Art and Brain with Kazuo Takiguchi

– Revealing the Meme Structure from the Process of Creating Traditional Crafts –

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***Abstract*— What factors make traditional art what it is? This paper attempts to answer this question through an analysis from the cognitive science perspective. The subject of the study is Japanese traditional crafts. We believe that the process of artwork production is formed as a result of the interaction between the individual behavioral ecology of the artist and the collective behavioral ecology surrounding them, and attempt to analyze it using a functional brain model. This study aims to elucidate memes that interface the Perceptual, Cognitive, and Motor (PCM) processes that artists employ while creating artworks with the individual and collective behavioral ecologies that are used in these processes. This study focuses on the artwork production process of Kazuo Takiguchi, a leading Japanese ceramic artist. In elucidating the processes, Model Human Processor with Realtime Constraints (MHP/RT), cognitive architecture that can simulate human behavioral processes by means of PCM processes and Multi-Dimensional Memory Frames (MDMFs) that represent memes, and Cognitive Chrono-Ethnography (CCE), a survey method to understand the characteristics of behaviors expressed on the basis of these processes are employed. The CCE results revealed that the collective behavioral ecology, which contains the individual production experience of each artist folded into the individual behavioral ecology of the artist, and the skill acquisition of the production area formed over a long time, enables the artist to unconsciously imagine and meditate on the production process results, working on the production itself and on the firing and glazing process that bring irreversible changes to the production, to predict with accuracy, and to consciously evaluate the actual results.**

Keywords—Traditional arts; Inheritance; CCE; MHP/RT; Meme.

I. INTRODUCTION

A. Objective: A Meme Perspective on Traditional Arts

In the modern era, information worldwide is interconnected, and modern educational systems are widespread. Historically, such a situation was unusual. In fact, in the past, each region had its own unique collective behavioral ecology, formed over a long period of time while adapting to the local climate. The generated collective behavioral ecology formed region-specific memes, which have become the basis for individual behavioral ecologies today. In other words, the natural and spiritual climates are reflected in the collective behavioral ecology, which in turn is reflected in the individual behavioral ecology through memes.

This paper focuses on traditional arts, which are creative activities rooted in the local community and developed as traditions in a collective behavioral ecology, and describe the process by which they were established and the environmental conditions that enabled them to continue. An individual's artistic disposition belongs to their individual behavioral ecology and is expressed through a structured meme that is formed on the brain's parallel distributed memory structure [1] and the activities that utilize them [2][3]. Therefore, the focus of this study will be to answer the following research questions:

- RQ-1 What does the structured meme look like?
- RQ-2 How is it formed?
- RQ-3 What are the environmental conditions that allow its formation to continue?
- RQ-4 How are the artistic activities performed on it?

B. Subject: Japanese Traditional Crafts "Ceramics"

Some of the Japanese traditional crafts have been handed down to recent times. This study focuses on Japanese ceramics, a traditional art form with a strong regional flavor, as the subject of study. The basis of the modern Japanese cultural genealogy is represented by the expression "wabi and sabi," which was systematized around the tea ceremony from the Azuchi-Momoyama period (1568 – 1598 or 1600) to the early Edo period (after 1603) (see e.g., [4][5]). During the next 300 years of the stable Edo period (1603 – 1868), ceramics became firmly established as the foundation of Japanese culture.

From the cognitive science perspective, the behavior of ceramic artists in creating ceramics can be captured in the four bands of Newell's time scale of human action [6, Fig. 3-3]. The four bands are biological (B-band), cognitive (C-band), rational(R-band), and social bands (S-band), corresponding to human activities in the time rages of $10^{-4} \sim 10^{-2}$, $10^{-1} \sim 10^{1}$, $10^{2} \sim 10^{4}$, and $10^{5} \sim 10^{7}$ in seconds, respectively. The actions in each of these bands are continuously passed down through generations in the environment in which the artwork is created. However, unpredictable changes in the environment, trigger discontinuous leaps, and the continuously inheritable behavior survives in a different form.

Major ceramic production centers are scattered throughout Japan. It is one of them. Kyoto is the center of a culture represented by the tea ceremony, and a strong creative orientation has long existed here. The purpose of this study is to understand the characteristics of inheritance in Japanese traditional arts, focusing on the RQs mentioned above.

 ISBN: 978-1-68558-046-9

C. Organization of This Paper

This paper is organized as follows. In Section II, we will give an overview of traditional art activities and look at the brain functions that make them possible. Then, the six steps of CCE, a method for understanding collective and individual behavioral ecology involved in artistic activities, are presented. In Section III, we apply the CCE explained in the previous section to a famous Japanese ceramic artist, Kazuo Takiguchi, and attempt to understand the activity of ceramic art from a cognitive science perspective. In Section IV, we conclude the paper by presenting the core of inherited ceramic activities.

II. Traditional Art Activities and Memes

A. Imagination, Meditation, and Memes in Ceramics

Artifacts for daily use in each region are made from materials available there. The materials reflect the constraints of the *natural climate* unique to the region. As production activities continue in that environment, the techniques for making artifacts progress, and production methods and works suited to the natural climate are established. Technological progress in the production of daily necessities is supported by the ability to imagine the “desired state” and the path to it. Imagination can be paraphrased as the ability to design and imagine how one would like things to be. The source of imagination is the parallel and distributed memory in the brain [1], which makes it possible to imagine a variety of desired states and explore a vast amount of pathways from the current state to that state.

The same process of using one’s imagination to create everyday objects can be used to “explore beauty.” The *spiritual climate* has a great influence on this process. The ceramics initially existed as an aminist craft of Shinto shrines, but its artistry was further enhanced by the influence of the tea ceremony, a representative of traditional Japanese arts that formed the basis of the Japanese aesthetic system under the strong influence of Zen Buddhism. The influence of the spiritual climate on ceramics is evident here. In the activity of “exploring beauty,” the “desired state” is much more abstract compared to the case of producing daily necessities. Therefore, the activity of searching for a quasi-stable activation pattern by spreading activation inside the memory network through “meditation,” in which the target state does not exist, and “imagination,” in which the target state does exist, requires a long time. Not only that, it also requires a lot of experience to form a memory network for imagining and meditating, which is a necessary condition for performing such activities.

The memory network is developed in the form of a Multi-dimensional Memory Frame (MDMF) [7, Fig. 3] by projecting Newell’s human behavioral bandwidth [6, Fig. 3-3]. MDMF has the function of providing the foundation for the execution of $M \otimes N$ mapping, a cognitive process that maps M-dimensional perceptual information input to humans from the environment via sensory organs to N-dimensional motor information output to the environment via effectors.

The memes that exist between the individual and the collective behavioral ecologies and interface between the two play a major role in how the behaviors in the respective time bands are generated. There exist three types of memes: action-level, behavior-level, and culture-level memes. All of them are acquired through imitation, and their complexity increases in this order. The B- and C-bands are for the activities using action-level memes, the R-band is for the activities using behavior-level memes, and the S-band is for the activities using culture-level memes [2, Fig. 5].

The “exploration of beauty” process that the ceramic artist performs can be seen as the processes of “imagination and/or meditation” practiced through $M \otimes N$ mapping, using memes that interface the collective and individual behavioral ecology.

B. Cognitive Chrono-Ethnography (CCE)

This study attempts to understand the individual behavioral ecology of artists by addressing the aforementioned RQs. In doing so, we will apply CCE [8], a method for investigating and analyzing behavioral ecology. In CCE, we first identify behaviors of interest that occur in the target domain. Second, we perform brain simulations for those behaviors based on a cognitive architecture that can handle perceptual, cognitive, motor, and memory processes in a unified manner. We use the Model Human Processor with Realtime Constraints (MHP/RT) [8][9][10] for this purpose. Finally we identify the parameters that characterize the behavior and clarify the relationship between the values taken by the parameters and the behavior expressed.

CCE consists of six steps. Below is a brief overview of each step of the CCE and how each step relates to the RQs.

1) CCE-Step 1 – Phenomenological Observations for Dealing with RQ-2 and RQ-3: In traditional art activities, the individual behavioral ecology is an imaginative and meditative activity for drawing a path to a desired state expressed in abstract form, while the collective behavioral ecology encompasses the individual behavioral ecology over several generations. The collective behavioral ecology contains an “education and training system” constrained by the existence of the natural and spiritual climate of the region. In ancient times, education conducted within a professional group was incorporated into the collective behavioral ecology as a form of family inheritance or apprenticeship. The RQs can be addressed by clarifying the educational constraint’s parameters and educational content parameters to understand how the practice and inheritance of characteristic techniques in specific traditional arts are carried out in the field through field observations and documents reporting on them. More details on this are given in Section III-A.

This study focuses on ceramics as a specific traditional art form, this study will focus on. In this study, based on the idea that a unique person recognized as a ceramic artist should be an instance of a combination of values of characteristic parameters, we will observe the activities of such an artist and interview him to understand how the practice and inheritance of characteristic techniques in ceramic art are carried out. More details on this are given in Section III-B.

2) CCE-Step 2 – Matching with Brain Properties: For an art form to be called "traditional," it must have inherited techniques essential to the creative practice of that art form (e.g., ceramics) through generations. The inheritance of techniques in traditional Japanese arts is done through the practice of "watching and stealing work." The results obtained by "watching and stealing work" appear as imaginative and meditative activities that are concretely put into practice. These activities are simulated by the cognitive architecture MHP/RT. More details on this are given in Section III-C.

3) CCE-Step 3 – Structural Modeling: The performance of imagination and meditation activities can be characterized as the "variety" and "coverage" of $M \otimes N$ mappings from perception to motion. For these practices to take place, "what is stolen" must be present in the visible range. Since traditions are unique to a region, it is a prerequisite that the people who maintain them have been born and raised in the region. The availability of information, the diversity and coverage of $M \otimes N$ mappings, and the relationship between feedforward and feedback processes become the set of parameters that characterize an individual's behavioral ecology. More details on this are given in Section III-D.

4) CCE-Step 4 – Formulation of the CCE Survey Methodology: In a typical CCE survey, screening is conducted using a questionnaire that includes the values of a set of parameters in the questions for selecting an elite sample. In the ceramic survey conducted in this study, we found "Kazuo Takiguchi" as a subject that can be called a super elite sample with the characteristics of traditional art bearers and with whom we can see the entire sample in one example when we assume the parameter space set by CCE-Step one through three.

5) CCE-Step 5 – Conduct CCE Survey: Therefore, focusing on Kazuo Takiguchi, we attempted to clarify the individual behavioral ecology, collective behavioral ecology, and memes.

6) CCE-Step 6 – Match against Characteristics for Dealing with RQ-1 and RQ-4: By observing the activities of Kazuo Takiguchi, specific examples of imaginative and meditative activities can be obtained when a person, represented by the parameter value combinations, performs creative activities using memes at the site. This will validate the model constructed in CCE-Step 3.

III. Elucidating Memes with CCE

A. CCE-Step 1-1: Field Observation

1) Collective Behavioral Ecology as a Foundation for Traditional Arts: Emmanuel Todd [11] lists the following as inherited collective memes: 1) Group form, 2) The nature of authority to choose the group's behavior, and 3) The implicitly practiced action selection rules as a method for the inheritance of the group. These are inherited as collective memes, and groups are managed and developed accordingly. Here, what and how is taught, RQ-2, in the form of inherited, RQ-3, is encapsulated. Therefore, different collective memes develop in different ways.

The culture of a group is part of the collective memes. Therefore, in culture, each group possesses its own distinctive way of passing on its manufacturing methods and techniques that are unique to the group and distinguishable from those of other groups. Behind this is the existence of evaluation criteria for cultural products that are unique to that culture.

The collective memes that have been nurtured as a Japanese tradition has become effective in the acquisition of individual skills. The reality of this effectiveness can be characterized as follows. The collective and individual behavioral ecology develop by influencing each other in an interdependent relationship in which the individual, as a member of the group, influences the formation of the collective behavioral ecology and thus, influences the formation of the individual memes. This interdependence determines the forms that make it possible to maintain, develop, and inherit traditions – RQ-3.

Individual behavioral ecology can be viewed as action-level, behavior-level, and cultural-level memes. The development of perception and movement leads to the development of the action and behavior level memes. The development process is unique to each individual's developmental environment and is often acquired through trial and error based on "imitation."

The acquired memes are incorporated into the collective behavioral ecology of the group to which they belong. This is effective for the next creative activity within the group. The incorporation of diverse experiences through trial and error into the collective behavioral ecology gives individuals in the group the opportunity to "imitate" them and become the source of new innovations. In the traditional arts, memes are acquired and utilized in the creative activities of the entire field, functioning as a cyclical system of inheritance and continuity. This defines the characteristics of the collective behavioral ecology of the group – RQ-2 and RQ-3.

2) Japanese Traditional Art, "Ceramic Art": In this study, "ceramics" is taken up as a traditional Japanese art form. It is the art of making ceramics by molding clay and firing it at high temperatures. In ceramics, the process consists of imaging the desired form of the object, molding the clay base into the desired form, applying a glassy coating, heating it in a kiln to increase strength, hardening, and fixing the form. It is the activity to be imitated (individual behavioral ecology) that is handed down, and the environment in which imitation is practiced (collective behavioral ecology) enables the inheritance of the imitated activity. The ceramic art process is described below.

a) Master Planning: The first step in ceramic art is to solidify the image of the form.

b) Modeling: It is necessary to remove air from the clay. This process is called "degassing," and is done either by using a vacuum kneader or by hand. After the clay has been degassed and kneaded, it is dried in preparation for firing. There are several stages of drying. At the stage where the clay has a moisture content of approximately 15%, the clay is very firm and not very plastic. Cutting, attaching handles, etc. are often done at this stage. When the moisture content is nearly 0%, the clay is very brittle and easily broken. Before the clay is formed, something can be kneaded into it to create the desired effect in the ware.

TABLE I. STEPS IN THE PRODUCTION OF ARTWORKS OF YUDAI AND MUDAI. THE STEPS INDICATED IN ∗ ARE THE STEPS COMMON TO BOTH WORKS

	YUDAI	**MUDAI**
Artwork	 (a)	 (b)
Work Step	For YUDAI	For MUDAI
Master-Planning	∗ Decide on the rough image of the work ● Decide on the specific title of the work ● Decide on the image of the work that adequately represents the title ● Decide on the number of parts that comprise the work ∗ Decide on the material / Decide on the size	∗ Decide on the rough image of the work ∗ Decide on the material / Decide on the size
Natural-Modeling		● Form the overall shape of a plate-like material by effectively utilizing the gravity field
Modeling	● Create the model you have in mind (if the modeling consists of multiple parts, make that number of parts) with the consideration that it will not break during unglazed-firing ∗ Consider a plan for unglazed-firing	● Modify the overall shape of the foundation according to one's own inspiration to create the final form ∗ Consider a plan for unglazed-firing
Unglazed-Firing	∗ Fire in a kiln according to the unglazed firing plan	∗ Fire in a kiln according to the unglazed firing plan
⇒ *End*		
Coloring *repeat*	● Select a glaze that matches the finished image of the work ● Glaze it ● Considering glazed firing plan	
Glazed-Firing	● Fire in kiln according to glaze firing plan	
⇒ *End*		
Glazing *repeat*	∗ Choose a glaze that is matched to the surface texture of the piece ∗ Glaze ∗ Consider a firing plan that suits the glaze	∗ Choose a glaze that is matched to the surface texture of the piece ∗ Glaze ∗ Consider a firing plan that suits the glaze
Main-Firing	∗ Fire based on the firing plan	∗ Fire based on the firing plan
⇒ *End*		

c) Unglazed-Firing: Firing brings about irreversible changes in the clay. Only after firing does the work become ceramic ware. In low-temperature firing, a change called sintering occurs, in which the coarse powders in the clay fuse with each other contact. For porcelain, where different materials are used and fired at higher temperatures, significant changes occur in the physical, chemical, and mineral properties of the constituents. In both cases, the purpose of firing is to permanently harden the ceramics. The firing method must be consistent with the materials used.

d) Glazing: Glaze is the glassy coating of a ceramic ware. Its main purpose is to decorate and protect. Glaze is applied by sprinkling solids or by spraying, dipping, pouring, or brushing on dilute mixtures of glaze and water. The color of the glaze can be very different before and after firing.

e) Main-Firing: The environmental air of the kiln during firing can affect the appearance of the finished product. An oxidizing environment causes oxidation reactions between the clay and glaze. A reducing environment deprives the clay and glaze surfaces of oxygen. This affects the appearance of the finished piece. By adjusting the kiln environment, complex effects can be produced in glazes.

B. CCE-Step 1-2: Observation of the Super Elite Sample

The second part of CCE-Step 1 takes the ceramics artist as a super elite sample, a singularity in the individual behavioral ecology of ceramics activity, and summarizes his ceramics activity as a structure of individual behavioral ecology. The super elite sample is the ceramic artist "Kazuo Takiguchi," who has been creating ceramics mainly in Kyoto, the center of traditional Japanese art, for a long time, sublimating imagination and meditation activities in ceramic production, and practicing perceptual and motor $M \otimes N$ mapping at a level that cannot be reached by ordinary people. We observed and interviewed him during the process of ceramic production. The results are shown in Table I.

1) Craft Artist "Kazuo Takiguchi": He is one of the leading contemporary ceramic artists in Japan, born in 1953 as the son of a tableware wholesaler in Gojozaka, a traditional ceramic production area in Kyoto. He studied briefly under Rokubei Kiyomizu VI (1901–1980) followed by a brief time under Kazuo Yagi (1918–1979). It was Yagi's aesthetic and focus on non-traditional, sculptural forms that made a lasting impact on him. Years later, he studied at the Royal College of Arts, London and graduated in 1992. Living overseas made him realize the important role the Japanese language played in his life and how it impacted his artwork. Since then, he has focused on words as a source of inspiration. He emphasizes that just as he is free to use language according to his own desires and needs, he endeavors to give each work a presence unique to itself. It is important to him that his works touch the viewers' hearts outside the context of functionality.

2) Description of Kazuo Takiguchi's Production Process: Kazuo Takiguchi has produced two very different groups of works, YUDAI and MUDAI, both extremely different in appearance. Examples of each of these works are shown in Table I. Table I also shows the working process of YUDAI and MUDAI according to the work processes described in Section III-A2.

The most important perception in making clay and creating works of art, especially MUDAI, is the tactile sense of the palm. The palm of the hand can be used to judge a wide variety of conditions, such as dampness/dryness, hardness, the state of the clay joints, and the resistance of the clay to breakage during drying and firing. Kazuo's sculpturing process is both complicated and highly creative. Using pulleys, he first flattens a slab of thinly pounded clay between 1/8-1/4 inches of thick and lays it in a canvas sheet. As shown in Figure 1, with the use of pulleys, he then hoists it and suspends it in the air, molding it into the amoebic form he wishes. After the clay body is dry enough to maintain its shape, he tears open a hole at the top. His ambitiously abstract forms have made him one of the standard-bearers of contemporary Japanese ceramics.

Figure 1. Natural modeling using a canvas sheet.

C. CCE-Step 2: Matching with Brain Properties

In this step, the results of the CCE-Step 1 survey are reviewed from the perspective of individual behavioral ecology. We will perform brain simulations assuming the action-level, behavior-level, and culture-level memes on the cognitive architecture to identify the way the brain works, in a way that best explains the results of the survey. That is, we identify critical parameters that characterize the behavioral ecology of individuals. Brain simulations are based on the cognitive architecture MHP/RT [8][9][10]. In the following, we will give an overview of MHP/RT, focusing on the part related to the identification of critical parameters.

1) Outline of MHP/RT: MHP/RT consists of two components. Figure 2 provides an overview of each component.

a) Perceptual-Cognitive-Motor (PCM) Processes: The first component comprises cyclic PCM processes (Figure 2, left). They execute a series of events in synchronous with changes in the external environment. The parallel distributed processing [1] for realizing these PCM processes is implemented as hierarchically organized bands introduced by Newell [6, Figure 3-3]. These bands are characterized by characteristic operation times, as mentioned in Section I, which are defined by associating relative times with individual PCM processes. Events occur by connecting what happens in a band to what happens in its adjacent band *non-linearly*. A mechanism is required to connect the events; MHP/RT suggests that this connection is provided by *the resonance mechanism* via the MDMFs.

b) Multi-dimensional Memory Frame (MDMF): The second component is the autonomous memory system consisting of five MDMFs, which are perception, motion, behavior, relation, and word MDMFs (Figure 2, right). The MDMFs store information associated with the corresponding autonomous processes defined in the PCM processes. The MDMFs are subservient to the PCM processes because they do not exist unless the PCM processes do.

A copy of MDMFs is shown in Figure 2. This indicates that the memory that has been constructed up to that point is used in the PCM processes. Since both the memory system and the PCM processes are autonomous systems, there is no relationship in which one system subordinates the other. Any active states in the autonomous memory can be used by other autonomous systems through "resonance." This is indicated by the symbol "●—●" in Figure 2.

c) Four Operation Modes: Humans interact with the external environment and select appropriate actions to achieve behavioral goals through a cycle of PCM processes. In MHP/RT, the action selection process is controlled by System 1 and System 2 of Two Minds [12]. 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 II shows the Four

TABLE II. FOUR OPERATION MODES OF MHP/RT AND THEIR RELATIONSHIP WITH THE FOUR BANDS IN THE TIME SCALE OF NEWELL'S HUMAN ACTION [6, FIGURE 3-3]

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.

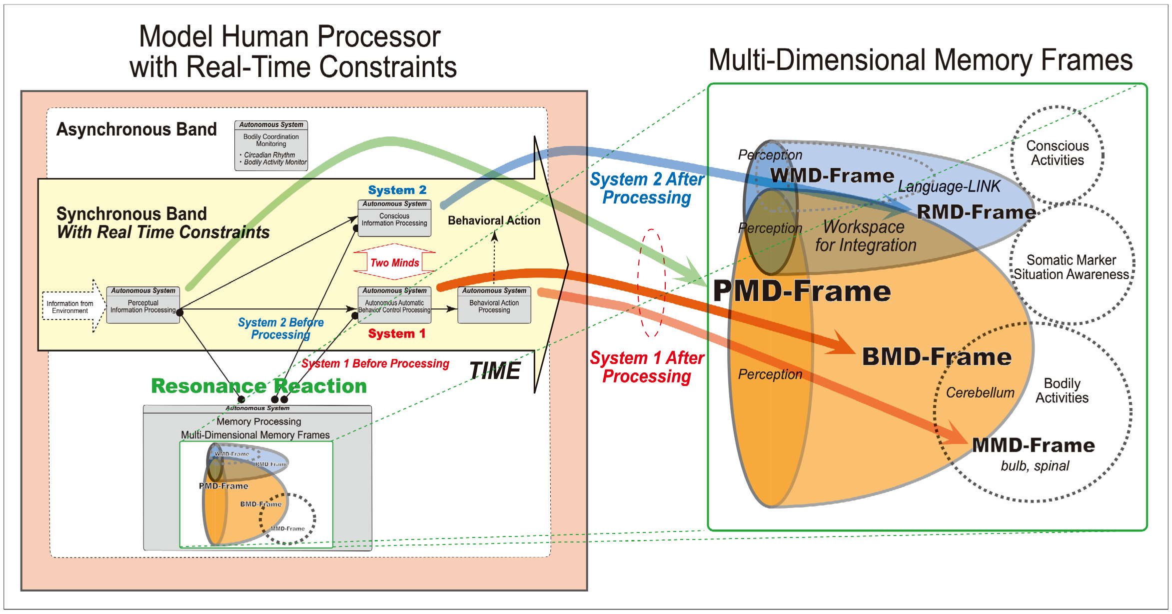

Figure 2. MHP/RT and Multi-dimensional Memory Frame [7, Figure 2].

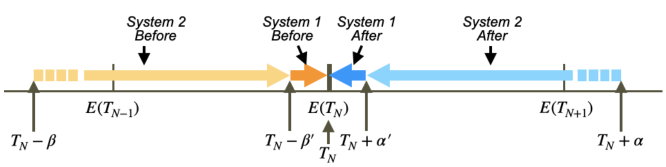

Figure 3. Four processing modes of MHP/RT.

Operation Modes characterized by the relationship between System 1 and System 2. There are synchronous and asynchronous modes. The ceramic work is performed primarily in the synchronous mode.

d) 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.

Before the Event ($T < T_N$)

The event $E(T_N)$ that occurs at time T_N reflects the result of the resonance between MDMFs and the perceptual and cognitive systems during the time before T_N. The part of the system that resonates is indicated by •—• in the left diagram of Figure 2. $E(T_N)$ is generated by the activities of System 1 and System 2 in the time period before T_N. The different time bands of processing activities result in two processing modes before the event:

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

The minimum value of β' is $\sim$ 150msec, and β ranges from seconds to hours and months. In these two modes, the part of MDMFs activated through resonance in response to perceptual processing could resonate with System 1 and System 2 processing (Figure 2, left).

After the Event ($T > T_N$)

When event $E(T_N)$ occurs at time T_N, the result is stored. Actions occur by integrating the resonances that emerge through interacting with the environment prior to the event, and after the actions are taken, they are bundled and collected. The existing MDMFs are updated to reflect the results of $E(T_N)$ by the activities of System 1 and System 2 during the time period after T_N. This process is indicated by the arrows from each element of the PCM cycle shown in the upper left of Figure 2 to the MDMFs in the upper right. The different time bands of processing activities result in two processing modes after the event:

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

The minimum value of α' is $\sim$ 150msec, and α ranges from seconds to months. In these two modes, action selection results for the event at T_N would be reflected in the network connections of the respective MDMFs (Figure 2, right).

2) MHP/RT Simulation of Each Ceramic Process: In this section, we present an MHP/RT simulation of the ceramic process shown in Table I, which is a summary derived from intensive interviews with Kazuo Takiguchi and observations of his work processes. We explain which of the four operation modes MHP/RT operates in, and what kind of processing is carried out regarding the four processing modes with a focus on the memory use represented by the MDMFs. Brief discussions for some work processes concerning the implication of the contents of simulated processes for the individual behavioral ecology of ceramic process follow.

a) Master-Planning: This work process consists of the following steps as shown in Table I.

1) Decide on the rough image of the work.
   – In the case of YUDAI, this step is accompanied by the following steps.
   a) Decide on the specific title of the work.
   b) Decide on the image of the work that adequately represents the title.
   c) Decide on the number of parts that comprise the work.
2) Decide on the material.
3) Decide on the size.

Steps 1, 2, and 3 for MUDAI and YUDAI, and a, b, c for YUDAI, is carried out in Mode 2 of MHP/RT shown in Table II. Each step is essentially a conscious decision-making process for accomplishing the purpose of that step, i.e., forming the rough image of the work, selecting the material, selecting the size, and so on. It starts with an initial idea followed by an evaluation-update cycle of the idea. It terminates when an idea is evaluated satisfactory for the purpose established.

The chart below will be used to schematically illustrate 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. At α, the event is consciously reflected. During the period of $(\beta',\ \alpha')$, unconscious activities related with the event are carried out.

Each Step of Master-Planning in Mode 2

$$(\beta \text{ —— } \beta' -\!*\!- \alpha' \text{ —— } \alpha) \quad \textit{Repeat}$$

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

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 MDMFs proceeds through a series of divergences starting at β', followed by the moment of decision on the updated idea at $*$, and the period for convergences terminating at α'. Afterward, the decision is evaluated at α. The events correspond to the moments when decisions on the rough image of the work, material, size, specific title, and so on, are obtained. This process is repeated until a satisfactory evaluation for the current idea is obtained. The result is "master plan of the work," which consists of a series of images that should appear in the P-MDMF as the results to be achieved in subsequent steps.

The content of the master plan of the work is affected by the extent to which activity is propagated within the MDMFs during the period leading up to it. The individual behavioral ecology of this work process is characterized by the richness of the MDMFs. These steps are carried out by initially placing seeds that represent the initial idea *consciously* in the P-MDMF that ultimately lead to a final decision by means of spreading activation in the MDMFs, which has been constructed through extensive $M \otimes N$ mapping experience; the updated ideas are obtained as activated patterns of the network in the MDMFs centered on P-MDMF. When accompanied by title setting as in the case of YUDAI, the center of *conscious* activity appears in the W-MDMF as well.

b) Natural-Modeling for MUDAI: In this process, the shape is created by modifying the material. The overall shape is formed by effectively utilizing the gravitational field operating on the plate-like material. The reasons for conforming to the gravitational field is to make it resistant during firing and to make maintaining the balance of the overall shape easy. Figure 1 are the photos from the process of natural modeling. The ceramic clay is placed on the suspended cloth to form the shape by utilizing the gravitational field (Figure 1, left). A cone-like piece is attached to the base while maintaining the overall balance (Figure 1, right). It takes a certain amount of time for the materials formed to reach equilibrium in the gravitational field. During that time, the laws of nature govern the change in shape. The Natural-Modeling for MUDAI is carried out solely by hand.

In this process, the state of the material is perceived primarily by sight and touch, and the material is formed into the final model defined by the master plan, by moving one's hands and fingers. Therefore, this process is simulated by MHP/RT's Mode 1, where action selections are carried out mainly by System 1 with timely interventions of System 2.

Natural-Modeling for MUDAI in Mode 1′

$$\beta - \beta' -\!*\!- \alpha' \text{ ———— // ———— } \alpha$$

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

At β, the final modeling is consciously clarified in the MDMFs. Then, a modeling candidate is placed in the P-MDMF for each piece of the work, followed by $M \otimes N$ mapping from there into the MDMFs to have the M-MDMF get activated, which specifies hands' movements for modeling. Unconscious $M \otimes N$ mapping is carried out during the period of $(\beta',\ *)$ for making decisions on the modeling and accomplishing it at $*$. After completion of modeling at $*$, the form changes according to the laws of nature.

After a certain amount of period shown by —//— , the result of the work will be evaluated at α by System 2. During the period $(*,\ \alpha)$, two things happen before the shape of the material is established at α as its equilibrium. The shape of material changes in the gravitational field due to the weight of the self, and simultaneously, the moisture content of the material gradually decreases and the material becomes harder and less deformable. There might exist discrepancies between the final modeling imagined at β and the resultant modeling obtained at α. By integrating the traces of spreading activation from β to $*$ for modeling and the evaluation result at α, the MDMFs, which can be used in the $M \otimes N$ mapping for the future Natural Modeling step, is updated. The four processing mode characterized by this pattern will be called Mode $1'$.

c) Modeling: The purpose of this step is to create the modeling manually that will not break in the next process, Unglazed-Firing. For MUDAI, the result of Natural Modeling is finalized. For YUDAI, the pieces are assembled together to accomplish the plan. At β, a candidate of modeling is placed consciously in the P-MDMF. Then, $M \otimes N$ mapping is carried out during the period of $(\beta',\ *)$ to obtain a candidate movement of hands in the M-MDMF at $*$ for creating the model defined in the master plan. During the period of $(*,\ \alpha')$, the result of candidate movement, which is virtual, plays the role of a seed in the P-MDMF to spread activation in the MDMFs, to make a judgement at α whether the final modeling defined in the master plan of the work would be obtained after the next step, Unglazed-Firing. This updating process is repeated until a satisfactory one is obtained. The satisfactory one is carried out at $*$, followed by conscious reflection of the work at α including what will be obtained after the next step, Unglazed-Firing. The satisfactory modeling is carried out at $*$ according to the active M-MDMF. The four processing mode characterized by this pattern will be called Mode $1''$.

Modeling in Mode $1''$

(β – β' ——//——$*$——//—— α'– α) *Repeat*

- β: Consciously think of the finished form of modeling.
- β': Spread activation in the MDMFs.
- $*$: Create a form as a candidate for the finished form of modeling.
- α': Organize activation in the MDMFs.
- α: Imagine the results of unglazed firing for the finished form of modeling.

d) Unglazed-Firing: Upon completion of Modeling, the result of the expected Unglazed-Firing process is activated in the P-MDMF. From there, the MDMFs involved in the Unglazed-Firing are also activated. The Unglazed-Firing plan appears as an activity pattern in the W-MDMF, R-MDMF, and B-MDMF. In these MDMFs, the activation patterns come from the P-MDMF that resonates with the results of Modeling, providing the basis for conscious reasoning by System 2. Firing is a process in which heating the clay causes irreversible changes in the physical, chemical, and mineralogical properties of the constituents, just as gravity works in Natural-Modeling. The firing plan, carried over from Modeling, activates the M-MDMF within the MDMFs to perform Unglazed-Firing. It takes time to obtain the results of Unglazed-Firing. The process is similar to Natural-Modeling carried out in Mode $1'$.

e) Coloring for YUDAI: This step is executed only in the case of YUDAI production. The process is carried out in Mode $1''$ similar to Modeling. The subject of Modeling is to form the shape while considering the next step, Unglazed-Firing; the subject of Coloring for YUDAI is to put color with the consideration of the next step, Glazed-Firing.

f) Glazed-Firing for YUDAI: This step is executed only in the case of YUDAI production. Its process is similar to that of Unglazed-Firing. The process is carried out in Mode $1'$.

g) Glazing: This step consists of the following sub-steps: choosing a glaze that is matched to the surface texture of the piece, glazing, and considering a plan for Main-Firing that suits the glaze. The process is carried out in Mode $1''$.

h) Main-Firing: The firing plan that has been activated in Glazing is executed. Whether the kiln air environment during firing is oxidizing or reducing causes irreversible changes in the appearance of the fired piece. It takes time to obtain the results of the firing according to the firing plan. The process is carried out in Mode $1'$.

D. CCE-Step 3: Structural Modeling

Based on the considerations in CCE-Step 1 and 2, we can construct *a simplified individual behavioral ecological model of the surveyed space* that explains the differences among people acting in the collective behavioral ecology of that space. The results of the simulation by MHP/RT for each of the ceramic steps shown in CCE-Step 2, we can see that the unconscious spreading activation in the MDMFs by System 1 affects the performance of each process. Except for Master-Planning, MHP/RT operates in Mode 1. The following patterns characterize the way of operation.

Operation patterns

Mode $1''$
A: (β – β' ——//——$*$——//—— α'– α) *Repeat*

Mode $1'$
B: β – β' –$*$– α' ————-//———— α

Similarity between the patterns is the upcoming event $*$ is consciously processed by System 2 and the event that has occurred is consciously evaluated by System 2. In doing so, the part of the $M \otimes N$ mapping that was active during the period of $(\beta,\ \alpha)$ is made consciously available for future processing by System 2 at α. The contents of the MDMFs to be integrated at α will differ depending on where the event $*$ is located in relation to β, β', α' and α. Nevertheless, the contents that diverged during $(\beta,\ *)$ converge during $(*,\ \alpha)$, and the whole is organically related and integrated.

The characteristics of the way of operation can be summarized as follows. In Pattern A, processing by System 1 is performed for a long time before and after the event. In Pattern B, processing by System 2 is performed after a long time after the event. In Pattern A, System 1 executes imaginative and meditative activities by activating a variety of possible pathways of $M \otimes N$ mappings within the MDMFs, constructed through years of experience. How divergence and convergence are executed over time influences the ceramic activity.

E. CCE-Steps 4 and 5: Super Elite Sample

Unlike the usual CCE survey, in this study, Kazuo Takiguchi, a ceramic artist, practicing an inherited traditional art form, was identified as a super elite sample, and a field survey through observation and interviews were already conducted as the CCE-Step 1-2. The results are presented in Table I.

F. CCE-Step 6: Match against Characteristics

Two operating patterns, Patterns A and B, were identified in CCE-Step 3. They characterize how the MDMFs should be used in the respective steps. By checking that these patterns match the actually observed ceramic activity of Kazuo Takiguchi, RQ-1 and RQ-4 will be addressed.

1) Hierarchical Mapping Structure: Based on the results of the observations and interviews of Kazuo Takiguchi, the production process is summarized in the lower part of Table I. In each step, it was evident that the appropriate timings for starting, change in condition, and ending were applied; these were acquired empirically through repeated production activities. It was possible to identify the actually applied work conditions that should produce the desired results by memorizing the points indicating the changes within the perceivable range and their superficial changes through observation of the process of work, and comparing what has been memorized with the results after the work.

This is shown schematically in Figure 4(a). The left side of the figure shows the manipulated object, **O**, and the right side shows the artist, **A**, which is Kazuo Takiguchi. **A** executes the following processes:

1) Observe **O** under consciousness (OBJECT-Cognition-2), and 1) become aware of the timing to start the execution of work, 2) become aware of the conditions for changing and updating the work content that has been started, and 3) become aware of the conditions for ending the work. This is executed by System 2.
2) Execute the contents that have been made conscious by activating the work sequences that have been acquired through training. Execution is done by perceiving the state of **O** with the five senses (OBJECT-Cognition-1) and applying the appropriate exercise to **O**. This is done by System 1.

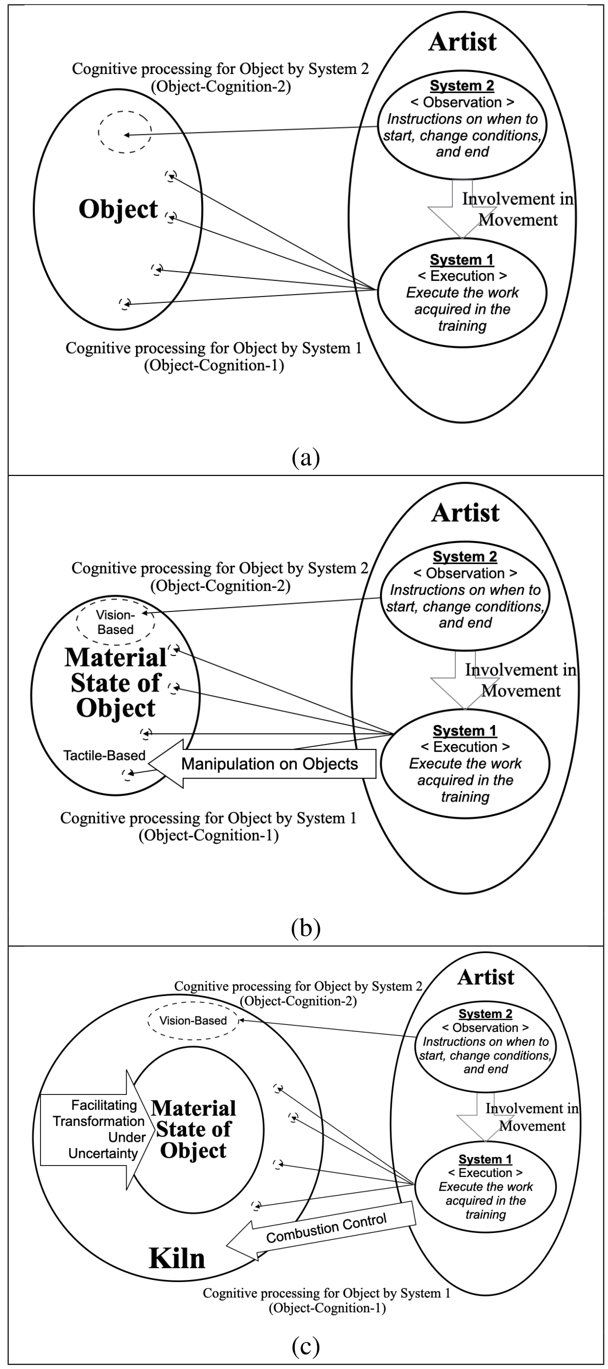

Figure 4. (a) hierarchical mapping structure characterized by $M \otimes N$ mapping; (b) changes in material state due to object manipulation in Modeling, Coloring, and Glazing; (c) changes in material state due to environmental manipulation in Natural-Modeling and Unglazed-, Glazed-, and Main-Firing.

The work is stored as an experience of System 1 and System 2, and influences future work.

The way in which each work step is carried out is well aligned with the four processing modes of the MHP/RT, each of which is carried out during the periods of $[\beta,\ \beta')$, $[\beta',\ *)$, $(*,\ \alpha']$, and $(\alpha',\ \alpha]$. Considering the activities performed in the respective four periods, they are represented by the following two hierarchical mapping structures.

2) Hierarchical Mapping Structure of Transformation caused by OBJECT Manipulation: When an operation is applied to **O**, it changes according to its contents. This is related to the steps of Modeling, Coloring, and Glazing shown in Table I. What is happening in these steps is shown schematically in Figure 4(b). The current state of **O** is mainly perceived visually (with the help of tactile sense), and the immediate aim is to reach the final goal and the contents of operations to reach it are selected and decided by System 2 through the experience accumulated thus far (OBJECT-Cognition-2). Based on this decision, **A** perceives the state of **O** mainly through the tactile sense and perceives the progress of the operation by System 1 (OBJECT-Cognition-1) while moving his limbs to interact with **O** to change it. Once the immediate goal is achieved, the next goal is set and this process is repeated until the final goal is achieved. The way these work processes proceed is well matched to Pattern A.

3) Hierarchical Mapping Structure of Transformation caused by Environmental Change: In the steps to perform the firing in Table I, Natural-Modeling and Unglazed-, Glazed, and Main-Firing, the objects created due to the direct transformation of the objects in the preceding steps are irreversibly transformed and fixed by the application of gravitational field or firing environment in the kiln. What is happening in this process is shown schematically in Figure 4(c). The following provides an explanation for the firing process, which can be applied to Natural-Modeling as well. The current state of **O** is perceived visually, and the firing parameters that realize the firing environment in the kiln to reach the final goal are selected and determined by System 2 using the experience accumulated (OBJECT-Cognition-2). Based on this decision, the kiln is adjusted for firing and firing is started. Firing is an unpredictable and uncertain process. During firing, the state of the kiln is recognized by System 1 via all five senses (OBJECT-Cognition-1) and integrated with previous experiences as a new experience. This way of proceeding with the work process is well matched with Pattern B.

IV. Conclusions

This study focused on ceramics, a traditional Japanese craft, and investigated the memes that make it a traditional craft by conducting a CCE survey with a ceramist as a super-elite monitor. In ceramics, the manipulation of objects that are malleable and whose properties change with time and the setting of firing conditions that produce irreversible physical and chemical changes in the clay and glaze, are performed. In both cases, the initial image is placed in the P-MDMF and the activity is propagated in the MDMFs, which are constructed with extensive experience as memes, to simulate whether or not a work that matches the final image is obtained. When time constraints are strong, the richness of the MDMFs related to System 1 can be an effective help. The quality of the memory is important for the experiential content during the training period. Tradition can be understood as a generic term referring to the results of improving the content quality of one's training over a long period of time.

In the West, there is a strong emphasis on logical thinking by System 2, seeking eternity and finding laws in nature. Based on this way of thinking, they have discovered objectivity, the golden ratio, perspective, and so on, and have applied them to their creations. In modern times, this attitude can be seen in the cubism of Picasso, for example. On the other hand, in Japan, as revealed in this study, there is a tendency to devise pseudo-expressive methods to express what one truly wants to express, based on the experiential perception obtained from interacting with the natural world. This can be seen in ink paintings and ukiyoe.

Acknowledgement

In this study, Kazuo Takiguchi kindly agreed to be interviewed about the inner aspects of the ceramic process, which could be observed superficially, and provided us with valuable information. He confirmed the results of the application of CCE. Without his cooperation, this study would not have been possible. We would like to express our deepest gratitude to him. This work was supported by JSPS KAKENHI Grant Number 20H04290. The authors would like to thank Editage (www.editage.com) for the English language editing.

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