Analysis of Sensory Impression Factor Structures of Jomon Potteries through a Semantic Differential Method Experiment Utilizing 3D Models on Microsoft HoloLens

Fujita Haruhiro
Niigata University of International and Information Studies
fujita@nuis.ac.jp

Miyao Toru
Niigata Prefectural Hitory Museum
Nagaoka City, Japan
miyao@hss.highway.ne.jp

Antonio Rene
Toyama Prefectual University
Imizu City, Japan
rene@pu-toyama.ac.jp

Sasaki Hiroyuki
Niigata University of International and Information Studies
sasakihi@nuis.ac.jp

Simon Kaner
Sainsbury Institute for Japanese Arts
s.kaner@uea.ac.uk

***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." Notably, symmetric patterns between the first factor ("vigor") and the third factor ("surface smoothness") were observed among these nine pottery types.**

***Keywords*— sensory impression, Jomon potteries, Flame-like pots, hologram, HoloLens, Semantic Differential Method, factor analysis, analysis of variance**

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. Characterized 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].

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 analyzing 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 Mixed Reality (MR)

Mixed Reality (MR) refers to the technology that projects holographic images into real space. Unlike virtual reality (VR), where the virtual space is entirely constructed within the head-mounted display (HMD), MR projects holograms onto the real space in front of the viewer, integrating with 3D objects visible in the actual environment. An example application is the use of Microsoft HoloLens for MR, where holograms of completed apartments are projected onto construction sites, facilitating construction planning and sales activities.

Despite ongoing efforts in digitizing cultural assets, particularly led by museums, there have been limited endeavors to utilize MR technology for experiencing digital cultural artifacts.

e Previous Study on Holographic Presentations of Cultural Properties

In July 2017, a trial of a virtual museum using Microsoft HoloLens to showcase holograms of nine local folk dolls was conducted with a total of 91 participants visiting Niigata University of International and Information Studies and Kyushu National Museum. Participant assessments were made regarding their levels of interest and curiosity. High school participants, influenced by their frequent use of smartphones and similar devices, exhibited slightly lower levels of interest and amusement towards new technologies such as HoloLens and holographic content compared to other age groups. However, participants of all ages generally responded positively regarding their levels of interest and amusement [4].

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

II. METHODOLOGIES

a 3D-RGB Scanning and Content Preparation

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 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:

Table 1: Potteries Used for Holograms 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 Hardware Specifications of the HoloLens Used

What decisively sets the HoloLens apart from enclosed VR head-mounted displays (HMDs) is its ability to allow the observer to directly perceive the surrounding space. Furthermore, the HoloLens autonomously observes and maps external information (such as light, sound, physical space, and object movement) to understand it. This observation and comprehension require numerous sensors and extensive processing capabilities[5].

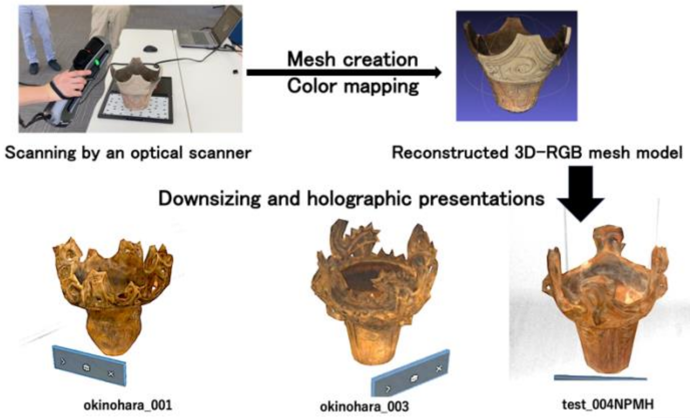


Figure 1 3D-RGB Scanning and Content Preparation

Figure 2 Microsoft HoloLens

Figure 3 Sensors (upper) and processing units (lower)

https://developer.microsoft.com/en-us/windows/mixed-reality/hololens_hardware_details

Figure 4 Optical units viewing bottom of HoloLens

Figure 5 See-through holographic lenses (light waveguides)

A front view of the HoloLens is shown in Figure 2, with inside views of the sensors (upper part of Figure 3) and processing units (lower part of Figure 3) depicted. According to Microsoft's HoloLens website, the following sensors are listed:

- One IMU (Inertial Measurement Unit), which measures the observer's orientation, movement, etc.
- Four environment understanding cameras (visible in the upper left and right of Figure 2)
- One depth camera (not visible in Figure 2, but visible in the upper center of Figure 3)
- One 2-megapixel still image/HD video camera (captures the mixed reality seen by the observer via a web app from a PC) (visible in the middle center of Figure 2)
- Four microphones
- One ambient light sensor

The arrangement and functions of these sensors can be referenced from the website [6]. Among these sensors, those visible from the front of the HoloLens include four environmental sensing cameras mounted at the upper left and right, and two still image/HD video cameras aligned in the center of the lens front. Although not disclosed by Microsoft, according to the website, emitters for depth measurement and one depth camera are located at the top of the sensor section and are hidden on the front glass, making them unnoticeable from the appearance. Emitters are believed to be necessary for measuring the external space and detecting the gestures of observers[7].

Below are the optical specifications from Microsoft's website [6]:

- See-through holographic lenses (optical waveguides)
- Pair of HD 16:9 light engines
- Automatic interpupillary distance calibration
- Holographic resolution: a total of 2.3 million light points
- Holographic density: 2,500 or more per radian

c Optical specifications of HoloLens used

Figure 4 shows the optical units viewed from the bottom up, and Figure 5 shows the see-through holographic lenses (light waveguides) inside the HoloLens as viewed from the observer's eyes. The holographic light projected from a pair of optical engines located above the optical assembly is directed through a see-through holographic lens (optical waveguide in Figure 4). After undergoing two orthogonal reflections within the lens, the light is then projected onto the observer's retina [7]. This setup allows the holographic images to appear three-dimensionally in the observer's perceived reality while they observe the surroundings outside the HoloLens and simultaneously receive holographic images on their left and right retinas.

At the core of enabling these holograms is a 32-bit CPU main processor and a custom Microsoft holographic processing unit integrated with the Windows 10 OS, coordinating with numerous sensors to facilitate interaction between the computer and the observer. The initial setup includes measuring the inter-pupillary distance, recognizing gesture movements by fingers, voice recognition, and more [7]. Upon each power-up with the HoloLens worn, infrared light is emitted into the field of view, and its reflection is measured by depth cameras to calculate distances to key points [7]. Peripheral light sensors and microphones are also utilized to automatically scan the observer's surrounding space and map its physical, optical, and acoustic environment geometry.

By selecting 3D content in the desired spatial location, it will be downloaded and projected using 3D viewer software, and can be fixed in any position chosen by the observer. Once fixed, a 3D hologram can be observed from any distance or angle or closely examined for details. Unless erased, the hologram persists indefinitely on the HoloLens within physical space, remaining unchanged regardless of changes in observers. This encapsulates the principles of the HoloLens.

d Jomon Pottery Hologram Experiment on Sensory Impression

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 the HoloLens 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 pottery items were surveyed using the Semantic Differential Method. Sixteen adjective measurements were taken for each pottery item across five scale ranges from "very applicable" to "strongly not applicable," involving 73 student testers. The results were analyzed using Factor Analysis with maximum likelihood extraction, Promax rotation (Power=4), and Kaiser normalization. Analysis of variance was then conducted on the mean factor scores of the nine pottery items to explain variations in impression factors among them.

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

III. 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 6 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.

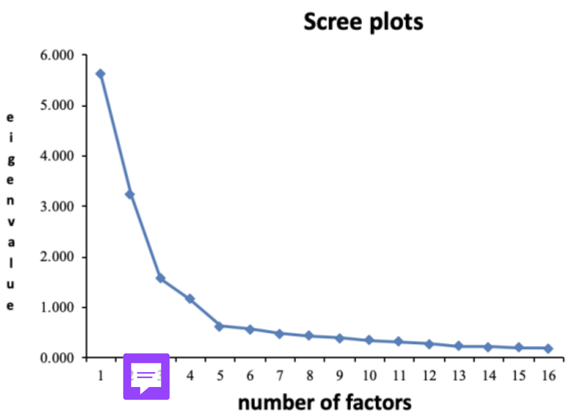


Figure 6 Scree plots of Semantic Differential Method

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.

b Factor Analysis with Four Factors

Table 3 presents the results of the four-factor analysis.

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 7 illustrates the variations among potteries across three factors.

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	[illegible]	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	**

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

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 analvsis 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	[illegible]	.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

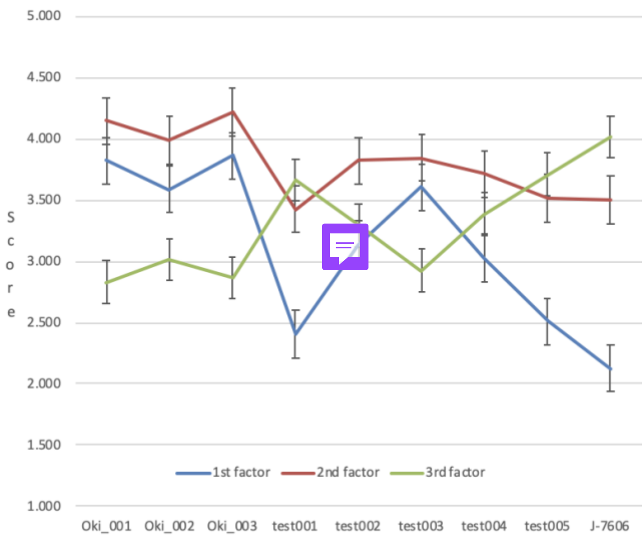


Figure 7 Three Factor Score Variations in Potteries

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	[illegible]4	2.623	**
test001	2.347	3.425	[illegible]5	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	**

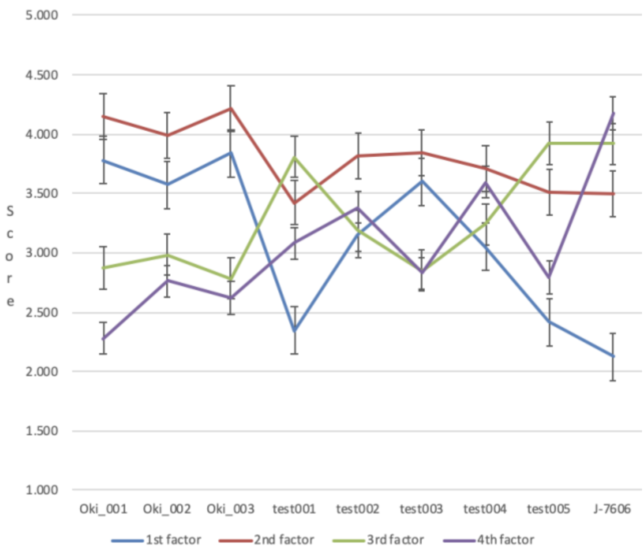


Figure 8 Four Factor Score Variations in Potteries

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 8 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.

IV. Discussions

a Prospects for the Digital Museum

Today, museums face challenges regarding the preservation and utilization of cultural heritage. With revisions to cultural heritage protection laws, museums are increasingly required to attract visitors as tourist destinations more than ever before. Especially after Tokyo 2020, there is an urgent need to cater to inbound tourism focusing on multilingualism and extended opening hours. Within this context, the issue of "utilization of cultural heritage" inevitably arises, whether desired or not. Particularly, many of Japan's cultural assets are composed of fragile materials, and an excessive focus on their utilization, risking damage, is unacceptable. Therefore, it is only natural that interest in digital cultural heritage has grown more than ever before.

b Technological Development for the Digital Museum

Interest in digital cultural heritage has been increasing, and this is not the first time. There has been interest in new technologies for some time, but due to a lack of clear vision for their utilization, sufficient results commensurate with the invested costs were not achieved, leading to a gradual decline. However, recent interest in digital cultural heritage has reached a point of no return. This is largely due to advancements in 3D printing and scanning technologies, as well as the increased performance of computers, enabling the handling of high-definition and high-precision digital cultural heritage. This has made it possible to create content that can substitute for actual cultural artifacts. Against this backdrop, VR emerged initially. VR represents a significant advancement by allowing the viewing of things not normally visible and enabling simulations.

c VR and MR for the Digital Museum

VR represented a significant advancement by enabling viewers to see and simulate things that are not normally visible. However, from the perspective of using VR technology in museums, it had a fatal flaw. This issue arises when VR content is presented to museum visitors, as it disconnects their perspective from the real world. In other words, instead of enhancing the appreciation of actual cultural artifacts, VR could undermine visitors' motivation to engage with the exhibits.

Therefore, MR (Mixed Reality) is considered the optimal technology for use in museums. As pioneers, we focused on HoloLens, which led to preliminary studies targeting museum visitors using the 2017 HoloLens. This research culminated in the sensory impression experiment with Jomon pottery conducted during this study.

d Sensory Impression Study of Jomon Potteries by Holograms

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".

V. CONCLUSION

Jomon potteries, considered formative artworks due to their divergence from modern sensibilities, garner attention primarily for their visual characteristics. Therefore, a sensory impression test was conducted using 3D holograms of Jomon potteries, including two flame-like pots and one Sue ware, aiming to analyze differences in sensory impressions and impression structures of Jomon potteries.

These artifacts are increasingly exhibited in art museums as works of art. When originally archaeological specimens like Jomon potteries are displayed as art in museums, they attract numerous visitors. Conversely, museums focused solely on historical presentations often fail to attract crowds, even when exhibiting the same Jomon potteries based on archaeological research findings. Examples of such typical Jomon potteries include flame-like pots.

Jomon potteries were initially 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 show 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].

ACKNOWLEDGMENT

The authors acknowledge the Grants-in-Aid for Scientific Research (B), "Verification of Sueki pottery types and dating criteria by deep learning cluster analyses of 3D-RGB data," funded by the Japan Society for the Promotion of Science, April 2022 - March 2025.

REFERENCES

[1] "What is it?" Flame potteries in Shinano River Basin and Culture of Snow Country, a guidebook of Shinano River Basin Kaen Root Cooperation Council, 2021.

[2] Kobayashi, Tatsuo. 1996. "The World of the Jomon People." Asahi Sosho. Asahi Newspaper.

[3] Ishii, Takumi. 2010. "Spatial Recognition and Manufacturing in the Jomon Period." Research Bulletin of Kokugakuin Traditional Culture Research Center, Vol. 2, pp. 59-70.

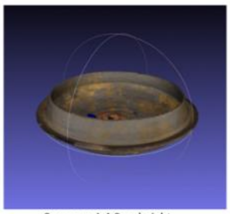
[4] Fujita, Haruhiro, Kazuyuki Kubota, and Kazutaka Kawano. 2018. "Demonstrative Experiments of Local Doll Hologram Displays by Microsoft HoloLens - For the Virtual Museum." Tofu-Seisei, Bulletin of Kyushu National Museum, 2017, Vol. 13, pp. 47-62.

[5] Ueda, Tomoaki. 2016. "Research into the world's most cutting-edge technologies, Glasses-type computer, Hololens." Interface, December, pp. 160-165.

[6] HoloLens hardware details. https://developer.microsoft.com/en-us/windows/mixed-reality/hololens_hardware_details.

[7] "What is MR? HoloLens Hardware/Functionality/Application Operation/User Interaction." http://www.buildinsider.net/small/hololens/001.

Appendix 3D-RGB mesh models used for the sensory impression experiment



Sue ware：4.0cm height

okinohara_001：37cm height

okinohara_002：37cm height

okinohara_003：31cm height

test001NPMH：62cm height

test002NPMH：28cm height

test003NPMH：33cm height

test004NPMH：24cm height

test005NPMH：48cm height