Framing the Past: How Virtual Experience Affects Bodily Description of Artefacts

Paola Di Giuseppantonio Di Franco[1], Justin L. Matthews[2], and Teenie Matlock[3]

1. Marie Curie Fellow, University of Cambridge, McDonald Institute for Archaeological Research, Downing Street, CB2 3ER, Cambridge, UK. Phone: +44 (0)1223 339353; email: pd408@cam.ac.uk.

2. Assistant Professor, Department of Psychology, California State University, Monterey Bay, Seaside, 93955-8001; Phone: +1 (831) 582-4797 email: jmatthews@csumb.edu.

3. Associate Professor, University of California, Merced, 5200 North Lake Road, 95343, Merced, California. Phone: +1 (209) 228-2954; email:tmatlock@ucmerced.edu.

Abstract

This study uses a novel, interdisciplinary approach to investigate how people describe ancient artefacts. Here, we focus on gestures. Researchers have shown that gestures are important in communication, and those researchers often make a distinction between beat and iconic gestures. Iconic gestures convey meaning, specifically, visual-spatial information. Beat gestures do not convey meaning; they facilitate lexical access. In our study, we videotaped participants while they described artefacts presented through varied media: visual examination, physical interaction, and three-dimensional virtual and material replica (i.e., 3D prints) interaction. Video analysis revealed that media type affected gesture production. Participants who viewed actual objects displayed in a museum-style case produced few gestures in their descriptions. This finding suggests that traditional museum displays may diminish or limit museum users degree of engagement with ancient artefacts. This interdisciplinary work advances our knowledge of material culture by providing new insights into how people use and experience ancient artefacts in varied presentations. Implications for virtual reproduction in research, education, and communication in archaeology are discussed.

Key Words: 3D digital replicas, 3D prints, embodied cognition, embodiment, perception, gestures, discourse, artefacts, frames, experience.

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1. Research Aims

This study is part of a larger work aimed at understanding how people perceive artefacts through different media. For this study we videotaped people while they interacted with ancient artefacts through different media (e.g., touching an original object, looking at a picture, interacting with a 3D digital replica on a computer screen, etc.) and then examined both how they described the objects and how they gestured while describing the objects, to investigate how people perceive and understand artefacts. Analysing the gestures and speech of people talking about objects, including the shape and function of objects, can provide useful insights into how people experience and make sense of artefacts in varied forms, including virtual copies. This study also aims to clarify how people negotiate inauthentic artefacts through the body in absence of original artefacts.

In a broader theoretical perspective, this research will clarify how people think with things, specifically how they think with *objects-from-the-past*.

2. Introduction

More and more, 3D technologies are being used to digitally preserve heritage with the goal of avoiding loss or destruction [1-5]. In the context of reduced funding, today, heritage specialists are challenged with the task of preserving and disseminating archaeological artefacts. Using 3D digital artefact reproduction to aid research and preservation results in fidelity of the reconstruction of the original materials and the ability to integrate 3D copies into comparative research. Today, advanced technologies, such as 3D laser scanning techniques allow for the creation of digital models that are both accurate to within a millimetre and able to capture an object's full colour surface appearance (*a texture map*) [2, 6]. The use of 3D digital representations of artefacts, within the context of heritage studies, is an economically effective way to introduce various aspects of material culture studies to large numbers of people [7-11]. A representative example of 3D digital archive is provided by the Smithsonian foundation through the *Smithsonian X3D* initiative (http://3d.si.edu/), a Web-based collection of artefacts, ecofacts, bones, etc., which is available for students and scientists to view at no charge. As these technologies are becoming more widely known, they are changing how professionals approach preservation, data sharing, and the communication of heritage [12-17].

Though the value of digital models for preserving and disseminating tangible heritage is generally recognized, some scholars believe these models lose important information, especially information obtained through real-world human-object interaction [18-22]. This concern opens up an epistemological question about the real value of digital object representations in both research and education. Studies demonstrate that, in fact, we do think *with* objects and that interaction with physical objects is critical when attempting to make sense of an object's function [23-28].

In recent times, many projects have started to incorporate 3D digital reproductions of artefacts in museum-based heritage and material culture studies. This is an exciting time to investigate how people interact with various reproductions and how they perceive artefacts in different media. Such work could advance our knowledge of how objects are perceived in museum settings and inform the design of museum display practices. In our current work, we study how people interact with physical and virtual artefacts in varied media.

According to David McNeill [29], cognitive scientist and a leading expert on gestures, manual gestures play an important role in communication [30]. Gestures are closely aligned with speech and facilitate reasoning and learning [31]. They can help people describe and understand abstract information and abstract objects [32]. Gesture scholars often distinguish between beat gestures and iconic gestures. Beat gestures are rhythmic hand movements that convey no semantic information, but are believed to facilitate lexical access [33]. When describing an artefact, for instance, a person might make three short repeated gestures to help formulate what she is trying to say (e.g., shaking one hand). Iconic gestures are manual movements that convey visual-spatial information about the topic of discourse [29]. While describing the function of a grinding stone, for instance, a person might say, "This is for grinding corn," while making a gesture that depicts the action of grinding.

3. Experiment

In the present study, we compared how people gestured while describing objects they experienced in different media: (1) visual examination, (2) physical interaction, and (3) three-dimensional virtual and material replica interaction (fig. 1). We analysed their descriptions of artefacts in five different forms of media (i.e., *independent variable* fig. 2):

Touch (real life haptic): participants were free to see, touch, smell and manipulate the real objects located on a table.

Look (real-life visual): participants viewed objects located in display cases; the cases were on a table. This condition simulates the experience participants usually have inside a museum.

3D screen (3D virtual visual): participants interacted with 3D copies of objects on a computer screen. Using the mouse they could move and rotate the objects and zoom it in and out.

Pictures (2D visual): participants viewed picture of objects. The pictures were located on a table and participants were free to either just look at them or hold them while talking.

3D prints (3D-printed haptic): participants were free to see, touch, smell and manipulate the 3D printed copies of original artefacts, which were located on a table.

We selected Touch, Pictures, and Look because these media are commonly used by heritage and museum specialists to study and display artefacts. We also selected 3D screen and 3D prints because they have been recently introduced in the field of archaeology as an alternative data recording mean and a valuable way to share the archaeological record both within the scientific community and with the general public.

Forty people participated in our study. Twenty were undergraduate students who received extra credit in a class. The other twenty were expert archaeologists (i.e., academics or contract archaeologists) who agreed to participate in the experiment. Half of the participants were female. All participants were highly proficient English speakers with normal or corrected vision.

All student participants and some archaeologists were video recorded in a laboratory. Some archaeologists were interviewed in their offices, on various university campuses, where we reproduced the same conditions experienced by the other participants to the best of our ability.

All participants completed a short survey that asked basic demographic questions about age and area of study as well as experience with real and digital artefacts. Participants were left alone in the lab after being told to describe the objects to a video camera, which would record their speech and gesture.

Interviews were analysed in an attempt to determine which type of interaction (physical or virtual) would best serve the research and presentation needs of archaeological material to the general public. We compared students with archaeologists to compare how different media would influence their experience with ancient artefacts. Each participant was in only one condition (i.e., *between subject* design). For instance, a single participant participated only in the Look condition or only in the 3D print condition, but not both. As a result, four archaeologists and four students were in all five conditions. Participants were balanced according to age, gender, and background.

Four artefacts, made from a range of different materials and from different geographic areas and chronological contexts, were selected for the experiment, with the aim of evaluating the degree to which the techniques of 3D scanning and printing are perceived differently for different materials (e.g., stone, pottery, etc.), shape, and other physical qualities such as weight, density, and so on (i.e., *dependent variables*). A characteristic like density, for instance, is more critical when studying objects like grinding stones than for the study of ceremonial objects like a support for figurines linked to ritual practice. The artefacts selected were: a. Wooden Buddhist ritual object from Nepal; b. grinding stone from California; c. ceramic vessel from Ethiopia; d. projectile point from California (Figs 1, 3). All participants interacted with the same set of objects.

Below we report a few of the most interesting findings we observed in our data.

4. Results

Our analysis compared how archaeologists and university students (non-experts) gestured when talking about artefacts. Our in-depth analysis examined when and how iconic and beat gestures were used in discourse about artefacts displayed in varied media. Table 1 shows the values for the average number of gestures produced by each group of participants in each condition.

We used both Analysis of Variance (ANOVA) and T-tests to analyse our data. An ANOVA compares mean differences among 3 or more experimental conditions. Here the null hypothesis states that the means of all experimental conditions are not statistically different from one another. The null hypothesis is rejected when at least one of the means being compared is reliably different from the others, which is indicated by a resulting p-value of less than .05. The T-test compares the means of two experimental conditions. Here the null hypothesis states that the two means are not statistically difference from one another. The null hypothesis is rejected when there is a reliable difference between the two means being compared, indicated by a p-value of less than .05.

Overall, media influenced the average number of gestures produced, $F(4,35)=7.83$; $p<.0001$. Participants (archaeologists and students together) generated the fewest gestures in the Look condition, and the most gestures in the 3D screen condition, with a reliable difference between these two means, $t(14)= 1.31$, $p= .02$.

Archaeologists used significantly fewer gestures in the Look condition than in the 3D screen condition, $t(6)= 3.16$, $p= .02$. Students also used significantly fewer gestures in the Look condition than in the 3D screen condition $t(6)= 1.45$, $p= .02$. No reliable difference was found when comparing participants in the Touch and 3D print conditions.

We also examined the two types of gestures separately to get a sense of how students and archaeologists experienced ancient artefacts in different media.

Archaeologists produced more iconic gestures than students overall, but with no reliable difference. These two groups produced about the same number of beat gestures (p=.9).

Archaeologists used more beat gestures in the 3D screen than in all other conditions. This finding was reliable only when comparing 3D screen and Look conditions, $t(6) = 1.36$, p=.02; 3D and Touch, $t(6) = 1.44$, p=.04; and 3D screen and Pictures, $t(6) = 2.52$, p=.04.

A similar pattern was observed with students. In the 3D condition, they used more beat gestures than the other students who interacted with artefacts in the Touch condition, $t(6) = 1.36$ p<.02; Look condition, $t(6) = 1.36$, p<.02; Pictures condition, $t(8) = 144.49$, p<.001; and 3D prints condition, $t(6) = 1.15$, p<.03.

Students in the Look condition produced fewest beat gestures overall. Reliable differences were observed when comparing beat gestures in the Look condition to those in the Pictures condition, $t(6) = 2.87$, p<.03.

We also analysed iconic gestures produced by archaeologists and students. In analysing iconic gestures produced by archaeologists, we found they produced the most gestures in the 3D condition, and the least in the Look condition. Unlike the results with beat gestures, there were no reliable differences for total iconic gestures between the 3D condition and the other conditions. Similarly, even if the Look condition seems to lead to the fewest iconic gestures, this difference was not reliable when comparing this to the other conditions.

When examining the number of iconic gestures students used in the various conditions we also found that 3D was the condition with the largest number of gestures while Look leaded to the fewest iconic gestures. Comparisons of 3D and Look with the other conditions revealed that differences were not reliable.

To explore how media influences gesture production, we examined the number of beat and iconic gestures produced in each condition by the participant groups. Here we observed that archaeologists in the 3D condition produced more beat gestures than iconic gestures on average. This finding was reverse in the other conditions, where archaeologists appeared to produce more iconic than beat gestures, but a reliable difference was not achieved. Students produced more beat gestures than iconic gestures in all conditions except the Touch condition. For possible interpretation of some of these results see the conclusions in paragraph 5.

Subsequently, we classified types of iconic gestures used by participants while describing the artefacts. Gestures were mainly used to describe motion. Iconic gestures conveying motion were frequently used to convey information about the function of an object. For instance, while talking about a projectile point, a few participants said: “It was used for hunting” and then mimicked the action of throwing a spear or dart to kill an animal. Similarly, while describing a grinding stone, some participants mimicked the circular motion performed by people to grind seeds or other vegetal foods (fig. 4).

Participants often used gestures while talking about how the artefact was manufactured. For example, while describing the projectile point, one participant simulated the flaking process. In a few cases, iconic gestures were used to simulate the action of weighing an object to determine its weight. Iconic gestures were also used to define the shape of an object and/or stress elements of shape (fig. 5). In the case of a pot, an object missing part of the lip and handle, gestures helped to stress the shape of the missing parts. Some participants performed iconic gestures while talking about the texture and material of an object. Iconic gestures also helped some people convey the size of an object, especially in cases where it was difficult to determine object scale (fig. 6).

As previously noted, with respect to how people described the size of an artefact, gestures were usually associated with an adjective, for instance, "it is/should be this big." In the Touch condition, to measure an object, a few participants simulated a ruler by moving their fingers along the objects, while other gestures included describing the original context in which the object was likely used; for instance, some people visually described the shape of a metate (i.e., milling slab) in association with the grinding stone (fig. 4 above) or the shape of a container presumably associated with the Buddhist object when the latter was believed to be a scoop. Other participants, who thought the circular incisions on the pot were used to attach a rope or string, simulated the action of lifting the pot up by making an upward moving gesture. Finally, some participants, those not in the Touch condition, simulated touching an artefact even if they did not have the objects in their hands.

Figures 7 and 8 show how gestures used to describe an artefact were distributed differently based on the medium used.

While we noticed homogeneity in the use of gestures in the Touch condition, all other conditions seem to influence the distribution of gestures. Both students and archaeologists in the Look condition produced most gestures to describe shape (archaeologists: 50%; students: 60%). In the Pictures condition, both archaeologists and students produced most gestures to mimic the function of the objects (archaeologists: 30%; students: 34%), but also to describe the size, indicating that graphic scales that are typically provided on a photo are not sufficient when attempting to convey information about the actual size of an object. Archaeologists in the 3D condition used most of their gestures (19%) to describe size when compared to other conditions. Interestingly, both archaeologists and students in the 3D condition used similar numbers of gestures to simulate the texture of objects (archaeologists: 14 %; students: 10%). Archaeologists also simulated texture by means of gestures in the 3D print condition, while students did not perform these types of gestures. In particular, it should be noted that students in the 3D print condition focused almost exclusively on shape and function when using gestures.

5. Observations of participants' behaviour while interacting with artefacts

A few other observations on how participants interacted with various media are in order. A tactile experience with a real-life artefact is a rich sensorial experience that includes touching, seeing, and even smelling an artefact. Some student participants in the Touch condition noted that some artefacts smelled old, for instance, the Buddhist object. They also reported what types of sounds artefacts made when shaken or thumped.

Such sensorial experiences have direct implications for people's experience with, and understanding of, ancient artefacts. Individuals who were non-experts of archaeology or heritage (in this case, students) often seemed excited about being allowed to touch ancient objects. In contrast, this was not the case with the archaeologists. One archaeologist said, “I do not even know what this object is doing here, since it is part of a collection…so, this object, which was stolen from the UCM collection…” In the Touch condition, both students and archaeologists seemed comfortable talking while interacting with artefacts. They carefully manipulated each one the entire time they talked, using gestures and pointing to specific parts while describing them.

In contrast to the Touch condition, all participants in the Look condition seemed less comfortable when interacting with artefacts. In viewing the objects displayed in cases, they often leaned close to examine specific details. At the same time, though, they kept their hands far from the case. Some participants put their hands behind their back, and others, rested their hands on the table.

Participants in the Pictures condition were free to talk while holding the pictures or leave them on the table. Most preferred to hold the picture while talking. This allowed them to point to specific parts of the picture while describing the object in the picture, but this did not prevent them from using gestures. The experience of these participants became a tactile interaction with the pictures, which mimic, in a sense, what would happen if the participants had real-life artefacts in their hands.

The participants in the 3D condition were able to interact with 3D replicas of artefacts with the mouse. They had the freedom to virtually manipulate the artefact before describing it (e.g., rotate, zoom in and out, etc.). However, these participants were asked to try not to touch the mouse while talking. In analysing the videos, we noticed that most of these participants seemed to find it difficult to avoid touching the mouse while they were talking.

Finally, participants in the 3D prints condition interacted with the prints as they would with real-life objects. Interestingly, in both the Touch and 3D prints conditions, when participants appeared to have difficulty determining the function of an object, they attempted to anchor their understanding of it by relating it to another object (i.e., they tried to find a context through association of nearby objects; fig. 9). None of the participants in all other conditions (i.e., Pictures, 3D screen, and 3D prints) associated more than one object to explain and/or understand their function.

Still, while archaeologists spent much of their time manipulating these prints to find cues to help them understand how similar the copy was to the original artefact, students were not all engaged with the 3D copies. Unfortunately, none of the students commented on the 3D prints after the experiment, so it is difficult to understand why they were not engaged with these objects.

6. Conclusions

This study investigated how presentation modality influenced the understanding of artefacts. We were specifically interested in how people would interact with, understand, and describe objects presented in five different media conditions: tactile experience with authentic artefacts, visual experience with authentic artefacts, 2D pictures, 3D digital reconstructions, and 3D prints.

Participants—both professional archaeologists and students—described ancient artefacts in front of a video camera.

The results reinforced the idea that people do think with objects, and that manipulation is a critical component of this engagement with artefacts. Yet, the analysis of gestures in the current study clearly shows that, in absence of a tactile experience, people reproduce stereotypical iconic gestures as if they were actually touching the object. Iconic gestures often convey spatial information; they help people mimic object manufacturing and function. Gestures can also be used to describe details of shape and help people figure out the size of an object.

As noted, when people described objects they also produced beat gestures. Participants who interacted with digital 3D objects produced a significantly higher number of beat gestures. Following Krauss [33], who argued that beat gestures often facilitate lexical access, it is possible that the high number of beat gestures reflects a lack of certainty about artefact details (i.e., participants were less certain about what they were talking about). Another possible explanation of the high production of beat gestures in the 3D condition could be that beat gestures helped participants compensate for the lack of a tactile experience. Recall that this experiment required participants to describe 3D replicas of objects displayed on a computer screen; it was not an immersive experience. The high number of gestures could indicate that participants recognized a difference, a *frame*[1][34-36], between the physical and the virtual world and tried to fill this gap using gestures. The use of gestures may have helped them have a more embodied experience with the artefact.

Participants in the 3D condition produced far more beat gestures, suggesting that the screen was conceived as a *frame* between the material and the digital. Conversely, participants who viewed artefacts in display cases generated the fewest gestures. It is possible that the cases represented not only a physical barrier but also a psychological barrier that inhibited their direct experience with the objects. This idea is reinforced by the fact that, when participants interacted with these objects, they kept their hands far from the case (i.e., they seemed afraid of touching the case).

In sum, the results of this work seem to suggest that traditional museum settings limit the experience people have with their material past. Unfortunately, even if museums are becoming more ‘tactile’, allowing visitors to touch artefacts is not always possible, due to safety issues. We should not forget that museums are devoted to the preservation of artefacts and this duty takes priority over how artefacts are displayed.

For this study we compared and analysed only five media. Future studies might include other media, such as 3D immersive systems (Powerwall and CAVE), Haptic Interface and Force Feedback. Three-dimensional immersive systems are stereoscopic interactive visualization system used to visualize the 3D models, which use camera (or similar) tracking of visitor’s movements to create interactive relationships between the visitor and the reconstructed/simulated environment [37, 38]. Haptic Interface and Force Feedback are able to reproduce the feel of physical contact with objects and the perception of tactile stimuli. [e.g., 17, 39-41]. A few studies show how HI can be applied to create virtual art and archaeology exhibitions wherein users interact with both the visual and haptic senses [e.g., 8, 42-45].

Future research could also investigate how engagement and perception are altered when museum visitors have the opportunity to both look at artefacts exhibited in a case and touch 3D printed replicas of those artefacts. Multimodal user interfaces (including 3D prints) have already been proposed in various museums to enhance the understanding of artefacts. One example in particular, the EPOCH multimodal interface at the ENAME museum in Belgium [46], has also been assessed (i.e., summative assessment; [47]), to test recollection of information about given artefacts and sense of virtual presence (through the evaluation of the interfaces). Our present and future studies are more concerned with perception of specific characteristics of artefacts than recollection of information about them. In other words, with our studies we are more concerned with the possibilities inherent in objects' material, sensorially perceptible characteristics (i.e., *affordances*). Our research start from the assumption that today we are used to "conceiving and presenting objects as always incomplete, even useless, without the (textual) provision of associated data and interpretations" and this "excludes the possibilities inherent in objects' material, sensorially perceptible characteristics –possibilities which appear *a posteriori* in conventional museum approaches to objects, but which are in fact *a priori* insofar as they are dependent primarily upon object's pre-existing and inherent, real and physical properties rather than their social and epistemological associations" [48].

Following this argument, we attempt to show that virtual or real interactions with copies of original artefacts can augment the museum experience because they allow museum visitors to form an intimate relationship with museum objects, including objects they are not allowed to physically manipulate. The results of our research suggest that traditional museum practices, which see textual or similar provisions as necessary *a priori* for a valuable learning experience in a museum, can be modified, so that the physical experience with artefacts becomes intimate *a priori*.

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References

[1] A.L. Martinez-Carrillo, A. Ruiz-Rodriguez, F. Mozas-Martinez, J.M. Valderrama-Zafra, An interactive system for storage, analysis, query and visualization of archaeological pottery, in: B. Frischer, J.W., Crawford, D. Koller (Eds.), Making History Interactive. Computer Application and Quantitative methods in Archaeology (CAA): Proceedings of the 37th international conference, Williamsburg, Virginia, USA, March 22-26, 2009, 1-6. Online Proceedings: http://www.caa2009.org/ articles/Carrillo_Contrib ution169.pdf, accessed November 15, 2013;

[2] J.A. Weber, E. Malone, Exporting Virtual Material Culture. Cheap and Easy Methods to Preserve ad Share data, The SAA Archaeological Record 11(1, 2011) 15-18;

[3] M. Forte, N. Dell'Unto, P. Di Giuseppantonio Di Franco, F. Galeazzi, C. Liuzza, S. Pescarin, The Virtual Museum of the Western Han Dynasty: 3D Documentation and Interpretation, in: Space, Time, Place, Proceedings of the 3nd International Conference on Remote Sensing in Archaeology (Tiruchirappalli, Tamil Nadu, India, August 17-21), edited by Stefano Campana, Maurizio Forte and Claudia Liuzza (BAR S2118, Oxford, UK, 2010), pp. 195-199;

[4] Di Giuseppantonio Di Franco, Paola and Fabrizio Galeazzi, Western Han Dynasty Mural Tombs: from the use of integrated technologies to the cybermap, in: Fusion of Cultures. Proceedings of the 38th Annual Conference on Computer Applications and Quantitative Methods in Archaeology (Granada, Spain, April 6-

9, 2010), edited by Francisco Contreras, Mercedes Farjas, and Francisco Javier Melero (BAR International Series 2010, 2494), pp. 345-352.

[5] A. Gruen, F. Remondino, L. Zhang, Reconstruction of the Great Buddah of Bamiyan, Afghanistan, International Archives of Photogrammetry and Remote-Sensing, Corfu, Greece, 34(5) (2002) 363–8.

[6] B. Rennison, M. Jacobsen, M. Scafuri, The Alabama Yardstick: Testing and Assessing Three Dimensional Data Capture Techniques and Best Practices, in: B. Frischer, J.W., Crawford, D. Koller (Eds.) Making History Interactive. Computer Application and Quantitative methods in Archaeology (CAA): proceedings of the 37th international conference, Williamsburg, Virginia, USA, March 22-26, 2009, 1-8. Online Proceedings: http://www.caa2009.org/articles/Rennison_Contribution349_c.pdf, accessed December 15, 2014.

[7] R. Doonan, M. Boyd, CONTACT: Digital Modeling of Object and Process in Artifact Teaching, in: H.J. Chatterjee (Ed.), Touch in museums: policy and practice in object handling, (BERG, Oxford-New York 2008), pp. 107-120.

[8] M. Bergamasco, Le Musee del Formes Pures, in: 8th IEEE International Workshop on Robot and Human Interaction, RO-MAN 99, Pisa, Italy, 1999.

[9] F. Tecchia, M. Carrozzino, A. Frisoli, E. Ruffaldi, M. Bergamasco, Multimodal Interaction for the World Wide Web, in: Museums and the Web, Proceedings. Toronto: Archives & Museum Informatics, 2007.

[10] K.M. Osberg, Virtual reality and education: where imagination and experience meet, VR in the Schools 1 (2, 1995) 1–3.

[11] M. Carrozzino, M. Bergamasco, Beyond virtual museums: Experiencing immersive virtual reality in real museums, Journal of Cultural Heritage 11 (4, 1987) 452-458.

[12] S.C.H Lin, M.J. Douglass, S.J. Holdaway, B. Floyd, The application of 3D laser scanning technology to the assessment of ordinal and mechanical cortex quantification in lithic, Journal of Archaeological Science 37 (4, 2010) 694-702.

[13] L. Niven, T.E. Steele, H. Finke, Tim Gernat, and J.-J. Hublin, Virtual skeletons: using a structured light scanner to create a 3D faunal comparative collection, Journal of Archaeological Science 36 (9, 2009) 2018-23.

[14] F. Gîrbacia, S. Butnariu, A.P. Orman, C.C. Postelnicu, Virtual Restoration of Deteriorated Religious Heritage Objects Using Augmented Reality Technologies, European Journal of Science and Theology 9(2, 2013) 223-231.

[15] M. Mehta, Virtual reality applications in the field of architectural reconstructions, in: Proceedings of 7th International Conference on Virtual Systems and Multimedia, IEEE, Berkeley, 2001, pp. 183-190.

[16] M. Gaiani, E. Gamberini, G. Tonelli, VR as work tool for architectural & archaeological restoration: the ancient Appian way 3D web virtual GIS, in: Proceedings of the 7th International Conference on Virtual Systems and Multimedia, IEEE, Berkeley, 2001, pp. 86-95.

[17] A. D. Gregory, S. A. Ehmann, M. C. Ling, Touch: Interactive Mulriresolution Modeling and 3D Painting with a Haptic Interface, in: IEEE Virtual Reality Proceedings, 45-52. doi:10.1109/VR.2000.840362.

[18] A. Clark, Being There: Putting Brain, Body and World Together Again. (MIT Press, Cambridge, MA, 1997).

[19] E. Hutchins, Material anchors for conceptual blends, Journal of Pragmatics 37(10, 2005) 1555-1577.

[20] D. Kirsh, Problem Solving and Situated Cognition, in: P. Robbins, M. Aydede (Eds.), The Cambridge Handbook of Situated Cognition, Cambridge University Press, Cambridge, 2009, pp. 264-307.

[21] D. Kirsh, Thinking with External Representations, AI & Society: Knowledge, Culture and Communication 25(4, 2010a) 441-454.

[22] B. Latour, Visualization and cognition. Thinking with eyes and hands, in: E. Long, H. Kuklick (Eds.), Knowledge and Society. Studies in the Sociology of culture Past and Present, Jai Press, Greenwich Conn, 1986, pp. 1-40.

[23] D. Kirsh, Comparing tangible and virtual exploration of archaeological objects, in: M. Forte (Ed.), Cyber-Archaeology, BAR International Series, Oxford, 2010b, pp. 119-124.

[24] S.J. Lederman, R.L. Klatzky, Haptic classification of common objects: Knowledge-driven exploration, Cognitive Psychology 22 (1990) 421-459.

[25] G. MacGregor, Making sense of the past in the present: A sensory analysis of carved stone balls, World Archaeology 31 (1999) 258-271.

[26] J.J Gibson, The Ecological Approach to Visual Perception, Houghton Mifflin, Boston, 1979.

[27] S.C. Kuzminsky, M.S. Gardiner, Three-dimensional laser scanning: potential uses for museum conservation and scientific research, Journal of Archaeological Science 39 (2012) 2744-2751.

[28] R.L. Klatzky, S.J. Lederman, V.A. Metzger, Identifying objects by touch: An "expert system", Perception and Psychophisics 37 (4, 1985) 299-302.

[29] D. McNeill, Gesture and Thought, University of Chicago Press, Chicago, 2007.

[30] T. Matlock, D. Sparks, J.L. Matthews, J. Hunter, S. Huette, Smashing new results on aspectual framing: How people describe car accidents, Studies in Language, 36 (2012) 700-721.

[31] S. Goldin-Meadow, Hearing gesture: How our hands help us think, The Belknap Press of Harvard University Press, Cambridge, MA, 2003.

[32] J.B. Bavelas, N. Chovil, D.A. Lawrie, A. Wade, Interactive gestures, Discourse Processes 15(4, 1992) 469–489.

[33] R.M. Krauss, Why do we gesture when we speak? Current Directions, Psychological Science 7(2, 1998) 54–59.

[34] I. Kant, Prolegomena to Any Future Mataphysics, English tran. by J.W. Ellington, Hackett Publishing Company, Indianapolis, 2011, original version 1783.

[35] J. Derrida, The Truth in Painting, translated by G. Bennington and I. McLeod, University of Chicago Press, Chicago,1987.

[36] G. Bateson, Steps to an Ecology of Mind. Collected Essays in Anthropology, Psychiatry, Evolution, and Epistemology, Jason Aronson Inc., Northvale, New Jersey, London, 1972.

[37] C. Camporesi, M. Kallmann, A Framework for Immersive VR and Full-Body Avatar Interaction, in: Proceedings of IEEE Virtual Reality (Orlando, Florida, 2013).

[38] S. Kenderdine, M. Forte, C. Camporesi, Rhizome of Western Han: an Omnispatial Theatre for Archaeology, in: Z. Mingquan, I. Romanowska, Z. Wu, P. Xu, P. Verhagen (Eds.), Revive the Past. Computer Applications and Quantitative Methods in Archaeology (CAA). Proceedings of the 39th International Conference, Beijing, April 12-16, (Amsterdam: Pallas Publications, 2012), pp. 141-158.

[39] G. Jansson, Can a Haptic Force Feedback Display Provide Visually Impaired People with Useful information about Texture Roughness and 30 Form of Virtual Objects?, in P. Sharkcy, D. Rose, J.-I. Lindstrom (Eds), Proceedings of the 2nd European conference on disability, virtual reality, and associated technologies (ECDVRAT 1998), Reading, UK: The University of Reading, pp. 105-112.

[40] P. Buttolo, P. Stewart, Y. Chen, Force-Enabled Sculpting of CAD Models, IMECE2000, International Mechanical Engineering Congress and Exposition, Orlando (Florida), November 2000, Ford Research Laboratory, ASME (American Society of Mechanical Engineers).

[41] K. Jeonghun, R. Mraz, N. Baker, K.K. Zakzanis, J.H. Lee, N. Kim, S.I. Kim, S.J. Graham, A data glove with tactile feedback for FMRI of virtual reality experiments, Cyberpsychology & Behavior 6 (5, 2003) 497-508.

[42] C. Loscos, F. Tecchia, A. Frisoli, M. Carrozzino, W.H. Ritter, D. Swapp, M. Bergamasco, The Museum of Pure Form: Touching Real Statues in an Immersive Virtual Museum, in: Y. Chrysanthou, K. Cain, N. Silberman, F. Niccolucci (Eds.), Proceedings of VAST 2004: The 5th International Simposium on Virtual Reality, Archaeology, and Cultural Heritage, 2004), The Eurographics Association, pp. 271-279.

[43] S. Brewster, The impact of haptic 'Touching' technology on cultural applications, in: J. Hemsley, V. Cappellini, G. Stanke (Eds.), Proceedings of the EVA Conference (Glasgow, UK, July 2001), pp. 1-14.

[44] M. McLaughlin, S.B. Goldberg, N. Ellison, L. Jason, Measuring Internet Audiences. Patrons of an On-Line Art Museum, in: S. Jones (Ed.), Doing internet research: Critical issues and methods for examining the net, SAGE Publications, Thousand Oaks, CA, 1999, pp. 163-178.

[45] T. Massie, J.K. Salisbury, The Phantom Haptic Interface: A Device for Probing Virtual Object, in: C.J. Radcliffe (Ed.), Symposium on Haptic Interfaces for Virtual Environment and Teleoperator Systems, Chicago, IL, 1994, ASME, pp. 1-6.

[46] P. Petridis, D. Pletinckx, K. Mania, M. White, The EPOCH Multimodal Interface for Interacting with Digital Heritage Artefacts, Lecture Notes in

Computer Science, Interactive Technologies and Sociotechnical Systems, presented at VSMM 2006, ISSN 0302-9743, October 2006, pp408-417, DOI 10.1007/11890881_45, http://www.springerlink.com/content/w8872631 3xl6v8m5,

[47] P. Petridis, K. Mania, D. Pletinckx, M. White, Evaluation of the EPOCH Multimodal User Interface, in: proceedings of Virtual Reality Software and Technology (VRST 06), Limassol , Cyprus, November 01, 2003, ISBN:1-59593-321-2, pp. 116-122.

[48] S.H. Dudley, Museum Materialities: Objects, sense, and feeling, in: S.H. Dudley (Ed.) *Museum Materialities: Objects, Engagements, Interpretations*, Routledge, London and New York, pp. 1-17.

Endnotes

[1] Kant defines a frame as parergon, a hybrid of outside and inside [34]. For Kant the frame can be defined parergon especially when it is beautifully decorated to “recommend the panting to our attention by its attraction” [34: 63-64]. Derrida defines a frame an edge between inside and outside, which can be both inclusive and exclusive [35]. Gregory Bateson clarifies the latter definition, specifying that a frame is not only physical but can also psychological [36]. Following Bateson and Derrida we conclude that non-immersive experience with 3D digital artefacts is exclusive because it separates the material world from its digital representation, but at the same time, inclusive because it produces interaction, engagement and excitement for the medium

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Table

Table 1. Average number of gestures produced by archaeologists and students while talking about the artifacts.

	Archaeologists		**Students**	
Condition	**Beat**	**Iconic**	**Beat**	**Iconic**
Touch	2.69	3.5	0.44	1.87
Look	0.62	1.75	1.62	0.62
Pictures	3.62	3.69	5.25	1.81
3D screen	20.94	8.12	20.87	5.37
3D prints	2.62	5.44	4	1.25