Analysis of Sensory Impression Factor Structures of Jomon Potteries through a Semantic Differential Method Viewing 3D Models on MR equipment

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***Abstract*—As Jomon pottery is perceived more as formative art rather than as archaeological artifacts by museum visitors, it is of interest to study the sensory impressions that modern people have of Jomon pottery, including flame-like pots. A sensory impression test utilizing 3D models of pottery on Microsoft HoloLens was conducted with 73 participants, who rated 16 sensory adjectives using the Semantic Differential Method. Factor analyses and analyses of variance were performed on these adjective groups, identifying factors such as "vigor," "attractiveness," "surface smoothness," and "weight." Okinohara and Umataka types consistently scored significantly higher on "vigor" (the firstfactor) and "attractiveness." The complete matching of two typological groups on sensory impressions and spatial cognitions implies a commonality between them.**

Keywords— sensory impression, Jomon potteries, Semantic Differential Method, factor analysis, analysis of variance, cognitive mind, spatial cognitions

I. INTRODUCTION

a Shinano River and the Jomon People

The Shinano River, sourced from Mount Kobushigatake on the borders of Nagano, Saitama, and Yamanashi Prefectures, flows through the Saku Basin, Ueda Basin, and Nagano Basin as the Chikumagawa in Nagano Prefecture. Upon merging with the Sai River in Nagano City, originating from Mount Yarigatake, it assumes the name Shinano River and continues to flow into the Sea of Japan at the border of Niigata Prefecture. As Japan's longest river, it spans a total length of 367 kilometers. The Jomon people, who settled in these basins 13,000 years ago, began producing pottery. Numerous archaeological sites from this era are densely concentrated in the upper reaches of the Shinano River basin [1].

b Emergence of flame-like pots in a Snowy Environment

Approximately 8,000 years ago, a significant environmental change occurred with the advent of a warm current flowing into the Sea of Japan, leading to increased snowfall. This snowy environment persisted, and around 5,000 years ago, during the middle Jomon period, flame-like pots emerged. Characteriszed by designs and forms that evoke vigorous flames, flowing water, and waves, this pottery style is remarkably expressive. A distinctive feature of middle Jomon period potteries in the Shinano River basin are the presence of protrusions, most notably exemplified by flame-like pots adorned with four particularly bold protrusions, which represent a hallmark of the era [1].

Flame-like pot appears to be perceived as a formative art rather than archaeological artifact by museum visitors. Therefore, studying the sensory impressions of modern individuals regarding Jomon potteries, including flame-like pots, is of significant interest.

c Spatial Cognition of the Jomon People and Potteries

Archaeologist and anthropologist Kobayashi Tatsuo (1996) proposed spatial cognitive differences between the Jomon people and modern societies. He described houses as "rather holy container spaces," a concept perceived as such by the Jomon people [2].

Ishii (2010) further developed anthropological hypotheses on the spatial recognition of ancient Jomon people, defining cultural spaces during the Jomon period. He expanded upon Kobayashi Tatsuo's hypothesis, focusing on the "container nature" of space and analyszing the structure of spatial cognition and the symbolism of human-made spaces in the Jomon period, encompassing "houses," "villages," "monuments," and earthenware spaces [3].

Building on these hypotheses, Ishii suggested that Jomon potteries represent micro spaces reflecting the sensibilities and sensory impressions of the pottery makers.

d Commonalities of cognitive processes and mind structures

"Cognitive Archaeology, Body Cognition and Evolution of Visuospatial Perception" (2023) [4] illustrated how body perception and spatial sensing might have evolved in humans, which suggests both body perception and spatial sensing have commonalities among human beings.

Matsumoto (2000) [5] used the theory and methods of cognitive archaeology to argue that the mind and body have had developed together in the course of human evolution, and therefore the structure of the mind should be considered to be common to the same extent as the structure of the human body. She also claimed that there was a certain degree of universality in human cognitive processes and cognitive structures, and that the same models and conceptual frameworks could be applied across differences in culture and social structure.

e Cognitive mind of Jomon people represented in earthenware

Abstract thinking is considered one of the characteristics of modern humans, Homo sapiens. Archaeological evidence includes ornaments like shell beads from the Skhul Cave in Israel, which may date back around 100,000 years, as well as widely known Paleolithic sculptures, such as the Lion Man and Venus figurines, found across Europe and Eurasia.

Though no cave paintings have been discovered from the Paleolithic or Jomon periods of the Japanese archipelago, there are artifacts believed to be stone and clay figurines and ornaments, which suggest that this population was part of the widespread dispersal of Homo sapiens. In particular, clay figurines (dogu) from the Jomon period are significant as they consistently appear, though in varying quantities, from the earliest stages of the period and then dramatically decrease and disappear by the Yayoi period. Thus, dogu can be seen as artifacts reflecting the unique cognitive minds of the Jomon period. Dogu is a general term for human-shaped clay artifacts, and in the early stages, only the torso was represented.

However, around 5,000 years ago, complete bodies and faces began to be depicted. On the other hand, even when faces were included, features such as eyes, noses, and mouths were not always depicted, and sometimes hands, arms, legs, and feet were left unrepresented or were rendered with three fingers. Furthermore, modern sensibilities often find the expression of the eyes, nose, and mouth to be bizarre. During the time these characteristics of dogu became evident, changes in the design of Jomon pottery were also observed, with more prominent protrusions and three-dimensional patterns. These protrusions were sometimes expressed on faces or had human-like patterns applied to the surface of the pottery. In some cases, there were even shapes where triangular clay plates, possibly dogu or a type of dogu, were attached to the rims of vessels. However, a method to analys~~z~~e and distinguish the relationship between these design characteristics and human cognition, as well as the shared or inherited design features within a group or across regions, ha~~ve~~s not yet been developed.

f Quantitative approach of sensory impression factor structure, Semantic Differential method

The Semantic Differential (SD) method, which involves presenting numerous pairs of simple sensory impression adjectives such as "beautiful-ugly," is a commonly used technique in psychological testing for extracting sensory impressions that arise when people observe objects. Subjects rate these adjective pairs on a scale, allowing for sampling of sensory impressions using individual linguistic adjective pairs. This provides primary data for analys~~z~~ing how people perceive objects as stimuli. Typically, the SD method uses over 20 adjective pairs, resulting in a large sampling of sensory impressions. Factor analysis is then employed to group adjectives with commonalities, compressing the dimensionality of the factors. Names are assigned to the extracted adjective groups, and the factor structure is interpreted (Suzuki & Gyoba, 2003)[6].

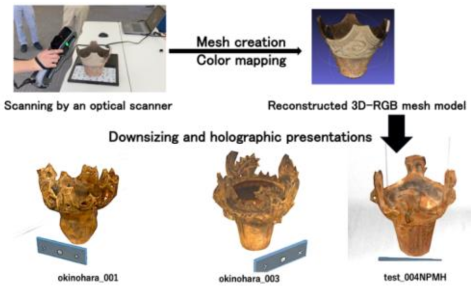

Figure 1 Jomon pottery hologram processing

II. Research Questions and Objectives of This Study

One of the research questions is if cognitive structures and body perception can be measured by MR equipment, using verbal words (adjective scales) and selections of impressive vessel parts. If the methods are unsuitable or insufficient for observing cognitive structures and body perception, what else should be measured? Should the subjects' verbal expressions of their sensations or bodily awareness be considered, or perhaps gaze tracking?~~If the methods are not suitable or not enough for the cognitive structure and body perception observation, what else we have to measure, oral expressions of those subjects themselves on impressible feelings or vessel parts, or gaze tracking?~~

Another question is whether the perception and cognitive understanding of modern people regarding Jomon earthenware are the same as those of the Jomon people, who lived approximately 5,000 years ago.~~Another question is if the perception and cognitive mind of modern people on Jomon earthenware are the same as ofJomon people, who lived approximately 5000 years ago.~~

The last question is whether, if parameters or data related to sensory impressions or the cognitive mind are successfully extracted through a data science approach, it is possible to represent the cognitive mind using deep learning models. ~~The last question is if we successfully extract parameters or data of sensory impression or something related to cognitive mind by data science approach, is it possible to represent the cognitive mind by deep learning models?~~

This is a preliminary study, focusing on subjects' response of sensory impression, to ancient artifacts, highlighting on middle Jomon potteries, using MR equipment. This study is aimed at obtaining basic information of subjects' perception and cognitive response, ~~-~~prior to a study, to represent cognitive mind by deep learning models applying a huge amount of material data and human cognitive response data, such as gaze heatmaps, using MR equipment.

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III. METHODOLOGIES

a Hologram Preparations

Eight Jomon potteries from the Middle Jomon Period, including two Flame-like pots and a Sue ware from the 6th century AD, were optically scanned using the Go!Scan 3D scanner from Creaform at a resolution of 0.05 mm. The scanner is equipped with three shape-tracking cameras, one color camera, and one white light projector, which collectively ~~generate~~generates mesh data containing color and texture information via VXelements software. Subsequently, the mesh data with color and texture information was exported in the OBJ file format. These nine pottery files were then downsized, and the color and texture maps were re-baked using Blender CG software for display on Microsoft HoloLens (Figure 1). The nine potteries are listed as follows:

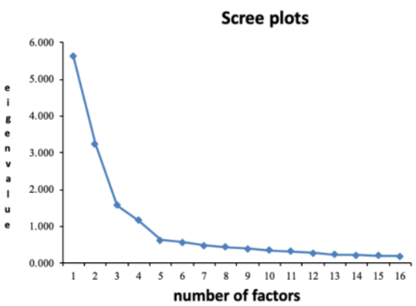

Figure 2 Scree plots of Semantic Differential Method

Table 1: Potteries used for the experiment with typologies

No.	Sample ID	Typology
1	Oki_001	Okinohara, Coil Building
2	Oki_002	Okinohara, Coil Building
3	Oki_003	Umataka (flame-like pot), Coil Building
4	test001	Upper Ento, Coil Building
5	test002	Umataka (flame-like pot), Coil Building
6	test003	Umataka (crown-like pot), Coil Building
7	test004	Umataka (crown-like pot), Coil Building
8	test005	Katsusaka, Coil Building
9	J-7606	Sue Ⅱ-2, Wheel Forming

b Sensory Impression Experiment and statistical analyses

The experiment was conducted on July 11 and 13, 2023, in an experimental laboratory at Niigata University of International and Information Studies. Three Microsoft HoloLens devices were used. Visibility, with special attention to color differences, was adjusted among those MR devices. Three parallel holographic exhibitions were set up, labeling 9 sample names in one line on the floor, and downloading hologram contents of potteries on top of those labels. Heights and sizes were adjusted manually. Thus, nine pottery items were arranged in three rows. However, each HoloLens only displays holograms that have been downloaded.

The sensory impressions of the nine potteries were measured using the Semantic Differential Method. Sixteen adjectives were referenced and chosen from 20 adjectives in a study on sensory impressions of words and drawings (Suzuki and Gyoba, 2003)[7].

The 16 adjectives were as follows:

- Beautiful-Ugly
- Pleasant-Unpleasant
- Likable-Repugnant
- Light-Heavy
- Cheerful-Gloomy
- Lively-Quiet
- Dynamic-Static
- Flashy-Modest
- Intense-Calm
- Powerful-Feeble
- Strong-Weak
- Soft-Hard
- Smooth-Rough
- Blunt-Sharp
- Relaxed-Tense
- Delicate-Rugged

Five scale ranges from "very applicable" to "strongly not applicable," were set each adjective, and 73 subjects chose an applicable scale each adjective. The results were analys~~z~~ed by HAD, a statistical macro script [6] using Factor Analysis with maximum likelihood extraction, Promax rotation (Power=4), and Kaiser normalis~~z~~ation. Analysis of variance was then conducted on the mean factor scores of the nine pottery items to explain variations in impression factors.

On top of the SD method of sensory impression measurements by those verbal adjectives, a measurement of impressive partial selections was made. This is asking those subjects. the impressive parts of the objects from the following parts, rim of the vessel, body of the vessel, bottom of the vessel, upper part of the vessel, lower part of the vessel, the whole vessel, inside of the vessel, and no particular part impressed. Frequencies of the choices of the above ~~choices~~ were calculated and compared~~ison among those potteries was made.~~

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"This asks the subjects about the most impressive parts of the objects from the following: the rim of the vessel, the body of the vessel, the bottom of the vessel, the upper part of the vessel, the lower part of the vessel, the whole vessel, the inside of the vessel, or no particular part being impressive. "

IV. RESULTS

The Scree plots are graphical presentations of factor variance plotted against the number of factors, used to determine the optimal number of factors before conducting factor analysis. Figure 2 depicts the Scree plots of the Semantic Differential (SD) method using 16 sensory impression adjectives. The lines show a sudden decrease at three factors, followed by four factors, both with eigenvalues exceeding 1.0. Therefore, three factors and four factors were selected for the factor analysis.

a Factor Analysis with Three Factors

The results are presented in Table 2. Three factor groups were derived from the sixteen adjectives based on factor load values greater than 0.448, as shown in Table 2.

Table 3 presents the results of the four-factor analysis. The first factor (referred to as "Factor1") was labeled "vigor," encompassing adjectives such as "dynamic/static," "lively/quiet," "flashy/modest," "intense/calm," "cheerful/gloomy," "powerful/feeble," and "strong/weak." The second factor was termed "attractiveness," representing adjectives like "beautiful/ugly" and "likable/repugnant."

The third factor was named "surface smoothness," capturing adjectives such as "smooth/rough," "relaxed/tense," "soft/hard," "blunt/sharp," "delicate/rugged," and "light/heavy.

Table 2 Factor analysis with three factors

samples = 657 variables = 16 factors = 3

extraction method = maximum likelihood
rotational method = promax rotation (Power = 4)
Kaiser normalization = Y

factor patterns

number of iterations = 6
convergence criterion = 0.0002

	vigor	attractive ness	surface smoothness	
SD adjective pairs	Factor1	Factor2	Factor3	Commonality
dynamic/static	**.932**	-.133	.082	.744
lively/quiet	**.924**	-.120	.117	.726
flashy/modest	**.879**	.012	-.025	.794
intense/calm	**.833**	.006	-.094	.748
cheerful/gloomy	**.645**	.110	.205	.468
powerful/feeble	**.600**	.177	-.114	.529
strong/week	**.579**	.165	-.150	.509
pleasant/unpleasant	-.060	**.915**	.052	.805
beantiful/ugly	.002	**.841**	.010	.710
likable/repugnant	.143	**.739**	.003	.660
smooth/rough	-.121	-.030	**.777**	.667
relaxed/tense	-.061	-.013	**.713**	.533
soft/hard	.226	-.009	**.683**	.435
blunt/sharp	-.036	-.040	**.679**	.473
deliate/rugged	-.100	.251	**.494**	.343
light/heavy	.137	.016	**.448**	.192
factor contributions	5.054	3.219	2.885	

fitness				
	Deviation =	0.829	CFI =	.923
	χ^2 =	537.062	RMSEA =	.098
	DF =	75	AIC =	633.832
	p =	.000	BIC =	835.778

reliability coefficient *α and ω coefficients are calculated from items in bold (negative loads are reversed)

	Factor1	Factor2	Factor3
α coefficients	.918	.880	.792
ω coefficients	.926	.885	.809
factor scores	.937	.896	.835

Reliability coefficient when not reversed

	Factor1	Factor2	Factor3
α coefficients	.918	.880	.792
ω coefficients	.926	.885	.809

Inter-factor correlation

	Factor1	Factor2	Factor3
Factor1	1.000	.437	-.258
Factor2	.437	1.000	.089
Factor3	-.258	.089	1.000

Factor structure (correlation coefficients with factors)

SD adjective pairs	Factor1	Factor2	Factor3
dynamic/static	.853	.281	-.171
lively/quiet	.841	.294	-.132
flashy/modest	.891	.394	-.251
intense/calm	.860	.362	-.309
cheerful/gloomy	.640	.410	.048
powerful/feeble	.707	.430	-.253
strong/week	.690	.405	-.285
pleasant/unpleasant	.326	.893	.149
beantiful/ugly	.367	.842	.084
likable/repugnant	.465	.802	.032
smooth/rough	-.335	-.014	.805
relaxed/tense	-.250	.024	.727
soft/hard	.045	.151	.624
blunt/sharp	-.229	.004	.685
deliate/rugged	-.118	.251	.542
light/heavy	.029	.116	.414

Table 3 Factor analysis with four factors

samples =	657	variables =	16	factors =	4

extraction method = maximum likelihood
rotational method = promax rotation (Power = 4)
Kaiser normalization = Y

factor patterns

number of iterations = 5
convergence criterion = 0.001

	vigor	attractive ness	surface smoothness	weight	
SD adjective pairs	Factor1	Factor2	Factor3	Factor4	Commonality
lively/quiet	**.955**	-.096	-.016	.190	.761
dynamic/static	**.947**	-.115	-.024	.125	.757
flashy/modest	**.857**	.018	-.060	-.021	.784
intense/calm	**.804**	-.014	-.059	-.148	.760
cheerful/gloomy	**.678**	.158	.034	.284	.528
powerful/feeble	**.527**	.105	.096	-.477	.715
pleasant/unpleasant	-.101	**.934**	.031	.019	.799
beantiful/ugly	-.039	**.868**	-.019	.024	.712
likable/repugnant	.111	**.774**	-.050	.058	.668
blunt/sharp	-.043	-.105	**.785**	-.110	.573
smooth/rough	-.111	-.048	**.749**	.100	.667
relaxed/tense	-.060	-.042	**.722**	.036	.556
soft/hard	.246	.011	**.558**	.238	.430
delicate/rugged	-.111	.248	**.472**	.059	.342
light/heavy	.221	.103	.167	**.584**	.399
strong/week	.504	.086	.073	**-.509**	.715
factor contributions	5.060	3.371	2.738	1.929	

fitness				
	Deviation =	0.223	CFI =	.986
	χ^2 =	144.445	RMSEA =	.046
	DF =	62	AIC =	262.417
	p =	.000	BIC =	522.702

reliability coefficient *α and ω coefficients are calculated from items in bold (negative loads are reversed)

	Factor1	Factor2	Factor3	Factor4
α coefficients	.912	.880	.809	.358
ω coefficients	.934	.886	.831	.623
factor scores	.936	.898	.834	.622

Reliability coefficient when not reversed

α coefficients	.912	.880	.809	-.557
ω coefficients	.934	.886	.831	.414

Inter-factor correlation

	Factor1	Factor2	Factor3	Factor4
Factor1	1.000	.478	-.178	-.325
Factor2	.478	1.000	.139	-.172
Factor3	-.178	.139	1.000	.318
Factor4	-.325	-.172	.318	1.000

Factor structure (correlation coefficients with factors)

SD adjective pairs	Factor1	Factor2	Factor3	Factor4
lively/quiet	.850	.326	-.138	-.109
dynamic/static	.856	.313	-.168	-.170
flashy/modest	.883	.423	-.216	-.322
intense/calm	.856	.388	-.251	-.426
cheerful/gloomy	.655	.438	.026	.047
powerful/feeble	.715	.452	-.135	-.636
pleasant/unpleasant	.334	.887	.185	-.099
beantiful/ugly	.372	.843	.116	-.120
likable/repugnant	.471	.810	.056	-.127
blunt/sharp	-.197	.003	.743	.172
smooth/rough	-.300	-.014	.794	.383
relaxed/tense	-.220	.023	.739	.293
soft/hard	.074	.165	.592	.334
delicate/rugged	-.095	.251	.545	.203
light/heavy	.051	.131	.328	.547
strong/week	.698	.425	-.167	-.665

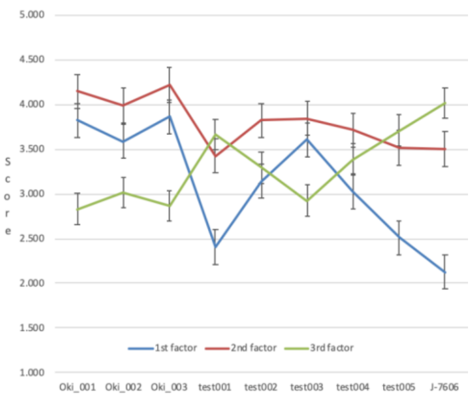

Figure 3 Three Factor Score Variations in Potteries

Table 4 Factor load scores of potteries

Interaction P value =	.000	**		
	1st factor	2nd factor	3rd factor	
Oki_001	3.820	4.146	2.831	**
Oki_002	3.587	3.986	3.016	**
Oki_003	3.861	4.215	2.861	**
test001	2.407	3.425	3.660	**
test002	3.139	3.822	3.292	**
test003	3.605	3.845	2.925	**
test004	3.027	3.712	3.384	**
test005	2.507	3.516	3.708	**
J-7606	2.127	3.502	4.011	**

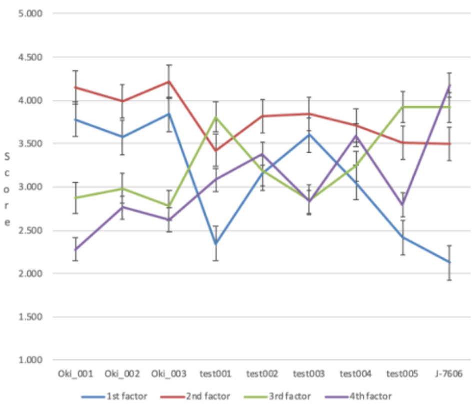

Figure 4 Four Factor Score Variations in Potteries

Table 5 Factor load scores of potteries

Interaction P value =	.000	**			
	1st factor	2nd factor	3rd factor	4th factor	
Oki_001	3.781	4.146	2.874	2.281	**
Oki_002	3.575	3.986	2.984	2.760	**
Oki_003	3.838	4.215	2.784	2.623	**
test001	2.347	3.425	3.805	3.082	**
test002	3.153	3.822	3.186	3.384	**
test003	3.598	3.845	2.849	2.829	**
test004	3.050	3.712	3.244	3.596	**
test005	2.418	3.516	3.923	2.795	**
J-7606	2.128	3.502	3.918	4.178	**

	Okinohara Oki_001	Okinohara Oki_002	Umataka Oki_003	Upper Ento test001	Umataka test002	Umataka test003	Umataka test004	Katsusaka test005	Sue ware J-7606
rim	36	29	34	7	31	30	31	18	10
upper part	41	35	40	6	30	34	28	17	4
lower part	3	10	7	14	6	11	10	9	3
bottom	3	5	3	3	4	4	2	2	5
whole vessel	4	6	9	35	9	13	11	32	36
inside vessel	7	7	11	8	5	4	6	6	12
not particularly	1	2	2	13	7	4	10	6	15

Table 6 Frequencies of impressed parts of vessels

b Factor Analysis with Four Factors

The first factor was labeled "vigor," representing adjectives such as "lively/quiet," "dynamic/static," "flashy/modest," "intense/calm," "cheerful/gloomy," and "powerful/feeble. The second factor was named "attractiveness," representing adjectives like "pleasant/unpleasant," "beautiful/ugly," and "likable/repugnant."

The third factor was termed "surface smoothness," encompassing adjectives such as "blunt/sharp," "smooth/rough," "relaxed/tense," "soft/hard," and "delicate/rugged." The fourth factor was named "weight," representing adjectives such as "light/heavy" and "strong/weak."

c Analysis of Variance of Potteries on Three Factors

Table 4 presents the factor load scores of the potteries, and Figure 3 illustrates the variations among potteries across three factors.

In terms of typologies, all Okinohara types (Oki_001 and 002) and Umataka types (Oki_003, test002, test003, and test004) showed significantly higher scores for "vigor" (first factor) exceeding 3.0, and scores for "attractiveness" (second factor) exceeding 3.7.

On the other hand, test001, test005, and J-7606 exhibited significantly lower scores in the first factor. Figure 7 displays symmetric patterns between the first and third factors, "vigor" and "surface smoothness." Therefore, significantly higher scores were observed for test001, test005, and J-7606 in the third factor.

d Analysis of Variance of Potteries on Four Factors

Table 5 presents the factor load scores of the potteries, and Figure 4 illustrates the variations among potteries across four factors.

All Okinohara types (Oki_001 and 002) and Umataka types (Oki_003, test002, test003, and test004) exhibited significantly higher scores for "vigor" (first factor) exceeding 3.0 and scores for "attractiveness" (second factor) exceeding 3.7 (consistent with the results of the analysis of variance on three factors). The factor load scores of the third factor displayed symmetric patterns similar to those of the first factor (matching the results of the analysis of variance on three factors).

The factor load scores for the fourth factor, "weight," exhibited a different pattern compared to that of the third factor. The second highest load score was observed in test004, followed by J-7606, while significantly lower load values were found in test005.

e Comparison of impressive parts of potteries

Table 6 presents the frequencies of impressed parts selected by those subjects. There are two clear groups of potteries in terms of impressed parts; all Okinohara and Umataka types showed highly impressive in rim and upper parts of vessels, while other three types showed high impressiveness on whole vessels.

V. DISCUSSIONS

a Sensory Impression factor structures

The results indicated that both Okinohara and four Umataka potteries (including two flame-like pots) yielded significantly higher impressions of "vigor" and "attractiveness" compared to other Jomon potteries and Sue ware. Conversely, the significantly lower scores of these six potteries in the third factor suggested stronger impressions of "roughness" as opposed to "smoothness". The scores of these nine potteries exhibited symmetric patterns between the first factor of "vigor" and the third factor of "surface smoothness". The study provided the initial evidence of sensory impression characteristics for Okinohara and Umataka types, which are chronologically and geographically close. They exhibited significant sensory impressions of greater "vigor" and "attractiveness", along with higher "surface roughness".

b Correlation of spatial impressive cognition and sensory impression factors

The pottery typologies of impressive parts showed strong correlations to the above sensory impression factor structures. The all Okinohara and Umataka types with highly impressive parts of rim and upper parts had higher impressions factor structures of "vigor" and "attractiveness", while other three types of Upper Ento, Katsusaka and Sue ware showed less vigorous and attractive.

c Commonality of spatial cognition and sensory impressions

The fact that the groups of pottery with similar sensory impression factor structures and the groups where impressive parts of the pottery were similarly noted, are identical, strongly suggests a commonality between human sensory impressions and spatial cognition. This implies that people are likely to form sensory impressions from the areas of an object they find interesting. These areas of interest capture the attention of the observer through distinctive shapes such as the rims of flame-like pots, prominent protrusions, and three-dimensional patterns. On the other hand, when pottery lacks particularly eye-catching features, people may either form an impression of the entire pottery or pay less attention, which might explain the selection of the whole pottery as a region of interest.

VI. FUTURE STUDIES

Jomon deep bowls were predominantly used for cooking purposes. However, the bold protrusions seen in Okinohara and Umataka types, including flame-like pots, would have been impractical for inserting and removing food during cooking. One might consider that these vessels were not designed for culinary purposes, but rather to express conceptual ideas derived from the worldview of the Jomon people. However, most of those with exaggerated protrusions bowls showed evidence of use in cooking.

Among pottery from antiquity worldwide, such exaggerated protrusions are uniquely found in middle Jomon period pottery from the Shinano River basin, typified by flame-like pots. This makes them a distinctive presence even on a global scale [1].

a Reproduction of cognitive mind using deep generative models

Machine learning, after a prolonged period of stagnation, reached a major turning point with deep learning for image recognition in 2012. Over the past 12 years, the analysis of cognition and the mind using deep generative models has advanced to a level far surpassing human capabilities, and it is now being gradually introduced into cognitive information processing for analyzsing the mind. In the future study, sensory impressions of subjects who viewed pottery and clay figurines are used to train a deep model equipped with 3D-RGB data of objects embedded within a large language model. When new 3D-RGB data of objects is input into the trained model, it reproduces heatmaps and impression texts, representing the "cognitive mind."

b Psychological Experiment on Pottery and Clay Figurines Using Apple Vision Pro

Apple Vision Pro is capable of capturing the viewer's gaze data using its built-in cameras and sensors. This data includes the 3D coordinates of the fixation point, the direction of the gaze, and the fixation duration (saccades and fixations), serving as indicators of where a person's potential attention is directed on an object. By projecting the duration of gaze fixation on the surface of the object as color-graded information, it can be visualized as a 3D heatmap.

c Training data for deep learning models

Pottery and clay figure holograms will be presented to via the Vision Pro, to subjects' psychological experiment. Subjects will be prompted to select from 5 scales based on 16 pairs of adjectives displayed on the Vision Pro screen. Following guidance, participants verbally express their impressions, which will be recorded. A program converts the

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Semantic Differential (SD) method impression results and the recorded impression audio into text, generating training impression text, for a Large Language Model.

The gaze data output from Vision Pro during viewing is processed through a gaze heatmap generation program, producing training 3D gaze heatmaps.

d Training processes of deep learning models

The 3D-RGB data is converted into high-resolution voxels (3D data with depth added to 2D pixels), and input into a 3D convolutional neural network (CNN),

which outputs feature vectors. These feature vectors are then input into a 3D deconvolutional neural network (DCNN), which is trained to output a heatmap with minimal error compared to the training gaze 3D heatmap. Simultaneously, the feature vectors are input into a large-scale language model, which is trained to output impression text with minimal error compared to the training impression text.

e Challenges on cognitive mind and deep mind models

The connection—the bridging point—between object data and the abstract thinking of the mind is the most challenging aspect of advancing practical research. Future studies will focus on how to derive psychological aspects from vast amounts of object data. When modern ~~peple~~people view holograms of Jomon pottery and clay figures, low-level impressions are evaluated using the Semantic Differential (SD) method, medium-level impressions are verbally expressed, and high-level impressions are captured through gaze tracking, all collected within a single MR device. A deep model bridges the gap between these multidimensional human impression data and the object data. The integration of objects, the mind, and deep mind models is the central focus of this research.

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CONFLICT OF INTEREST DISLOSURE

The authors declare they have no conflict of interest relating to the content of this article.

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