around two to one month prior to the competition qualifier (T_{C3}) undergoes a large change every year, which cannot be explained by the passage of time alone. By this time, the mechanical performance is almost complete in a form that is approximately 1.5 times less than the speed at which it is played on the day of the competition, but it is far from sufficient completion, and the so-called "composition expression and understanding." Around the transition from T_{C2} to T_{C3}, there is a significant change in the recognition of musical motifs and a shift to the recognition of larger motifs and the expression of *Dynamik* including expression marks. Other changes in timbre, for instance, from soft to hard sounds, are also observed.

This situation is further analyzed from the perspective of the disparities between the characteristic times of System 2 and System 1. In System 2 driven mode, the processing flow is controlled consciously as shown by Figure 4, whereas in System 1 driven mode it is controlled unconsciously as shown by Figures 5 and 6. In both modes, part of the memory network that connects perception and motion via cognition is used, created if necessary, and the connections are updated, which concerns usage and maintenance of $M \otimes N$ mapping. The period of T_{C1} is a practice process in which the System 2 process is dominant. The time scale for practice per phrase is primarily the cognitive band in Newell's Time Scale of Human Action [19], since the phrase itself is not very long. The time span of the cognitive band is about $\sim$10[s]. Given that information is exchanged between the working memory and long-term memory in about 10 seconds of very short chunks, all knowledge is likely to be recognized only as fragments. Therefore, even if one were to predict the next chunk that will appear during the performance of a piece of music, only a few chunks exist which is able to collation, and even if many chunks can make connected collation, only a few percent of the entire piece can be predicted, making it difficult to see the entire piece.

By repeatedly practicing a very short chunk, the body remembers new chunks in the order of ease with regards to memorizing. If a similar chunk had been utilized in the past, it is recognized as a “meme” and the chunk becomes an active meme [20]. At this stage, the chunk is considered an action-level meme. Conversely, even if a chunk exists in long-term memory, if it is never invoked again, the chunk is no longer imitated and becomes an extinct meme, therefore making it inactive. From the above, for a learner like P^3 who cannot engage in constant piano practice, score reading at the competition level will require an enormous amount of time.

However, by the time the T_{C1} period had elapsed, the information per chunk is considerably larger. Therefore, during T_{C2}, chunks of the larger size are available for the cognitive processes in the cognitive band. The number of chunks available for cognitive process, invoked chunks, is getting longer and longer, and their coverage is getting longer. As a result, the number of operations utilizing the working memory and long-term memory for a unit time will be gradually increased, and the addition of information to the chunks in long-term memory will be accelerated. In simple words, it is thought that the easily accessible active meme will change to behavior-level meme [20]. In this process, the time when a knowledge group is composed of only an appropriate chunk size may be approximately the time toward T_{C3}.

By the time T_{C3} is entered, the number of movements to call chunks from long-term memory is considered to be considerably reduced. As a result, cognitive-motor coordination is conducted more unconsciously. If all the chunk invocation patterns are optimized, almost all the performances will be performed unconsciously by System 1, and an abrupt phase transition from the T_{C2} state will occur. As a result, one should feel at least a dramatic improvement in their ability for good finger movement.

In the case of P^3, the pieces learned in the last three years, including the time of writing this article, were as follows:

- 2 years ago :
  Partita BWV 826, composed by J. S. Bach (score A)
- 1 years ago :
  Allegro Appassionate op.70, composed by Charles Camille Saint-Saëns (score B), Allemande in French Suites BWV 812, composed by J. S. Bach
- now :
  piano sonata op. 14 first movement, composed by Sergei Sergeyevich Prokofiev (score C), Allegro in Italian concert BWV 971, composed by J. S. Bach

Each of them spent about a year memorizing the scores prior to the competition. Despite the difference in the compositional age, compositional structure, and knowledge required, score A received 76 points and score B received 79 points in the final piano competition. This indicates that the learners’ performance skills themselves were well-developed, even though they performed different types of music. In simple words, the examples of the experience in Section IV can be considered to have a certain universality.

C. The Relation between Knowledge/Cognition Process and Two Minds

Finally, we discuss the relationship between the Two Minds and the knowledge as well as cognitive abilities acquired through a series of piano practice and lessons. Table II exhibits the results of subjective evaluation for each flow subphase in Figure 8. The items are: the process of the Two Minds, the knowledge system utilized (implicit/explicit), and the subjective evaluation of the degree of intervention by others. The higher the number of $*$, the stronger the effect on the item.

At initial glance, one might think that instrumental music performance is a continuous shift from long time-consuming mechanical training by System 2 (inference) to unconsciousness of musical expression including System 1 (intuition). However, in fact, this is not true.

For instance, in the case of the music selection phase, many factors are involved in the decision-making process, including player: 1) preference (System 1), 2) matching with performance ability (System 1/2), and 3) matching with the ability to read music (System 2), etc. It depends on the situation at that time which of these factors should be prioritized. In simple terms, if motivation is a given priority, preference is given priority, and if ability is given priority, a little more weight is given to the performance ability or reading ability. This indicates that the process of proficiency in instrumental performance is not determined solely by preference or ability. Conversely, music selection, although often neglected at the initial glance, is the most important phase as it is deeply related to the motivation of the student when he or she begins to practice. In the case of the piano beginner, the instructor often selects pieces at an appropriate level, but in the case of a proficient amateur learner, the selection requirements for the score selection are reduced to some extent. Therefore, the degree of freedom of parameters is high, and the decision-making process involves a mixture of perceptual processes to trigger preference by listening to the sound source, perceptual-cognitive processes to compare with the reading ability by score reading, cognitive-motor processes to consider the performance ability, and processes to coordinate all of these. Therefore, the ability to select appropriate music can be regarded as an important ability.

This also applies to the score selection process. It is easy to assume that a System 2 process takes precedence in *Analise* as well, since it requires a precise analysis of the music. However, various cognitive processes are intricately related as follows: Recognizing the motive and searching for methods to emphasize it (System 2), determination of the expression method that is perceived as effective (System 2/1), new expressions discovered by chance (System 1), and so on. Therefore, not only an orderly musical interpretation but also a balance with the impression is important. In particular, when representing a piece of music, it is necessary to “see the big picture”, i.e., the following items must be fulfilled at the same time.

- The player must have a complete understanding of how to perceive the entire piece (System 2).

- The player's natural behavior as if he/she were performing it unconsciously, which should be comfortable for the listener (System 1).

Therefore, it is necessary to understand the process of coordination between System 2 and System 1.

VI. Conclusion and Future Works

In this study, based on the MHP/RT cognitive architecture and its companion field study methodology, CCE, we attempted to understand the process of proficiency in music performance by proficient piano players as a brain model based on the coordination of perception, cognition, and movement, as well as the Two Minds.

In Section II, we reviewed MHP/RT and provided its fundamentals that are needed to understand the process of training and performance of proficient piano player in preparation for competition. It identified three basic processes constituting proficient performance, which served as the elements for the description hereafter.

In Section III, we theoretically explained the development process of the chunk structure that exists in the long-term memory, which is the most important part of the piano playing process – score reading and piano playing mechanics/technics. There is a structure, which consists of many small units of chunks in the long-term memory, and links are attached between chunks through practice. As a result, larger chunks are formed. The study argues that the proficient state refers to this state.

In Section IV, we ethnographically described the piano practice and proficiency process with P^3 as an example, aiming at participation in the competition. We exhibited that there are four major components: selecting score (System 1), practice (System 2), *Analise*(System 1/ 2), and the effort for fluent performance (System 1/2).

In Section V, a series of piano playing exercises and lessons were analyzed from the perspectives of the Two Minds, the knowledge system utilized (implicit/explicit), and the intervention of others. Post the analysis, the relationship between the acquired knowledge and cognitive abilities as well as the Two Minds was examined by incorporating the idea of the active meme. The results suggest that instrumental music performance requires both a complete understanding of how the player perceives the entire piece (System 2) and natural behavior that is comfortable for the listener (System 1), as if the player were playing unconsciously.

As an application, we can consider various educational support measures for performance proficiency by understanding the actual growth process of chunks and the player's proficiency process in more detail based on cognitive architecture. In recent years, there have been increasing opportunities for adults who are not professions of instrumental music performance to enjoy music as a hobby as amateurs. While he/she is not a professional with regards to instrumental performance, one of the elements necessary for proficiency, "motivation to practice" and "support for its maintenance", is left solely to the desire of the learner to play this piece, not to the instructor. In this situation, if learners cannot overcome the difficulties they encounter when practicing instrumental music, they may give up the hobby of instrumental music itself. However, if the instructor can appropriately understand the difficulties that the learner cannot overcome, and can demonstrate to the learner how to increase the possibility of overcoming the difficulties, the withdrawal rate of the learner may be reduced. We believe that this study will contribute to the research from this perspective.

The majority of prior research on the process of proficiency in musical performance has focused on the understanding of cognitive mechanisms for individual perceptual, cognitive, and motor processes. Research on the cognitive mechanisms of individual processes is primarily suitable for understanding proficiency or the process of developing literacy, in terms of how beginners can play music. This study's findings can apply to constructing efficient training methods for the novice learner.

However, learner's playing skill shifts slowly with time, so that it is necessary to improve teaching content and methods based on the learner's proficiency. In case the learner's goal level with regards to attending the competition, is not only the improvement of literacy but also the process of proficiency in the "big picture" of a piece of music. In order to establish such a sophisticated instructional method for individual cases, we need a method for analyzing successful/failed cases based on the empirical rules of instruction, and the resulting cognitive model of the learner. In this case, it is necessary to go into the resonance with past performance and appreciation activities, and there are many areas that cannot be elucidated only by the prior cognitive architecture. As one of the solutions to this problem, understanding performance proficiency utilizing a brain model based on the Two Minds is considered to be effective. As a future issue, we believe that further research based on this study will enable, for instance, remote performance instruction of musical pieces at a higher level.

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