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Talking about Things: A Cognitive Approach to Digital Heritage and Material Culture Studies in Archaeology

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Talking about Things: A Cognitive Approach to Digital Heritage and Material Culture Studies in Archaeology

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in

World Cultures

by

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2014

To Gianna, Mimmo, Ciola, and Tony; my roots, my strength, my sense of integrity, my dignity.
To Edoardo, the essence of love.

A Gianna, Mimmo, Ciola e Tony; le mie radici, la mia forza, il mio senso di integrezza e dignita'.
A Edoardo, l'essenza dell'amore.

To Merced:
At this point Kublai Khan expects Marco to speak of Irene as it is seen from within. But Marco cannot do this: he has not succeeded in discovering which is the city that those of the plateau call Irene. For that matter, it is of slight importance: if you saw it, standing in its midst, it would be a different city; Irene is a name for a city in the distance, and if you approach, it changes. For those who pass it without entering, the city is one thing; it is another for those who are trapped by it and never leave. There is a city where you arrive for the first time; and there is another city, which you leave never to return. Each deserves a different name; perhaps I have already spoken of Irene under other names; perhaps I have spoken only of Irene. (Italo Calvino)

A Merced:

A questo punto Kublai Kan s'aspetta che Marco parli d'Irene com'è vista da dentro. E Marco non può farlo: quale sia la città che quelli dell'altipiano chiamano Irene non è riuscito a saperlo; d'altronde poco importa: a vederla standoci in mezzo sarebbe un'altra città; Irene è un nome di città da lontano, e se ci si avvicina cambia. La città per chi passa senza entrarci è una, e un'altra per chi ne è preso e non ne esce; una è la città in cui s'arriva la prima volta, un'altra quella che si lascia per non tornare; ognuna merita un nome diverso; forse di Irene ho già parlato sotto altri nomi; forse non ho parlato che di Irene. (Italo Calvino)

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Curriculum Vitae

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ACADEMIC HISTORY

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2010-12 **Graduate Student Researcher**. Center for Research on Teaching Excellence for The Guidebook Project. University of California, Merced.

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Aknowledgments

This dissertation is the result of a long, challenging journey, which brought me to, first, cross the ocean and leave my cultural comfort zone (Italy) and, then, abandon my disciplinary comfort zone (Archaeology), to start interdisciplinary research at the University of California Merced. In this new campus I was the first graduate student in Archaeology. This "Far West" was as wide and full of opportunities as I had imagined it, but the lack of boundaries (no ancient walls surrounding the city?!) completely disoriented my embodied mind. Before coming in Merced I was not aware of how my rooted mindscape could influence the way I was moving in the world. I had to learn how to move in a completely different space (or place?). Not an easy task, but well accomplished at this point.

These acknowledgments are the soul of my dissertation work, which would have never happened without the love and support of a large number of people.

During the Ph.D. journey, my advisors Kathleen Hull and Mark Aldenderfer have generously given me a chance of expressing myself and reach my Ph.D. goal through this project. I do not have words to describe how much I owe them for my accomplishments. They have always enthusiastically welcomed my new ideas and encouraged me to do interdisciplinary research. Not only, they spent their time listening to my frustrations and gave me strength when I was about to give up for private reasons. Kathleen, I will never forget that coffee at Starbucks in September of 2011 and how much that meeting helped me to decide my topic of research. Mark, let me tell you how impressed I was every time I stopped by your office with issues, doubts, and dilemmas and went off with clear solutions and ideas after only 10-15 minutes!

I would be remiss without acknowledging my former advisor, Maurizio Forte, who introduced me to the world of 3D digital heritage and allowed me to participate in international projects concerned with digital preservation and dissemination of cultural heritage.

This dissertation would also not have been possible without the support of all members of my committee. Thanks to Teenie Matlock I fell in love with metaphor and embodiment theories, which inspired my dissertation topic. Teenie supervised my research design and data analysis and gave me guidance during the stage of writing my dissertation. I owe her immensely. I deeply enjoyed my conversations with Robin M. DeLugan on social memory and identity, heritage, and museum studies theories. Robin provided me with incisive comments that fostered the final version of my dissertation work.
My deepest gratitude goes to Anne Zanzucchi, co-director of the Merritt Writing Program at UC Merced. If I know how to write academic papers in English, it is especially thanks to her. She was my mentor for several education projects and thanks to her I acquired knowledge and experience in learner-centered pedagogy. Anne always motivated me to do innovative research, write and publish articles, and provided feedback to an infinite amount of text I produced while at UC Merced. If I ever end up working in academia, she will definitely be one of my inspirational models.

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During the writing stage of this dissertation I was supported by fellowships generously donated by UC Humanities Network and the Center for the Humanities at UC Merced. I would like to thank Susan Amussen, director of the Center for the Humanities for the opportunity to participate in the Topsy-turvy research theme and all fellows of the Center for the constant intellectual exchange, which nurtured me and my research.

My dissertation project included 3D prints and pictures of ancient artifacts. Some of the 3D prints were generously donated from the ZCorp company, some others were made by members of the 4D Parts Direct company, who I thank for their thorough work and constant support during the 3D printing phase. I am thankful to my friend and colleague Collin Closek for his appreciated help during the 2D digital image acquisition phase.

For the experimental part of my dissertation I interviewed a large number of professional archaeologists and academics and would like to thank all of them for this opportunity. In particular, I would like to thank the Far Western Anthropological Research Group, Inc., the Statistical Research, Inc. (Woodland office), and the Applied EarthWorks, Inc. (Corporate/Fresno office).

I would also like to thank Sharrol Brown, undergraduate student and Cognitive and Information Science here at UC Merced, for her valuable work of transcribing all video interviews.

I would be remiss not to thank all my professors in the World Cultures Program and my colleagues for sharing with me pains and challenges associated with the Ph.D. journey. May we all be rewardingly employed in a near future! Special thanks also to all members of the Center for Research on Teaching Excellence for their constant support in all aspects of my teaching and research. Thank you especially to Belinda Braunstein, English Language Institute Coordinator at UCMerced, who helped me to get acquainted with the US experience and supported my research and me for the duration of my graduate studies. Much gratitude to Mitch Ylarregui, for helping me navigate in the UC system.

For a woman like me, so rooted and attached to my origins, moving to another country was particularly difficult. All my love and gratitude goes to my US family, for welcoming me and allowing me to be part of their lives. For each of them I carry precious, unforgettable memories. Thank you: Justin, Collin, Michael, Erika, Roselia, Shaun, Josh, Nicole, Carlos, Ruthie, Kandice, Christiane, Johnny, Mayya, Angelo, Burcu, Orkan, Lucia, Amanda, Marco, Alicia, Carlo, Max, Gorkem, Gokce, Mentar.

Viaggiare significa, tra l'altro, allontanarsi dagli affetti di una vita, anche solo temporaneamente. Il mio amore e la mia gratitudine più profonda vanno alla mia grassa grossa famiglia Italiana e ai miei amici, quelli che mi hanno atteso, cercato e accettato, anche se i momenti di condivisione erano inevitabilmente diradati. Non scrivo i loro nomi, perché so che si sentiranno chiamati in causa non appena leggerano queste poche righe. Vi voglio bene.

Un ringraziamento particolare va ai miei genitori, per aver accettato la mia partenza e soprattutto per averla resa possibile, lì dove il mio impegno non aveva potuto…

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Abstract

Talking about Things:
A Cognitive Approach to Digital Heritage and Material Culture Studies in Archaeology
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University of California, Merced 2014
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This dissertation presents an innovative cognitive approach to material culture and the use of virtual reproduction in research, education, and communication in archaeology. This research aims to investigate the potential use of virtual copies of artifacts for knowledge production and acquisition in archaeology. Although scholars recognize the value of digital models for enhancing artifact studies in schools and universities and re-contextualizing objects exhibited in museums, some researchers suggest that these models lack information that is only available through real-world human-object interaction. This point opens up a question about the real value of digital object representations in both research and education. Studies demonstrate, in fact, that we do *think* with objects and that interaction with things is critical when trying to make sense of their use and function. The present study, done in collaboration with the program of Cognitive and Information Science at the University of California, Merced, intends to investigate how knowledge production and acquisition work through different media: visual examination, physical interaction, and three-dimensional virtual and material replica interaction.

This is an innovative interdisciplinary project that can promote the advancement of research and education beyond the frontiers of current knowledge. The results of this research can be applied to a number of fields, including archaeology, museum display, and modern heritage management. This project will also help to clarify the growing area of human-object interaction studies.

Chapter one. Introduction

Conceiving and presenting objects as always incomplete, even useless, without the (textual) provision of associated data and interpretations, 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* (Dudley 2010: 4).

Three Dimensional technologies are used frequently to digitally preserve heritage at risk of loss or destruction. In the context of reduced funding, today heritage specialists are challenged with the task of preserving, and disseminating archaeological artifacts.

The General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO) meeting, organized in Paris from October 17 to November 21, 1972, highlighted the increasing threat to heritage today, with destruction not only by the traditional problem of decay, but also by changing social and economic conditions (i.e., urban development, conflicts, etc.) that aggravate the situation with even more formidable levels of damage or destruction (http://bit.ly/ymuf1s). The protection of this heritage at risk often remains incomplete because of insufficient economic resources. As a consequence of the lack of money for heritage preservation, in the last ten years disciplines such as archaeology have experimented with new technologies for the three-dimensional (3D) documentation and reconstruction of archaeological sites.

The strength of 3D digital artifact reproduction as an aid to research and preservation lies in the fidelity of the reconstruction to the original materials and its ability to be integrated into comparative research (Addison 2008a: 28; Rennison et al. 2009; Weber and Malone 2011; Di Giuseppantonio Di Franco and Galeazzi 2013). These new technologies are so well established that they have revolutionized the approach preservation, data sharing, and communication in archaeology, changing perspectives on materiality and how material culture can be preserved today (Martinez-Carrillo et al. 2009; Weber and Malone 2011). For instance, digital archives and libraries of ancient artifacts are considered necessary comparative collections for scholars with limited or non-existent access to original collections. These access issues are primarily due to increased distances between laboratories and archaeological sites or laboratories and artifact storage facilities (Martinez-Carrillo et al. 2009; Weber and Malone 2011).

Although scholars recognize the value of digital models for preserving ancient material culture in contexts where artifacts and monuments are at risk of degradation or destruction due to urban development, conflicts, and/or wars (i.e., the looting of the Museum of Cairo in Egypt in 2011 or the looting of the National Museum of Iraq in 2003; Emberling 2008; Forte et al. 2010; Di Giuseppantonio Di Franco and Galeazzi 2013), some scholars suggest that these models lack information that can only be obtained through real-world human-object interaction (Renaud 2002). This raises a question about the significance of digital object representations in both research and education. Studies demonstrate, in fact, that we do *think* with objects and that interaction with things is critical when trying to make sense of their use (Clark 2003; Hutchins 2005; Kirsh 2009, 2010a; Latour 1986). This is especially true for archaeologists, who interpret the past from material remains. In this sense, archaeological experiences can be described as embodied material activities (Kirsh 2010b).

When archaeologists interact with objects, they weigh and feel them. While attempting to identify an object, an archaeologist may utilize a variety of exploratory procedures, including stereotypical hand movements (e.g., holding, rotating, moving the object to see it from different angles; Lederman and Klatzky 1990).

Tactile perception of a real-life 3D object is usually an active experience involving information gathered from a variety of senses related to touch such as texture and temperature, as well as movement and position of the hands and fingers during identification (Gibson 1979: 123-9). Touch provides an understanding of shape, size, and weight, and it is through this sense that people develop an understanding of other properties such as density, all key properties for the exploration of artifacts (Doonan and Boyd 2008; Kirsh 2010b).

The past few years have seen a considerable number of projects incorporating 3D digital reproductions of artifacts in heritage and material culture studies and inside museums. However, only a few works have explored how people interact with 3D reproductions and negotiate the absence of the real-life original objects; furthermore, none of these studies compared people's perception of the same artifacts in different media states to see if reproductions of artifacts duplicate the cognitive feel of real objects. This comparison is essential to the definition of authenticity, since scholars such as Jean Baudrillard (1994) even reject the existence of an objective reality, claiming the inability of consciousness to distinguish reality from a simulation of reality (i.e., hyperreality), especially in technologically advanced societies.

Given the importance of both visual and tactile experience, this project seeks to understand if and how the qualities associated with real-life object interaction can be replicated using digital copies of objects. Also of interest is how virtual object engagement can support or complement interactions that are enjoyed by scientists who are physically present at an archaeological site.

For this research I have investigated how modes of interaction influence how people perceive objects, addressing several research questions:

RQ1: How do people experience an object when they can touch it?
RQ2: Can this haptic experience be reproduced when the artifacts are presented in different media?
RQ3: Is virtual object interaction able to reproduce sensations of material qualities such as density and weight?
RQ4: How do people interpret archaeological artifacts and what is the difference, if any, between archaeologists and the "general public" in the interpretation process?
RQ5: Can 3D printed copies duplicate the cognitive feel of real objects?

Questions 1 to 3 were specifically aimed at understanding how the medium affects the way people experience past material culture. If we accept the idea that people think through manipulation of things, what happens when they cannot manipulate them? Furthermore, what happens to people's thinking and interpretation process when they manipulate things virtually? With these questions I wanted to challenge the notion of physicality and understand if the way people perceive the material world changes when they are asked to experience things virtually. Question 4 was more generally aimed at understanding if there is difference between scholars and the "general public" in the way they perceive and interpret artifacts. With this question, I was particularly interested at challenging the traditional logic of research and museum curatorship in archaeology. This logic emphasizes a dichotomy between experts (researchers and museum curators) who produce content, and the general public who receives such content. In a more democratic view of research and museums, this logic can to be turned upside-down, emphasizing a multivocal experience with the material past that challenges the notion of *knowledge producer vs. knowledge receiver* and the traditional scheme *sender-message-receiver* (Hodder 1997). From these premises, it is clear how crucial it is to understand how differently people perceive, describe, and understand ancient material culture.

Finally, Question 5 was driven by the growing interests that museums and have for 3D prints as an aid to artifact preservation and dissemination. In fact, due to advancements in digital object scanning and 3D object reconstruction, models of virtual objects can now be recreated using 3D printers, wherein objects are recreated using fine-grained plastic layering techniques. This technology gives researchers the ability to not only see objects, but also to physically engage and interact with object reproductions, affording the use of tactile and haptic information not typically utilized when simply viewing static 2D object photographs. Thus, 3D printing technology has major implications for research and education and, thus, the future of historic preservation. Situations in which human-object interaction is critical to learning the function and use of objects are now a reality. Printed copies of objects can be used in classes as alternatives to original artifacts that were previously difficult, if not impossible, to transport to universities and schools (Doonan and Boyd 2008). Yet, scholars have to determine best practices for the use of 3D prints at school and inside museums.

With the present study, I compared knowledge production and acquisition through different modes: (1) visual examination, (2) physical interaction, and (3) three-dimensional virtual and material replica interaction. To explore this, I collected data related to knowledge acquisition while experiencing objects via differential media (fig. 1):

1. *Real life Haptic*: participants touched the real objects.
2. *Real-life Visual*: the objects were located inside a display case, simulating the experience that individuals usually have visiting an archaeological museum.
3. *3D Virtual Visual*: participants interacted with the 3D copies of selected objects displayed on a computer.

4. *2D Visual (pictures)*: selected participants described objects looking at their pictures.
5. *3D–printed Haptic:* participants interacted with copies of real objects made using 3D printers.

Figure 1. Experiencing artifacts through different media. Media analyzed during the experiment.

All participants were asked to interact with the artifacts through different forms of media to see how the mode (i.e., tactile experience vs. interaction with 3D virtual copies) influenced the way people describe and understand individual objects.

Two different groups of participants were involved in this research:

a. Archaeologists; to understand if background knowledge facilitates new knowledge acquisition through interaction with virtual copies.

b. Subjects without archaeological experience; to understand how knowledge acquisition works for individuals in the general public (such as those who visit archaeological museums).

The participants were video recorded, and language and gestures were analyzed to determine which type of interaction (physical or virtual) best serves archaeological research and the presentation of archaeological material to the general public. The primary motivation for video recording the interviews was to identify groups of spontaneous gestures that could be clearly correlated with linguistic information about the artifacts (Sargin et al. 2006). According to cognitive scientist David McNeill (1992; 2005), the close synchrony between gesture and speech indicates that the two are inseparable parts of a single thinking process. As a result, a combined study of gestures and speech allowed me to understand how people think with both artifacts and their virtual copies.

For this research, I selected objects that varied in terms of their form, function, and material to see if these differences could affect the understanding of these objects in different media states. The objects were presented in isolation, that is, out of their original and archaeological context and participants were provided with basic information on the artifact's place of discovery and age. With this, I wanted to explore the power of material agency and understand how people perceive ancient objects through sensory experience, without the mediation of textual information (Dudley 2010:4-5).

This is a completely new line of research in archaeology, and so, required a multidisciplinary approach. The experimental design was made possible through an interdisciplinary conversation with the University of California, Merced program in Cognitive and Information Science (CIS), wherein scholars helped me investigate how different senses interact during perception and how individuals think while interacting with things. The addition of CIS colleagues sets this research apart. Interdisciplinary theories of material culture (e.g., Husserl 1970; Gibson 1979; Ingold 2000; Olsen 2010), heritage (e.g., Baudrillard 1981), digital heritage (e.g., Cameron & Kenderdine 2007), and cognitive science (e.g,. Lakoff 1999; Kirsh 2010) also inform this study.

This doctoral dissertation is comprised of six chapters, including the present introduction. Chapter 2 presents an overview of the most significant theories on material culture and human-object interaction studies in archaeology. In Chapter 2, I show how the concern with material culture in archaeology has taken different shapes through time and how the theoretical perspectives of the last few decades have mistakenly described culture and societies as existing prior to, or detached from, things.

Chapter 3 defines *digital heritage* and describes innovative technologies used by scholars to preserve and disseminate cultural heritage. Case studies of digital preservation, sharing, and communication of material culture are also discussed, including the Western Han Dynasty Virtual Museum project, in which I collaborated. These case-studies inspired and informed the research presented herein. This chapter also engages with theories and experiments focused on how people perceive artifacts through tactile experience, and discusses research efforts aimed at simulating haptic experience in the virtual world.

Chapter 4 provides a detailed, step-by-step description of how the experimental study was designed and what methodology was applied.

In Chapter 5, I present and discuss my research funding in the form of charts, graphs, and text.

Chapter 6 summarizes the results of this study and explains its implications and limits. Suggested directions for future work in this field of study are also discussed.

Generally speaking this research fits within the broad category of human-object interaction studies and the results of this study inform a broad community of experts who deal with this subject in different fields (e.g., computer science, psychology, cognitive and information science, socio-cultural anthropology, digital humanities, etc.).

Chapter two. Overview on Material Culture Studies

Cash isn't the only thing I take from my father's study when I leave home. I take a small, old gold lighter –I like the design and feel of it– and a folding knife with a really sharp blade. Made to skin deer, has a five-inch blade and a nice heft. Probably something he bought on one of his trips abroad. I also take a sturdy, bright pocket flashlight out of a drawer. Plus sky blue Revo sunglasses to disguise my age. (Haruki Murakami, *Kafka on the shore*)

2.1. Introduction

Leland Ferguson defines *material culture* as all the things that people leave behind, all of the things people make from the physical world–farm tools, ceramics, houses, furniture, toys, buttons, roads, cities, etc. (Ferguson 1977:8). Perhaps the simplest way to define the term is that material culture represents the "things" that people produce and use, the "material" products of a culture. Most importantly, using Tim Ingold's words (2007: 11): "materials are the active constituents of a world-in-formation" and can tell us about a place and a time (*hic et nunc*), about the people who created or used the artifacts, and also about changes over time. The study of material culture is an intensely interdisciplinary undertaking and benefits from the wide variety of methods and theories that different scholars have applied to their research: economists are mainly focused on individuals and their need for commodities; sociologists study the influence of material culture on contemporary society; anthropologists analyze the link between humans and things with a focus on symbolic meanings given to material culture by different people and societies; cognitive scientists are interested in the cognitive processes that are at the base of thing-making, in the symbols and metaphors applied to material culture, and in the process of perceiving things; and historians and archaeologists try to reconstruct relations between things and humans in the past.

Of all disciplines, archaeology is the discipline that needs material culture most, but has only relatively recently started to focus on this topic from a theoretical perspective (Tilley 2006; Hicks and Beaudry 2010). Material culture studies emerged during the 20th century in the disciplines of archaeology and anthropological archaeology to solve longstanding archaeological and anthropological problems linked to the idea of relationships between "social"/"cultural" and the "material." Archaeologists are mainly concerned with material culture in order to reconstruct human dynamics in the past and to study human evolution. The concern with material culture has taken different shapes through time, and according to Bjornar Olsen (2010), the theoretical perspectives of the last few decades helped create an idea of a dematerialized world wherein things are entirely constructed and culture and societies exist prior to, or detached from, things. Central to this idea is the question recently posed by Amiria Henare, Martin Holbraad, and Sari Wastell: "What would an artifact-oriented anthropology look like if it were not about material culture?" (Henare et al. 2007:1).

Discomfort with the notion of "material culture" in archaeology and anthropology is linked to the idea of culture and the way this idea has changed in post-modern studies, after two decades of postcolonial, feminist, and historical critiques of the static, synchronic, and normative tendencies of the "culture concept." This idea (of culture) took hold in the 1940s with structural-functionalist anthropology, and was well established by the mid-1960s when the so-called Processual or New Archaeology had its genesis in the work of Walter Taylor, Albert C. Spaulding, Lewis R. Binford, and others. The structural-functionalist anthropologists and processual archaeologists stressed the operational reality of artifacts, and started to question previous archaeological assumptions and the obsession with cataloguing things that was common in archaeology at the time. In *Material Culture and Mass Consumption* (1987), Daniel Miller defined this obsession with objects as "a genuine fetishism of the artifacts." The critique of the old school of thought was also clearly stated by Frederik Barth when he wrote: "It often seems that …even artifacts are treated analytically as if they were cultural elements. It ought to be clear that patterns of behavior described as 'customs' or artifacts in a museum are not cultural elements…Culture consists of ideas" (Barth 1961:39, translated in Olsen 2010:23). The definition that sees artifacts as mere "cultural elements" is clearly influenced by the Cartesian "Cogito, ergo sum;" that is, the Cartesian classical dualism of mind/body, mind/material world, which does not give any space to the idea of mind and body as a complex unity that allows humans to experience the world. In this context, the *material* becomes only a means for studying culture and society, and "*material culture* seems to have hardly to say about *materials*" (Ingold 2007:1).

The purpose of this chapter is to retrace the evolution of material culture studies in anthropology and archaeology, and to analyze the main topics embedded in these studies. The conclusion of this chapter explores the limits of an archaeological discipline that takes place at a distance from material culture since the discipline is embedded in Cartesian thinking. The main argument here is that people cannot be understood apart from the things they produce, use (interact with), and exchange, since these things are the expression of how people live in the world. And the world is material. In this chapter, I argue for a cognitive approach to material culture that, as Carl Knappett (2005) states, needs to be developed in new post-Cartesian and non-dualistic directions. In this chapter and more generally throughout this entire dissertation, I use the terms *artifact*, *thing*, and *object* interchangeably, even if their definitions and meanings have been subjected to important theoretical discussions (see in particular Miller 1997; Gell 1998; Henare et al. 2007; Olsen 2010; Ingold 2012).

2.2. Functionalism and Processual Archaeology

Processual or New Archaeology originated in the United States during the second half of the last century grew from structural-functionalist anthropology. Structural-functionalist anthropology was an innovative perspective at that time, since scholars turned their attention from the study of technology to that of material culture. More precisely structural-functionalists studied objects to understand their role in social institutions. Walter Taylor in the 1940s and later Louis Binford in the 1960s–both considered the fathers of New Archaeology–were significantly influenced by structural-functionalism. In their works, they questioned the dominant cultural-historical perspectives, which privileged the study of typology above that of human behavior, claiming instead a scientific approach to archaeology. In 1962, Binford published an article with a revolutionary and innovative title, *Archaeology as Anthropology*, and inaugurated the New Archaeology. In the article, he claimed that archaeology, rather than just focusing in time-space systematics, should further the aims of cultural anthropology and "directly test hypotheses concerning the process of evolutionary change" (Binford 1962:224). Culture was the key to archaeological studies and could not be understood by simply tracing changes in the typology of artifacts. Following his professor Leslie White, who was a cultural anthropologist, Binford viewed culture as "man's extrasomatic means of adaptation to the physical and social environment" (White 1959:8), with artifacts having a role in the structure and function of cultural systems and in human adaptation.

Following White and Binford, processual archaeologists were mainly concerned with human cultural evolution and adaptation, and considered variations in material culture as the reflection of differences in ecological adaptation and social status. Processual archaeologists mainly focused on the study of things' function, technology, and adaptation, placing more emphasis on economic aspects of the past. American processual archaeologists espoused positivist archaeology and trusted in scientific objectivity, based on hypotheses and rigor in the reasoning used to address these hypotheses. Their work was based on statistical analysis rather than seriation and cultural typology, and aimed at explaining, instead of describing (as the old school used to do), how and why changes occurred in past cultural systems.

One of the most representative approaches in processual archaeology was the ethnographic work conducted by Binford in Alaska. His research involved the study of Nunamiut people, a North American Artic group of hunter-gatherers, and he aimed identify and understand global patterns and variations (present and past) in hunter-gatherer mobility, technological organization, site structure, demographics, and adaptation. With this study, Binford also aimed to give a methodological contribution to processual archaeology, providing scholars with a method for using ethnographic data in the service of archaeology.

Binford's ethnoarchaeological comparison helped him prove that Mousterian assemblages, a group of stone artifacts from France dating to the Pleistocene, were adapted to changes in the environment (Binford and Binford 1966: 240). This contradicted argument by Francois Bordes, who argued that the stone tool assemblages present in alternating stratigraphic levels in the site of Combe Grenal were the remains of different Neanderthal groups. Most of the processual work emphasized the materialistic and economic aspects of prehistoric societies. Ideology was considered a subsystem that could be approached with the same methodology as social and economic subsystems. If this methodology failed, it was argued, then ideology could not be determined from archaeological remains because "motivation cannot be derived from material objects" (Zubrow 1994:108-109).

2.3. Textualism and Post-processual Archaeology

In contrast to the position of processualists, the post-processualist school of Ian Hodder and his disciples believed that past cognition can only be understood using interpretative techniques. For post-processual archaeologists, social and cultural realms are thought to exist prior to or detached from things. It is often assumed, for example, that things are entirely "constructed" by social or cultural perceptions and have no existence in and of themselves. In this context, the material continues to be only a means for studying culture and society, as it was for processual archaeology.

Non-positivist and interpretative, post-processual archaeology is based upon hermeneutics and the philosophical works of Foucault and the post-structuralist school (Barthes, Derrida, Kristeva, etc.) and was initially espoused by Ian Hodder, Michael Shanks, and Christopher Tilley. It is directed at the ideological and cognitive aspects of prehistoric individuals, and its methodology has been interpretative and literary, whether one is considering space or objects (Hodder 1993:12). For this reason, post-processualism is also sometimes defined as textualism. According to this school of thought, material culture can be studied as texts, and it is important not only to understand what the author (producer) meant when he/she made an object but also what the reader (user) understands; that is, which meanings the reader assigns to the object. The meaning of ancient things is produced rather than recovered, because readers of material culture (e.g., archaeologists interpreting things, users of a museum) become producers of meaning as well. In this sense, Hodder invokes a multivocal approach for the interpretation of past material culture (Hodder 2001; 1993).

This position can be divided into three sub-schools well described by Buchli (1995: 182):

- Ian Hodder and Henrietta Moore approached material culture as most directly analogous to a text or narrative to be decoded and manipulated by various historical agents and accessible to the archaeologist. These two authors privileged the skill and eloquence of the archaeologist interpreting the archaeological record.

- The second tendency, influenced by the works of Michel Foucault and Marxian critiques, focuses more on relations of power and domination in social practice and the creation of knowledge, particularly emphasizing the implications of archaeology to late capitalism and the roles that archaeology plays in reproducing society and how that might be changed. *Text* here is still understood as a narrative to be decoded, but the importance of social conditions, under which material culture and other narratives are produced and interpreted to reinforce and reproduce dominant social structures, are given greater significance.

- The third tendency, very closely related to the second, is concerned with the role and implication of communication and ideology in the constitution of archaeological discourse in the present day. The primary influences are the works of Jurgen Habermas and Louis Althusser, as well as the tradition of critical theory. This strain provides a critique of how archaeological texts and the archaeological record, which constitutes these texts, are produced and disseminated.

According to a post-processualist approach to material culture, we can use objects to write narratives of the past. In her article titled *Objects as meaning; or narrating the past* Susan Pearce (1994:19-29), discusses the meaning that historical associations given to objects, showing how objects accumulate meanings as time passes. In this sense, objects can work as "message-bearing entities" and are seen as "one of several ways to of narrating the past" (Pearce 1994:20-21). Similarly, Igor Kopytoff (1986) proposes study of material culture that takes into account all the meanings an object acquires through time (i.e., from its production and original consumption to the meaning it acquires in the present). In other words, Kopytoff proposes study of ancient artifacts that takes into account their biography (the "cultural biography of things"). In this process, it is important to know the biographical possibilities inherent to the status of things:

> What, sociologically, are the biographical possibilities inherent in its "status" and in the period and culture, and how are these possibilities realized? Where does the thing come from and who

> made it? What has been its career so far, and what do people consider to be an ideal career for such things? What are the recognized "ages" or periods in the thing's "life," and what are the cultural markers for them? How does the thing's use change with its age, and what happens to it when it reaches the end of its usefulness? [Kopytoff 1986:66-67].

While Kopytoff studies cultural biographies from an economic point of view, other anthropologists and archaeologists have explored the idea of object biographies to study the social dimension of artifacts and architecture. The exploration of an object's biography has become a popular theme in archaeology and this idea has been applied to a broad variety of case studies, that range in time and space; for example, the site of the Neolithic site of Opovo (Serbia) studied by Ruth Tringham (1995), or the Roman colonies in Great Britain studied by Gosden (2005). The main problem with this perspective is that when archaeologists reconstruct the biography of objects, they tend to isolate these objects, thus creating linear narratives that separate artifacts from their broad material context. As a consequence, some scholars (Gosden 2005; Kanppett 2002; 2004; 2011; Joy 2009) have explored new ways to study the biography of things that acknowledge the importance of assemblages. Further, Karl Knappett (2002; 2004; 2011), drawing on Bruno Latour's Actor-Network Theory (ANT), positions objects within a network of meanings wherein humans and things are both *actants*; thus recognizing the material agency of artifacts. Ultimately, Jody Joy proposes a non-linear relational biography of things that consists of "a series of connected jumps as the object becomes alive within certain clusters of social relationships and is inactive at other points in time and space, undergoing a series of different lives and deaths" (2009:544).

2.4. Consumption, commodities, and the process of commoditization

An important sub-field of processual archaeology is influenced by a Marxist approach to material culture and production, and focuses on how mass production, possession, and consumption determine and regulate social relationships. From this perspective, things are described as commodities or goods.

In 1987, anthropologist Daniel Miller wrote *Material Culture and Mass Consumption*, a book that was interpreted by many as a gradual turning away from archaeology. In the book, Miller presented a study of material things in the contemporary West, and traditional archaeological methods (traditional classifications) played no role in this research due to "the kind of fetishism to which material culture studies are always prone, when people are superseded as the subject of investigation by objects" (1987: 143). The study was instead largely influenced by the structuralist and semiotic works of Roland Barthes, Jean Baudrillard, and especially by *The World of Goods* by Mary Douglas and Baron Isherwood (1979), who describe goods as a visible part of culture, or ritual adjuncts, where the ritual is consumption (1979:44). The study of material culture was defined by Miller as "simply the study of human social and environmental relationships through the evidence of people's construction of their material world" (Miller 1987:5).

According to Igor Kopytoff (1986), while commodities "simply are" from an economic perspective—in the sense that they are produced, circulated, and exchanged, usually in exchange for money—from a cultural perspective the production of commodities is a cultural and cognitive process. Commodities are not only produced materially as things, but are also marked with an ontological meaning (Kopytoff 1986:64). Just some things become commodities, and the same "thing" can be considered a commodity in some socio-cultural context, but not in others. This assertion is perfectly in line with Lévi-Strauss's ideas on communication systems constituting social life. He distinguished three main systems: communication of goods (goods), communication of women (kinship), and communication of words (myth) (Douglas and Isherwood 1996:61).

Consumption studies are based on the notion that commodities should be considered a universal cultural phenomenon since the existence of commodities is concomitant with the existence of transactions that involve the exchange of things—exchange being a universal feature of human social life and, and for some theorists, at the very core of it (Kopytoff 1986:68). Where societies differ is in the ways commoditization, as a special expression of exchange, is structured and related to the social system. Some authors argue that commoditization is not pertinent just to complex societies–by which I mean not only large-scale societies with a strong hierarchical apparatus, but also small-scale societies. in fact, according to Kopytoff there have been small-scale societies in which commoditization (helped by indigenous money) was very extensive, such as the Yurok of northern California or the Kapauku of western New Guinea (Kopytoff 1986:79).

In small-scale, non-commercialized societies, the drive to commoditization was usually contained by the inadequacies of exchange and absence of a well-developed monetary system. This left space for the cultural categorization of the exchange value of things, usually in the form of closed-exchange spheres. Commodities, thus, presuppose a well-organized exchange system more than a strong monetary system. When new technological advances open areas that were previously closed to trade to the possibilities of exchange, these areas tend to become quickly commoditized. That said, the problem of commodities must not be considered in isolation, or even regarded as the central problem when studying societies in general, but rather, as the central structural problem of capitalist society in all its aspects. In other words, the analysis of commodities and commoditization is very effective when we want to study capitalist society, but could be meaningless in another socio-cultural and historical context. As Georg Lukacs pointed out, what is at issue is the question: how far is commodity exchange together with its structural consequences able to influence the *total* outer and inner life of society? (Lukacs 1971). Only in this context does the "reificiation" produced by commodity relations assume decisive importance for the evolution of a society. Reification (from Latin "res" meaning "thing")—literally "objectification"—is the consideration of a thing as if it had human or living existence and abilities. At the same time, reificiation implies the *thingification* of social relations; that is, the fact that social relations are regulated by trade and the relationship between traded objects. A form of reification is what Karl Marx called the fetishism of commodities. According to Marx, the fetishism of commodities in modern societies subordinated people to things, so that the life of individuals occupied in their industrial production process was entirely shaped and organized by this process (Marx 2001).

Adapting the Hegelian theories on relationships between subjects and objects, Miller defined objectification as the "process of externalization and sublation essential to the development of a given subject" in which "the concrete material object" was "one particular potential medium or vehicle" (Miller 1987: 85).

Arjiun Appadurai's article *Commodities and the Politics of Value* (1988) outlined a socialized view of commodities. He argued that commodities may be said to have social lives because they embody value, as created by a society. Moreover, he affirmed that "commodity" is only one possible phase in the social life of an object; as it travels within different regimes of value, it may exit and re-enter the commodity sphere several times (Appadurai 1988:7). Therefore, commodities transmit multifaceted, context-dependent messages operating within a cultural construction. Appadurai stated that it is only through the analysis of the "lives" of "things" that social context can be illuminated in a new way; "we have to follow the things themselves, for their meanings are inscribed in their forms, their uses, their trajectories" (Appadurai 1986:5). Even though "from a theoretical point of view human actors encode things with significance, from a methodological point of view it is the things-in-motion that illuminate their human and social context" (Appadurai 1986:5).

Luxury goods are a sub-group of consumption goods that provide information on social status. Appadurai affirmed that luxury good "use" is exhausted in their social meaning, not in opposition to "necessity," but rather as "incarnated signs" responding to the "necessities" of a fundamentally socio-political variety (Appadurai 1986:38). In fact, as Mary Douglas and Baron Isherwood argued, in a highly diverse society, the demand for luxury goods has to be correspondingly diversified (Douglas and Isherwood 1996: 101). In a complex system of social relationships, such goods can be weapons of exclusion. For example, in a society in which the luxury system is standardized, a strong form of social control emerges—a sign of a competitive system in which small differences matter (Douglas and Isherwood 1996: 102).

<u>Social Dimension of Material Possession:</u>

Commodities studies investigate the profound symbolic significance of material possessions and the role that possessions play in everyday life, influencing the ways in which we think about ourselves and about others (Dittmar 1992:3). Writers from various social scientific disciplines describe Western society before the industrial revolution as one in which a sense of self was mainly derived from kinship ties with family or clan. Life was public, rather than private, with respect to these kinship groups. Identity was conferred on individuals through their closely-knit group (Featherstone 1990:11). Identity was "ascribed" on the basis of one's inherited position.

According to Featherstone, after the industrial revolution identity was no longer "ascribed," but became "achieved", especially in the name of material possession. Material possession has become symbolic of personal and social identity (Featherstone 1990:13).

If possessions and identity are intimately related, what is the nature of this link? It appears that attachment to, and derivation of meaning from, objects occurs among all peoples, including nomadic tribes who place a premium on mobility. For example, among the Samburu and the Nuer of East Africa, cattle take on multi-layered meanings. For cattle pastoralists, diverse values and notions about status and rank are intertwined in one type of object (Wallendorf and Arnould 1988:536). In many cultures in the Third World, the number of commodities in circulation and the frequency and multiplicity of occasions for their exchange, consumption, and display have been more limited than in the West. These cultures frequently compress multiple meanings into a few types of property, rather than into many types of objects, such as clothing, automobiles, houses, home furnishings, and foods used by Westerners for conveying such meanings. A cross-cultural comparison of American Southwest and Nigeria serves as an example. In both, the favorite object is described as reflecting personal meaning and attachments. These objects serve as cultural icons that reflect local culture as experienced by the individual. The examples from the American Southwest indicate how affective memories of personal experiences or the person who made the item for the owner are often symbolized. This form of favorite object attachment is associated with stronger affinity for the object than is attachment based on object-based characteristics. Thus, favorite objects most often serve as symbols of, rather than replacements for, close interpersonal ties. For the Nigerian sample, fewer types of objects were selected as favorite, reflecting not only the smaller number of consumer objects owned, but also individual commitment to a restricted set of cultural values (Wallendorf and Arnould 1988:542). If in the U.S. status is measured by what one has, in rural peasant Nigeria, the wealth of people expressed through the circulation of conventional objects with shared meanings as opposed to sheer possession continues to have cultural significance. The data indicate that Nigerian women emphasize social connections through favorite objects, while men represent their accomplishments and mastery through favorite objects. This research supports the idea that object-preference is built up after acquisition through a dialectical process in which meaning and affect are transferred between individuals and objects over time (Wallendorf and Arnould 1988:543). From this research, it does not appear that materialism expressed through generalized possessiveness is a cultural universal.

In conclusion, it can be said that theories of commodities and objectification contributed to define anthropological theories during the 1990s (Hicks and Beaudry 2010). Using Miller's words, these theories were based on the idea that "the human subject cannot be considered outside of the material world within which it is constructed" (Miller 1987:86. Unfortunately, the latter statement seems to contradict the ontology itself of this new turn to material studies, since materiality and the material world are considered here mere mental constructions, and anthropological theories continue to be subordinated by a Cartesian logic. With this material turn scholars contributed to the dematerialization of both things and relationships between people and things.

2.5. Cognitive Archaeology and symbolism of things

Collin Renfrew, one of the main representatives of the so-called Cognitive Archaeology, claims that cognitive archaeology only can be considered the real post-processual archaeology, since processual archaeology "far from expiring, has entered a new phase which one might term 'cognitive-processual' archaeology (Renfrew and Bahn 1991:431-4). In support of this statement, Renfrew claims that processual archaeology, far from expiring, has entered a new phase in which scholars focus upon symbolic and cognitive issues (Renfrew 1994:5). This new school of thought does not reject the existing methods of archaeological inquiry; if anything, cognitive archaeology is concerned with developing an approach based on the existing methods of archaeological inquiry to investigate the early use of symbols and the development of cognitive processes. In the article *Towards a cognitive archaeology*, Renfrew (1994) claims that the scope of cognitive archaeology is the "ancient mind." As Renfrew states: "the term is not meant to imply that there is necessarily something inherently different between the thought processes of yesterday and those of today. No distinction is implied between ancient mind and modern mind." This premise serves to distance this perspective from previous works such as "La pensee' sauvage" (The savage mind) by Levi Strauss (1966), which implies a judgmental evolutionary approach toward ancient minds. Nonetheless, it is important to recognize a difference in thinking between past people and us. As a consequence, the preserved material culture offers opportunities for studying the reasoning activities involved in the production of things. In other words, cognitivist archaeologists "seek to study the way in which cognitive processes operated in specific contexts, and to investigate the interrelationships between those processes and the social contexts which harbored and promoted them" (Renfrew 1994:5). More specifically, cognitive archaeology is aimed at exploring human ability to construct and use symbols. Symbols are used to cope with several aspects of existence: design, planning, measurement, social relations, the supernatural, and representation. What is the role that things of the past play in this inquiry? It is assumed that the production of most artifacts involves the use of a mental (symbolic) template that serves as a guide in the production phase (design). Moreover, artifacts of a special type can be used to study measurements. Eventually, special types of artifacts have been created and used through time to structure social relations and show ideas about the supernatural.

According to Renfrew, in opposition to the post-processual hermeneutics, the philosophical perspective that many cognitive archaeologists might advocate may be defined as realistic, because it considers the past as really existing in the physical world:

> The past really happened…But this notion of the past which really happened is to be distinguished from our own knowledge of the past, which has to be based upon our own observations and inferences, and is thus constructed using those observations….That we can view the past, like the present, from different standpoints, does not prevent our asserting, however, that some constructions of the past may be in error in failing to use existing data appropriately or in employing erroneous data [Renfrew 1994: 10].

With these words, Renfrew does not reject the multivocal approach to archaeological studies advocated by Ian Hodder; however, Renfrew encourages scholars not to distance themselves from a scientific approach to material culture and to try to be as objective as possible in the archaeological inquiry.

It is clear how post-processual and cognitive archaeology have two distinct approaches to the study of material culture. In one thing, however, these two schools of thought are identical: both see objects as the product of mental processes. Objects are "acted upon," are entirely "constructed" by social or cultural perceptions, and have no existence in and of themselves. Even in commodities studies, the term reification implies mental constructs; that is, it implies that the mental act of giving power to things names their symbolic meaning and social significance.

2.6. Phenomenology and landscape

In the 1990s, British archaeology, for the first time, started to move gradually away from the symbolic/communicative and representational aspect of things and developed some interest in the engagement of people in the world. This theoretical shift in the study of material culture derives from landscape studies and it is mainly influenced by phenomenology (i.e., Heidegger, Merleau-Ponty, Lefebvre, Husserl, and Bergson) and other social theorists ranging from Pierre Bourdieu to Foucault. According to phenomenologists, we need to "re-learn to look at the world" (Merleau-Ponty 1962: xx).

Phenomenology, as it has been popularized and theorized in archaeology, is a way of dealing with how people experience landscape, particularly through visuality. In his book *A Phenomenology of Landscape*, Christopher Tilley (1994) was the first to introduce phenomenology to archaeology, advocating the use of a phenomenological approach for the study of cultural landscapes. He defined phenomenology as "the understanding and description of things such as they are experienced by a subject" (Tilley 1994:12). With this definition the problem starts. According to Bjornar Olsen, phenomenology is about things-in-themselves (Olsen 2010:63). Thus, while for Tilley's successors "open, multi-vocal and ever-changing" landscapes are conceived as something that exist by "virtue of its being perceived" (Olsen 2010:29), Olsen claims that phenomenology is the exact opposite' that is, a radical challenge to the notion of perception based on human relevance (Olsen 2010:65).

The challenge is especially evident for Olsen in Heidegger's writing, and particularly the early Heidegger(1927) of *Being and Time* that is given precedence over the late Heidegger. For the philosopher, things that are ready-to-hand (*zuhanden*) are not seen by us; rather, we are "practically and skillfully involved" with them (Heidegger 1962:98). We live in a state of immersion ("thrownness") in the totality of the world (Heidegger's *Geworfenheit*) and, in this state, the things of which we are aware are a minority, an accident. Reading the philosophical sources of phenomenology, it can be argued that both Tilley and Olsen's visions are correct; the two scholars just refer to different philosophical positions on the topic. On one side, in fact, we have the phenomenology of Kant and the early Husserl; on the other side, we have the late Husserl, Heidegger, and Merleau-Ponty. According to Kant, only things as they appear, phenomena, are knowable objects of sense (Kant 2001:55). When Husserl developed his theory on transcendental phenomenology, he appeared to be strongly influenced by Kant. For early Husserl, in fact, our conscious awareness of objects is always intentional. The intentional object is always a construction that does not need to correspond to any real object (Husserl 1970a). Only later does Husserl introduce the term *lifeworld*, emphasizing the importance of ordinary life experience as constitutive for our understanding of the world (Husserl 1970b). From this latter perspective, humans can be described as engaged subjects who are actively involved in the world they experience. In other words, if for early Husserl the theoretical question was "how does the world exist in us?", the question later became "how are we in the world?" (Matthews 2002:28-29). The later Husserl is clearly influenced by Heidegger. In Heidegger, for instance, the term "subject" or "human" is substituted with "Daisen" (being there), being-in-the-world. Phenomenology thus focuses on the world as it manifests itself to those who take part in it (rediscover phenomena).

As for Olsen 2010:XX): "to give phenomenologists 'proper' all the credit for this 'tangible' turn leaves out one of the scholars for whom perception and matter were so close that their difference was claimed to be a matter of degree, rather than kind." This scholar is Henri Bergson, for whom our knowledge of the world is founded on a practical competence acquired by constantly having to deal with things (Bergson 1994:291, 299). According to Bergson, we recognize objects by using them and by being bodily engaged with the material world. He developed the concept of "image" how we experience things or matter through our active and direct engagement with them. Image is something more than a representation and something less than a thing. Image is the way things appear to us in an intimate bodily experience of them. From this perspective, it can be stated that we have a corporeal involvement in the world. This involvement implies a relationship with things. However, our image-based involvement with the world cannot embrace all aspects of this materiality, since a thing is bound up in infinite relationships with other things. Therefore, to render this network of things intelligible, we need to simplify it. In other words, a thing cannot be grasped in all its relationships with other things, "it would be necessary not to throw more light on the object, but to the contrary, to obscure some of its aspects, to diminish it by the greater part of itself, so that the remainder, instead of being encased in its surrounding as a thing, should detach itself from them as a picture" (Bergson 1994: 28). This theoretical approach is strongly influenced by Merleau-Ponty and Heidegger.

2.7. Materiality and embodiment

Consumption studies and phenomenology have in common the idea that people establish a kind of quasi-social relationship with things. People, in their daily lives, not only become embodied in artifacts and landscapes, but also in practices. Embodiment is the act by which people establish a kind of quasi-social relationship with objects (Dant 1999:2). People are embodied in things when they produce, use, and exchange them.

Engaging with theories in psychology and cognitive sciences, some archaeologists see material culture as "consubstantial" with mind. Lambros Malafouris (2004), for instance, sees mind "absorbed in, rather than detached from, the world, embracing cognitive theories claiming for an extended (e.g., Clark 2003), enacted (e.g., Varela et al. 1991), embodied (e.g., Ratey 2001; Lakoff and Johnson 1999, 1980; Cole 1985), distributed (e.g., Norman 1988; Hutchins 2005), mediated, and situated (e.g., Suchman 1987; Lave 1988; Wilson and Myers 2000) mind (fig. 2). From this new perspective, material culture becomes a process wherein mind as well as body are involved and the material engagement involves "a synergic process by which mind emerges out of brains, bodies, and things" (Malafouris 2004).

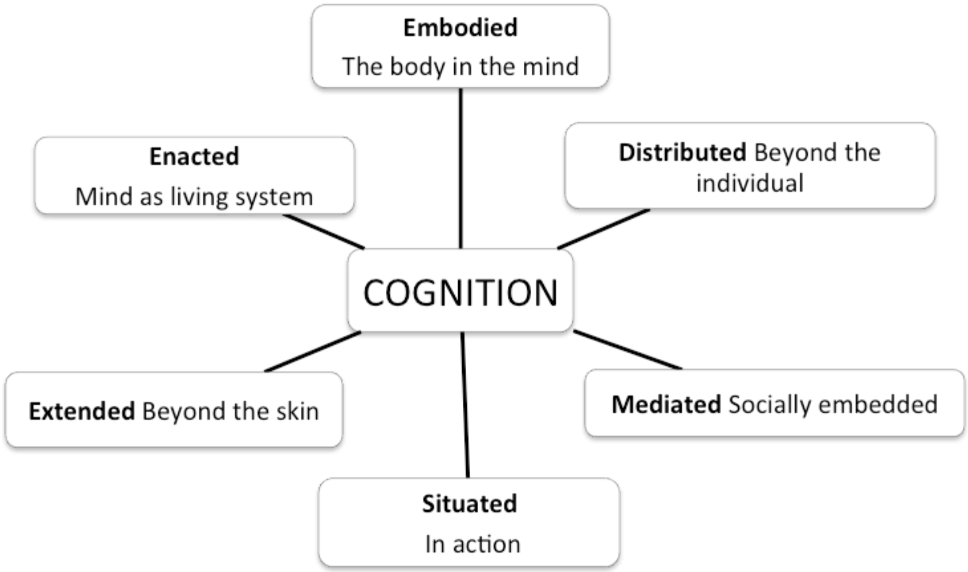


Figure 2. Definitions of "human cognition" (after Malafouris 2004:57).

The act of making things presupposes a set of repetitive gestures. Other gestures are then involved in the use of things and in general in the interaction with material culture. Those repetitive gestures can be seen as daily practices that are ritual-like. Their repetition combines to consolidate cultural practices, shape individual and social identity, and facilitate cultural transmission.

According to Marcel Mauss (1935), the body is Man's first and most natural instrument, and the more natural technical object. But our movements in space cannot be simply considered natural. Techniques of the body are, in fact, also socially determined and, therefore, variable from society to society. We learn them through imitation from the time we are young. They cannot be analyzed unless one is willing to do so from three different points of view: biological, psychological, and sociological (Mauss 1935). It follows, then, that it is impossible to divorce material culture studies from the study of the body.

Serge Tisseron (1996) provides one of the most articulate psychoanalytic theories of the workings of internalization and introjection, or, using his terms, of "symbolization." By "symbolization," he means the process by which a subject introduces into his psychic envelope his experiences of the outside world. Pierre Bourdieu defines the same process as "internalization." According to Bourdieu, the subject (called "agent") is socialized in a "field" where he/she is able to internalize relationships through *habitus*. External structures are internalized into the *habitus* while the actions of the agent externalize interactions between actors into the social relationships in the field (Bourdieu 1977). In other words, there must be internalization through personal experience for communication and expression to take place, and this comes through sensori-affectivo-motricity, elaborated by means of images, words, and practices.

"Embodiment," "symbolization," and "internalization" of practices are considered embedded in the relationships between things and people, starting from the stage of producing things. With regard to production, Mauss argued that when people create things, at the same time they create themselves: "He creates his means of livelihood, purely human things, and his thoughts inscribed in these things. Here is elaborated the veritable practical reason" (Mauss 1927:120). André Leroi-Gourhan formalized Mauss' approach and gave it practical coherence. He coined the term *chaîne opératoire*: "Techniques are at the same time gestures and tools organized in a veritable syntax, one which simultaneously grants to operational series their fixity and their flexibility" (1964:164). Fixity emphasized the cultural *fait*, flexibility the *tendance* (which can be called also process or *habitus*, using the term of Marcel Mauss and Pierre Bourdieu; Mauss 1927; Bourdieu 1977). *Chaîne opératoire* is the materiality of the technical act (and its outcome), which according to Schangler (1994:144) in no way renders the technical act less social, cultural, or human.

<u>Embodiment and production</u>

From Mauss and Bourdieu's perspectives, things can shape our ideas starting with the production process. To give a practical example, it is assumed that to make pottery means to have different ideas. These ideas might be technological, functional, social, behavioral, economic, or anything else. "Our modern, highly fragmented perception is probably the only one which distinguishes these areas anyway" (van der Leeuw 1994:136).

According to Pierre Lemonnier, the three main technological steps, or "orders of facts," in material production are suites of gestures and operations (technical processes), objects (means of action on matter), and specific knowledge (Lemonnier 2002:1). As he points out, any technique in any society is always the physical rendering of mental schemas learned through tradition and concerned with how things work, are to be made, and are to be used (Lemonnier 1980:341). In other words, the phase of production starts from mental stages that are necessarily learned. People develop mental skills and translate them into bodily actions on the matter. According to Lemmonier, for years most studies of technologies and the way they interface with other social behaviors have been reduced either to the study of effects of technological systems on culture and society, or to a search for what human groups communicate when they make and use artifacts. But since technology is first of all a mental process, a complex symbolic system is involved in the process. The assumption here is that some techniques, which become also techniques of the body, are used for manipulating certain matter and creating some tools and not others because of social concepts attached to that matters and tools. Thus, the study of technology should be the study of technological choices through time because such choices are also social (Lemonnier 1980:347).

Embodiment, cultural transmission and social memory

Moving beyond Mauss, Bourdieu has shown how daily routines in eating, sitting, sleeping, and moving in domestic space can be the mechanisms by which people are socialized into particular rules and orientations. As people go about their daily tasks and interact with material culture, they may learn rules and constraints through the movements of the body. The rules become "embodied." It also follows that repetitive simple daily gestures, through internalization, can irreversibly shape our mind. Mauss and Bourdieu's theories are the basis of archaeological research of the post-processualist school, and they also influenced other disciplines, such as cognitive science. Their arguments have been used by Ian Hodder, for example, to study daily practices in the Neolithic site of Çatalhöyük in Turkey. Thus far, research on that settlement has shown the presence of an egalitarian society in which all the material structures present the same pattern that had been constantly repeated for centuries. Even though the repetition of social practices could imply a centralized control, there is no indication of such hierarchy. Therefore, Hodder's study was aimed at demonstrating that instead of social rules being imposed by centralized authorities, the reproduction of dominant groups (elders or lineage heads) was linked to the construction of bodily routines that were repeated in daily house practices over centuries. Since these practices involved productive, consumptive, social, and ritual spheres of life, they constituted a *habitus* (Bourdieu 1977) and a set of social codes (Hodder and Cessford 2004:22). Hodder's argument is that even though all societies have rules about movement in space and in houses, at Catalhöyük there was particular emphasis on segmenting space in the house and regulating movement around that space. At Çatalhöyük, particular emphasis on repetition is seen, with layer upon layer of re-plastering using similar divisions of space over time (Hodder and Cessford 2004:30).

Hodder argues that at Çatalhöyük daily practice and social memory were inseparable and that regulation was constructed through the "habituation of practices." He affirms that in societies without any form of writing, the construction of social memory becomes an important mechanism of social reproduction. In his essay "Techniques of the Body," Mauss describes techniques of the body as "traditional." There is no technique and no transmission in the absence of tradition. Tradition of bodily practices is what we learn through imitative processes. In Hodder's words, at Çatalhöyük the term "memory" replaces "tradition" and implies an active process of memorizing that is socially embedded. We do not just remember biologically (Ebron 1998). Instead, what we remember is selective and thus can be socially constructed and contested (Connerton 1989).

How is memory formed? The process of memorization is an "act of recollection." The mental recollection is strongly linked to the social context in which an individual grows up. It always has to do with a conscious, collective way to recreate the past in the base of our collective present. The idea of *collective memory* is opposed to that of *individual memory*. Individual memory exists, for Maurice Halbwachs, but it is located just in the unconscious dreaming activity (Halbwachs 1992:50). If it is true that we recollect by creating images, it is also true that images in individual memory are fragmented, while the ones in collective memory are structured and organized. And we can call that kind of organization *collective storytelling* shaped by our mind.

But, as mentioned above, memory is not just a biological, mental recollection. Memory of groups is, in fact, conveyed and sustained by recollection and bodies. What is the importance of bodies? Imitation and education, then, are the means of transmission of the techniques and result in the development of bodily expression *habitus*. Paul Connerton explores body rituals linked to memory transmission. He defines three types of memories:

- personal: acts of remembering that take as their object one's life history. It is linked to personal past and it influences our self-description.

- cognitive: memory knowledge. What this type of remembering requires is that the person who remembers must have met, experienced, or learned in the past. In my opinion, this is more connected with historical reconstruction.

- habit: having the capacity to reproduce a certain performance. In this case we do not usually recall the *when*, *where*, and *why* of the acquired knowledge. A substantial part of human behavior can be described in terms of the notion of habit, such that neither the idea of a rule nor the idea of reflexiveness is essential to it.

According to Halbwachs, memories are created in social frames of memory, their basic references are the family, religion, and social class. "Our recollections, each take in itself, belong to everybody; but their coherence or arrangement belong only to ourselves–we alone are capable of knowing and calling them to mind" (Halbwachs 1992: 171). *Social memory* is constituted by several markers that change in relation to the society. Concerning social memory we may notice that images of the past commonly legitimate a present social order. It is an implicit rule that participants in any social order must presuppose a shared memory. The reciprocal need of past and present is clear—present factors, in fact, tend to influence our recollection of the past, as well as past factors tend to influence our experience of the present (Connerton 1989:3).

Memory is always selective, either when it is individual or collective. It is, in fact, a combination between effacement and conservation. In a selective process, a part of the past is effaced in favor of another that is preserved. "Memory does not form an opposition with *oblivion*. The two terms that form a contrasting pair are *effacement* (forgetfulness) and *conservation*. Memory is always and necessarily an interaction between the two. The complete restitution of the past is terrifying and a clear impossibility" (Todorov 1996:8). This process can be also called *deliberate forgetting* (Connerton 1989:46).

Tvetzan Todorov defines two kinds of memory: literal and exemplary. The first is focused on a singular event without making any connections to other similar occurrences. The latter is focused in particular on horrific events, and makes connections between the suffering they recollect and other similar events of horror that occurred in other historical periods and in other places. Joseph Nevins recalls Todorov's differentiation of literal and exemplary memory, but he introduces also a very interesting and important concept: the geography of memory, or the memorialization of landscape (Nevins 2005:268). Every event that is part of our memory is recollected in time and space. Commemorative ceremonies are always practiced in a specific time and place, and the place is a memorial site.

So, how were memories constructed at Çatalhöyük and how were they used in the interests of social regulation? Hodder argues that one important mechanism was the house. The notion that the house can act as a site for social memory has been widely recognized ethnographically and archaeologically (Carsten and Hugh-Jones 1995; Joyce and Gillespie 2000). In Claude Levi-Strauss's (1982:174) definition of "house societies" we see a move away from kinship classificatory models toward the "house" as a corporate body holding an estate that reproduces itself through the transmission of its name, goods, and titles. The transmission of houses and objects kept in houses forges social memory and constitutes social units (Joyce and Gillespie 2000). In Polynesia, for example, an important component of the reproduction of the corporate group is the burial of ancestors and the transformation of houses into ritual temples (Hodder and Cessford 2004:31-32)

2.8. Things, meanings, thingness, and material agency

After an analysis on material culture studies and how they have evolved in the last twenty years, I can only agree with Olsen (2010) and Ingold (2007) when they argue that material culture studies have moved away from things and their materiality, that latter intended, in this case, to refer to the properties of materials. As Tim Ingold (2007:3) claims, : "what academic perversion leads us to speak not of *materials and their properties* but of the *materiality of objects*? It seemed to me that the concept of materiality, whatever it might mean, has become a real obstacle to sensible enquiry into materials, their transformations and affordances." Using Latour's words, it seems today that "to become a social scientist is to realize that the inner properties of objects do not count, that they are mere receptacles for human categories" (Latour 1993:52). Pinney offers a clear manifesto of this anthropological perspective on things, when he states that the "declaration of objects' emptiness has become proof for an anthropology committed to the victory of the cultural over the material, and the discursive over the figural" (Pinney 2005:258). These material studies are impregnated with Dukheimian theories, according to which objects offer only a surface for the projection of our social needs and interests. In this view, objects become empty spaces, of interest only because of the "meanings" that invest them with significance.

In the last few years, however, a few scholars and artists have started to explore how inner qualities of objects (such as weight, density, shape, etc.) enhance the perception of past and present material culture and can lead to the creation of "material narratives." For Ingold, the properties of materials, which also have to be considered constituents of an environment, "cannot be identified as fixed, essential attributes of things, but are rather processual and relational. They are neither objectively determined nor subjectively imagined, but practically experienced. In that sense, every property is a condensed story. To describe the properties of materials is to tell the stories of what happens to them as they flow, mix and mutate" (Ingold 2007:14). Simply put it, we should again "*take materials seriously*, since it is from them that everything is made" (Ingold 2007:14). In doing so, he denies the dichotomy between natural and cultural (artifacts) and proposes a Gibsonian ecological approach that considers materials as components of the environment; "whereas the physical world exists in and for itself, the environment is a world that continually unfolds in relation to the beings that make living there. Its reality is not of material objects but for its inhabitants. It is, in short, a world of materials. And as the environment unfolds, so the materials of which it is comprised do not exist –like the objects of the material world- but occur" (Ingold 2007:14).

To give an example, in the summer of 1916, the photographer Paul Strand began to take pictures of abstract shapes on porch of the Twin Lakes cottage in Connecticut (http://www.metmuseum.org/toah/hd /pstd/hd_pstd.htm; Paul Strand et al. 1945; Pinney 2005: 259). Using some bowls from the kitchen as his subject matter, he produced the first abstract photographic still-life. By fragmenting the objects, Strand freed them from their domestic, human/social context and enabled them to achieve a formalism that disguised any social meaning the objects possessed. As pointed by anthropologist Christopher Pinney, Strand nonetheless conferred on these objects an aesthetic value, transforming them into both something less (fragments), but also something more (i.e., forms), emphasizing their *thingness* obscured by the everyday use as objects.

A similar performance aimed at underlying the *thingness* of things was organized in the winter of 2009 at the New York Museum of Modern Art (MOMA) by artist Vik Muniz (http://www.moma.org/visit/calendar/exhibitions/304). In an exhibition called REBUS, the artist took the role of museum curator and brought together eighty-two works from MOMA's collection, organizing them according to the principle of a rebus, a puzzle in which unrelated visual and linguistic elements create a larger deductive meaning. He wanted to strip artworks from their original taxonomies and focus on creating intuitive connections based on form, color, scale, quantity, function, and pattern. He wanted to encourage users inside a museum to think about the connections between each object and the next, with a cognitive approach.

The experiments I just described stress the importance of innate qualities pertinent to objects, for they are material products. Moreover, these examples demonstrate how the material qualities of objects enhance people's perception of their functions. Using Gibson's words, I call this perception *direct perception*. *Direct perception* is used here in opposition to the generalized idea that humans are only able to understand the function of an object indirectly, through internal representations. According to this belief, once we perceive the physical structure of an object, we place it in a specific category, which is archived in our brain. Thus, human perception is considered mediated by a process of perception and then conceptualization.

According to Gibson (1979) the potential of an object as something for sitting on, for instance, could be observed without a process of conceptualization. He termed the potentialities held by an object for a particular set of actions "affordances." Following a Gibsonian approach to material culture (i.e., *ecological approach*), some scholars in psychology, cognitive science, and also archaeology have developed a more balanced approach incorporating elements of both direct and indirect perception (Clark 1996, 1997; Kirsh 1995; Norman 1993; Hutchins 1995; Knappett 2004, 2005).

Presenting a post-Gibsonian approach, archaeologist Carl Knappett (2004: 43) argues that the affordance and meaning of an object reside in the object and human minds at once, and affirms that while the affordance of an object could also be perceived if the object is out of context, objects in-context are more "directly" perceivable (Knappett 2004:44). If mind and matter are "co-dependent," as Knappet argues, we should not privilege one or another, but should instead view them as mutually interdependent and constitutive. In sum, affordances, for Knappett, have three key aspects: *relationality*, *transparency*, and *sociality*. *Relationality* means that that they are a "relational property shared between object and agent" (Kanppett 2004:46); *transparency* means that the affordance of an object, to be perceived, has to be transparent to the observer, and this is not always true in an object physical form alone. To be clearer, Knappett provides the example of a postbox and states that this object's affordances are not merely shape and size, and that a postbox is only transparent to those with the requisite cultural knowledge; without the requisite knowledge, the postbox could be mistaken for something else.

As cognitive scientist David Kirsh (2010:34) points out, objects are, in fact, part of a dynamic ecology of users, designers, supporting artifacts, tasks, and practices, and are constrained by culture's momentary technological advancement. According to Kirsh, however, the ecology of artifacts is transmitted and encoded in the artifacts themselves: "Artifacts crystallize practice; they are a type of *meme* reservoir that people interpret through interaction. So in a sense artifacts transmit cognition; they help to transmit practice across generations, shaping the ways people engage and encounter their world."

Using the term *meme,* Kirsh clearly expresses his sympathy to memetic theories of cultural transmission. In 1976, Richard Dawkins coined the term *meme* to define a "unit of cultural transmission, or a unit of imitation" (Dawkins 1976:6). With his book, Dawkins gave a thorough definition of memes, and argued that ideas and elements of culture were semi-autonomous elements working to replicate and adapt like genes. Memes were also defined as "successful replicators" provided with three main characteristics (Dawkins 1976:195):

1. copying-fidelity: the more faithful the copy, the more will remain of the initial pattern after several rounds of copying;

2. fecundity: the faster the rate of copying, the more the replicator will spread;

3. longevity: the longer any instance of the replicating pattern survives, the more copies can be made of it.

According to Bjarneskans, Grønnevik, and Sandberg, memes (as genes) are surviving machines responding to the theory of natural selection. Natural selection occurs whenever the following conditions exist (Bjarneskans et al. 2000):

- Variation: a continuing abundance of different elements.

- Heredity or replication: the elements have the capacity of creating copies or replicas of themselves.

- Differential "fitness:" the number of copies of an element that are created in a given time varies, depending on the interaction between the features of that element (whatever it is that makes it different from other elements) and features of the environment in which it persists.

Therefore, it can be said that memes vary, they replicate (by definition), and have differing fitness. This leads to phenomena of competition, co-evolution, population dynamics, and adaptation. The set of memes in a cultural transmission is defined as the "meme pool" (in analogy with the "gene pool"), or the "population thinking" (Hull 2000).

In his article Kirsh argues that users, artifacts, practices, and tasks have coevolved (Kirsh 2010:2). In this work he mainly focuses on "practice" sustaining the interdependence of practices, users, and artifacts: "Once new artifacts are built, however, people are able to address their tasks in different ways" (Kirsh 2010:2). From this sentence we can infer that things, or artifacts using Kirsh's term, have a "material agency" that influence practices. The concept of agency requires a more adequate account of what material things "do," rather than just what they "mean" to a society (Hicks and Beaudry 2010:75). Bruno Latour was the first to attempt to theorize material agency. Latour, a French sociologist and anthropologist, argued that a society is to be considered a complex network of people and things. His theory is known as actor-network-theory (ANT; Latour 1999). For ANT, relations between things and humans are not simply bilateral; they are networks emerging from the actions of both humans and non-humans. In his book *We Have Never Been Modern* (Latour 1993), he proves the fallacy of the dualisms object/subject, subject/society, and culture/nature. Reality is a network of hybrid relations in which everything can be actor and can have agency. Both humans and nonhumans achieve agency as a relational property, distributed across hybridized human-non human networks. Latour's perspective is both non-dualistic and symmetrical (in the sense that the relations between humans and nonhumans are symmetrical):

> Consider things and you will have humans. Consider humans, and you are by that very act interested in things. Bring your attention to bear on hard things, and see them become gentle, soft or human. Turn your attention to humans and see them become electric circuits, automatic gears or softwares. We cannot even define precisely what makes some humans and technical, whereas we are able to document precisely their modification and replacements, their rearrangements and their alliances, their delegations and representations [Latour 2000: 20].

He calls things quasi-objects, hybrids of cultures-natures produced by and within networks of relations (Latour 1993: 54). Things are hybrids because they link.

2.9. Conclusions

The literature regarding material culture summarized in this chapter demonstrates that the topic needs an interdisciplinary approach. Even if the focus of my research is decidedly material culture in archaeology, a multidisciplinary analysis has helped to clarify the complexity of this multifaceted topic. Starting from the second half of the last century, scholars have tried to answer two questions regarding things: how and why are things significant to us? In accordance with the recent studies in "defense of things" discussed above, I have showed how material culture studies have been too focused on the meanings of things rather than on their materiality. That objects carry meanings given to them by people is clear, and it is clear that those meanings can change through time, sometimes becoming very different from the original meaning; but these meanings can also be transmitted through time. And some of them have a very long life-span, as Neo-Darwinian archaeologists have tried to demonstrate through a memetic approach to material culture.

We shouldn't forget, however, that the primary characteristic of objects is materiality. And this materiality cannot be fully understood if we consider things as texts and we try to interpret them relying on analogies, dualisms, and oppositions. If we recognize things' materiality, we should be able also to recognize thingness in things:

> The answer given starts from the fact that things are not words, nor are they primarily signs to be read or products ready to be consumed or "sublated." Things possess their own nonverbal qualities and are involved in their own material and historical processes that cannot be disclosed unless we explore their integrity *qua* things. Things come to us primarily as ready to hand equipment: as chairs, beds, stoves, axes, kayaks, fridges, houses, cars, roads –in other words, as things that work, not as symbolic consumables. Contrary to the linguistic signifier, the tasks they fulfill are primarily due to their irreplaceability or superiority in conducting precisely these tasks and to their non-arbitrariness in significant operations such as shooting, boating, traveling, bridging, sitting, housing, and so on. In conducting these tasks, things normally come to us as reliable and familiar. We can trust them. They are, and they last. Not without exception, of course, but as the normal state of their being –in other words, the overwhelming majority of the everyday instances [Olsen 2010: 173].

According to Gibson (1979), the thingness is linked to the objects' physical qualities (texture, density, weight, shape, dimensions etc,); these physical qualities afford function (i.e., the texture and density of a flint afford chipping and fracturing) and function often can be directly perceived by people when they interact with objects. Gibson calls this thingness "affordance" (Gibson 1979). With this dissertation, I intend to inquire whether affordances of things can be used as bridges for linking present people to past things. Due to the affordances, present people and things have their "first contact:" if present people grasp the materiality of past things–to be intended as the set of material qualities or affordances–they might be able to also grasp the function of the thing.

Following Olsen, humans can trust things because they are in place and they last, and because they come to us reliable and familiar. This means that a certain kind of objectivity exists when archaeologists try to interpret and reconstruct the past through its material remains. How can we reconstruct the past, then, and what kind of past can we reconstruct? The question is whether we have just one "Past" (unified, monolithic, and directly retrievable), many little "pasts" (multiple, contradictory and oftentimes inferred), or no past at all that can be meaningfully grasped. I would argue that we have just one past that is "polysemous", but this dissertation will maybe help to clarify this point. However, my theory on the reconstruction of this past mediates between processual and post-processual archaeology. I think there are objective data that can be grasped from the past, especially if we study the past with a focus on functions or when we approach material remains from a cognitive point of view more concentrated on the understanding of the "how" of past processes instead of the "why." When we enter into the domain of meanings applied to material culture and perception of the environment, then everything becomes more complicated.

Quoting Italo Calvino, *the* Italian 20th century writer:

> Irene is the city visible when you lean out from the edge of the plateau at the hour when the lights come on, and in the limpid air, the pink of the settlement can be discerned [to] spread out in the distance below...Travellers on the plateau, shepherds shifting their flocks, bird-catchers watching their nets, hermits gathering greens: all look down and speak of Irene...Those who look down from the heights conjecture about what is happening in the city...At this point Kublai Khan expects Marco to speak of Irene as it is seen from within. But Marco cannot do this: he has not succeeded in discovering which is the city that those of the plateau call Irene. For that matter, it is of slight importance: if you saw it, standing on its midst it would be a different city in the distance, and if you approach it changes…There is the city where you arrive for the first time; and there is another city which you leave never to return. Each deserves a different name… [Calvino 1974: 124-5].

Calvino is a post-modern writer *par excellence*. He attributes importance to the users of the city because they construct meanings based on the place from which they look at the city. In this sense, his idea is close to that of the post-processual archaeologists, who believe that meaning of ancient things is produced rather then recovered, because readers of material culture (who are archaeologists interpreting things, users of a museum, etc.) become producers of meaning as well. In opposition to these theories, I would use this passage as metaphor of the archaeologists' work: we are the travellers and the archaeological site is the city that we discover. Material culture (things or what remains of them) is our only informant of the past society that we are studying. Things help us to mediate our etic perspective of past societies.

In conclusion, when we study material culture we should focus on two aspects of things. The first is their thingness, because it is the first "direct" connection that we can have with them; then we should turn to the meanings that past societies gave to them. Objects aren't just empty boxes that we can fill up with our meanings. Things have agency, since their materiality influences peoples' daily practices and changes peoples' environments. In other words, human society is built with things. To be more challenging, I want to argue that things have to be treated as beings in the world and be considered in their relationship with the other beings. With this statement I am not trying to create a new animistic religion. I am, indeed, trying to dismantle the anthropocentric view that has largely influenced material culture studies since they were conceived. In opposition to Pinney's (2005: 258) manifesto of the anthropological perspective on things, I argue that everything is material and that what we call culture does not exist outside of a discourse on materiality, especially because, in accordance to Olsen, "if there is one history running all down from Olduwai George to Post-Modernia, it must be one of increasing materiality–that more tasks are delegated to non-human actors; more and more actions mediated by things" (Olsen 2003:88).

Chapter three. When *real* becomes *digital*: Digital Heritage and 3D replicas of artifacts

This blind man, an old friend of my wife's, he was on his way to spend the night…Something about the church and the Middle Ages was on the TV…the TV showed this one cathedral…Then something occurred to me and I said: "Something has occurred to me. Do you have any idea what a Cathedral is?..."…"Cathedrals," the blind man said. He sat up and rolled his head back and forth. "If you want the truth, bub, that's about all I know…But maybe you could describe one to me?..."…"Hey, listen to me. Will you do me a favor? I got an idea. Why don't you find us some heavy paper? And a pen. We'll do something. We'll draw one together. Get us a pen and some heavy paper. Go on, bub, get the stuff," he said…He closed his hand over my hand. "Go ahead, bub, draw," he said… "Close your eyes now"… "Don't stop now. Draw"…Then he said, "I think that's it. I got it," he said. "Take a look. What do you think?"…My eyes were still closed. I was in my house. I knew that. But I did not feel like I was inside anything. "It's really something," I said. (Raymond Carver, *Cathedral*).

3.1. Introduction

In the previous chapter I provided an overview of material culture studies, and introduced the concepts of *materiality*, *thingness*, *agency*, and *material engagement*. What happens to the *thingness* of past artifacts, when we preserve them *digitally*? How do we define *digital heritage*? And how do we cope with it? The relatively new discipline of "digital heritage" originated about 30 years ago with the aim to preserve the past and increase possibilities for public awareness and interpretation. Digital heritage (also called virtual or cyber heritage, when it deals with 3D reconstructions of past environments) can be described as a discipline that uses advanced technologies and the internet to record, replicate, and digitally preserve heritage (i.e., artifacts, sites, and artworks, but also intangible heritage) and openly disseminate digitally preserved heritage to a global audience (for a discussion on the definition of "digital heritage" see Bianchi 2006; Stone and Ojika 2000).

In the last few years, heritage projects including the 3D component have tremendously increased (Betts et al. 2011; Lin et al. 2010; Niven et al. 2009). The strength of digital artifact reproduction as an aid to education, research, and preservation lies in the reproductions' fidelity to the original materials and its ability to be integrated into comparative research.

Two broad ranges of purposes can be identified for digitally representing artifacts: (1) applications concerned with documentation and analysis for use of cultural heritage professionals; (2) applications with a component of dissemination. The many ways of classifying digital heritage also vary depending upon the means used to digitally preserve it. Alonzo Addison (2008b:11) provides a list of means that are used to make digital heritage based on the analysis to be undertaken:

1. Visual: Still/video cameras, color scanners

2. Dimensional: 3D scanning, photogrammetry (remote-sensing technology in which geometric properties of objects are determined from photographic images), digital surveying (employing electronic distance measuring devices [EDM] linked to a total station), ground-penetration radar systems (GPR)

3. Locational: Global Positioning System (GPS) sensors

4. Environmental: Thermal registration, acoustic measurement systems, radiocarbon dating.

For the purpose of the present study, this chapter focuses on 3D digital replicas of artifacts, providing an overview of the most common media utilized today to digitally preserve and disseminate artifacts: 2D images and 3D replicas. Further, this chapter presents an overview of case studies dealing with documentation, analysis, and dissemination of cultural heritage. Finally, I provide an epistemological background on how people think with objects, presenting the ontology behind the experimental part of this doctoral research.

3.2. Preservation and dissemination of cultural heritage before the advent of 3D: photography and 2D digital archives.

Photography—and more often digital photography—is one of the primary methods of documenting, preserving, and disseminating artifacts. Photographs are useful for conservation because they provide a fast, simple, and inexpensive way of documenting notable characteristics observed in artifacts. This is perhaps one of the reasons why archaeologists began utilizing photography surprisingly early for recording antiquities. At the end of the 19th century, with a reliable camera using bromide-gelatine emulsions (Dorrell 1989:1), British inventor, photography pioneer, and antiquarian Fox Talbot took photographs of manuscripts, engravings, and busts. Soon, in the latter part of the century, photography began playing a major role in the development of a more scientific, analytical approach to recording and excavation. According to Peter Dorrell (1989:1-2), by the 1850s archaeologists had started to regard photography as a "panacea," mainly for its alleged objectivity. Probably the first archaeological expedition to use photography was that of Egyptologist Richard Lepsius in Egypt in 1842-45, soon followed by one of the most significant archaeological photography campaigns in Assyria by V. Place, French Consul in Mosul (1852-55; Dorrell 1989:4). These first pictures were made using a Daguerrotype, wherein the images were formed on a silvered metal plate coated with silver iodide, then exposed to light in a camera, and eventually fumed with mercury vapor and fixed by a solution of salt.

So many things have changed in the archaeological practice of photography since the first Daguerreotype image was produced in 1837. As early as 1904, Sir Flinders Petrie published an entire chapter on photography in *Methods and Aims of Archaeology*, with the intent to include photography into field methodology and standardize the practice of photography in archaeology . In the same period, the use of aerial photography in archaeology emerged in Britain. The first known aerial photo, taken from an Army war-balloon in 1906, was of Stonehenge (Wilson 1982). The practice of photography in archaeology was refined in the following years, when Mortimer Wheeler inaugurated the season of large-scale excavations, and pictures became necessary for intra-site comparisons of different excavation areas (Guha 2002:98). Wheeler imposed a code of rules for site photography, using the camera as a scientific recording device. These regulations included using a measuring scale and removing the names of the photographers from the individual photographs in the name of *objectivity* (Guha 2002:99).

By the mid-1970s, photography in archaeology became more complex, including aerial photography, underwater photography, and even public presentation of technical photographs (Harp 1975). Later, manuals also included infrared and ultra-violet photography, which were considered an effective method in archaeology and museum studies since they enhance the visibility of material records.

By the early 1980s archaeological photography had, for the most part, become standardized: the photo scale was now accompanied by an arrow to indicate north and a photo board with the photograph's locale prominently displayed. Artifacts were photographed in isolation inside labs, with a neutral background.

While analogue photography was being standardized in archaeology, in 1969 Willard Boyle and George Smith, working at the Bell Laboratories in the U.S., invented the Charge-Coupled Device (CCD), which became commercially available in 1973. Since then, digital cameras have slowly replaced analogue cameras: Lindsay MacDonald (2006:189) shows how in 2003 more than 100 million cameras were sold worldwide, of which approximately 46 per cent were digital and 54 per cent were analogue. These numbers seem to indicate that for most users digital cameras had reached a level of performance whereby they could substitute traditional analogue film cameras.

Digital photography provides the advantage of immediate feedback through the display, easy processing, copying, and circulating of the digital images compared to images taken using a traditional film camera (for advantages and disadvantages linked to using a digital camera see: Rudolf 2006). Moreover, it allows editing the pictures and changing the background, for instance, or adding a digital scale and other symbols, cutting and scaling images, etc.

Another benefit of 3D digital photographs is that the images can be stored on a computer hard drive or an inexpensive external backup device. This gives material culture experts access to complete archives of images of archaeological sites, artifacts, and the excavation process. From the digital photographs, curators can enhance their data collection procedures by recording information about the material data, sort of collections by site number and location, and share the digital pictures with visiting researchers. Nonetheless, Rudolf notes that while a traditional film can endure more than 100 years if stored in a cool, dry and dark environment, digital photos do not endure that long, since devices necessary to read them change very fast; therefore, digital image data must be copied to new media devices at regular intervals that do not usually exceed 10 years (Rudolf 2006:190).

Digital cameras have made it possible to create and manage large collections of digital images and the advent of the Internet has created new opportunities for the use of digital imagery. In the last few years, collections of digital images with appropriate metadata have been recognized as significant resources for heritage management. A quick search on the Internet allows access to exemplary *corpora* of digital images. Some digital collections of pictures integrate information and documentation of excavation projects. Among currently available all examples, it is worth citing the Swedish Pompeii Project (http://www.pompejiprojektet.se/index.php) directed from the Department of Archaeology and Ancient History at Lund University, and the Çatalhöyük research project (http://www.catalhoyuk.com/) directed by Ian Hodder (Stanford University). Other collections of digital pictures give access to digital representations of artifacts stored in museums facilities: one notable example is the Cuneiform Digital Library Initiative (CDLI; http://cdli.ucla.edu/), which represents the efforts of an international group of Assyriologists, museum curators, and historians of science to make available digital images of cuneiform tablets dating from the beginning of writing, ca. 3350 BC, until the end of the pre-Christian era. More than 290,000 images have been catalogued in electronic form by the CDLI, which is directed by the University of California, Los Angeles.

The digital projects described above are just a few examples of the large number and variety of 2D digital collections, but well-illustrate the centrality of 2D imaging for the preservation and dissemination of cultural heritage. After the advent of 3D reproduction techniques, 2D archives have been paired by these new 3D collections. Below, I provide just a few examples of 3D reproduction techniques and try to define pros and cons of 3D use in the heritage fields.

3.3. Laser scanning and photogrammetric techniques: when digital preservation becomes three-dimensional.

Although photographs provide images of artifacts that work well for documentation, some scholars (e.g., Kuzminsky and Gardiner 2012) argue that 2D image is not an ideal replacement, when the original artifact is unavailable. A digital picture can show remarkable detail, but photographs alone are insufficient to address many aspects of an artifact that archaeologists and museums and heritage specialists study. For this reason, in the last few years, scholars interested in the study of past material culture have started to experiment with 3D technologies in their work. Three-dimensional reconstructions of real objects have become a common method to analyze and study artifacts when the real objects are located in facilities that are difficult to access for diverse reasons (e.g., risk of damage for real objects, distance, conflicts, etc.). Three-dimensional replicas have also been used in museums and schools for educational purposes.

Real object models can be reconstructed automatically using active and passive methods. Laser scanning and structured light are typical examples of the active methods. One of the most significant advantages of laser scanners is their high geometrical accuracy. The most common passive method, known as Dense Stereo-Matching Techniques (DSM), use images acquired by digital cameras placed at different viewpoints and reconstruction the 3D model using a structure-for-motion algorithm (i.e., Photoscan®). These passive methods are inexpensive and useful when direct access to the object is prohibited. The use of 3D technologies allows the replication of real objects without the use of molding techniques, which in many cases can be more expensive, more difficult, or too invasive to be performed, particularly in cases where the direct contact of the molding substances could harm the surface of the original object.

Laser scanning technique

Laser scanners were originally designed for the manufacturing industry, but in the last few years 3D scanning has generated interest and become widely used in archaeology, museum studies and heritage management. An article recently published in the *Journal of Archaeological Science* (Kuzminsky and Gardiner 2012) reflects this interest and demonstrates how 3D scanning is now considered a useful methodology for the analysis of the past. In this article, the authors show that since the interest in laser scanning techniques has greatly increased in the last few years, and laser scanning in archaeology was even the subject of a special forum at the 2007 Annual Meeting for the Society for American Archaeology (Sumner and Riddle 2009). In addition, it was a topic of conferences dedicated to Digital/Virtual/Cyber heritage, including the CAA (Computer Applications in Archaeology), VAST (International

Symposium on Virtual Reality, Archaeology, and Cultural Heritage), to mention just a few representative examples.

Laser scanners are capable of creating images that vary in size and shape, ranging from something as small as a coin to larger objects as an amphora, and they allow for the creation of digital models that are both accurate to within a millimeter and able to capture an object's full color surface appearance (a *texture map*; Addison 2008:28; Rennison et al. 2009; Weber and Malone 2011; Di Giuseppantonio Di Franco and Galeazzi 2013). Although the instrument settings can be lowered to reduce scan time, higher resolution more adequately captures the detail that is needed for archival purposes and most research projects.

A wide variety of commercial laser scanners can be used for artifact reproduction. Blais (2006) reviewed various commercial range scanning systems, but a simple Internet search is always recommended to find information on up-to-date 3D laser scanners and other active 3D reproduction devices, since these technologies improve quickly. Generally speaking, laser-scanning devices range widely in price, from affordable machines ($3,000) to expensive instruments ($20,000 –$ 100,000). Most laser scanning methods require a post-processing step for object texture acquisition and registration (for a discussion of some techniques for texture-mapping see Bernardini and Rushmeier 2002; Bernardini et al. 2001), but in recent years portable laser scanners capable of creating high-resolution images have also become available. These scanners are inexpensive, simple to operate, and non-destructive. A major benefit is that they offer a cost-effective method of creating 3D digital artifact collections. One affordable option is the Next Engine HD Desktop Laser Scanner and Scan Studio HD software, which have also been used for this doctoral research (see Chapter 4).

The Next Engine is widely used in archaeology and related fields to scan artifacts and other archaeological material remains (e.g., animal and human bones) because it is inexpensive, portable, non-invasive, and user friendly; in fact, it requires minimal skills for reproducing an object in 3D. Moreover, the 3D reproduction process is fast and semiautomatic, especially for globular shapes (which can be acquired with a single 360 scan, as shown in Chapter 4), since texture mapping is not necessary (textures are automatically applied on the 3D model through use of the RGB camera present in the scanner).

This scanner comes equipped with a turntable that connects to the scanner. The turntable has a platform on which the object is placed and a part-gripper that keeps the object stable, which is essential for handling fragile objects. First, the scanner collects surface data from the object, capturing data points that form polygons that form the geometric structure of the object. Once a single scan is complete, the turntable rotates by a user-determined degree and the process begins again until the desired number of scans is achieved (Weber and Bookstein 2011). Thousands of polygons form a mesh structure of geometric and surface data that can be viewed in three-dimensions (Tocheri 2009). After the scanning process is complete, unwanted parts of the scan can be trimmed out of the image and the individual scans are fused together. This process results in a complete 3D virtual copy of the original artifact containing the objects' surface details and point cloud. The final model can be viewed with the "photo" surface (texture) visible, as a solid surface, as a mesh, or as a point cloud.

Archaeologists have demonstrated the potential of laser scanners for preserving and disseminating cultural heritage. Yet this technology has some limitations that need to be discussed. The 3D scanning technology is new, and there is as yet no standard protocol for creating and analyzing the 3D digital models. Tocheri (2009:89) points out that it is important to remember that laser scanners create a "model" of the original specimen and that the accuracy of the image depends on the 3D software, algorithms, and expertise of the person using the scanner. Furthermore, scanning complex objects at high resolution can be time-consuming. Each scan made of a complex object can take hours to complete, if the researcher wants to have a higher resolution model. Another issue is that of data storage and preservation. While short-term storage of digital models is a relatively simple task with computer hard drives, external devices, or DVDs, these devices break down over time and backups require ongoing maintenance. In addition, while there are methods for 3D digitization of artifacts with high geometric resolution, there are still limitations in achieving high textural resolution (Chow and Chan 2009). Texture is very critical for the study of artifacts and also for visual exhibitions, and often must be of much higher resolution than the range data (Blais and Beraldin 2006).

One major problem is that the object surface exhibits highlights (specular reflections of illuminated light) during the acquisition of surface texture. Some scholars have proposed solutions to this problem. For instance, Shu-Kam Chow and Kwok-Leung Chan (2009), electronic engineers at the University of Hong Kong, propose a new method that is applicable for the separation of diffuse and specular reflection components in multi-view image sequence. They first estimated the illumination color, which is used for normalizing and renormalizing the image sequence. An algorithm, specifically designed for multi-view image sequence, was proposed to identify and change the color of specular pixels. The diffuse image sequence can then be used to generate the texture map for the geometric object model. They tested their method using multi-view image sequences of Yixing ceramic teapots. Each sequence contained 36 images acquired by a 6-million-pixel digital camera. The geometric models of the ceramic teapots were captured by the 3D laser scanner (Konica Minolta Vivid 910) and further refined using 3D Studio Max.

Dense Stereo Matching and other passive methods

As previously stated, Dense Stereo-Matching (DSM) Techniques are one of the most common passive 3D reproduction methods used in archaeology and heritage management. They allow production of 3D replicas of artifacts starting from a series images. Images can be acquired with inexpensive systems and can contain all the information for the generation of a textured 3D model. Different steps usually compose the photogrammetric process: (1) camera calibration and orientation; (2) 3D measurements (e.g., via image matching; and (3) structuring and modeling (using software such as Photoscan, Asc3D, etc.). For a review of the entire image-based modeling pipeline see Remondino and El-Hakim (2006) and Dellepiane and colleagues (2012). In general, the amount of time needed for the processing of the image set is on the order of a few hours. This kind of 3D reproduction approach is specifically useful in the fields of archaeology and cultural heritage management, since it is a non-contact, low-cost alternative to laser scanning methods. However, Matteo Dellepiane and colleagues (2012:3) claim that comprehensive studies on the accuracy and repeatability of dense reconstruction tools are missing. Therefore, although some consider dense stereo reconstruction an effective alternative to 3D scanning, no convincing comparison has been proposed until now.

Recently, some initial effort has been made in this direction (Harmon et al. 2010) ,but an overall methodological definition and an accurate data assessment are still missing.

Moreover, deriving a complete, detailed, accurate, and realistic 3D image-based model is still a difficult task for reproducing both large or complex objects and, particularly, small and intricate artifacts. DSM is even more challenging if non-experts acquire the images or if uncalibrated or widely separated images are used. Matteo Dellepiane and Roberto Scopigno (2012) demonstrate how DSM still lacks geometric details when used with small objects (i.e., less than 9-10 cm in size). Moreover, the generated 3D data are at an unknown scale. The system is able to determine the spatial relationship between the various reconstructed points— thereby producing geometry with the correct proportions—but the general scale of the scene cannot be recovered. As Dellepiane et al. argue (2012:4) the scale can be easily and precisely obtained by a few measurements on the real-world scene. The same issue is found in most photogrammetric software tools, which require the manual specification of the distance between two (or more) points to recover the scale value. The basic idea is to find some points in the scene, measure them in the real world and in the 3D data, and use the ratio of these two measures as the scale factor.

Recently the Microsoft research group has designed new software that is able to provide 3D object scanning and model creation using a Kinect for Windows sensor. Kinect is a motion-sensing input device designed by Microsoft for the Xbox 360 video game console and personal computers that enables its users to interact with the Xbox without the need to touch a game controller, using gestures and spoken commands. The Kinect for Windows sensor, called Kinect Fusion, allows users to create a 3D model of a real environment in just a few minutes (Izadi et al. 2011: 559-568) by simply holding and moving the Kinect camera (fig. 3).

The Kinect camera uses a structured light technique to generate real-time 3D models. Even though the Kinect fusion enables users to generate in real time high-quality, geometrically accurate, 3D models of settings within this system, it is not fine-grained enough to provide highly accurate reproductions of small objects. Nevertheless, its potential seems promising, and once refined, this method will likely provide an economical, convenient, highly accurate, and fast method to reproduce artifacts.

The examples above demonstrate that we are not far from that moment when "do it yourself" (DIY) 3D reproductions will substitute for pictures both in research (to document and record past remains) and for tourism (to bring home memories of our experience with cultural heritage). On January 31st, 2014, the Massachusetts Institute of Technology (MIT) released news of an innovative smartphone 3D scanning technique that will make these DIY 3D reproductions possible. In 2011, MIT designed the spinout Vitzu technology that, similar to other hardware available today, creates 3D reproductions with personal cameras. News is that this technology has been sold to a "tech giant", that intends to bring it to the public worldwide (http://phys.org/news/2014-01-d-scanning-smartphone.html).

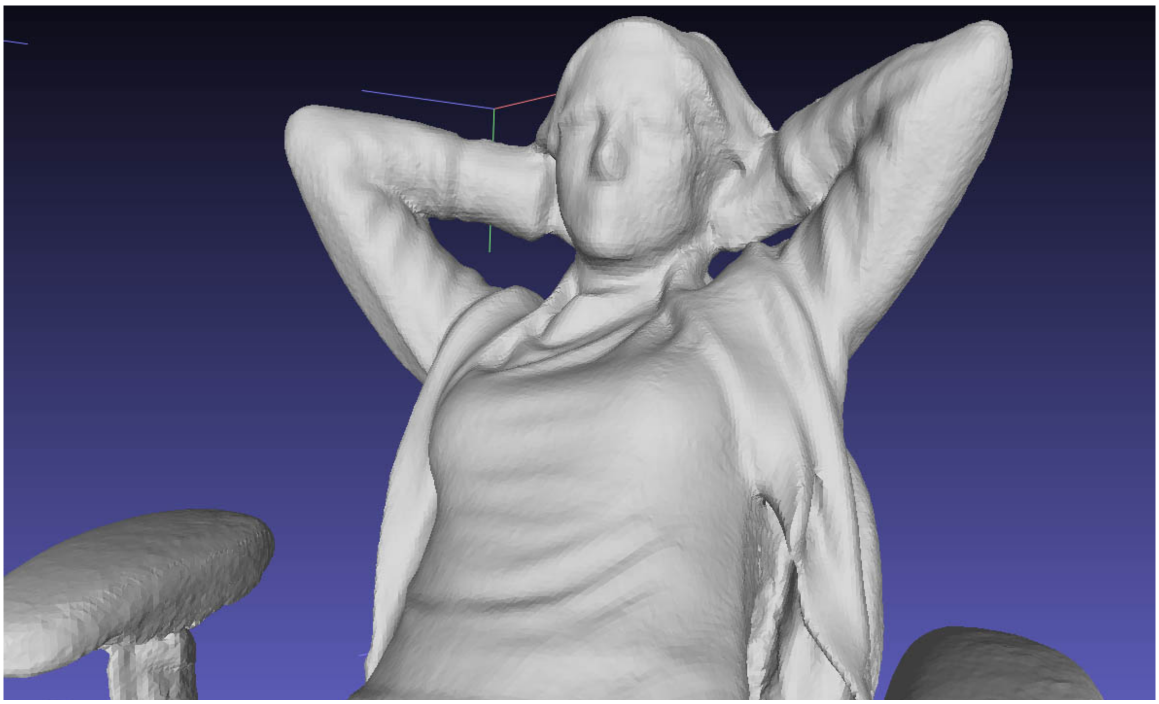


Figure 3. Virtual me. Three-dimensional reconstruction (3 minutes) of a human body using Kinect Fusion.

3.4. The benefit of 3D artifacts: applications and case-studies.

Given all the technological advancements, 3D reproduction techniques offer affordable options to preserve artifacts and other cultural heritage, and create large databases to share 3D digital data. An exemplary case of a 3D digital archive is provided by the Smithsonian

Foundation through the *Smithsonian X3D* initiative (http://3d.si.edu/), a web-based database of artifacts and ecofacts, which is available for students and scientists to view at no charge.

New databases containing high-resolution 3D digital models are innovative tools that can be used by researchers to collect data tailored to specific research questions (Kuzminsky and Gardiner 2012:2749). Indeed, many things can be done with the completed 3D digital models. Using software packages such as Scan Studio a researcher can take screen shots of an image, record points on an object, calculate surface area and volume, or make precise measurements (Weber and Bookstein 2011). The scanned images can also be used to reconstruct missing parts of objects. For instance, in a recent paper Sorin Hermon and colleagues (2012) from the STARC Cyprus Institute describe a case study in which they reconstructed a fragmented vessel in 3D from the 3D scan of its sherds found during an excavation in Cyprus.

Another advantage of the 3D replica is that it can be used to calculate surface areas and extract original profiles of an object from potsherds (Tocheri 2009; Karasik and Smilansky 2008). These profiles are indispensable components for the study of specific categories of objects, such as wheel-produced ceramic vessels. In fact, through the analysis of profiles, archaeologists can identify the correct axis of rotation of the wheel. This information is extremely important, since false positioning (occasionally occurring through manual drawings) may lead to misinterpretation of such objects (Griffiths and Wilson 1991:51e, 58; Joukowsky 1980:423; Orton et al. 1993:173; Rice 1987: 222).

Educational research suggests that digital representations are also effective means by which to introduce aspects of artifact study to large numbers of students when they cannot access collections of original objects. To provide an example, the CONTACT project (Doonan and Boyle 2008) was designed to enhance material culture studies in archaeology, providing students with an opportunity to interact with 3D digital artifacts. Specifically, the authors of this project created virtual collections of artifacts to increase engagement, motivation, and retention. The idea behind this project was to bring students into "contact" with original archaeological materials "through the mediation of experts" (Doonan and Boyle 2008: 107), and then use virtual archives to back up the learning experience through interaction with virtual replicas. With this project, Doonan and Boyle (2008: 115)conceived

3D digital collections as perceptive *aide memoire* that have the ability to partly maintain the moment of engagement beyond the classroom or museum.

Case study 1. 3D Virtual Dig (3VD).

A study conducted by Di Giuseppantonio Di Franco and colleagues (2012) suggests that 3D digital reproductions, more than just functioning as *aide memoire*, can improve learning processes when they are incorporated into traditional classroom settings. Even if this project does not specifically address issues related to artifacts studies, it helps show how 3D virtual replicas of material culture enhance learning processes in archaeology and heritage studies. For this study, a 3D reproduction of an archaeological environment was created and inserted in a virtual reality software application that allowed users to work with a virtually reconstructed excavation area. Assuming that an archaeological excavation can be described as a sensory and kinesthetic material experience, it is usually difficult to communicate the physicality of fieldwork in traditional classroom settings. This initial conceptual struggle suggests that students at the introductory level need active engagement with the materiality of archaeology in order to master important concepts and subsequently to succeed in fieldwork opportunities.

Di Giuseppantonio Di Franco and colleagues' (2012) instructional approach was to provide a practical challenge of implementing the principles and experiences of fieldwork with a 3D application to simulate the archaeological excavation process to freshmen students. The archaeological site virtually documented was Çatalhöyük, a Neolithic town in south central Anatolia, Turkey, which in the 1960s became the most celebrated Neolithic site in western Asia (Hodder 1997). The ongoing excavation is recognized as one of the most important in the world, and currently Çatalhöyük is on the Turkish list for proposed UNESCO World Heritage Site status. The 3D application allowed students to virtually excavate one of the houses of the town, using the stratigraphic method. The 3D reconstruction was based on real data digitally recorded in summer 2010 by a team of students of heritage studies and archaeology directed by Dr. Maurizio Forte. The excavation area was laser scanned with highly accurate 3D digital representations made using a Vivid Minolta Laser Scanner (fig. 4).

3VD was a real-time application, designed for classroom use, to test the individual capacity of students to interact with a 3D representation of the archaeological context and determine the chronological relationships between units of an excavation area. Therefore, 3VD was not conceived as a collaborative environment (e.g., Forte 2008; Forte *et al.* 2010) and/or as a web-delivered application.

The advantage of this experimental and innovative project was that it allowed lower-division or freshmen students to reflect on data collected during the fieldwork without losing the feel of the immediate, hands-on experience. In other words, the application provided a wide array of students with a simulation of the archaeological process. If a virtual reconstruction cannot activate the kinesthetic intelligence needed for fieldwork, it can stimulate sensory-motor learning processes, complementary to traditional instruction in textbook or lecture formats (i.e., textual or symbolic-reconstructive learning processes). This technology or technical affordance (Gibson 1979) expands our ability to bring expert knowledge and organizing principles to introductory coursework, ensuring a stronger pathway to success in critical thinking skills.

Figure 4. Laser scanning process of stratigraphic layers that are testimony to the occupation of a building at Çatalhöyük (Di Giuseppantonio *et al.* 2012).

The application interface was user-friendly and especially intuitive for students, who now have frequent access to technologies such as computers, the Internet, email, and mobile phones in everyday life (Waycott *et al.* 2010: 1206). When the application starts, a window appears with information about the archaeological site and instructions about how to use the application (fig. 5). To make the simulation activity and the recognition of the units easy, the researchers chose not to add texture to the units. They assigned each unit a distinct color; the goal of this activity was to stress the importance of the volumetric reproduction of the layers and to enhance students' understanding of the layers' physical relationships; that is, of the *law of superposition*.

In the application students were asked to use the mouse to excavate layers in the right order (see Screencast). Every time a student failed the task, red color text appeared on the screen and reminded them of the law of superposition (fig. 6). Each time the student was able to virtually excavate a unit, green color text confirmed that the task was accomplished, while on the left side of the screen, the matrix of the excavation area was created (fig. 7).

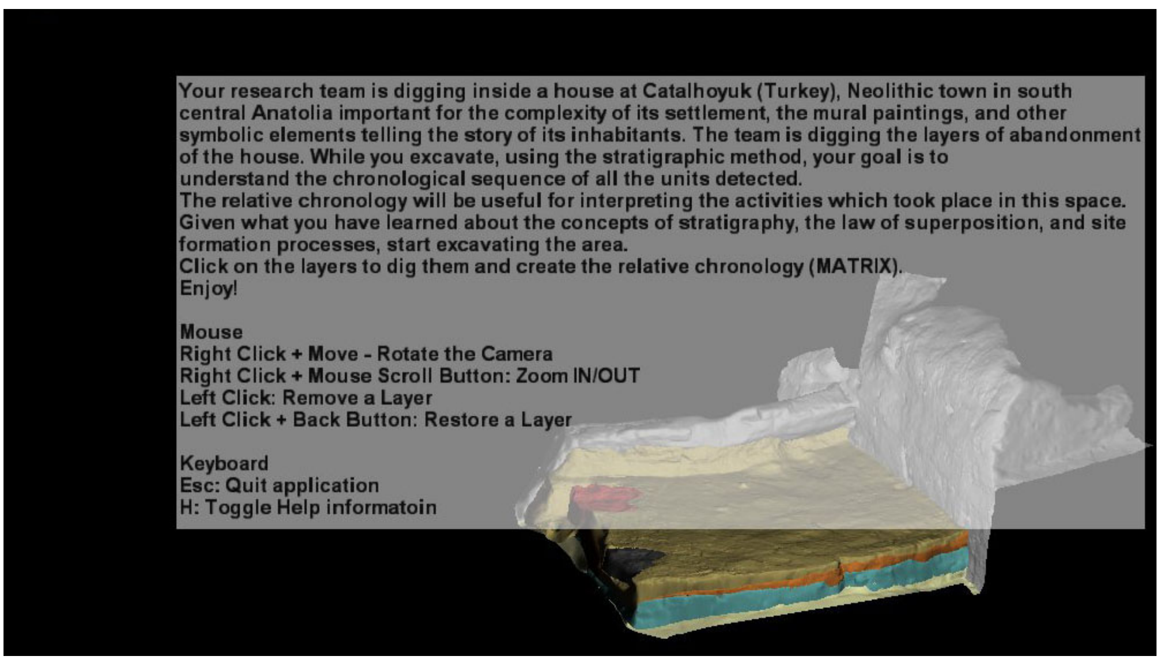


Figure 5. 3D Virtual Dig. Introductory window with instructions on how to use the application and on the archaeological site of Çatalhöyük (Di Giuseppantonio *et al.* 2012).

The software was tested in class with 150 students. The study employed a pre-survey, post-test, and post-survey design. The pre-survey was aimed at documenting the students' previous familiarity with archaeology and their attitude toward the discipline. The post-test was an ill-defined problem, wherein students had to demonstrate their acquired knowledge of the stratigraphic method after the use of the 3D application, for comparison to the knowledge of those students who had used conventional methods (i.e., 2D reconstructions of the same environment). The post-survey was conceived as a summative assessment of the 3D application versus the 2D exercise and its complementary activities (i.e, lecture on stratigraphy, ill-defined problem). The results showed that students studying with the 3D application demonstrated increased engagement and strengthened abilities to complete ill-defined problem sets characteristic of the higher-order thinking in the field.

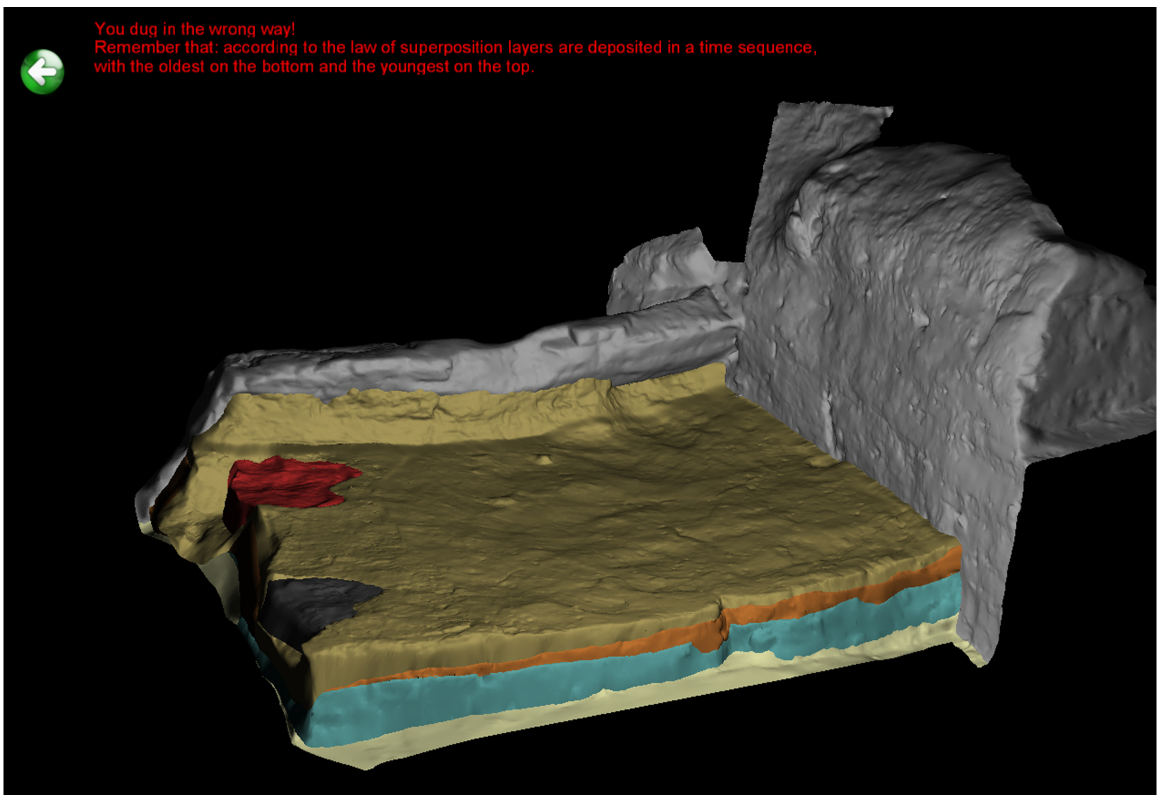


Figure 6. 3D Virtual Dig. Red color texts explaining why the user was not able to recognize the exact unit (Di Giuseppantonio et al. 2012).

The authors noted that repeating the test with a new set of students would reinforce the results of this research and provide additional information on the learning processes linked to 3VD, while implementing the application for virtual immersive environment would enhance the learning experience.

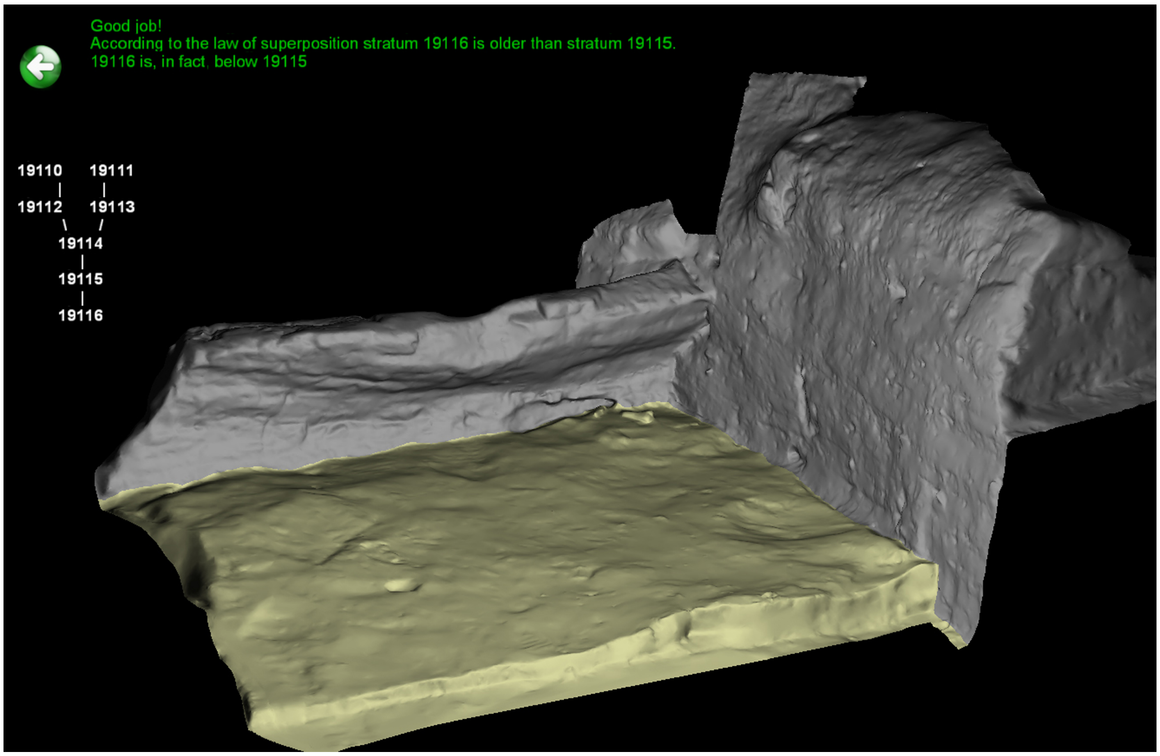


Figure 7. 3D Virtual Dig. Green text showing the user that the right unit was recognized and, therefore, virtually excavated (Di Giuseppantonio et al. 2012).

Even if this 3VD application did not fully provide an immersive experience and could not activate a kinesthetic intelligence, it could stimulate sensory-motor learning processes, complementary to textual or symbolic-reconstructive learning processes (Antinucci 2004a:17; 2004b). In the sensory-motor learning process, students learn through perception and action about a historical reality. In other words, students perceive an event with the senses, act on objects, and change their perception of the event after the action. This second process is augmentative: the action can be seen as a cause producing an effect, which is a new action. In a reconstructed excavation area, students virtually interact with the archaeological layers and act on them (i.e., remove the layers). Every action helps students to develop a constructivist process, since they are able to investigate the virtual area and pose questions on the relationship between the units.

In conclusion, this study demonstrated that 3D replicas of material culture not only facilitate learning as *aide memoire* (as in the CONTACT project), such replicas also enhance experiential learning, simulating hands-on activities with real-life objects.

<u>Case study 2. The Western Han Dynasty Virtual Museum</u>

Three-dimensional copies of artifacts can also be displayed in high definition immersive systems for research and educational purposes. Immersive systems are 3D stereoscopic displays that allow users to have an immersive experience in a reconstructed virtual environment. The main scope of these displays is to provide a sensorial experience with tangible heritage that simulates real-life experience. Immersive large-scale display systems such as the Powerwall, next generation CAVE systems, and 360-degree 3D panoramic spaces are considered places for enhancing innovative studies of cultural heritage, and they provide researchers with new ways to interpret material culture (Kenderdine et al. 2011; Galeazzi et al. 2010; Kenderdine 2009). These systems can also be viewed as non-mediated places where a user can interact with a simulated past independently or with other virtual users and create both personal and collective narratives of past environments (Kenderdine et al. 2009; Forte 2008).

This discussion is at the base of the Western Han Dynasty Virtual Museum project (Di Giuseppantonio Di Franco and Galeazzi 2013). For this project, researchers digitally documented archaeological sites, artifacts and cultural relics representative of the Dynasty, with two primary purposes: the first purpose was the preservation of some of the most representative artifacts of the Dynasty, which are at risk of destruction due to urban development. In fact, the city of Xi'an, ancient capital of the Western Han Dynasty (under the name of Chang'an) is experiencing rapid urban development, so every year archaeologists discover hundreds of monuments during emergency surveys in construction sites that they cannot preserve for lack of economic resources. The second purpose of this project was to disseminate information of the Western Han Dynasty through 3D reproductions and reconstructions of its material past (Di Giuseppantonio Di Franco and Galeazzi 2013).

The final outcome of the overall project was an off-line digital installation in two locations: the University of California, Merced (Forte et al. 2010) and the City University of Hong Kong (Kenderdine et al. 2011). Later developments of the project involved the creation of an immersive system for research and analysis of Western Han tombs (Forte and Kurillo 2010).

Integrated technologies allowed collection of the most representative material remains of the Dynasty for a virtual museum. A time of flight laser scanner was used for 3D documentation of recently discovered tombs in the center and surrounding the city, a Next Engine desktop triangulation laser scanner was used to create 3D replicas of artifacts, and a DGPS (Differential Global Positioning System) was used to collect information on actual and ancient landscape.

Although high-resolution models are not necessary for the purpose of a virtual museum, the researchers recorded all data in high resolution to efficiently preserve this heritage through 3D digital models. Three-dimensional laser scanning was paired to an accurate set of 2D digital pictures (using a Canon 50D) of all artifacts and other archeological records. Moreover, the data acquisition process was videotaped for future reference.

In the summer of 2009, Di Giuseppantonio and colleagues (2012) supervised the artifacts 3D laser scanning campaign of the artifacts, reproducing some of the most representative artifacts of the Dynasty, preserved in storage at the Xian Institute of Cultural Relics (fig. 8).

Some of those artifacts were part of grave goods that belonged to the Green Bamboo Garden Mural Tomb; their 3D acquisition allowed recreating the original context of this tomb.

The 3D scanning of these artifacts was complicated by the environmental conditions of the facility (i.e., humidity prevented the scanner to work properly) and the variety of materials of which the artifacts were made. Environmental conditions particularly slowed the data acquisition process, since the hardware often stopped working due to high humidity. As for the material of the objects, while the instruments could easily scan bronze and non-glazed pottery, glazed pottery and jade required extra time and some post-processing (hole filling) because of their transparency and brightness. Nonetheless, it was possible to reproduce 3D replicas of about 50 artifacts (figs 9, 10).

Globular artifacts were scanned using an automatically aligned 360 scan for the body, combined with two single scans for the bottom and top part of the objects. All other objects that were larger than 30 cm and characterized by complex shapes were reproduced through manual alignment of single scans (fig. 11). The final result allowed a multi-visualization of the scan, including the final model with original color (*texture*) reproduction, the mesh of the object (model with no color applied), and the geometric details (wireframe) and point cloud (*vertexes*; fig.12).

Figure 8. Laser scanning campaign of Western Han Dynasty artifacts. The laser scanning phase took place in a facility at the Xian Institute of Cultural Relics (© UC Merced).

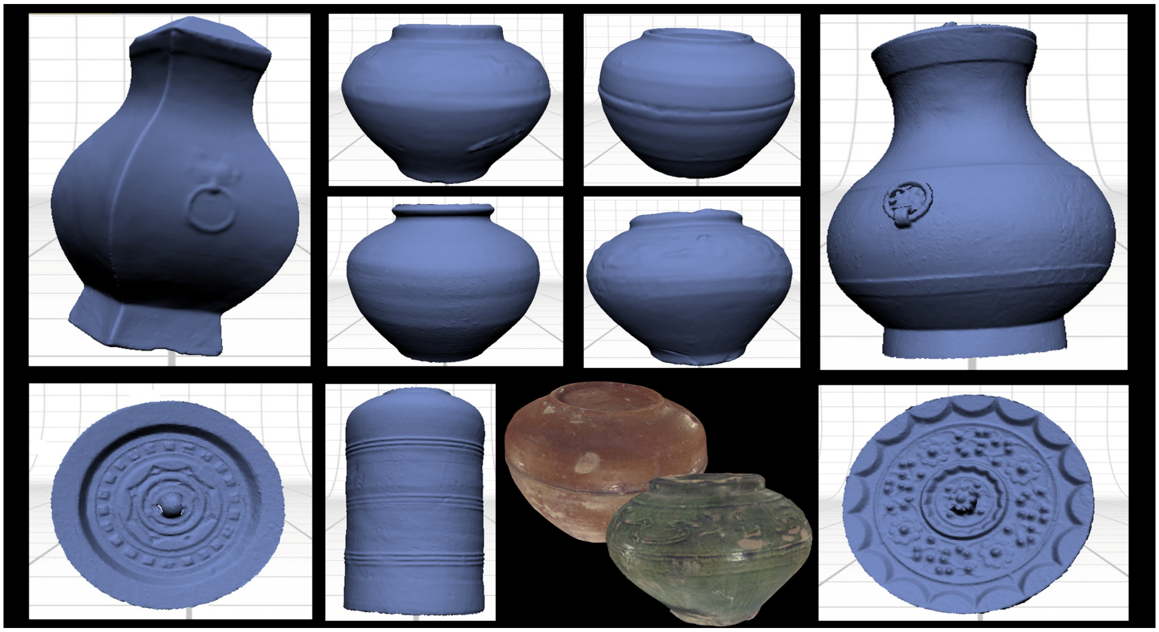


Figure 9. Three-dimensional reproductions (*mesh*) of Western Han bronze and ceramic vessels.

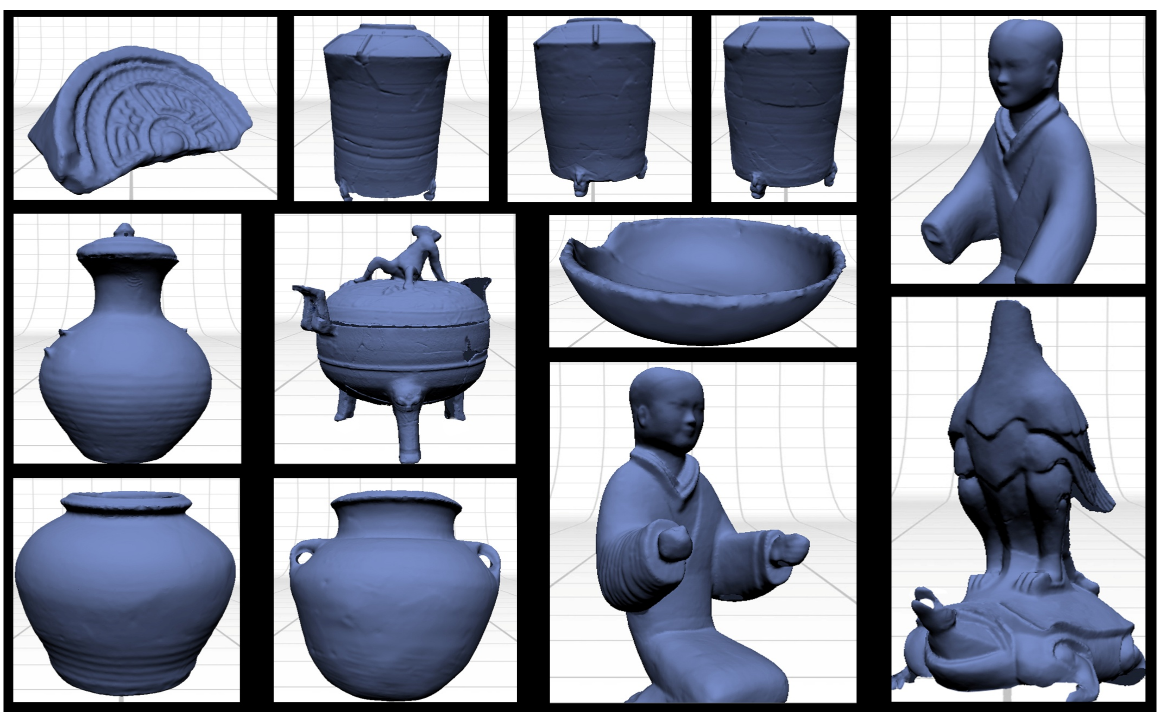


Figure 10. Three-dimensional reproductions (*mesh*) of Western Han ceramic artifacts.

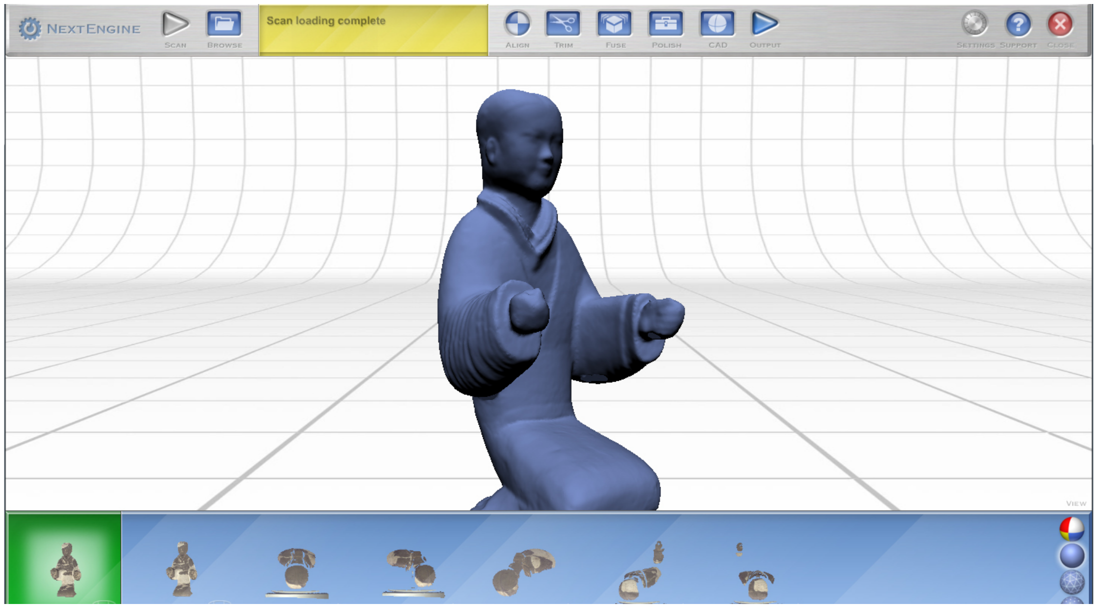


Figure 11. Human figurine reproduced manually aligning single scans.

Figure 12. Three-dimensional reproduction of the figurine. From left to right: *wireframe*, *mesh*, *texturized* model.

As previously mentioned, 3D replicas of Western Han Dynasty monuments and artifacts were displayed in three different immersive displays: the Powerwall at the University of California, Merced (Galeazzi et al. 2010), a 360-degree 3D panoramic space (Advanced Visualization Interaction Environment – AVIE) at the University of Hong Kong, China (Kenderdine et al. 2011), and a 3D real-time environment (Forte and Kurillo 2010).

The Powerwall is a large high-resolution display wall at the University of California, Merced that is used for projecting large computer-generated images. It is complemented by a Vicon full-body optical tracking system that allows full-body immersion in a virtual environment. This system was used to visualize the 3D reconstruction of one of the 3D reconstructed tombs of the Dynasty (M1), which was complemented by a three-dimensional mind-map (*cybermap*) revealing all the spatio-semantic relationships of the paintings realized in the main tomb chamber (Galeazzi et al. 2010; fig. 13). This project did not include artifacts, and was just meant to show the complex meaning of the tomb's murals, explaining the relationship between life and death during the Western Han Dynasty.

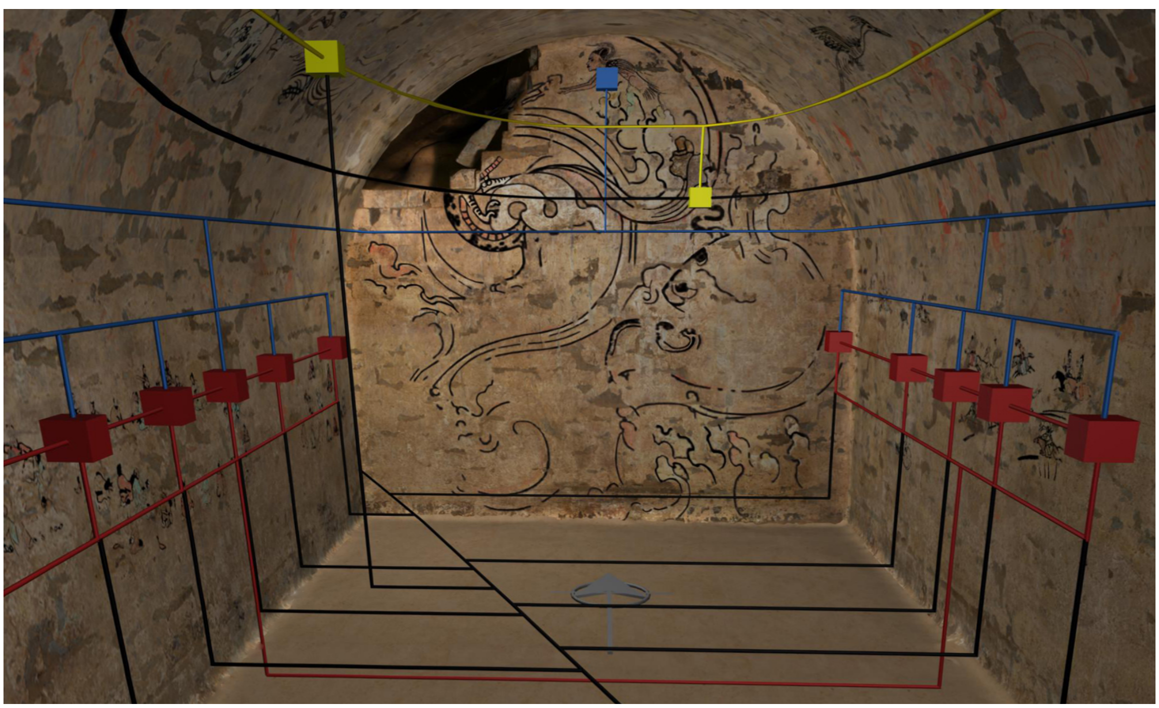


Figure 13. Three-dimensional cybermap of Western Han Dynasty funerary paintings.

The AVIE 360-degree stereoscopic interactive visualization system is a cylindrical projection screen that uses camera tracking of visitor's movements to create interactive relationships between the visitor and the reconstructed/simulated environment (Kenderdine et al. 2011:145-6; fig. 14). This system allowed an immersive experience with Western Han Dynasty material culture through two different scenarios: the first was a 1:1 reproduction of tomb M1 that the user could navigate to scale and explore. This scenario was completed with a cybermap that guided users through the complex semantics of the tomb's frescos. The second scenario, called Object Viewer (OV), displayed the virtual reconstruction of the artifacts. The objects float around the user, who can manipulate and magnify each object independently. The object can also be explored through its mesh (i.e., 3D model without original colors).

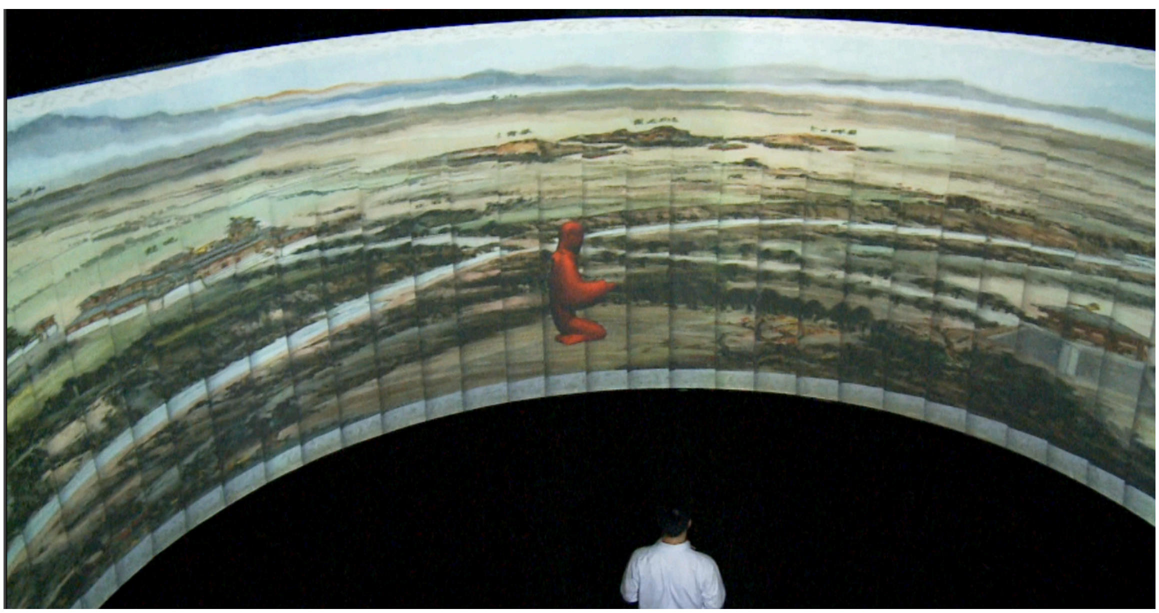


Figure 14. Rhyzome of Western Han ©. Applied Laboratory of Interactive Visualization and Embodiment, CityU, Hong Kong (Kenderdine et al. 2011).

The tele-immersive real time system was intended to facilitate remote collaboration between scholars (up to five users at a time), sharing the same virtual space while being able to interact with 3D replicas in real time (fig. 15). With this kind of system, each user navigates and interacts with the simulated environment in the first-person perspective (which is represented in real time in the immersive environment), and can select and manipulate objects, measure them, and obtain metadata of the objects from drop-down menus. This immersive system was used for re-contextualizing and studying all artifacts found in one of the reconstructed tombs (M1) during the excavation. As explained by Forte and Kurillo, "the tentative repositioning of the objects, after the restoration, is very important since it is possible to study their volumetric relations with the funeral chamber, the rituals and their social symbolic value" (Forte and Kurillo 2010: 160). In other words, this kind of tele-immersive system allows international scholars to collaborate actively on the study and interpretation of the past through its virtual material remains.

Figure 15. Tele-immersive archaeology. Western Han Dynasty Tomb M1 and its grave goods (Forte et al. 2010: 428).

In conclusion, this case study shows the capabilities inherent to new media technologies applied to cultural heritage. These technologies provide new ways of producing and acquiring knowledge in archaeology and heritage studies. The potential of 3D technologies goes beyond the essential aspect of data-sharing; 3D technologies inevitably influence the way we analyze and interpret material culture, producing new research questions and modes of interaction with our past.

3.5. Thinking *with* artifacts: the embodied mind.

All the case studies described above the value of 3D digital models for preservation and dissemination of cultural heritage. Nonetheless, some scholars suggest that these models lack information that can only be obtained through real-world human-object interaction (Lederman *et al.* 1990; Renaud 2002). This raises a question about the significance of digital object representations in both research and education. Studies demonstrate, in fact, that we do think with objects and that interaction with things is critical when trying to make sense of their use (Clark 2003; Hutchins 2005; Kirsh 2009, 2010a; Latour 1986).

Proponents of distributed, situated, embodied, embedded, and enactive cognition, and of extended mind (see Chapter 2) accept the idea that when people engage with material things, they think with them. To explore how people use things as vehicle of thought, Kirsh (2009:1106; 2010:122) used the example of a 6-piece puzzle. In a physical condition, people can move these six pieces and physically try to assemble them and create an image. In a mental imagery condition (i.e., when people cannot touch the pieces), people virtually move these pieces in their head (i.e., mental rotation and assembly). Both activities (i.e., the physical and the mental) show how our thoughts include material things: "People are assumed to include the pieces, a bit like the way a blind man's perceptual system is extended to include his cane. The result is to extend the envelope of thought to include material things outside the head" (Kirsh 2010:123). When we think through external representations, we can compare them, build on them, rearrange them (as shown by the example of the puzzle), recast them, and perform other kinds of manipulations. Through these activities we are able to produce more efficient computation and deepen our understanding of things. Kirsh further explains: "The point is simple: we are able to project farther into possible worlds, to see how the world might be, if we can physically play with objects" (Kirsh 2010b:124). According to Kirsh (2010a), however, all these arguments focus on material vehicles that represent propositional thought (i.e., abstract logic), and artifacts may mediate thought differently. They may have more to do with non-linguistic thinking. The question here is: "How do people co-opt non-propositional things for thought?" (Kirsh 2010a:121; emphasis original). In other words, how do people engage with material things?

According to psychologist Jean Piaget (1988), objects help us think about such things as number, space, time, causality, and life. Piaget affirms that our learning is situated, concrete, and personal. Tactile perception of a real-life 3D object is usually an active experience involving information gathered from a variety of senses related to touch such as texture and temperature, as well as movement and position of the hands and fingers during identification (Gibson 1979: 123-9). Touch provides an understanding of shape, size, and weight, and it is through this sense that people develop an understanding of other properties such as density, all key properties for the exploration of artifacts (Doonan and Boyd 2008; Kirsh 2010b). For example, assessing the weight of an object can be critical for determining its function. Through several experiments Klatzky and colleagues have shown that people are relatively competent at recognizing objects haptically (i.e., through touch). In one experiment Klatzky (*et al.* 1985) asked blindfolded people to recognize common objects just by touching them, and these people did so with very few inaccuracies. Subsequent studies clarified how people haptically explore objects to recognize them. These studies show how people actively explore their environment, executing a series of exploratory hand movements in search of the "perceptual attributes" of things (Lederman and Klatzky 1990: 422). In another experiment, Lederman and Klatzky (1987) blindfolded people and presented them with a multidimensional object (i.e., *standard*) followed by three comparison objects. They asked people to pick the comparison object that best matched the *standard*, given a particular physical characteristic (e.g., roughness). While each subject was exploring the objects, the experimenters videotaped and then analyzed all hand movements used for the exploratory procedures. The results of this experiment demonstrated that specific classes of hand movements were executed when a particular object characteristic (of what?) was designated for matching.

What happens when people are asked to explore and describe objects through different media? MacGregor (1999) demonstrated that differences in object descriptions exist when objects are experienced through different interactive media (i.e., visual versus tactile). Simple perception tasks using carved stone balls were used to demonstrate how the sensory perception of certain artifacts could lead to a deeper understanding of an object's ancient use. MacGregor suggested that a haptic analysis of material culture is an avenue available to the archaeological interpretation of past sensory orders, and that this analysis is conceptually and functionally different from analyses made using static visual images. For instance, when scholars studied carved stone balls circulating in the Aberdeenshire region of Scotland during the third and second millennia BC (1852-55 BC) they frequently made reference to their appearance (decoration and number of knobs) in support of the interpretation that these balls were used in a ceremonial context to enhance the social status of those holding them. Clearly, scholars privileged vision above all other senses. According to MacGregor, however, when someone holds a carved stone ball decorated with knobs and rotates it quickly, the object visually takes another form, becoming a complete sphere (i.e., the knobs visually disappear). This transformation of the object could have been witnessed by a much larger group of people and may have been considered magical. In this case the haptic analysis of the balls results in a new interpretation of these objects' function.

3.6. Simulating a tactile experience with real-life artifacts: haptic interface, augmented reality, and 3D printing.

These studies show how important it is to manipulate objects in order to activate thinking processes that help with the interpretation of past material culture. To respond to this need of "physical" manipulation in a virtual environment, computer scientists have sought to develop complex systems that simulate the tactile experience with real-life objects. Over more than twenty years, they have designed devices able to reproduce the feel of physical contact with objects and the perception of tactile stimuli (i.e., *haptic interfaces* – HI –and *force-feedback*). HI and force-feedback have been widely studied in the last 20 years (e.g., Jannson 1998; Buttolo et al. 2000; Gregory at al. 2000; Jeonghun et al. 2003), and have been commercialized by companies such as Sensable and Immersion. 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. One of these applications for museums, the *Interactive Art Museum* (McLaughlin 1999), was developed at the University of Southern California to create a virtual art exhibition of the collection of teapots preserved at the Fisher Gallery. This project aimed to create an online virtual museum of more than 150 teapots to allow virtual fruition of these artworks and users' real-time remote interaction with museum staff members to engage in joint tactile explorations of these objects through a commercial haptic device (i.e., CyberGrasp; http://www.cyberglove systems.com/products/cybergrasp/overview).

Although many projects in computer science have been concerned with reproducing real-life tactile experience with material culture, these projects do not yet allow a widespread use of HI for 3D museum and research applications.

Another key element to fill the gap between real and digital is augmented reality. Augmented reality (AR) is a real-time view of real-world environments augmented by computer-generated sensory input such as sound, video, and graphics. Augmented reality, unlike virtual reality (VR), tries to enrich reality instead of just reproducing it (Benko et al. 2004; Kayalar et al. 2008). As a result, the technology functions by enhancing one's current perception of reality. To give a basic practical example, 3D modeling software (i.e., 3D Studio Max, Next Engine, Maya, etc.) allows the user to visualize the 3D model of an object with or without texture applied. The ability to eliminate the texture from an object (i.e., a painted object) and look at its mesh provides an opportunity for the user to focus on the shape and formal details of this object more efficiently than when the texture is applied. In other words, the ability to eliminate the texture is an augmented reality element that enhances the perception of the real object.

Tactile augmentation is considered an effective alternative mixed-reality technique for introducing tactile cues. In the late 1990s, Hoffman (1998) designed an experiment aimed at exploring tactile augmentation in VR as an alternative to force feedback, to predict the properties of virtual objects. For this experiment, one sample of individuals had to describe a virtual plate without touching it, while the other sample of individuals could virtually touch the object. Results of the experiment showed that people in the augmented reality condition could predict considerably more physical properties of a virtual object and were able to do so better than the non-augmented group. This experiment was the first to empirically demonstrate the effectiveness of mixed reality as a simple, safe, inexpensive technique for adding physical texture and force-feedback cues to virtual objects.

InFORM (Follmer *et al.* 2013:417-426) is a Dynamic Shape Display that can render 3D content physically, so the user can interact with information in a tangible way. Using InFORM people can also interact with the physical world around them; for example, moving objects on a table's surface. Remote participants in a videoconference can be displayed, allowing for a strong sense of presence and the ability to interact physically at a distance. According to Follmer *et al.* (2013) InFORM allows 3D modelers and designers to prototype their 3D designs physically without 3D printing (at a low resolution). In archaeology, this prototype would allow scholars and museum users (i.e., the general public) to manipulate real objects remotely and have a sense of touch through Dynamic Physical Affordances and Constraints (DPAC) (i.e., Hoffman 1998; Jansson et al. 2003; Jeonghun et al. 2003; http://www.pureform.org/).

<u>3D prints of artifacts</u>

Due to advance in technologies, it is now possible to physically reproduce ancient artifacts using 3D printers. Three-dimensional digital copies of artifacts can be printed using Rapid Prototyping (RP) technique. RP is the process whereby physical objects are created from computer-generated programs (i.e., CAD, 3D Studio Max, etc.) using prototype 3D machines that can build a 3D object out of liquid, solid, or powder material. The first techniques for rapid prototyping became available in the 1980s (Bradshaw et al. 2010:6-12; Chua et al. 2010). Since then, RP has made significant progress and become an essential part of 3D modeling and design engineering. RP is especially used for visualization, prototyping/CAD, metal casting, architecture, education, geospatial applications, healthcare, and entertainment/retail arts and crafts (Bradshaw et al. 2010: 12; Chua et al. 2010). Other applications include reconstructing fossils in paleontology, replicating ancient artifacts in archaeology, reconstructing bones and body parts, and reconstructing significantly damaged evidence acquired from crime scene investigations.

RP generally uses additive fabrication in which material is added until the 3D model is complete. Additive manufacturing is extremely versatile because of its ability to create almost any geometry. The standard interface between 3D software and RP machines is the STL file format, but some techniques require VRTML. 3D models typically take three to 72 hours to build, depending on machine type and model size.

An exhaustive overview of all existent RP techniques is not provided here, since this is outside the scope of this chapter. However, in order to reproduce the artifacts selected for my experiment, a screening of the existent techniques was necessary. Thus, it is useful to describe some of the most representative techniques in this field. To find the most suitable 3D printing technique for my experiment, I contacted several companies and asked for 3D printing samples of my 3D digital models. Before deciding which technique seemed most appropriate for my experiment, I compared the potential of three different machines: 1. U-Print, 2. ObJet24, and 3. Z-Corp.

1. U-Print (http://www.stratasys.com/landing/uprint-affordable-3d-printer) is a portable and economic 3D printer that uses fused-deposition-modeling (FDM) techniques. This technique is able to create 3D prints that have high strength and durability. This process uses a plastic filament of material supplied to an extrusion nozzle. The FDM fused deposition model process is additive and extrudes material in layers. The nozzle is heated to melt the material and can be moved in both horizontal and vertical directions. When the model is complete, it requires no hardening. FDM is an excellent choice for any 3D model that needs to closely represent the final product in strength and durability. Using this technique, 3D models can be produced in about 24 hours depending on the size and complexity. The accuracy of this machine is 0.02 cm.

2. Objet (http://www.stratasys.com/3d-printers/design-series/precision/objet24) uses an innovative inkjet polyjet technology that is currently the fastest growing segment of the RP market place. Polyjet models are very similar to stereolithography[1] or SLA models, which use a photosensitive polymer to create 3D models, but the method of

[1] Stereolithography or SLA is a widely used process that creates 3D prints with an extremely high level of detail and excellent surface finish making. Stereolithography uses additive fabrication method where a UV-sensitive photopolymer resin is cured by a laser to build parts a layer at a time. The standard material is SOMOS 11120, a photopolymer resin designed to simulate ABS plastic. Like ABS it can be sanded, machined and painted for a more cosmetically accurate prototype. 3D printing machines working in stereolithography do not have the potential to match colors and reproduce objects' original colors.

application with polyjet parts allows parts to be created with more accuracy and detail than with SLA. Polyjet injects photopolymer materials in ultra-thin layers (16μ) onto a tray built layer-by-ayer until the part is completed. Each photopolymer layer is cured by UV light immediately after it is jetted. The polyjet techniques have an accuracy of 16 microns. The models built have a smooth surface and fine details without any post-processing. The only problem with the use of polyjet in artifact reproduction is that the final product has a side that is shiny and the other that is matte.

3. Z Corp RP is the only process that allows for photo-realistic, color design prints and have a resolution of up to 650 x 540 DPI. The material used is a powder that is combined with an adhesive and simultaneously embedded with an ink jet print head. Finally, the part can be finished using infiltrants including wax, cyanoacrylate (super glue), and epoxy materials, which increase the 3D parts' strength and create the desired finish to ensure durability and more vivid colors. The printed product is a hard, rigid material that is slightly delicate and not suited for structural parts under great load. The disadvantage of this technology is that the surface finish is less accurate and resistant than the surface of other 3D rapid prototyping methods, such as polyjet.

As I will explain in Chapter 4, to physically reproduce the objects selected for my study I selected Zcorp because of its capacity to reproduce color appearance. It is important to specify, however, that while Zcorp was at the time of my prints the only affordable machine able to replicate colors of a real-life object, other companies are now experimenting with art museums to 3D print famous paintings with high quality colors, to capture the "physical presence of these paintings" (http://www.3dprintingevent.com/wp-content/uploads/23-okt-TU-Delft-Jo-Geraedts.pdf). With the notion of "physical presence," some scholars suggest that texture/relief is as important as colors to understand the uniqueness of a painting. Van Gogh, for instance, used thick layers of colors (i.e., a thick impasto) to create games of lights and shadows in his paintings. In this sense, 2D reproductions such as posters do not provide an experience with paintings close to the real-life experience. For this reason Tim Zaman, a computer scientist from the Delft University of Technology, in partnership with OCE' Canon Company, worked on 3D reproductions of selected paintings such as the *Self-Portrait* by Rembrandt (1669; painting conserved in the Mauritshuis), *Flowers in a Blue Vase* by Van Gogh (1887; Kroller Muller Museum) and the *Jewish Bride* by Rembrandt (1667; Rijksmuseum). In this case, the paintings were photographed and a high-resolution pictures were applied to the 3D model, which were eventually 3D printed in full color by OCE'. A similar project was presented in August 2013 at the Van Gogh Museum in Amsterdam, which has developed high-quality 3D replicas of Van Gogh's paintings in collaboration with Fujifilm to sell them in place of traditional 2D replicas. These 3D prints were made for tourist revenue purposes and will be sold for £22,000 (http://www.theguardian.com/artanddesign/2013/aug/24/3d-replicas-van-gogh).

3.7. Conclusions

In this Chapter, I described case studies that exemplify how technologies are creating new ways of preserving, studying, and disseminating tangible cultural heritage. These new ways also present opportunities for new research questions and inevitably affect our perception of past material culture. If, as shown, significant recent efforts have been made to reproduce a sensorial experience with past material culture that is similar to real-life experience; research and museums cannot fully enjoy and apply HI and augmented reality yet. Conversely, online 3D digital libraries, 3D renderings and videos, and immersive reality systems are more and more commonly used in museums and research labs, and it is from these that we should start focusing our attention to see how differently media can shape our perception of the past.

The question still remains: how do we understand and interpret past material culture in absence of a tactile experience? If we agree that our experience with the world is embodied and if we deny any dichotomy between mind and body, we should in fact try to understand what happens when people have a virtual experience with material artifacts; what happens especially when this experience is not immersive. With the term *virtual* I have in mind an experience with 3D reconstructed artifacts, even describing artifacts through a picture is also a virtual experience, as it is going to a museum and looking at objects exhibited in a display-case, since we cannot have a full sensorial experience with past material remains. This perspective means that we perceive and interpret the past through a virtual experience more often than we even think. From this perspective, it is clear how important it is to understand if and to what extent different media affect our perception of the past.

Chapter four. Interdisciplinary Methodological Approach to the Study of How People Perceive Artifacts through Different Media

My child, the Duck-billed Platypus
A sad example sets for us:
From him we learn how Indecision
Of character provokes Derision.
This vacillating Thing, you see,
Could not decide which he would be,
Fish, Flesh, or Fowl, and chose all three.
The scientists were sorely vexed
To classify him; so perplexed
Their brains, that they, with Rage at bay,
Called him a horrid name one day,
A name that baffles, frights and shocks us,
Ornithorhynchus Paradoxus.
(Oliver Herford, *The Platypus*).

4.1. Introduction

With the present study, I am interested in knowledge acquisition through different media: (1) visual examination; (2) physical interaction; and (3) 3D virtual and material replica interaction. As discussed in the introduction (Chapter 1), this research addresses five main questions: *How do people experience an object when they can touch it? Can this haptic experience be reproduced when the artifacts are presented in different media? Is virtual object interaction able to reproduce sensations of material qualities such as density and weight? How do people interpret archaeological artifacts and what is the difference, if any, between archaeologists and the "general public" in the interpretation process? Can 3D printed copies duplicate the cognitive feel of real objects?*

This is a completely new line of research in archaeology, and required a multidisciplinary approach. As stated in Chapter 1, the experimental design of this research was facilitated through conversations with faculty and graduate students affiliated with the UC Merced program of Cognitive and Information Science (CIS), whic provided guidance on how different senses interact during perception and how we think while we interact with things. To explore these issues, I designed an experiment to collect data related to artifact perception via differential media (fig. 1):

1. *Real life Haptic*: participants touched the real objects.
2. *Real-life Visual*: the objects were located inside a display case, simulating the experience that individuals usually have visiting an archaeological museum.
3. *3D Virtual Visual*: participants interacted with the 3D copies of selected objects displayed on a computer.
4. *2D Visual (pictures)*: selected participants described objects looking at their pictures.
5. *3D–printed Haptic:* participants interacted with copies of real objects made using 3D printers.

In this chapter, I first provide an overview of the materials used for the experiment. The artifacts selection phase face was central to this experiment, since selected objects had to vary in terms of their form, function, and material to see if these differences could affect the understanding of these objects in different media states. After selecting the artifacts for the experiment, I replicated them using different media: 2D digital pictures, 3D digital replicas, and 3D prints. In the materials section I describe techniques and methods used to reproduce the artifacts and provide an in-depth description of all challenges that occurred in the acquisition and post-processing phase. After providing an overview on materials and 2D and 3D replicas technique I describe the experimental design, specifying how each task (scenario) was organized and differences (if any) between each scenario.

Finally, I present the various categories of participants, and then summarize the analysis procedures chosen for data analysis.

4.2. Materials selected for the experiment

Four were the objects selected as *stimuli* for this experiment (fig. 16):

Ceramic vessel (pottery): This closed ceramic vessel comes from an archaeological site in Ethiopia, Africa, from the Christian era, probably dating sometime between A.D., 200 and 800.

The body of this vessel is made of clay, with medium and large calcareous inclusions and medium-size inclusions of sand.

The bowl is grey, with significant charring, suggesting that it was heated but not significantly burned. It appears to have made on a wheel, but it is difficult to demonstrate this, since there is no trace of a wheel ridge on the internal surface of the object. The vessel is about the size of a melon, (i.e., Cantaloupe) and may have stored liquids since it is hard fired with an interior and exterior slip or surface treatment. In fact, the external surface is quite smooth compared to the coarse fabric. The orifice has a relatively small diameter (i.e., the size of an orange) and its lip is partly broken, allowing the textures and inclusions of the vessel's fabric to be seen. This pot has just one loop handle, which was formed separately and then attached to the pot before firing. The loop was broken in the past. This object was decorated with a pattern incised in the wet clay, including three crosses and two parallel lines that go around the body at the center of the pot. These circular lines seem associated with three solid lugs, whose function is difficult to determine. Perhaps a cord was tied beneath the lugs to allow the suspension of this vessel. Alternately, the lugs may have allowed the the vessel to be lifted, or have been purely decorative. Since the lugs of this vessel are relatively small and associated with the incised decorative lines, lugs likely have served a decorative function. The base of this object is slightly flattened, but asymmetrical.

This is a utilitarian vessel; somebody had it at home and then he/she lost it for whatever reason.

Figure 16. Pictures of the artifacts selected for the experiment.

Buddhist ritual object: This is a ritual object found in Upper Mustang Nepal. It dates between A.D. 1200 and 1600. It is a very finely carved piece of wood with no damage. It is about the size of a hand, and is a tapered ovoid shape. This artifact is composed of a robust handle—almost half of the entire object—and an upper ovoid part. The latter part is reminiscent of the shape of a lotus leaf, which is commonly found Northern China Buddhist contexts during the 5th century[1] (fig. 17). It was probably used in household ceremonies and placed either in a clay altar or at the end of a pole (the altar is more probable). The shape is meaningful within Tibetan Buddhist ritual and is meant to remind the user of the Kalachakra ceremony, a ritual process that is devoted to time and energy (Henning 2007). The shallow interior of the object may have had a small icon affixed in it, or possibly, it was painted with an image that is now faded. A red stain, likely remnant of a depiction, is visible at the center of the leaf-shaped "palette."

Figure 17. Mogao Cave 254 (Dunhuang -Gansu province, China) 5th cent. leaf-shape nimbi and architectonical elements framing Buddha images. (Picture from Abe 1990, fig 3, p. 19).

[1] During the 5th century leaf-shaped nimbi and architectonical elements were used, for instance, in the Mogao Caves, southeast of Dunhuang (Gansu province, China), an oasis strategically located on the Silk Road, (Abe 1990).

Projectile point: This object is a lithic biface, more precisely a corner-notched, Elko series projectile point that was found in the interior deserts of California. It dates between 2000-5000 years ago. This artifact was probably the point of a dart, since it is too large and robust to be an arrow point. It is about the size of a key, and is made from whitish chert—a locally available material—that has a waxy feel, and is shiny and smooth. Some brownish stains can be observed on the tangs and on one side of the object. It is a finely worked lithic artifact, which was made by flaking the stone to create the desired shape. This kind of point would have been used for hunting, but also for defense or offense. The environment in this particular area has varied over time (Hull 2007). When people used this point, the area would have been drier than today at times, while at other times the area was wetter than it is today. People would have lived in small settlements and moved at certain times of the year to different areas to acquire resources. This object was probably more associated with the activity of men than women. The owner could have lost the object while he was hunting or using it for other reasons. The object could have been used to hunt antelope or other game of similar size.

Grinding stone or hand stone: this object was used for grinding plants material, probably seeds or nuts of some kind, either in a circular motion or back-and-forth motion. This stone is consistent with grinding stones that were used in California for thousands of years. The age of this particular artifact is unknown, since the artifacts was found out of context and donated to the University of California, Merced, by the San Bernardino County Museum for educational purposes. These kinds of objects are simple to make and use, have been produced in California and other parts of the world for thousands of years, and are similar to the pestle still used today for grinding herbs and spices. Thus, this object represents a food preparation utensil similar to those used throughout the world and still in use in many societies. This specific grinding stone fits comfortably in the hand, and is about the size of a potato. It was made of schist, a stone that is rough and rounded, and that is why it was used to grind. The two opposite grinding surfaces are smooth instead of rough. Given the local geology, the material may not have been locally available). The handstone is oval in plan view and fits in one hand. The object was probably used by a woman, and it was small and light enough that it could have been carried around. We should suppose the presence of a grinding slab. This tool does not appear to have been used intensively because little use wear is evident. It has been minimally shaped. The maker just found a good stone for his/her purpose without having to significantly shape it for use. One of the working surfaces has been recently damaged, perhaps by a pick or agricultural machinery. These kinds of objects are usually used to grind grass seeds, and even though no lab analysis was conducted to study this object more in depth, traces of red color on both sides of the objects may indicate processing of nuts and other reddish grass seeds

This combination of objects (i.e., *stimuli*) was varied and well-suited to the purpose of the experiment. In fact, the objects are made of different materials (i.e., wood, ceramic, and two different lithic materials) and shapes, have different functions, and date to different time periods. Moreover, while the grinding stone and projectile point come from the U.S. (California, specifically), the pot and Buddhist ritual object come from other regions of the world (Africa and Asia, respectively). Therefore, both archaeologists with different regional and/or technical expertise and California students would find describing some objects more challenging than describing others. With specific regard to the grinding stone, projectile point, and pot, these types of artifacts were produced and used by different cultures in different regions of the world and historical periods, and are well-known to people of different cultural backgrounds. Conversely, the Buddhist object has a unique shape that can be well-recognized and understood by Nepali people, archaeologists expert in Tibetan culture, and more generally, people who know Buddhism and Tibetan culture. With regard to object function, while the grinding stone, projectile point, and vessel are utilitarian objects, the object from Nepal has a ritualistic, symbolic function. However, the decorative motives inscribed in the pot represent crosses that might influence participant's decisions when trying to guess the function of this object.

4.3. Techniques and methods for 2D digital pictures, 3D acquisition, and 3D printing of the artifacts

2D digital pictures

The pictures of the objects were taken using a Nikon D90 (see fig. 16). The pictures were shot with black background and an artificial incandescent light located on the right side of the object. Natural light coming from a window on the right side of the objects was another illuminating sources for these pictures. The reason for choosing incandescent light was that it is warm in color. No flash was used and the use of tripod allowed long exposure pictures.

3D digital replicas through laser scanning

The following section presents a description of the 3D laser scanning of each object:

Ceramic Vessel (fig. 18): The vessel was scanned twice. The first round of scans was done choosing a 360-degree *wide* setting. Selecting "wide," the object's main body was automatically aligned. In a second step, I scanned the lip and bottom of the artifact through single scans and manually aligned these scans to the main body. Unfortunately, even though the object was quickly reconstructed, the reconstruction missed important details such as the incised crosses. As a consequence, a second scan was necessary, this time using a *macro* setting. With this setting, three 360-degree scans (automatically aligned) were necessary to reconstruct the objects' full body. In a second step, the three 360-degree scans were manually aligned. Eventually, I scanned the lip and bottom parts using single scans and manually aligned these scans to the rest of the object. It was impossible to scan the internal part of the vessel. Once all the scans were aligned I fused them using the *fuse* command

To make the interior surface of the 3D pot, the 3D model was imported in 3D Studio Max and an artificial sphere inserted inside the digital artifact. The sphere was then linked to the lip of the pot and texturized (i.e., colors were added to the model) to give the idea of a real internal surface of the artifact.

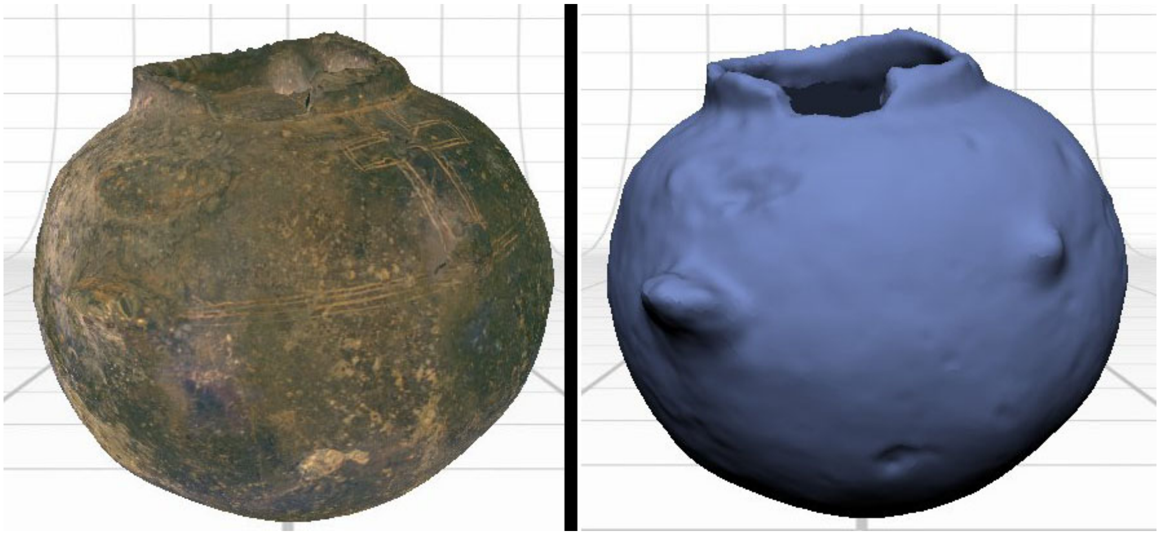


Figure 18. Three-dimensional digital replica of the ceramic vessel.

Buddhist ritual object (fig. 19): This was the most challenging object to scan. The challenge resides in the object's shape, which is quite complex to reproduce. The first strategy was to reproduce the main part of the body using a wide 360-degree scan and then align this scan to the top and bottom single scans. Unfortunately, every time I tried to align either the bottom (i.e., the bottom of the handle) or the top part of the object to the main body, the main body lost its alignment, becoming a set of unaligned single scans. For this reason, I decided to scan the object using single scans and then manually align them. The final model was then fused, but the mesh presented some holes that I had to fill using the *fill* command.

Projectile point (fig. 20): The projectile point was scanned using a 360-degree macro scan that was then fused, setting the fuse to 0.0015. After fusing the object, I regenerated the file with a simplification of 2. To complete the reproduction, it was necessary to fill some holes at the edges using the *Smooth Boundaries* hole-filling settings.

Grinding Stone (fig. 21)*:* The grinding stone was the easiest object to scan. Its shape, in fact, is round and smooth and its texture matte. A 360-degree alignment and two single scans of the dorsal and ventral surfaces of the stone allowed complete reproduction of this object. These three final scans were manually aligned and fused.

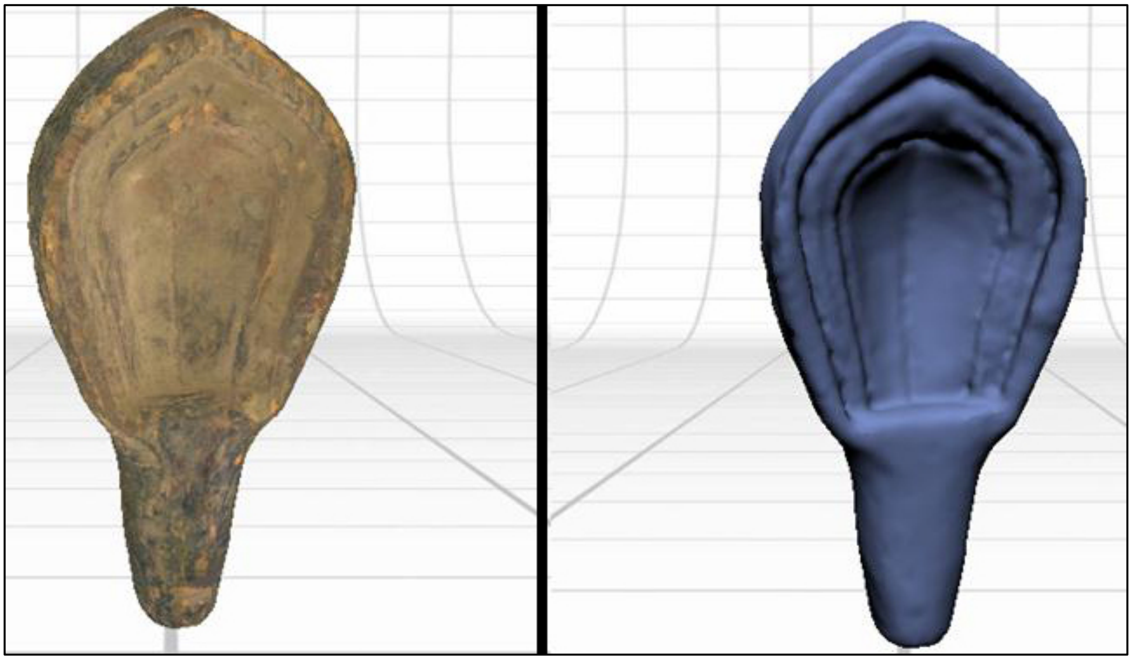


Figure 19. Three-dimensional digital replica of the Buddhist ritual object.

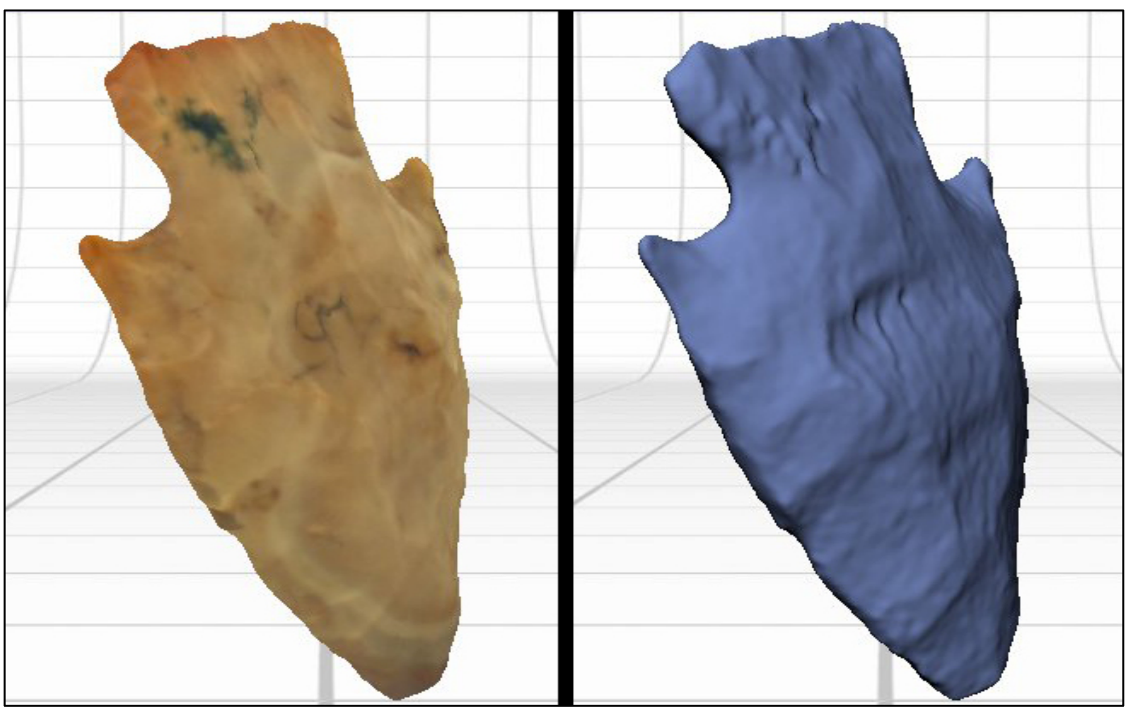


Figure 20. Three-dimensional digital replica of the projectile point.

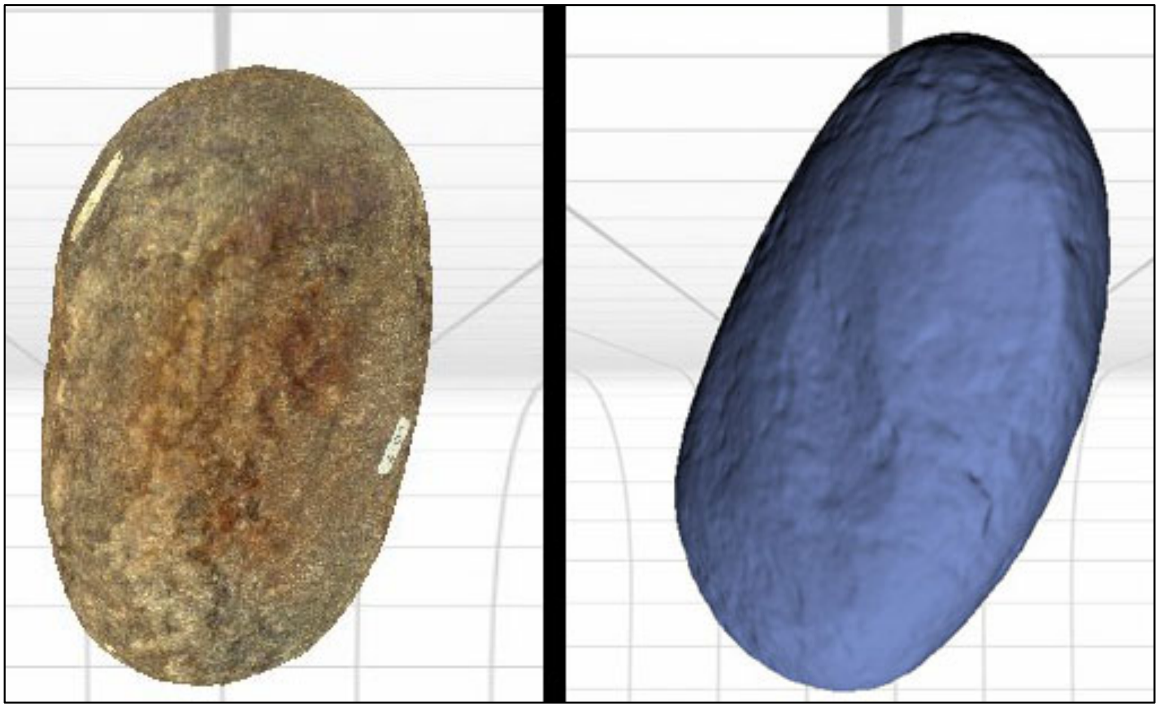


Figure 21. Three-dimensional digital replica of the projectile point.

In conclusion, as discussed in Chapter 3, the 3D digital laser scanning phase reveals that the 3D reproduction of artifacts is a subjective process dependent on multiple variables: the skills of the operator; climatic conditions of the lab or facility where the 3D data acquisition took place; the capacity and accuracy of the acquisition hardware and software; and the size, shape, and material of the object to be scanned.

Three-dimensional prints

The 3D models were used to reproduce all artifacts using RP technique, which creates physical objects from computer-generated programs (i.e., CAD, 3D Studio Max, etc.) using prototype 3D machines that can build a 3D prototype out of liquid, solid, or powder material (figs. 22, 23). As already discussed in Chapter X, Z Corp rapid prototyping is the only process that allows for photo-realistic, color design prints, and it has a resolution of up to 650x540 DPI. The material used is a powder that is combined with an adhesive and simultaneously embedded with an ink jet print head. Since color is one of the characteristics that allows people to describe an object and make sense of its use, Z-Corp seemed the most convenient technique for this experiment. That said, there are disadvantages to this technique. For this experiment, I requested 3D prints from three different companies: Z-Corp, and 2 service companies. Z-Corp sent me samples of the vessel made by two different groups, and the 3D prints were different in terms of color, surface finish, and accuracy. For the other three objects (i.e., Buddhist ritual object, projectile point, and grinding stone), I requested 3D copies from two different service companies, and the different color output was remarkable. While the first company sent 3D prints that were all pinkish, the second company's prints (printed on the ZCorp Spectrum Z510 at a resolution of 600 x 540 dpi) were significantly closer to the real object colors, but with a greenish patina. Moreover, since the three objects were printed in one printing process, their final texture (i.e., color appearance) was very similar. When I asked for an explanation for this problem, the answer was that the printer software does its best to convert the colors and textures of the digital object into the closest possible color match for the printed object. As a result, it is virtually impossible to adjust the color of an existing VRML file in the software, as all textures are linked into the VRML file itself and altering them could change the appearance of the object entirely. In other words, this current technology cannot guarantee that any object will be a 100% perfect color match.

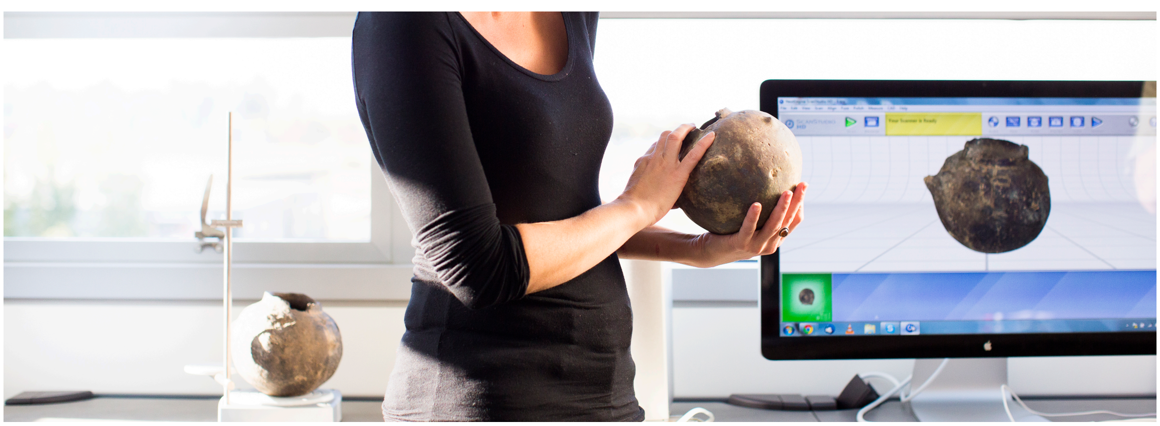


Figure 22. From left to right: original ceramic vessel located on the laser scanner base; 3D print of the ceramic vessel; 3D digital model of the vessel displayed on a computer screen.

Figure 23. 3D prints of the Buddhist object and grinding stone. The original artifacts (in the center of the picture) in comparison to 3D printed copies made using a Zcorp.

4.4. Experiment design and methods

After the artifacts were selected and replicated using different media, it was possible to design the experiment making sure that all scenarios were as similar as possible to one another. In other words I decided the order of presentation of the objects (their location in relation to the participants/observers, and made sure that the place were the experiment was taking place was as empty as possible (reducing oversight factor). Each scenario was organized as follows:

1) *Real-life Haptic* (fig 24): in this case scenario, subjects touched real objects. The objects were placed on a table, in the following order: from left to right, ceramic vessel, Buddhist ritual object, projectile point, and grinding stone. Approximately 2 cm behind each object a caption typed on paper explained where the object came from, its age, and its size. A camera was located on the other side of the table (in relation to the participant), approximately 1, 5 m far from it. The participants had to take one object at a time in their hands and, while touching the object, look at the camera, describe the object, and try to guess its function in the past.

2) *Real-life Visual* (*looking at objects;* fig 25): in this case scenario, a real object was located inside a display case, simulating the experience that people usually have when visiting an archaeological museum. Each object was located in a 25--X 25-cm display case located on a table, in the following order: from left to right, ceramic vessel, Buddhist ritual object, projectile point, and grinding stone. A typed caption on each object was placed outside the display, 2 cm behind it. The caption provided succinct information on provenience, age, and size of the artifacts. A camera was located on the other side of the table, approximately 1, 5 m far from it. All participants in this scenario were asked to stand in front of the display cases, look at each object, read the caption, and then, while looking at the camera, describe the object and guess the function of the object in the past.

Figure 24. Participant touching an original artifact.

Figure 25. Participant looking at artifacts exhibited in show cases.

3) *Two-dimensional Visual (pictures*; fig. 26*):* in this case scenario, subjects looked at a picture of the artifact. These pictures were located on a table, in the following order: from left to right, ceramic vessel, Buddhist ritual object, projectile point, and grinding stone. The pictures' size was 8 X 12 inch and they did not reproduce exact measures of the original objects. All pictures included a graphic scale to help the participants determining the size of the objects. A typed caption on each object was placed outside the display, 2 cm behind it. The caption provided succinct information on provenience, age, and size of the artifacts. A camera was located on the other side of the table, approximately 1, 5 m far from it. Participants were asked to hold the picture and show it to the camera for a few seconds; after that they were free to keep holding the picture or put it back on the table while describing the object (always standing in front of the table and looking at the camera).

Figure 26. Participant describing the picture of an artifact.

1) *Virtual Visual (3D*; fig. 27*)*: in this task, 3D virtual copies of the artifacts were displayed on a computer, one at a time. For this task, 3D copies were displayed in

a computer linked to a projector. The Next Engine software was used to display the 3D reconstructions. The 3D copies were displayed in a 24-inch computer screen linked to a projector. The computer was located on a table. A typed caption on each object was placed outside the display, 2 cm behind it. The caption provided succinct information on provenience, age, and size of the artifacts. A camera was located on the other side of the table, approximately 1, 5 m far from it. For this task, subjects were asked to interact with the 3D copies using the mouse, since the Next Engine software allows moving and rotating the objects, and zooming it in and out. Moreover, the software permits the removal of the original colors of the objects so as to explore them without-color-interference, either in the form of *mesh*, *vertexes*, *wireframe*. In other words, the Virtual Visual (3D) experience gave the users multiple levels of perception of the objects (augmented reality). The goal of this sub-experiment was to determine if and to what extent multiple levels of perception of 3D objects could improve knowledge production and acquisition of ancient artifacts. This task required four steps; for each step, I displayed one 3D object and asked participants to, first, interact with the 3D object through the computer scree using the mouse and, second, to start describing and talking about function of the object once they felt confident with their exploratory procedure. The objects were shown in the following order: ceramic vessel, Buddhist ritual object, projectile point, and grinding stone. When participants were ready to describe the object, they did so while looking at the camera and without touching the mouse. The reason for behind the projector was that the projection of the computer desktop on the wall allowed recording the interaction of the user with the 3D object. As a result to this multi-setting this second task required four videos, one for each 3D object, unlike the previous tasks, which only required just one video. For this task, participants were asked to interact with the 3D copies using the mouse, since the Next Engine software allows the object to be moved and/or rotated, and permits zooming it in and out. Moreover, the software allows removal of the original colors of the object so subjects could explore them without-color-interference, either in the form of *mesh*, *vertexes*, *wireframe*. In other words, the Virtual Visual (3D) experience gave users multiple levels of perception of the objects (i.e., augmented reality). The goal of this sub-experiment was to determine if and to what extent multiple levels of perception of 3D objects could improve knowledge production and acquisition of ancient artifacts.

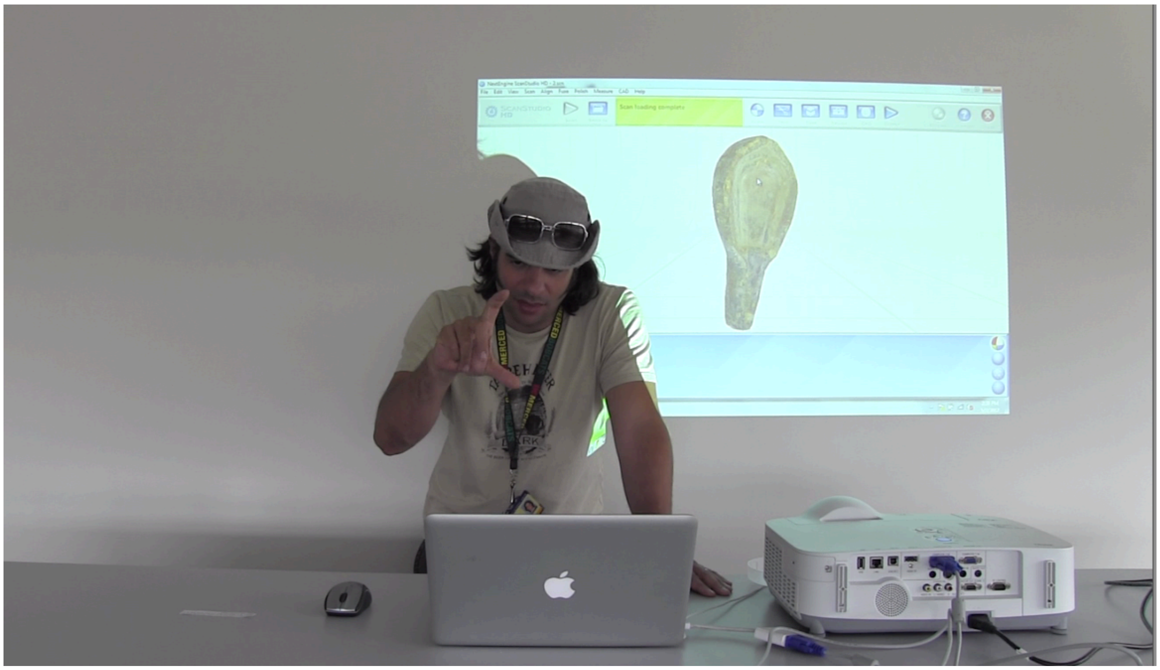


Figure 27. Participant talking about the 3D replica of an artifact.

2) *Three-dimensional –printed Haptic* (fig. 28): in this case scenario, participants interacted with 3D printed copies of real objects. This task was aimed at understanding if 3D prints of original artifacts are able to reproduce the haptic experience people have with a real artifact. Each 3D print was located on a table, in the following order: from left to right, ceramic vessel, Buddhist ritual object, projectile point, and grinding stone. A typed caption on each object was placed outside the display, 2 cm behind it. The caption provided succinct information on provenience, age, and size of the artifacts. A camera was located on the other side of the table, approximately 1, 5 m far from it. Similar to the *touch* condition, participants in this task had to take one object at a time in their hand(s) and, while looking at the camera and touching the object, describe it and guess its function in the past.

Figure 28. Participant describing the 3D print of an artifact.

4.5. Participants and description of the tasks for the experiment

Forty people participated for the whole experiment. Half of these participants were University of California, Merced, undergraduate students (50% female, 50% male), who received extra course credit in exchange for their involvement. The other half were expert archaeologists (i.e., either academics or contract archaeologists; 50% female, 50% male) who agreed to participate in the experiment. All were proficient speakers of English, either native speakers of English or bilingual with dominant English experience. All had normal or corrected vision.

After signing a consent form, all students were video recorded in a large and bright laboratory at UC Merced. Some of the archaeologists were also interviewed in the lab at UC Merced, but most were interviewed in their offices or labs, where we tried to reproduce the same conditions and atmosphere experienced by the other participants at UC Merced.

Since this research involved human subjects participation, it required Institutional Review Board (IRB) review and informed consent of all participants, which was granted in writing by all participants before starting the experiment (see Appendix 2). After signing the informed consent, participants were, asked to complete a survey (see appendix 3) and provide us with information on their age, title of study, and experience with artifacts (either real or digital). Eventually, they were given verbal instructions (see Appendix 4) and then left alone during the experiment so that they could feel more comfortable in front of the camera.

4.6. Data Analysis

The interviews were video and audio recorded, and language and gestures were analyzed to determine which type of interaction (physical or virtual) best serves archaeological research and the presentation of archaeological material to the general public. As explained in the Chapter 1, the primary motivation for videorecording people while they described objects was to identify groups of gestures that could be clearly correlated with speech (Sargin *et al.* 2006). According to cognitivie scientist David McNeill (2005), the close synchrony between gesture and speech indicates that the two are inseparable parts of a single thinking process and contribute semantic content (e.g., Cienki and Mueller 2008, Cooperider and Núñez 2009, Chui 2011;Matlock et al. 2012;). Gestures also facilitate reasoning and learning (Goldin-Meadow 2003) and can help in describing abstract objects (Bavelas et al. 1992). As a result, a combined study of gestures and speech allow understanding of how people think with artifacts and their virtual copies. All data were analyzed as follows (see Table 1 for details):

1. Interviews were transcribed.
2. Spreadsheets were prepared with a transcription of the complete available discourse and a description of where in the files specific gestures (e.g., iconic gestures) were to be found.
3. Passages of interest were labeled according to certain speech and gesture parameters under investigation (e.g., phases of iconic gestures in relation to eye lid closings, pitch movements, etc.).
4. Discourses were analyzed based on number of words, adjectives, nouns, and

verbs used', and presence of adjectives and nouns used to describe shape, dimensions, density, and function; and metaphors.

5. The gestures associated with each part of interest in the discourses were analyzed.

Table 1. Data source and intended purpose (after Hede and Thyne 2010).

Data source	**Intended purpose of data**
Surveys of participants	To gain information about participants' previous experience (as professionals or as visitors of historical, anthropological, and/or archaeological museums) with ancient artifacts and their familiarity with 3D digital reproductions of artifacts.
Transcripts from video-interviews.	To understand how people describe artifacts with specific regard to word choice, how they focus on innate qualities of artifacts (i.e., shape, weight, material, etc.), and how they try to determine the function of these objects in the past.
Analysis of gestures	To understand to what extent gestures give a bodily support to participants' discourses, to observe which medium enhances a higher number of gestures, and to see when participants use gestures and which kind of gestures.
Observations of participants' behavior while "interacting" with each medium	To gain insights into how people interact with the medium, to better understand the findings (speech and gestures)

Table 2 uses selected criteria to justify the trustworthiness of this research and findings. This aspect of the research was modeled after work by Anne-Marie Hede and Maree Thyne (2010), and was influenced by interpretive research (Wallendorf and Belk 1989) and grounded theory (Strauss and Corbin 1990).

Table 2. Trustworthiness of the study and findings (after Hede and Thyne 2010).

Trustworthiness of criteria	**Method addressing in this study and findings**
Credibility Extent to which the results appear to be	Research conceptualization, design, data collection, and interpretation were done in

acceptable representations of the data	collaboration with scholars in the programs of Cognitive and Information Science and World Cultures at the University of California, Merced. The data collection and analysis was undertaken over a period of 24 months.
Transferability Extent to which the findings from one study in one context will apply to other contexts	The main goal of this study was to design a new methodology that will be transferable to studies concerning the use of technologies in archaeology and heritage. The combined analysis of speech and gestures has never been used to study how people perceive the archaeological record, but it represents a cutting-edge method used in linguistics, behavioral psychology and cognitive and information science to study thinking processes.
Dependability Extent to which the findings from one study in one context will apply to other contexts	Research participants were provided the opportunity to reflect and describe in their own words and their own time their experience with the artifacts. Many consistencies were detected across data and a number of data sources were used to gain a holistic view on how people perceive artifacts through different media. Nonetheless, this is a new study in the field of digital heritage; therefore further analysis will help to clarify the results of this work.
Confirmability Extent to which the findings are unique to this study; the stability or consistency of explanations	Various aspects of the findings were presented and discussed with mentors and peers for feedback. The author also asked a peer to independently analyze the data to detect specific utterances based on given categories. The independent analysis was then compared for a final interpretation of the data.
Integrity	Survey responses were anonymous, thus allowing

Extent to which interpretations are influenced by misinformation or evasions by participants	respondents to respond in ways they chose. All videos of participants describing the artifacts were checked to see if each participant understood the instructions. In all cases where participants did not understand the instructions provided, the videos were not included in the analysis.
Fit Extent to which findings fit with the substantive area under investigation	Upon completion of the study, the researcher went back to the research questions and considered whether they answered them to an acceptable level.
Understanding Extent to which participants buy into results as possible representations of their worlds	It was not possible to communicate with research participants on this matter.
Generality Extent to which findings discover multiple aspects of the phenomenon	Research design was aimed at gathering a holistic perspective of the phenomenon under analysis. Further analysis will allow to broaden research findings, taking into account a broader range of participants, to see how *age*, *gender*, *education, etc.* may be influences in their perceptions of different objects, virtual and real.
Control Extent to which organizations can influence aspects of the theory	Academic mentors informed this theory; future research in collaboration with museums will allow broadening empirical and theoretical perspectives.

4. 7. Conclusions

In this chapter, I described an interdisciplinary method used to answer my research questions. As already explained in Chapter 1, the quantitative analysis of speech and gestures is not new in cognitive psychology and cognitive information science, but its application to heritage and archaeology studies is new. In fact, this method seems a powerful tool to answer research questions that investigate phenomena of mind and body that engage with the material past through different media. We should not forget that heritage studies and material culture theories are interdisciplinary in nature, since they deal not only with study and interpretation of the past, but also with its preservation and dissemination. Interpretation, preservation, and dissemination processes necessarily take into account issues related to emotions, consciousness, physical and social environments, and individual and cultural differences. Therefore, the combination of a cognitive approach to traditional analytical methods for the study of how people perceive and engage with the past seems ideal. For this reason, the methodology used combined quantitative analysis of speech and gestures with qualitative analysis of the same aspects of observations of participants' behavior while engaging with artifacts through different media. Moreover, this methodology is clearly transferable to other studies concerned with material culture, digital heritage, and museum studies.

Chapter five. Talking about things: an embodied experience

The subject will claim
that she has been taken
to the wrong place.

That the room
she is brought back to
is not the room she left.

That these comings and goings
are happening
to someone else,

are gathering momentum
controlled by a secret
mechanism.

That she needs to tell
someone.
(Rae Armantrout, *Mistakes*)

5.1. Introduction

The previous chapter described the experimental design of the main study presented in this work and discussed the methodological approach used to analyze the research data. This chapter describes the analysis of data, followed by a discussion of the research findings. The findings relate to the research questions that guided this study: *How do people experience an object when they can touch it? Can this haptic experience be reproduced when the artifacts are presented in different media? Is virtual object interaction able to reproduce sensations of material qualities such as density and weight? How do people interpret archaeological artifacts and what is the difference, if any, between* *archaeologists and the "general public" in the interpretation process? Can 3D printed copies duplicate the cognitive feel of real objects?* (see chapter 1). Data were analyzed to identify, describe, and explore the relationship between perception of past material culture and different modalities of presenting this material culture. This chapter is divided in four main parts. The first part provides a detailed description of the sample of people who participated in the experiment. The information on the participants was gathered with a questionnaire that each participant completed before the experiment started (see Chapter 4).

The second part examines all research findings related to speech, and the third part) is dedicated to a combined quantitative and qualitative analysis of gestures. Finally, the fourth part discusses observations of participants' experience with the artifacts through different media. These parts are followed by a final conclusion that synthetizes and discusses all findings.

5.2. Participants

As explained in Chapter 4, participants in this experiment represented two categories: (1) archaeologists; and (2) undergraduate students with minimal or no experience with artifact studies and the fields of heritage and archaeology. Half of the participants in each scenario were men, the other half were women. The mean age of the archaeologists was 46.55 years; the mean ranged from 41.5 years in the *pictures* scenario to 55.5 years in the *3D prints* scenario. Most hold a Ph.D.; five archaeologists hold an M.A. They all had laboratory experience with artifacts of different kinds (e.g., especially ceramic and lithic artifacts, but also bronze, shell, human and animal bone, fibers, etc.) and 90% had familiarity with 2D digital libraries (archives) of artifacts. However, only 65% of the archaeologists were familiar with 3D digital artifacts. Their areas of interests were mainly North America, Europe, and Near and Middle East. Other areas of interests were Mesoamerica, South America, and Asia (one archaeologist).

The mean age of students was 22.2 years; the mean ranged from 18.5 years in the *3D* scenario to 34 years in the *Touch* scenario. Just one student had taken an introductory class in archaeology before the experiment and only 30% of the students had visited an historical, anthropological, and/or archaeological museum (e.g., the Smithsonian, Pompeii, Valley of Kings, etc.).

All participants were proficient speakers of English, either native speakers of English or bilinguals with dominant English experience. All had normal or corrected vision and did not have any health issue that would impair sensory perception.

5.3. Analysis of speech

5.3.1. How do people describe artifacts? Description vs Function

First, a preliminary analysis on verbal responses was conducted. Analysis began by examining the number of words generated by all interviewed participants. Before comparing the number of words produced in the five scenarios, the total number of words produced by archaeologists and students were compared and t-tests were performed to see if differences were reliable. Differences were reliable (Archaeologists: $M = 304.69$, $SD = 233.43$; Students $M = 144.07$, $SD = 109.73$), with $t(38) = 2.74$, $p = .001$. On average, archaeologists produced more than double the number of words to describe each object, regardless of assigned scenario (i.e., *Pictures*, *Touch*, *Look*, *3D*, *3D prints*).

The mean number of words used for *describing* the objects compared to the average number of words used to estimate/determine the object *functions* was then examined. Interestingly, while a significant difference in the mean number of words used to describe the objects was observed (Archaeologists: $M = 235.66$, SD = 209.05; Students: $M = 77.95$, SD = 70.35), with $t(38) = 3.12$, p = <.0001, no significant difference was found between archaeologists and students with regard to the mean number of words used to elaborate upon the function of the objects (Archaeologists: $M = 69.02$, SD = 38.58; Students $M = 66.12$, SD = 49.78), with $t(38) = .20$, p = .14).

These results underline the importance of discipline-specific knowledge for describing and analyzing past material culture. Archaeologists, who are trained in describing things as an important part of their inquiry about material culture, spend most of their interview time describing the objects before providing an hypothesis about function. This task of describing things, which is an essential part of an archaeologist's investigation process, seems more difficult and not immediate for students with minimal or no archaeological experience.

Next, this aspect of language was further investigated and each scenario was compared. As illustrated in fig. 29, on average, participants in the *3D* scenario (both archaeologists and students) used the most words to talk about a given artifact, while archaeologists in the *Pictures* scenario and students in the *Look* scenario used the fewest. *t*-tests were performed to see if there were significant differences between participants in the *3D* scenario (with the highest number of words regardless of participant type) and all other participants. With regard to archaeologists, the data show a statistically significant difference between *3D* and *pictures* scenarios (*3D* Archaeologists M = 400, SD = 143.90; *pictures*, Archaeologists M = 160.62, SD = 32.10), with $t(8)$ = 20.1, p = .02. Conversely, comparison of archaeologists in the *3D* scenario (M = 400, SD = 143.90) and archaeologists in the *Touch* scenario (M = 366.19, SD = 360.85) revealed no significant differences between the groups, with $t(8)$ = 6.3, p = .08. Similarly, archaeologists in the *Look* (M = 400, SD = 143.90) did not differ in number of words from archaeologists in the *3D* scenario, with $t(8)$ = 1.12, p =.5, and comparisons with participants in the *3D prints* scenario (M = 374.56, SD = 326.7) revealed analogous findings, with $t(8)$ = 5.15, p = .1.

These findings show that even if archaeologists in the *3D* scenario use the greatest number of words, the difference is significant only when we compare archaeologists in the *3D* scenario with their colleagues in the *Pictures* scenario. So, other *t*-tests were run to see if there was significant difference between archaeologists in the *Pictures* scenario (i.e., archaeologists who used the fewest number of words) and those archaeologists in all other scenarios.

Comparison of *Pictures* (M = 160.62, SD = 32.10) and *Look* (M = 400, SD = 143.90), showed that archaeologists in the *Look* scenario produced a significantly greater number of words than those using *Pictures*, with $t(8)$ = 17.9, p = .02. The comparison between archaeologists in the *pictures* and *Touch* (M = 366.19, SD = 360.85) scenarios revealed an even stronger difference, with $t(8)$ = 126,38, p =.001. This is almost the same finding revealed when comparing archaeologists in the *pictures* scenario and those who touched *3D prints* (M = 374.56, SD = 326.7), with $t(8)$ = 103.59, p =.001.

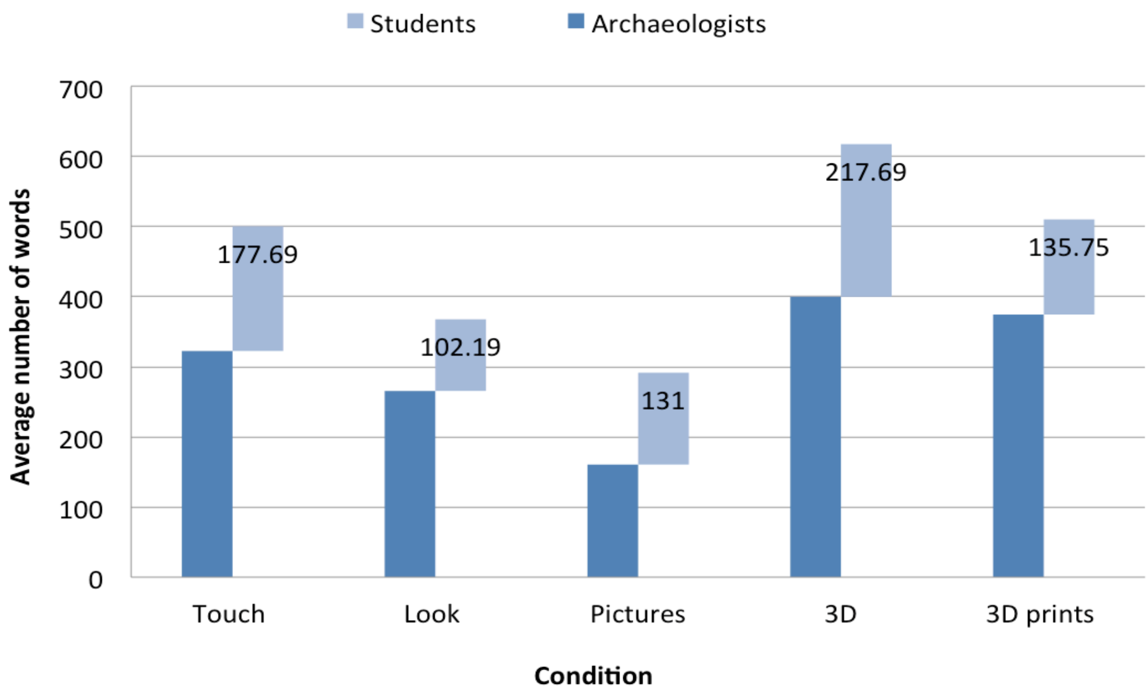


Figure 29. Total mean number of words used by archaeologists and students, respectively, to talk about function in different scenarios.

In summary, the result for the *Pictures* scenario varies significantly from those of other scenarios.

After comparing archaeologists, statistical analyses were performed to compare the number of words produced by students in the different scenarios. Similar to what was observed with archaeologists, comparison between students in the *3D* scenario (M = 217.7, SD = 129.66) and the *Pictures* scenario (M = 131, SD = 29.48) also revealed significant differences, with $t(8)$ = 19.34, p = .02. The group of students using 3D digital replicas of artifacts used significantly more words to describe each object than their peers who looked at real artifacts located inside cases (M = 58.25, SD = 36.7), with $t(8)$ = 12.5, p = .03.

Conversely, comparison of students in the *3D* scenario with their peers in the *Touch* scenario (M = 177.69, SD = 75.94) revealed no statistical difference, with $t(8)$ = 2.92, p =.2. Similar results were revealed when comparing *3D* and *3D prints* (M = 135.75, SD = 145.8), with $t(8)$ = 1.26, p = .4.

Students in the *Look* scenario (i.e., those who used the fewest words to talk about artifacts) were then compared to all other students. Comparing students in the *Look* (M = 58.25, SD = 36.7) and *pictures* (M = 131, SD = 29.48) scenarios revealed no significant difference, with $t(8) = 1.55$, p = .4. Similarly, there were no significant differences between students in the *Look* and *Touch* scenarios (M = 177.69, SD = 75.94), with $t(8) = 4.28$, p = .1. The only comparison that produced significant results was that between the *Look* and *3D prints* scenarios, since the latter seemed to result in a significantly greater number of words (M = 135.75, SD = 145.8), with $t(8) = 1.26$, p = .02.

In conclusion, with respect to students, varying scenarios of engagement resulted in notable differences between *3D* and *Pictures, 3D* and *Look,* and *Pictures* and *3D prints*.

Additionally, all scenarios were compared to see if *description* and elaboration upon *function* was influenced by the medium used when engaging with and talking about artifacts.

With regard to archaeologists, the *description* results are slightly different than those observed with the mean total words, since participants in the *3D prints* scenario produced the greatest number of words (Table 2). The number of words produced in the *3D prints* scenario (M = 314.06, SD = 316.81) was significantly different than that produced in the *Pictures* (M = 101.87, SD = 18.12 —$t(8) = 305.65$, p = .0003—and in the *Look* scenario (M = 191.69, SD = 95.15), with $t(8) = 11.09$, p = .04. However, analysis revealed no significant difference between archaeologists describing 3D prints and those describing original objects (M = 265.87, SD = 245.35), with $t(8) = 1.67$, p = .4. These results are similar to those produced when comparing *3D prints* and *3D* (M = 304.81, SD = 129.97), with $t(8) = 51.44$, p = .09. As observed for the total mean number of words, archaeologists also produced quite a high number of words in the *3D* scenario, but as previously observed, this number (M = 304.81, SD = 129.97) was only significantly different from the number of words produced by archaeologists in the *Pictures* scenario (M = 101.87, SD = 18.12), with $t(8) = 51.44$, p = .004. In fact, statistical analysis revealed no significant difference between archaeologists in the *3D* scenario and those in the *Touch* scenario (M = 265.87, SD = 245.35) — $t(8) = 3.56$, p = .2—, *Look* (M = 191.7, SD = 95.15) — $t(8) = 51.44$, p = .3—, and *3D prints* scenarios. (For the comparison between *3D* and *3D prints* see above.)

Archaeologists in the *Pictures* scenario produced the fewest number of words to describe the artifacts (M = 101.87, SD = 18.12). Moreover, as discussed above, , the number of words produced in this scenario was significantly lower than that produced in the *3D* and *3D prints* scenarios. Significant difference was also revealed when comparing *Pictures* and *Touch* (*M* = 265.87, *SD* = 245.35) — *t*(8) = 183.31, p = .0007— and *Pictures* and *Look* (*M* = 191.7, *SD* = 95.15), with *t*(8) = 27.6, p = .01.

With regard to students, the *description* results mirror what was previously observed with the mean total words, with student participants in the *3D* scenario producing the highest number of words (*M* = 115. 87, *SD* = 88.21; fig. 30) and student participants in the *Look* scenario producing the fewest number of words (*M* = 31.5, *SD* = 9.29). Similarly, analysis revealed significant differences between *3D* and *Look*—*t*(8) = 90.12, p = .002—and between *3D* and *Pictures* (*M* = 62.75, *SD* = 19.88), with *t*(8) = 19.68, p = .02. Conversely, no reliable differences were found when comparing *3D* and *Touch* scenarios (*M* = 113.75, *SD* = 78.78) — *t*(8) = 1.25, p = .4— and *3D* and *3D prints* (*M* = 65.87, *SD* = 70.87), with *t*(8) = 1.55, p = .4. Interestingly, while no significant difference was found when comparing *3D* and *Touch*, comparisons between *Touch* and all other scenarios revealed that the number of descriptive utterances (i.e., words) used in the *Touch* scenario was significantly greater than that produced by students in the *Look* (*M* = 31.5, *SD* = 9.29) — *t*(8) = 71.88, p = .003—, *Pictures* (*M* = 62.75, *SD* = 19.88) — *t*(8) = 15.7, p = .02—, and *3D prints scenarios* (*M* = 65.87, *SD* = 70.87),with *t*(8) = 1.24, p = .04.

When comparing students in the *Look* scenario to those interacting with *3D prints*, the number of *description* words used by the latter students was notably greater than that produced by students in the *Look* scenario, with *t*(8) = 58.17, p = .004. However, comparisons between *Look* and *Pictures* (*M* = 62.75, *SD* = 19.88) scenarios revealed no significant difference, with *t*(8) = 4.58, p = .1. Finally, similar to students in the Look scenarios, these and previous findings also show how students in the *Pictures* scenario used significantly fewer words than students in the *Touch* (see above), *3D* (see above), and *3D prints* scenarios (*M* = 65.87, *SD* = 70.87), with *t*(8) = 12.7, p = .03.

In summary, these results show that although students are very poor in describing pictures and objects exhibited in a display case, they seem more willing to describe both real-life objects when they can touch them, 3D virtual copies of real objects, and, to a lesser extent, 3D prints.

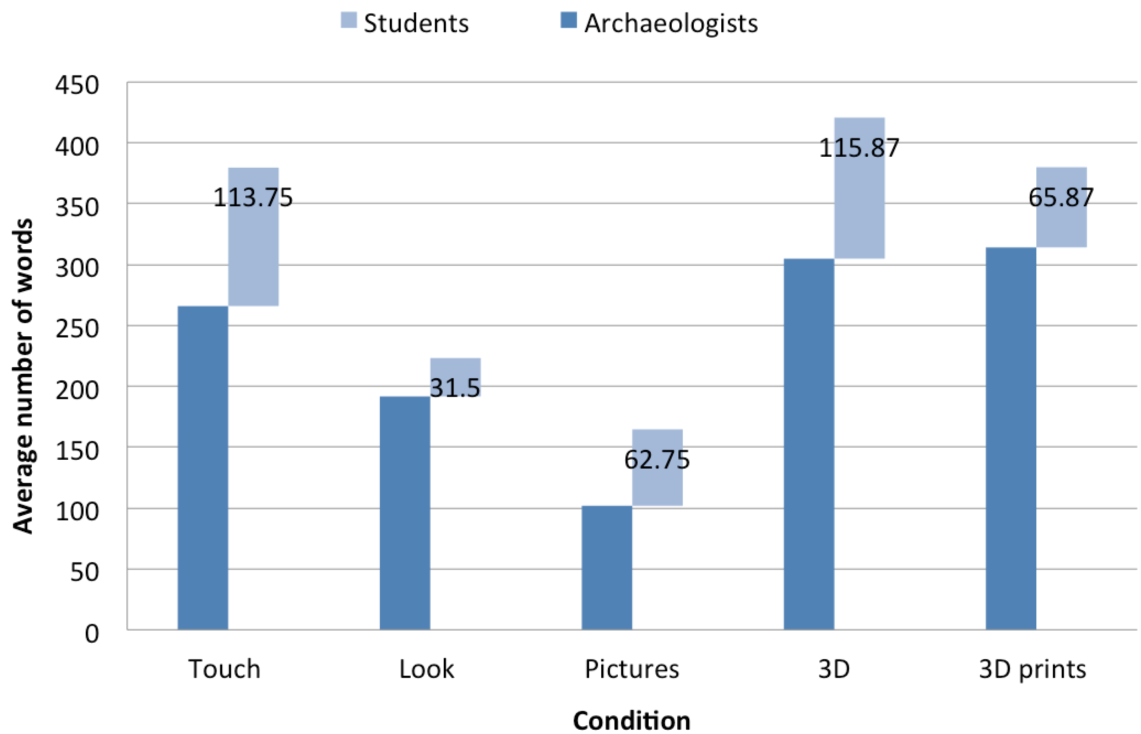


Figure 30. Total mean amount of words used by both archaeologists and students to describe the artifacts in different media states.

Fig. 31 shows the number of words produced when talking about the *function* of artifacts and seems to confirm the trend seen before; that is, participants in the *3D* scenario, regardless of category, used slightly more words than those in all other scenarios; however, the difference was not significant. In fact, archaeologists showed significant differences between *3D* (M = 95.19, SD = 49.82) and *3D prints* (M = 60.5, SD = 11.47), with $t(8)$ = 18.9, p = .02. Conversely, comparisons between archaeologists in the *3D* scenario and their colleagues in the *Pictures* scenario (M = 58.75, SD = 17.12) only revealed a difference close to significance— $t(8)$ = 18.9, p = .056—while the differences between *3D* and *Touch* (M = 56.75, SD = 42.40) and between *3D* and *Look* (M = 73.94, SD = 41.20) were far from significant—$t(8)$ = 1.38, p = .4; and $t(8)$ = 1.46, p = .4, respectively.

Comparing the number of *function* words produced in the *3D prints* scenario with the number of words produced in all other scenarios, revealed significant differences. As seen before, there was significant differences between *3D prints* and *3D*, p = .02; likewise, statistics revealed significant differences when comparing *3D prints* and *Touch* (*M* = 56.75, *SD* = 42.40) —*t*(8) = 13.67, p = .03—and *3D prints* and *Look* (*M* = 73.94, *SD* = 41.20), with *t*(8) = 2.23, p = .03. The only comparison that did not reveal significant differences was that between *3D prints* and *Pictures* (*M* = 58.75, *SD* = 17.12), with *t*(8) = 2.23, p = .3.

Archaeologists in the *Touch* scenario used, on average, the fewest number words to talk about function (*M* = 56.75, *SD* = 42.40), but also in this case, differences were significant when comparing *Touch* with *3D prints,* p = .03. In fact, there was no significant difference between *Touch* and *Pictures* (*M* = 58.75, *SD* = 17.12) —*t*(8) = 6.14, p = .08—*Touch* and *Look* (*M* = 73.94, *SD* = 41.20) — *t*(8) = 1.46, p = .5— and *Touch* and *3D*, p = .4.

Examination of the number of words used by students to talk about the function of the artifacts revealed similarities to what observed with archaeologists (table 3). In fact, students in the *3D* scenario used the greatest number of words (*M* = 101.81, *SD* = 46.68), but this number was not significantly different from the number of words produced by students in the other scenarios (table 3).

Table. 3 T-test showing no significant difference between students in the *3D* scenario and those in the other scenarios.

Scenarios	**Results of t-test**
3D vs Touch	*3D* (*M* = 101.81, *SD* = 46.68), *Touch* (*M* = 63.94, *SD* = 17.03) *t*(8) = 7.51, p = .06;
3D vs Look	*3D* (*M* = 101.81, *SD* = 46.68), *Look* (*M* = 26.75, *SD* = 27.47) *t*(8) = 2.89, p = .2;
3D vs Pictures	*3D* (*M* = 101.81, *SD* = 46.68), *Pictures* (*M* = 68.25, *SD* = 25.10) *t*(8) = 3.46, p = .2;
3D vs 3D prints	*3D* (*M* = 101.81, *SD* = 46.68), *3D prints* (*M* = 69.87, *SD* = 75.43) *t*(8) = 2.61, p = .2.

Similarly, even if students in the *Look* scenario used very few words to talk about the *function* of the artifacts, the number is not significantly different that the number of words used by their peers in all other scenarios (table 4):

Table. 4. T-test showing no significant difference between students in the *Look* scenario and those in other scenarios.

Scenarios	Results of t-test
Look vs Pictures	*Look* (*M* = 26.75, *SD* = 27.47) *Pictures* (*M* = 68.25, *SD* = 25.10) *t*(8) = 1.2, p = .4;
Look vs Touch	*Look* (*M* = 26.75, *SD* = 27.47) *Touch* (*M* = 63.94, *SD* = 17.03) *t*(8) = 2.6, p = .2;
Look vs 3D prints	*Look* (*M* = 26.75, *SD* = 27.47) *3D prints* (*M* = 69.87, *SD* = 75.43) *t*(8) = 7.54, p = .06.

Performing other tests revealed that the only significant difference was between students in the *Touch* scenario (*M* = 63.94, *SD* = 17.03) and those in the *3D prints* scenario (*M* = 69.87, *SD* = 75.43), with *t*(8) = 19.61, p = .02. Nonetheless, it is important to note that comparisons between students interacting with 3D prints and students describing pictures of artifacts revealed a strong trend toward significance, with *t*(8) = 9.03, p = .05.

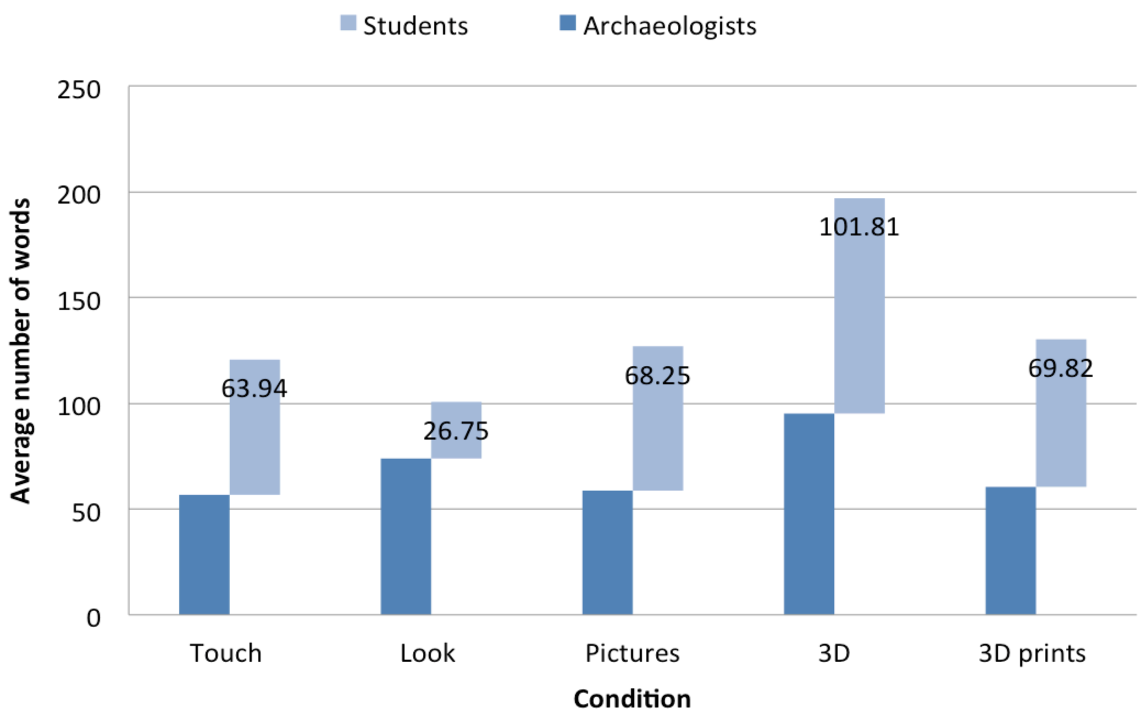


Figure 31. Total mean number of words respectively used by archaeologists and students to elaborate upon the function of the artifacts in different media states.

Overall, archaeologists, who are usually trained at describing things when they can touch them, are very critical with other media of analysis and often express their frustration about having to talk about artifacts without being able to touch the real-life object. Conversely, undergraduate students with no archaeological experience, who are neither accustomed to describing things nor to touching archaeological artifacts, seem less critical with media other than *the tactile experience with real-life objects,* and they often showed their excitement and emotion regarding the opportunity to touch "old things" even in absence of a supervisor: For example: "This object, I don't wanna drop it, um…"[1] (#8, student, talking about the pot); "It smells old. I can tell it's old, yeah" (#11, student, touching the pot). Students are not the only people who feel excitement when touching original ancient artifacts. For this work, in fact, I interviewed other people who are not included in the quantitative analysis, so the samples are more homogeneous. A literature professor expressed the same excitement: "Well, these are some amazingly old artifacts; uh, I can't believe I have a chance to work with them, um…" (#45, touching the pot).

How do people determine the function of an object? Determining the function of an object is a difficult task, especially when the object is presented in isolation; that is, out of its original or archaeological context (i.e., in which they were found). This is because artifacts are rarely ever isolated, void of the context where they were found or when they were preserved and subsequently exhibited inside museums. For this reason, some participants attempted to associate some of the objects to better describe the artifact function (e.g., they tried to find a context through association with nearby objects). For instance, while describing the grinding stone, a student simulated the action of knapping in proximity of the projectile point: "Let's see. Well, it looks like could have been used as a chipping block; maybe for things such as the arrowhead" (#10, *Touch*). Another student simulated the action of pouring liquids into the pot using the Buddhist object: "I do not know, like, you use this to put stuff in it (the pot), like this: psh, psh, psh, psh". (#11, *Touch*; fig. 32). Talking with a participant after the experiment, he confessed to me that, while he was describing the pictures of the artifacts, he felt the need to associate them to determine their function (#48, *Pictures*).

[1] This quote is part of a transcribed video-interview. All quotes in this chapter are literal (i.e., word-by-word) and this explains fragments and redundancy encountered while reading them.

Figure 32. Student participant simulating the function of the Buddhist object.

When trying to determine the function of an object, people are often influenced either by their personal experience with the physical world (*experiential knowledge*; see Lakoff and Johnson 1980) or by background knowledge acquired while reading about similar artifacts (*notional knowledge*). While examining the videos, I found several examples that might explain how personal, sometimes intimate, experience guided students' guesses; the following is one of the most representative:

> And yeah. I don't think it's not, it's not ancient./[2] Mmm Like honestly, like I do, I used to play with stones like all the time when I was young because I'm from Mongolia and I ride horses all the time when I was young, and like all we do is like play with stones, like we make home and we'd make an area, like private area, with like stones, and we actually get the shapes of the stone like, and I usually found lot of like stones that shaped like in heart so it w[as] it was silly [#11, *Touch*, talking about the grinding stone].

[2] The use of a "/" is a conventional choice I made to indicate that a participant talked about an object in a non-linear way. In this specific example, for instance, the participant talked about the grinding stone, then about the Buddhist object, and eventually gave some more information on the grinding stone and how it recalled her youth in Mongolia.

In one case, a non-expert participant used his museum experience with one of the objects to reinforce his hypothesis: "Given what I've seen of objects like this in a museum setting" (#42, *Touch*, talking about the grinding stone). To reinforce his argument, another student tried to dress the part of a professional, claiming he acquired knowledge about projectile points from to his expert uncle: "This is an arrowhead. I know because it's pretty familiar to me, I actually have one of my uh uncles uh far removed [name of the uncle] is an expert in Ohio arrowheads and they look a lot familiar to this one, a lot similar" (#45, *Touch*, talking about the projectile point).

Intimate experience can also be used by archaeologists, even if it is rare: "This I think was actually um used for holding I would say water; it certainly would've kept some liquid in there quite nice and cool. Dad had a similar one, so that's what I am guessing is its impact" (#29, *Touch*). In fact, archaeologists usually rely on either their professional experience or background knowledge to talk about the function of an artifact:

> Uh there was an article by [author] many years ago in the *Journal of California and Great Basin Anthropology* of uh objects that he termed hammer grinders from San Diego County and this appears to be one of those multi-function uh objects that can be used as a grinding stone a mono uh or as a hammer stone used to re-sharpen the metate or to uh pound any number of objects (#24, *Pictures*, talking about the grinding stone).

As previously discussed, discipline-specific training enhances and influences *descriptions* of the artifacts. The finding seems to suggest that this training can also influence interpretation of the objects' function. An example helps explain this point. One archaeologist in the *Touch* scenario, who was providing various hypotheses regarding the function of the Buddhist object, said that it could be a lantern, because of its shape. This means that she was so concentrated on the shape as a guiding characteristic that she lost sight of the fact that the object was made of wood and would have caught fire if someone had used it as a lantern.

Personal experience and background knowledge strongly influenced individual's description of these artifacts, but specific physical characteristics of objects are also strong affordances that influence thinking processes. For instance, the Buddhist object (which was the least familiar object for all participants) has a unique shape composed of two main parts: an upper concave part resembling a leaf or lotus flower divided with several grooves, and a handle. The upper part might strike one as a decorative element that could be simplified if it were purely functional (fig. 33).

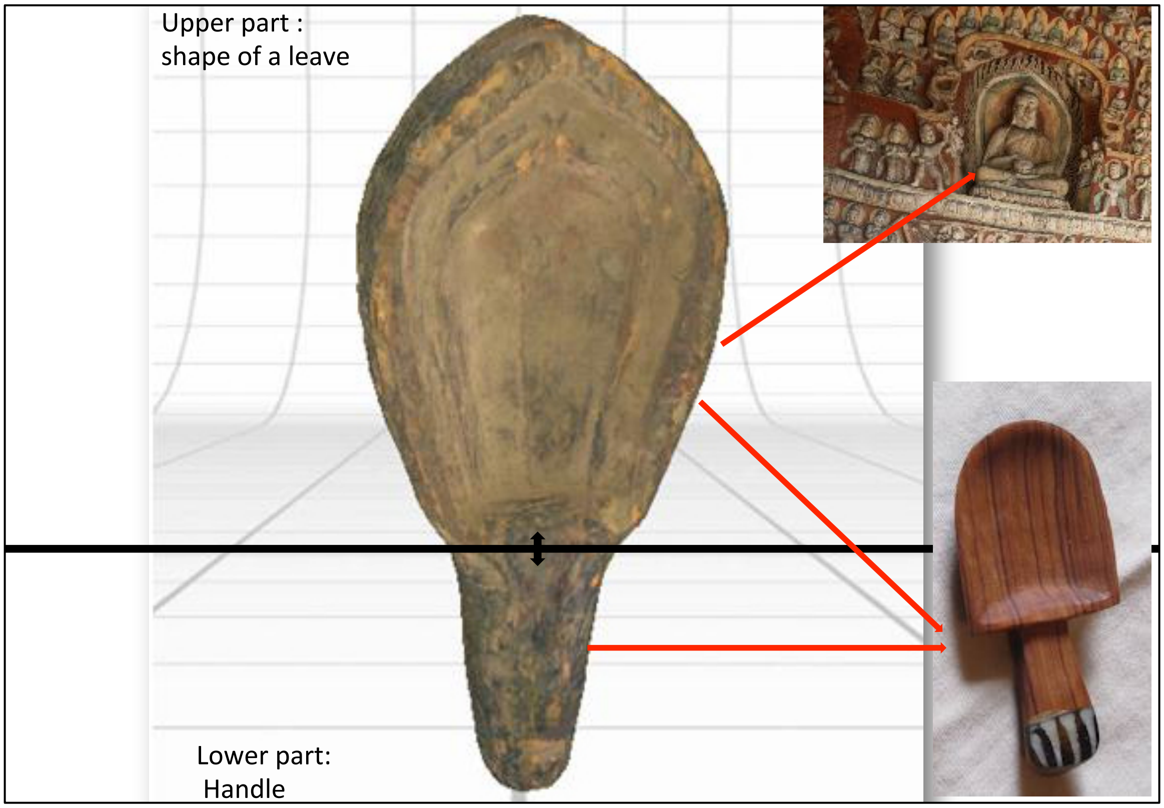


Figure 33. Buddhist object: even if this object could resemble a paddle, the shape of its upper part clearly prompts Buddhist art.

Nonetheless, most participants (both archaeologists and students) primarily interpreted this as a utilitarian object (i.e., spoon or scoop) because of the handle. Even if the affordance of the handle was more easily perceived when touching the object or its 3D print (i.e., people often observed that the object "fits well in the hand"), this affordance was also strongly perceived in the absence of a tactile experience (i.e., *Pictures*, *3D*, *Look*). The concavity of the upper part and the handle influenced people's perception, and almost everyone thought this object could be either used as a scoop or as a palette.

In contrast, when people described the vessel, even if most of participants determined that the object was used to contain liquids or small seeds based on the size of the object (small) and mouth (narrow), many participants mentioned that this object had symbolic meaning and could be used for rituals due to the presence of the cross.

5.3.2. How do people perceive innate qualities of objects?

After a combined quantitative and qualitative analysis of how people describe artifacts, I then analyzed all texts to see if reliable differences could be found with regard to the way people perceive innate qualities of objects through the chosen media. I was also interested in understanding if specific media would better stress some qualities over others, and how media would affect the overall perception of ancient artifacts and their function(s) in the past. The following analyses examine participant responses regarding material, color, shape, size, and weight.

With respect to the *material*, four categories were used in analysis: *correct*, *incorrect*, *uncertain*, and *absent*. *Uncertain* included all cases in which participants were unsure about the material of an object, but eventually indicated the correct material (see table 5). *Absent* was ultimately not included since multiple factors could explain why people did not mention material or other characteristics of an object. For instance, it could be that the medium does not stress/afford a specific characteristic, or that some people do not consider a specific characteristic crucial in their description of an object. In addition, some participants might have felt that the perception of a characteristic was so obvious that they did not need to explicitly provide a description of it. For all other categories, I was not interested in correct versus incorrect answers, since determining weight and size of an object, for example, could be challenging under any scenario. Thus focus was on if participants either mentioned or did not mention each characteristic, and, if so, how frequently such characteristics were mentioned.

Material

As shown in table 5, the proportion of participants in the *Touch* scenario who mentioned the material of the artifact is higher than that of the other categories and usually correct. However, in the *Look* scenario, uncertainty can be registered; these data seem to indicate that vision alone is sometimes not enough to determine the material of an object, even in in presence of the real-life object. Participants in the *Pictures* and *3D* scenarios showed a similar result, even though a higher number of participants in the *3D* scenario were not sure about the material of the objects. Overall, *3D* participants were most likely to mention material. Participants in the *3D prints* scenario mentioned material less often. This could be casual, but it could also be due to the higher level of uncertainty with 3D prints. In fact, as explained in Chapter 4, 3D prints do not reproduce original colors of artifact effectively. Nonetheless, as shown in the qualitative analysis below, people (especially archaeologists) who viewed 3D prints were able to discern the material of the artifact due to their tactile experience with the print. This tactile experience gave them clues about texture, which were very useful in elaboration when talking about the material.

Table 5. Proportion of archaeologists and students who either talked about *material* (correctly, incorrectly, or with a level of uncertainty) or for whom words regarding material were absent.

Material								
Scenario	**Response**				**Percentage**			
	Correct	Incorrect	Uncertain	Absent	Correct	Incorrect	Uncertain	Absent
Touch	23	0	0	9	72%	0%	0%	28%
Look	18	0	1	13	56%	0%	3%	41%
Pictures	20	4	1	7	62%	13%	3%	22%
3D	20	4	4	4	62%	12%	13%	13%
3D prints	13	1	3	15	41%	3%	9%	47%

Comparing archaeologists and students revealed different behavioral patterns: archaeologists mentioned the material of an object less frequently in the *3D* and *3D prints* scenarios (see table 6); this may be due to the fact that they were very critical of these media, since the media are new to archaeology and professionals have only started to use them for archaeological analysis. Conversely, students seem more inclined to elaborate upon the material of the artifacts in the *3D* and *Pictures* scenario, even if with a high level of uncertainty, which often produced the wrong interpretations (table 7).

Table 6. Proportion of archaeologists talking about *material* (correctly, incorrectly, or with a level of uncertainty) or words regarding material are absent.

Material: Archaeologists								
Scenario	**Response**				**Percentage**			
	Correct	Incorrect	Uncertain	Absent	Correct	Incorrect	Uncertain	Absent
Touch	15	0	0	1	94%	0%	0%	6%
Look	14	0	1	1	88%	0%	6%	6%
Pictures	14	0	1	1	88%	0%	6%	6%
3D	12	1	0	3	75%	6%	0%	19%
3D prints	10	0	3	3	62%	0%	19%	19%

Table 7. Proportion of students talking about *material* (correctly, incorrectly, or with a level of uncertainty) or words regarding material are absent.

Material: Students								
Scenario	**Response**				**Percentage**			
	Correct	Incorrect	Uncertain	Absent	Correct	Incorrect	Uncertain	Absent
Touch	8	0	0	8	50%	0%	0%	50%
Look	4	0	0	12	25%	0%	0%	75%
Pictures	4	8	3	1	25%	50%	19%	6%
3D	8	3	3	2	50%	19%	19%	12%
3D prints	3	1	0	12	19%	6%	0%	75%

Determining the material of an artifact is not easy when the artifact is ancient and often physically altered by time. As an archaeologist who has conducted numerous excavations, I can say that vision itself is often not enough to discern the material of an object, especially when the object is unfamiliar to the observer. As an undergraduate, I often mistook burnt bones for pieces of ceramic or even wood. Our sense of touch is critical when determining the material of an object. This statement seems to be confirmed by the interviews. Overall, it is clear that most participants, independent of the medium used, were readily able to discern the material of the grinding stone and projectile point, since those objects were very familiar to the participants. Conversely, since the Buddhist object is not familiar to the observers, when the sensorial experience was incomplete (e.g., in absence of the sense of touch), vision alone was confusing. This is exemplified by the following example of a student looking at the picture of the Buddhist object (made of wood): "So what it is is/ It looks like it's maybe made from rock" (#1).

Challenges to recognizing the material of an object were found for all media other than the tactile experience with original artifacts, and both archaeologists and students struggled with this task. The following example shows the response of an archaeologist interacting with the 3D digital copy of the Buddhist ritual object: "Um other than that um I can't even say what material it is/ It's probably ceramic uh could be stone uh" (#34).

It's interesting to note that in absence of a tactile experience, or in presence of a tactile experience with a 3D print, participants use multiple visual cues to discern the material of an object:

1. Color:

- *Pictures*: "S[o] this is what I'm guessing it is for and it's again like it's flat and it's white and maybe made out a rock, bone, or it was an animal's teeth at a point" (#1, students, looking at the picture of the projectile point). "And uh it looks like there is some sort, so yeah the color of this thing is/ uh sort uh dark brown kind of mottled with lighter brown or tan it could well be wood" (#28, archaeologist, looking at a picture of the Buddhist ritual object in the case);
- *3D digital copies*: "As for the material of what it could've been in the first place/ Uhm, the brown-like color and how it's shaded/ It looks like a rock."
- *3D prints*: "From the coloration of the replica I'm assuming that it's meant to be a ceramic object" (#40, archaeologist, touching the 3D print of the pot). "clearly

uh what I would call a projectile point/ flaked stone if the colors are accurate" (#40, archaeologists, touching the 3D print of the projectile point).

2. Texture:

- *Look*: "Kinda hard to tell/might be might be wood/Might be wood or it might be stone/it's got a grain to it/mm I think it's stone" (#28, archaeologist, looking at the Buddhist object in the case).
- *3D digital copies*: "Uhm it has you know marks on it that look like it was chiseled on wood and uhm" (#33, archaeologist, interacting with the 3D digital copy of the Buddhist object). "Uhm I say that it's made of wood uhm from what I could tell uh it looks as though uhm it has you can see marks where it's been uhm chiseled away by hand" (#36 archaeologist, interacting with the 3D digital copy of the Buddhist object).
- *3D prints*: "Uh I guess on the on the whole I think it's made of ceramic/ It has lots of uhm lines going around it that could be weare from making the pot" (#39, archaeologists, touching the 3D print of the pot). In another case:

> However the way that the object almost looks like it has cut marks on it/ uhm I wouldn't rule out it being actually a wood object/… um but it uh I'm confused as to what the original material might have been/ a number of the places that look like they're meant to imitate wear/ um look more like ceramic/ erosion of ceramic surface while this one looks much more like wood and the surface overall surface modeling with its faceted or uh cut-mark like surface/ cut planes like surface/ gives uh more of a suggestion of wood [#40, archaeologists, touching the 3D print of the Buddhist object].

3. Shape:

- *3D digital copies*: "The structure of this uh/ Of this thing would be made up of some type of metal/ Um as you can see/ Um as I infer that this darker spot her e um inside of the sphere/… It I was originally thought like a grenade or something like that" (#15, student, interacting with the 3D digital copy of the pot).
- *3D print*: "Um um I guess from the shape of the break at the top um I would say it was made of ceramic/But I guess it could have been made of stone/ Also/

And some of the pitting here indicates perhaps of stone but it could also be pottery" (#39, archaeologist, touching the 3D print of the pot). "Uh it could be wood/ Some some of the formally look like wooden/Yeah the shape of it here but I guess it could also be ceramic or or stone/It's very difficult to say/… The shape of it in inside here um sometimes suggests that more stone-like but I'm not really sure whether these surfaces are accurate or not" [#39, archaeologist. touching the 3D print of the Buddhist object].

One archaeologist even stressed the importance of how certain visual cues combined to influence her familiarity with the projectile point, as strong affordances to determine the function of this particular object:

> Uh this is a stone projectile point uh in this case it's uh in part because of my familiarity with the object and uh also in part because of the surface characteristics that are visible both in the visual scan and then also uh in the data points uh in the underlying layers it's clearly um it's very easy to see clearly visible uh flaking scars uh stone and uh glass um are two materials that uh respond that way to uh certain kinds of impact pressure so we can actually get a pretty good clue about the material from these visual cues because I have familiar familiarity with um stone tools and how the materials they're made of uh work in this situation [#35, archaeologist, interacting with the 3D copy of the projectile point].

Familiarity with a type of artifact, also known as background knowledge, was often used to validate a hypothesis regarding an object's material, as shown in this example: "Uh just because I figure I'm supposed to surmise I assume this is probably some kind of ceramic in real life" (#38, archaeologist, touching the 3D print of the pot). Another example shows how a student tried to determine the material of an object based on the geographic origin and cultural context of the pot: "the material if you're wondering what it's made out of I can't really say because it's a copy but if I had to give a or take it probably might be clay because it's usually the um usually the material that is used by ancient African cultures per se/ I could be wrong but that's just my observation" (#18, student, touching the 3D print of the pot). He uses the same mental process for the Buddhist object: "what's made what it's made out of I could assume probably clay again/ or a different granite or different granite uh mixture/ but considering it's from Nepal it's probably um it's probably made from the mountainous terrains area" (#18, student, touching the 3D print of the pot).

When it comes to recognizing object material, three-dimensional replicas seemed more problematic than other media, since the textural resolution reproduced by the scanner was not high and some visual cues might be misleading:

> Uh it seems in my estimation/ although it's difficult because I can't actually see or touch the material but it's likely made out of clay/ Ceramic object uh/… Alternatively um it could also be a metal object there's some sheen and some other discolorations on there that are reminiscent of uh metals known from archaeological contexts especially those in dry areas/ I don't know if it's I don't work with metal very often in my own work uh/ Also it's something I don't um have a lot of experience reading visually/ If I could get my hands on it um I could tell you for sure [#35, archaeologist, interacting with the 3D the 3D digital copy of the ceramic pot].

Texture:

Examination of how different media afford a sense of texture/surface of artifacts revealed that participants in the *Look* and *Pictures* scenarios provided only a few observations of texture, while participants in the *Touch*, *3D* and *3D prints scenarios* talked about texture more often during interviews (table 8). The data from the *Touch* and *3D prints* scenarios were not surprising, since the sense of touch presents obvious opportunities for a sensorial experience with object surfaces. What was more surprising was to see how participants in the *3D* scenario often focused on texture and noticed the smoothness or roughness of an object, since they were just interacting with a digital copy.

Table 8. Proportion of both archaeologists and students mentioning *texture* once or more than once or, conversely, words regarding material are absent.

Texture						
Scenario	**Response**			**Percentage**		
	Present	Present >1	Absent	Present	Present >1	Absent
Touch	6	6	20	19%	19%	62%
Look	5	2	25	16%	6%	78%
Pictures	5	0	27	19%	0%	81%
3D	9	7	16	28%	22%	50%
3D prints	3	11	18	10%	34%	56%

Comparison of archaeologists and students revealed some differences: while archaeologists made quite a few observations regarding function in the *Look* scenario (table 9), students in the *Look* scenarios did not provide any information on the texture of the objects (table 10).

Table 9. Proportion of archaeologists mentioning *texture* once or more than once or, conversely, words regarding material are absent.

Texture: Archaeologists						
Scenario	**Response**			**Percentage**		
	Present	Present >1	Absent	Present	Present >1	Absent
Touch	3	4	9	19%	25%	56%
Look	5	2	9	31%	13%	56%
Pictures	4	0	12	25%	0%	75%
3D	6	5	5	38%	31%	31%
3D prints	2	8	6	12%	50%	38%

Table 10. Proportion of students mentioning *texture* once or more than once or, conversely, words regarding material are absent.

Texture: Students						
Scenario	**Response**			**Percentage**		
	Present	Present >1	Absent	Present	Present >1	Absent

Touch	3	2	11	19%	12%	69%
Look	0	0	16	0%	0%	100%
Pictures	1	0	15	6%	0%	94%
3D	3	2	11	19%	12%	69%
3D prints	1	3	12	6%	19%	75%

Video recording of participants provided interesting insight into how people experienced texture of the artifacts: both students and archaeologists often highlighted how the 3D software was able to provide the sense of texture. In fact, they often stressed the importance of removing original colors from the 3D digital replicas to recognize texture and specific details of the object under analysis. For instance, a student interacting with the 3D digital copy of the grinding stone noticed:

> But um another interesting thing is the fact of how/ Many points it has or the geometry I think is what um this button and this button is for/ Um it is very very intricate and very small things that make these indents/ Um very small changes which is not easy to do on purpose/ Um so that would lead me to think that the the water itself from the ocean um/ Would've hit or just would've deformed the rock in these subtle ways/ Um making this overall structure of the rock and this um the texture of this rock" [#15].

Similar observations of the grinding stone were made by another student in the *3D scenario*: "Okay um when I remove the texture/ from this the texture seems to be kind of like rough" (#16). Archaeologists' responses similarly stressed the importance of removing original colors from digital reproductions to better perceive the surface of an object: "even if we take away the color it still it looks like a rock itself was um/ incised with little holes in it and so those little pits could be just natural or it have had some wear on the um on the tips (#33, archaeologist, interacting with the 3D digital copy of the grinding stone).

Some examples particularly point to the possibility that removing original colors from the digital artifact is an added value for the perception of specific physical cues that facilitate the inquiry process:

> Um looking at it from the visual um visual spectrum uh it's very clear that um it is uh likely made out of stone/ And if we take away the visual uh layer um the texture below um in the next layer in the image also uh supports that uh that inference/ Um this object most likely is a grinding stone/…With this technology we can actually take away the visual uh spectrum and you can basically do the same thing/ Um see what the underlying surface looks like so I'll do that/ In this case there's no indication um uh that the discolored area we can see in the visual uh image uh is actually uh a different level than the surrounding area [#35, interacting with the 3D digital copy of the grinding stone].

When looking at the mesh (i.e., surface) of the grinding stone (in the *3D* scenario), one archaeologist tried to see if an area of the stone showing red stains coincided with changes in texture (e.g., a smoother texture indicating signs of wear). Another archaeologist interacting with the 3D digital copy of the projectile point made similar observations:

> Um and the reproduction the reproduction is interesting in its regard because/ Um when I turn off the sort of skin of color I can actually see things I can see the the fine texture of the object better than um when it's on and this is the first time that's happened in the three objects that I've been shown/… And when I turn off the color actually there's a certain a a certain amount of roughness um in that place and so I'm wondering if this is a a um if this is a layer a layer of stone and that there's this is a place where the top layer is missing and so I'm catching glimpses of the layer of of stone underneath uhm" [#36].

In contrast to what happened with all participants in the *3D digital replica* scenario, archaeologists were very critical of 3D prints and often questioned the capability of the prints to reproduce the texture of original objects: "It's a big oval I assume it was always just one stone that's been roughly shaped/ and then smoothed over years of use or a period of use/ It's hard to know because some of these textures are obviously uh from your printer" (#38, archaeologist, talking about the 3D print of the grinding stone). Archaeologists are particularly critical with *texture* reproduction when describing the projectile point: "And it's also very difficult to see the flaking on this copy/ I don't know whether that's because the copy is just not a very good one or whether it's because of um there was a lot of erosion uh erosion uh of it/ Uh after it had been deposit" (#39).

<u>Color:</u>

Examination of how many times participants described color showed differences between students and archaeologists;. While archaeologists confidently talked about color in the *Touch* and *Look* scenarios—that is, in presence of real-real life objects (table 11)—students were more inclined to talk about color in the *Touch* and *Pictures* scenarios than in the other scenarios (table 12).

As described in Chapter 3, color is one of the most difficult characteristics to replicate; archaeologists were clearly very critical of the copies. For this reason, archaeologists felt more comfortable talking about colors while in the presence of the real artifact. On the other hand, students, who have been less influenced by discipline-specific training, were less critical of replicas and rarely questioned the quality of the color reproduction. As a consequence, they unconsciously focused on color in the *Pictures* scenario because this medium favors the perception of visual clues such as color at the expense of other qualities such as texture and weight, which are better represented in other media forms.

Table 11. Proportion of archaeologists mentioning *color* once or more than once or, conversely, words regarding material are absent.

Color: Archaeologists						
Scenario	**Response**			**Percentage**		
	Present	Present >1	Absent	Present	Present >1	Absent

Touch	8	5	3	50%	31%	19%
Look	6	5	5	38%	31%	31%
Pictures	3	1	12	19%	6%	75%
3D	5	2	9	31%	13%	56%
3D prints	1	4	11	11%	25%	64%

Table 12. Proportion of students mentioning *color*, once or more than once or, conversely, words regarding material are absent.

Color: Students						
Scenario	**Response**			**Percentage**		
	Present	Present >1	Absent	Present	Present >1	Absent
Touch	3	3	10	19%	19%	62%
Look	3	0	13	19%	0%	81%
Pictures	4	1	11	25%	6%	69%
3D	3	0	13	19%	0%	81%
3D prints	3	0	13	19%	0%	81%

Analysis of interview transcripts showed that both 3D digital representations and 2D pictures were able to convey detailed analysis of color variance in the artifacts. This is shown in the following example of a student looking at the picture of the grinding stone and using a fictive motion phrase to describe color variation: "But it's definitely gradi[ent?] ah and you can see different colors in here it goes from brown and right here is grey" (#1). Similar examples were also found for participants in the *3D* scenario: "Uh looking at it you can see again much like the last object we saw a sort of you know dark um muddy-brown color" (#35, archaeologist describing a brownish variation in color in the 3D digital replica of the projectile point).

As already demonstrated for other qualities, archaeologists were especially critical of 3D prints, especially when it came to color reproduction, since 3D prints are still inaccurate in this sense (see Chapter 3). Nonetheless, one archaeologist stressed the fact that the printer accurately reproduced color variation, making it easier to recognize the material of an object based on color variation details:

> Generally the color is nice uh/ but maybe the hardest thing to interpret/ Getting kind of a purple blackish tinge over a good part of it where the replication of this eroded condition/ um hasn't otherwise removed it/ This suggests that there is a surface character to the pot which is what the model is portraying probably accurately/ Also the bases shows some wear through that patina or surface color/ um this suggests that the model is capable of showing the coloration relative to the preservation scenario of the original [#40, archaeologist, talking about the pot].

<u>Shape:</u>

Archaeologists and students responded very similarly when examining shape. Generally speaking, both archaeologists (table 13) and students (table 14) in the *Look* and *Pictures* scenarios focused less of their attention on shape than participants in other scenarios.

Table 13. Proportion of archaeologists mentioning *shape*, once or more than once or, conversely, words regarding material are absent.

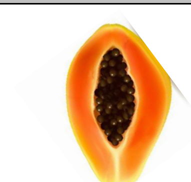
Shape: Archaeologists						
Scenario	**Response**			**Percentage**		
	Present	Present >1	Absent	Present	Present >1	Absent
Touch	5	5	6	31%	31%	38%
Look	4	2	10	25%	12%	63%
Pictures	4	2	10	25%	12%	63%
3D	3	7	6	19%	44%	37%
3D prints	9	5	2	56%	31%	13%

Table 14. Proportion of students mentioning *shape*, once or more than once or, conversely, words regarding material are absent.

Shape: Students						
Scenario	**Response**			**Percentage**		
	Present	Present >1	Absent	Present	Present >1	Absent
Touch	5	3	8	31%	19%	50%
Look	5	1	10	31%	6%	63%
Pictures	4	1	11	25%	6%	69%
3D	7	3	6	44%	19%	37%
3D prints	3	7	6	19%	44%	37%

An in-depth analysis of speech provides insight into specific word choice used to describe the shape and other decorative elements that characterize each object. When the shape of an object is difficult to describe, participants usually used analogies to give an immediate and strong visual representation of the object. As shown in the following table, analogies were especially used to describe the complex shape of the Buddhist ritual object (table 15), but they are also used for the projectile point, which was commonly associated with the shape of a fish.

Table 15. Analogies used to describe the shape of the Buddhist ritual object.

		***Looks like*, *resembles*, and *seems like*:**	
	Horse-shoe shape (#13, *3D*, stud.)		When you cut up a papaya open (#16, *3D*, stud.)

	Lotus blossom (#25, *Pictures*, arch.)		Cupped hand (#27, *Look*, arch.)
	Light bulb (#28, *Look*, arch.)		Teardrop shape (#28, *Look*, arch.)
	Spoon shape or ladle (#18, *3D prints*, stud.; #29, *Touch*, arch.)		Paddle shape (#32, *Touch*, arch.; #36, *3D*, arch.)
	Leaf (#18, *3D prints*, stud.)		Ear-like appendage (#40, *3D prints*, arch.)
	Petal-like appendage (#49, *3D prints*, stud.)		

The Buddhist object is composed of a distal concave part, defined by two grooves, and a proximal handle. Some participants tried to describe each part of this object using sentences containing motion verbs (i.e., sentences involving an implicit type of motion) also called *fictive motion* (FM), to describe the grooves, even though the grooves are unmovable attributes. As shown below, these fictive motion phrases are usually associated with gestures. Teenie Matlock (2006; 2004a; 2004b) has demonstrated through a series of experiments that FM phrases involve mentally simulated motions. In case of the current research, it could be that participants mentally reconstructed the linear representation of the grooves by beginning at one point, continuing to the next point and incrementally on to the next points, and eventually stopping. An in-depth analysis of FM phrases is outside the scope of this research. For the aim of this work, it will suffice to notice that FM phrases used to describe the shape of the Buddhist object can be divided in two categories:

1. In the first category participants described the grooves, emphasizing their shape in a plan view. The FM phrase was usually accompanied by a circular motion of the hand describing the shape of the grooves as one would see them in a plan (i.e., horizontal) view. Examples include:
   "…have some concentric circles going around here…" (#23, *Pictures*, archaeologist);
   "…it appears to have um some semi-circular markings that go in grooves…" (#10, *Touch*, student);
   "…the shape of the very first groove is rounded on one end …/ and the other grooves kind of follow it…" (#32, *Touch*, archaeologist).

2. In the second category of responses described the grooves by focusing on the depth of the object (i.e., profile or section view). In this case, a motion of the hand visually describing the depth of the grooves usually accompanied the FM phrase. Examples include:"…it seems to have three levels of um a of cowling uh going up going from an inner ring to an outer ring…" (#21, *Pictures*, archaeologist);
   "…moves in uh in its concavity uh from the outer edges towards the center …"(#35, *3D*, archaeologist).

It is interesting to note that while participants in the *Touch*, *Pictures*, *Look* and *3D prints* scenarios use both kinds of FM phrases, participants in the *3D* scenario exclusively used the second category. This finding may suggest that they were more focused on the third dimension (*z*) when looking at the objects, but this will require further analysis.

FM phrases were used also in describing the shape of the projectile point. For example: "It goes from it's a triangular shape with sharp points and then goes in to a little handle part which was probably tied to a stick" (19, student, *3D prints*). Moreover FM phrases were frequently used to describe two decorative lines incised on the body of the ceramic vessel. For example:

- "…there's a little indention lines going through here…" (#1, *Pictures*, student);
- "…and some markings around the outer surface in a horizontal that goes clearly all the way across…/ The lines across that are horizontal on the on thee image right here of which there's one two three four are not uniform and they were crudely done" (#10, *Touch*, student);
- "…this incisions incised lines following the Following the line of the round line of the pot…" (#29, *Touch*, archaeologist).

The qualitative analysis helps clarify the importance of 3D multi-visualization for the analysis of digital replicas of artifacts. More than one participant stressed the importance of geometries with no colors applied to better understand the shape of the object. The following example shows how a student coped with the difficulty describing the shape of the Buddhist object: "If you look at the the topography [i.e., *mesh*] of it you can see that there is, in fact, some type of horseshoe-sized indent um" (#13, student, interacting with the 3D digital copy of the Buddhist object). Archaeologists gave similar answers:

> Um looking at just the visual or the uh the optical uh image of it uh here on the screen/ It actually to me looked quite flat um/ but if we take away uh the optical scan you can see that it's actually um got quite a concave uh surface on the front side of the object and I'll show you that now/ As you can see from that earlier obser[ved?] underlying scan without the color data/ Um it's concave uh and it sort of moves in uh in its concavity uh from the outer edges towards the center [#35, interacting with the 3D copy of the Buddhist object].

It is important to mention, however, that both archaeologists and students usually started noticing the importance of mesh and geometries for the analysis of the artifacts with the Buddhist object or projectile point, which are, in sequence, the second and third objects displayed on the screen (see Chapter 4). This finding suggests that participants needed some time to acquire familiarity with the 3D software and understand how certain commands could facilitate their experience with the 3D objects. As a consequence, some archeologists and students found it difficult to define the shape of the pot, since—as stated by an archaeologist—the 3D replica with colors applied gave the impression that it was a solid object and, thus, made it difficult for participants to apprehend the hollow interior: "I would say that I can't see very well into the object and so it almost looks as though um from the the reconstruction it's as though it's solid um so it's hard to get a sense of um how it functioned as a as a container um" (#36, archaeologist).

While archaeologists had the professional experience and the background knowledge to overcome this challenge and recognize the exact shape and function of the pot, students found this challenging and/or misleading. This led students to the wrong interpretation of shape, function, and even material:

> The structure of this uh/ Of this thing would be made up of some type of metal/ Um as you can see/ Um as I infer that this darker spot here um inside of the sphere/… It, I was originally thought like a grenade or something like that/… So I would have to say maybe uh uh a very primitive form of a grenade/ That um will go off when you throw it um with the gun powder in it/ Um that seems to be the only likely way of forming these outside bumps/ on the outside of this sphere um/ And it must have exploded the top, letting out most of the explosion/ Um yet still having some on the sides though the little bumps here um/ It would have to have been blown out from the top and a little on the sides [#15]

<u>Size:</u>

Unlike the other innate qualities, responses for the analysis of *size*, were categorized into three types: *word present*, *given info present*, *word absent*. This distinction was aimed at highlighting all the cases in which participants provided information on the size of the object that was in addition to the information in the object caption (i.e., *it is the size of a melon, a potato, a key, a hand*). In other words, I wanted to see how people spontaneously described the size of the artifact and if there were differences in how they talked about size across the media scenarios.

Archaeologists tended to mention *size* most often in the *Touch*, *Look* and *3D* scenarios (table 16). Conversely, students mentioned object *size* in less frequently (table 17). In the *Touch* scenario, students talked about size without repeating the given information; in the other scenarios, a few participants added extra information.

Table 16. Proportion of archaeologists talking about *size* (*word present*, *given info present*) and times words on *size* are absent.

Size: Archaeologists						
Scenario	**Response**			**Percentage**		
	Word present	Given info present	Word absent	Word present	Given info present	Word absent
Touch	12	2	2	75%	12.5%	12.5%
Look	10	3	3	62%	19%	19%
Pictures	8	5	3	50%	31%	19%
3D	14	2	0	87%	13%	0%
3D prints	6	4	6	37%	25%	38%

Table 17. Proportion of students talking about *size* (*word present*, *given info present*) and times words on *size* are absent.

Size: Students						
Scenario	**Response**			**Percentage**		
	Word present	Given info present	Word absent	Word present	Given info present	Word absent
Touch	8	0	8	50%	0%	50%
Look	3	2	11	19%	12%	69%
Pictures	2	6	8	12%	38%	50%
3D	2	2	12	12%	13%	75%
3D prints	3	4	9	19%	25%	56%

Further analysis of size data was undertaken to better understand what kind of extra information participants provided regarding object size. The intent was to understand why and how archaeologists focused on size more in the *3D* scenarios than in all of the other scenarios. Remarkably, while archaeologists in the *Touch* and *Look* scenarios tried to measure the artifact and did provide metrical information, archaeologists in the *Pictures* and *3D* scenarios used gestures to simulate the dimension of the artifact (table 18). It appears these gestures were not only meant to provide a visual representation of the size to the camera (virtual audience), but especially to mentally visualize—and hence, to understand—the exact size of each object. Other ways to describe object size included general adjectives such as "big" or "small." These common descriptive terms were sometimes associated with gestures. In addition, in the *3D print* scenario, archaeologists mainly used general adjectives or given information; this finding is further clarified with a more qualitative analysis of the texts (below). Similar patterns were also found when comparing archaeologists to students, with only one difference: students also tended to use gestures in the *Look* scenario (table 19).

Table 18. How archaeologists talk about the size of an object.

How do archaeologists talk about size?								
Scenario	**Response**				**Percentage**			
	Mentioned				Mentioned			
	Given info	Adjective	Measure	Gesture	Given info	Adjective	Measure	Gesture
Touch	2	6	7	0	13%	40%	47%	0%
Look	3	4	9	0	19%	25%	56%	0%
Pictures	5	1	0	6	42%	8%	0%	50%
3D	2	4	3	12	10%	19%	14%	57%
3D prints	4	9	0	0	31%	69%	0%	0%

Table 19. How students talk about the size of an object.

How do students talk about size?								
Scenario	**Response**				**Percentage**			
	Mentioned				Mentioned			
	Given info	Adj	Measures	Gestures	Given info	Adj.	Measures	Gestures
Touch	0	4	4	0	0%	50%	50%	0%

Look	2	2	0	1	40%	40%	0%	20%
Pictures	6	0	0	3	67%	0%	0%	33%
3D	2	1	0	1	50%	25%	0%	25%
3D prints	4	3	0	0	57%	43%	0%	0%

The qualitative analysis helped to clarify how people perceive size in absence of the original artifact. For instance, some participants in the *3D* scenario thought that some objects seemed bigger when viewed on the computer screen: "Um and uh the object is I guess in some ways it th the um the reproduction makes it somehow seem bigger than it is but, in fact, it's we're told it's the size of a hand/ Um so uh I have to keep re-imagining it to be a little smaller than it actually is" (#36, talking about the 3D replica of the Buddhist object).

A similar observation was made by a student participant in the *Pictures* scenario: "it's about of the size of a hand so um maybe the size of mine but I think the picture got stretched out" (#1, student, talking about the Buddhist object).

As noted before, some archaeologists were skeptical of 3D prints and thought 3D printers were unable to reproduce objects at an accurate scale. For instance, while describing the projectile point, one archaeologist stated: "Um the this model seems to be rather deficient in that regard and again it seems to be scaled" (#40).

<u>Weight:</u>

Just a few observations can be made with regard to weight; neither archaeologists (table 20) nor students (table 21) routinely included this characteristic in their descriptions. In fact, just a few participants, mainly in the *Touch* scenario, provided some interesting observations regarding density and weight.

Table 20. Proportion of archaeologists mentioning *weight*, once or more than once or, conversely, words regarding material are absent.

Weight: Archaeologists						
Scenario	**Response**			**Percentage**		
	Present	Present >1	Absent	Present	Present >1	Absent
Touch	0	2	14	0%	12%	88%

Look	1	0	15	6%	0%	94%
Pictures	0	0	16	0%	0%	100%
3D	0	0	16	0%	0%	100%
3D prints	0	1	15	0%	6%	94%

Table 21. Percentage of times students mentioning *weight*, once or more than once or, conversely, words regarding material are absent.

Weight: Students						
Scenario	**Response**			**Percentage**		
	Present	Present >1	Absent	Present	Present >1	Absent
Touch	4	2	10	25%	12%	63%
Look	0	0	16	0%	0%	100%
Pictures	0	0	16	0%	0%	100%
3D	0	0	16	0%	0%	100%
3D prints	0	0	16	0%	0%	100%

With regard to weight information, the pattern was similar to that observed for object size; that is, in the *Touch* scenario, a few participants tried to guess the exact weight of the object. Moreover, some participants were surprised by the relative lightness of the Buddhist object, which, visually, seems heavier. Upon lifting the Buddhist object, and observing how light it was, an archaeologist shifted it it from on one hand to the other lifted the ceramic vessel in her free hand to compare the weights of the two objects, and then exclaimed: "Ok here we have this object very light, its um definitely made of wood" (# 29). Some participants in the *Pictures*, *3D*, and *Look* scenarios who were given the chance to touch the original artifact after the experiment were surprised by the relative lightness of this object and pointed out how they thought it would be heavier.

Regarding the weight of the 3D prints, it is important to note that the powder used in Z-Corp printers has a specific weight; therefore, the printer is incapable of reproducing the exact weight of the original artifact. Nonetheless, in the case of the pot, grinding stone, and projectile point, the weight of the 3D print was, by chance, very similar to the that of original. In contrast, the 3D print of the Buddhist object is much heavier than the original wooden object, and this likely caused misinterpretation of the material of the real-life artifact.

In fact, all participants, thought that the Buddhist object could be made of stone or ceramic, based not only on the color, but also, perhaps, because of the inaccurate weight reproduction. In addition, one archaeologist who had familiarity with 3D prints made using Uprint technology (see Chapter 3), which are considerably lighter than Zcorp prints, thought that the 3D printer was capable of reproducing the weight of the original artifact: "So it's my belief now it looks like the modeling material is the same between these/ thus it may not be possible to um use weight as an issue/ compared to 3D models I've seen before/ um these are heavier/ and uh look like they at some level are trying to uh get at the weight of the original" (#40). Fortunately, this observation did not completely guide his interpretation of the Buddhist object, since he was able to discern the material (wood) given the texture and color variation reproduction of the printer: "…this one looks much more like wood and the surface overall surface modeling with its faceted or uh cut-mark like surface/ cut plains like surface/ gives uh more of a suggestion of wood".

Figs 34 and 35 show the distribution of words (i.e., the percentage of words present once or more than once) used to describe *innate qualities* and *function* of the artifacts. Data in Table 20 indicate that archaeologists evenly talk about function and all physical characteristics considered in this study with the exception of weight, which is present only in the *Touch*, *Look,* and *3D prints* scenarios. The only major differences were visible in the *Pictures* scenario, wherein the participants seemed more focused on *function* than on *innate qualities*; in the *3D* scenario, in which the texture was mentioned more often than in the other scenarios; and in the *3D prints*, wherein participants seemed to focus more on shape at the expense of size.

This portrait changes for student participants. In this case, while students in the *Touch* scenario seemed to focus evenly on all categories considered, the same did not happen in all other categories. In the *Look* scenario, for example, there was a major focus on shape. Students in the Pictures scenario focused instead more on *function* (53%) and then *shape* and *color* in equal measure (18 %). Similarly, in the *3D* scenario, the highest percentage of words related to *function*, followed by *shape* and then *texture*. Finally, *shape* words were more common in the 3D prints, followed by words related to *texture* and *function* (17% each), and lastly words related to *color* and *size* (12% each). In summary, these data suggest that media affected how people described artifacts, enhancing some characteristics of the objects more than others. However, since archaeologists are trained at describing artifacts and usually classify them based on specific physical caracteristics, they seem less affected by media than students.

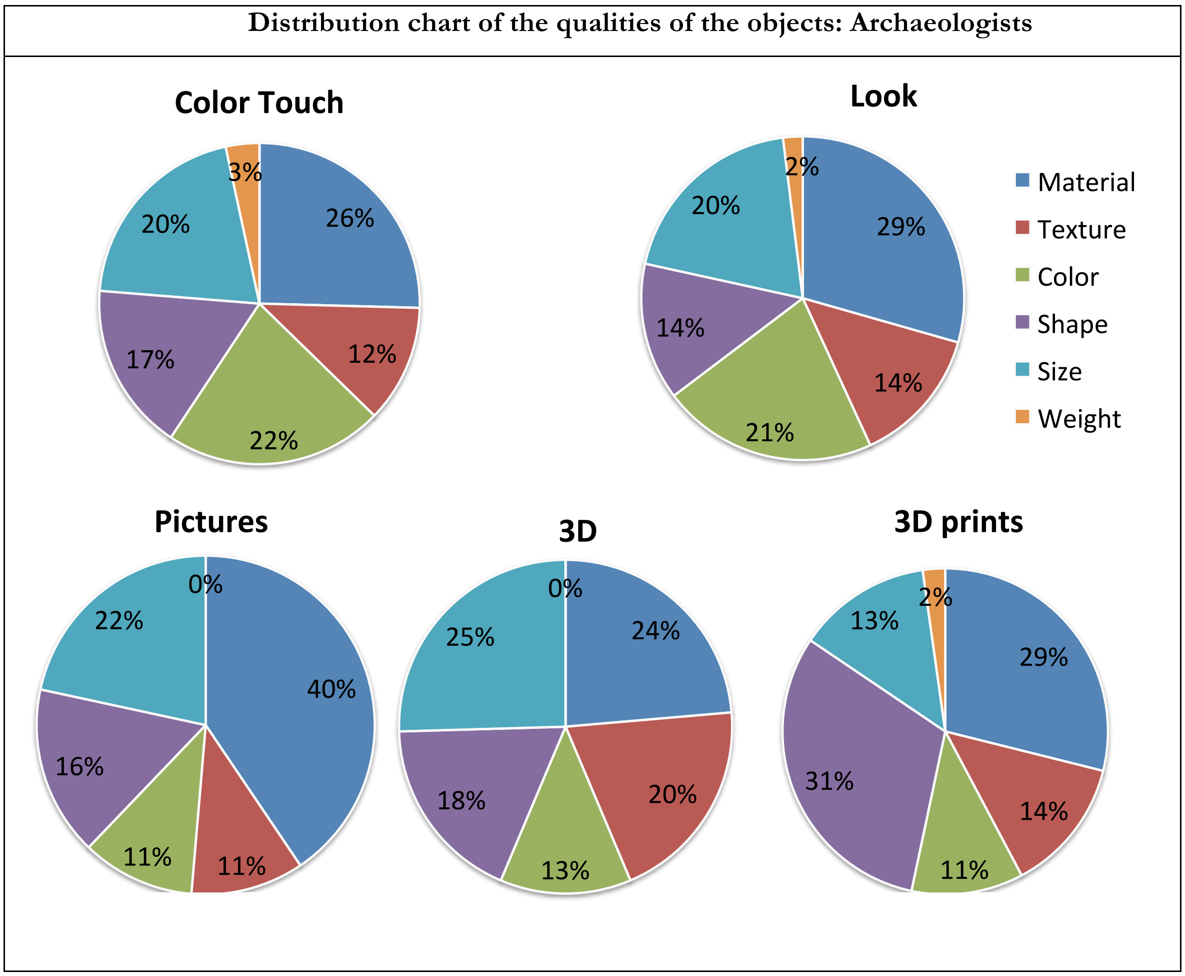


Figure 34. Distribution chart showing the percentage of words used by archaeologists to describe innate qualities of the artifacts in the various scenarios.

Distribution chart of the qualities of the objects: Students

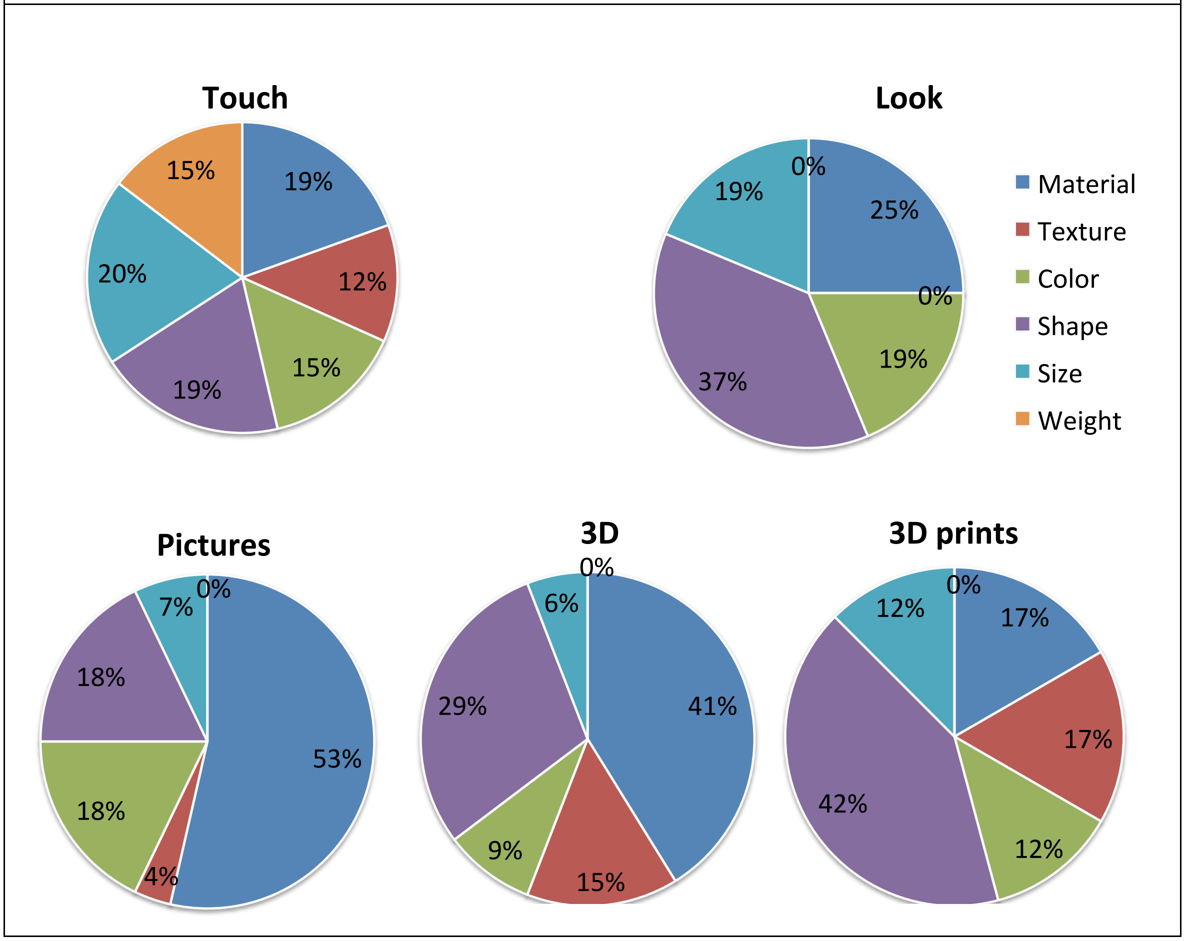


Figure 35. Distribution chart showing the percentage of words used by students to describe innate qualities of the artifacts in the various scenarios.

5.3.3. Modals, mental phrases, and hedges: expressing uncertainty when describing artifacts

The number of words used to describe physical qualities of the objects and the number of verbal expressions of uncertainty used while talking were also compared (table 22). To quantify the level of uncertainty expressed while describing artifacts, three specific categories of words were identified: modal auxiliaries, mental phrases, and hedges.

Modality is a part of language used to express uncertainty. English has a rich set of modal auxiliaries, such as *could*, *might*, *may*, *should*, and *would*. Participants used these modal verbs to express their level of uncertainty while describing artifacts. Mental phrases, such as *I think* and *I believe* are another kind of verbal expression of doubt, and are often associated with hedges. Brown and Levinson (1987: 145) define a hedge as "a particle, word or phrase that modifies the degree of membership of a predicate or a noun phrase in a set; it says of that membership that it is partial or true only in certain respects, or that it is more true and complete than perhaps might be expected". This definition, supported by other scholars such as Lakoff (1972: 195), defines hedges as both detensifiers and intensifiers; however, many users of the term limit hedges only to expressions that show a level of uncertainty in one's use of certain words. In this sense, a hedge is an adjective, adverb, or clause used to mitigate the impact of a word. For instance, while defining the function of an artifact, a participant might say: "This would be used to store liquids, but I am not sure". "I am not sure" is a hedge that expresses a particular level of uncertainty while a person is talking about the function of an artifact. For the experiment described herein i was only interested in detensifier hedges.

Tag questions such as *I think it's…, isn't it?* are also frequently used by people when expressing uncertainty (Bradley 1981), but questions like these were not used by participants in this experiment. This could be because participants were left alone in a room and did not have any real audience.

For the purpose of this study, I was not only interested in the number of expressions of doubt used by participants, but also when they used such expressions. Did a participant express uncertainty while talking about the material/shape/function/etc. of an object? And if so, which scenario produced the greatest number of expressions of doubt?

Table 22. Verbal expressions of doubt used while talking about artifacts.

Verbal expressions of doubt used while describing artifacts
Modal Auxiliaries
Could
Would
Might
May

Should
Mental Phrases
I imagine, could imagine, can imagine;
I guess, can't guess, I am not going to guess, I am not guessing;
I wonder, makes me wonder;
I suggest, would suggest, suggests;
I would say;
I assume, would assume, am assuming;
Hedges:
Maybe, perhaps, possibly, probably;
hard/ difficult to know; hard/difficult to tell, say, describe;
I am not sure;
looks/seems like, looks as, looks; appears to be

For this analysis, the total number of expressions of doubt used by archaeologists and students were examined, and no significant difference was detected between the two groups (Archaeologists *M*=12.24, Students *M*=8.17), with *t*(38)=1.53, p =<.18. This finding indicates that archaeologists and students showed a similar level of uncertainty while describing ancient artifacts.

Table 23 shows the percentage of expressions of doubt in the total number of words for each scenario. For archaeologists, this percentage ranged from 15.19% to 18.83% of total words, with participants in the *Look* and *Pictures* scenarios having the highest percentage of expressions of uncertainty.

Table 23. Percentage of expressions of doubt in the total amount of words produced by archaeologists and students for each scenario.

Total words (average) used to express uncertainty				
Scenario	**Total expressions of doubt (mean)**		**Percentage of expressions of doubts in Total words**	
	Archaeologists	Students	Archaeologists	Students
Touch	10.25	9.06	15.19%	21.9%
Look	10.87	2.19	18.16%	11.25%

Pictures	7.31	6.81	18.83%	21.9%
3D	13.06	11.87	15.62%	24.23%
3D prints	10.87	7.37	14.61%	23.2%

The percentage of expressions of uncertainty used by students varied from 11.25% to 24.23% of total words, with students in the *Look* scenario using the fewest modals, mental phrases, and hedges (proportion to the total number of words; 11.25%) and students in the *3D* using the largest percentage 24.23%.

Comparison of all ratios of the mean number of expressions of doubt to the total mean number of words revealed no significant difference between the categories with regard to archaeologists (table 24).

Table 24. T-test showing no significant difference between archaeologists in the various scenarios.

Scenarios	Results of t-test
Pictures vs Look	*Pictures* (*M* = 0.048, *SD* = 0.011), *Look* (*M* = 0.042, *SD* = 0.005) *t(8)* = 7.24, p =<.07
Pictures vs Touch	*Pictures* (*M* = 0.048, *SD* = 0.011), *Touch* (*M* = 0.044, *SD* = 0.018) *t*(8) =1.76, p =<.33
Pictures vs 3D	*Pictures* (*M* = 0.048, *SD* = 0.011), *3D* (*M* = 0.035, *SD* = 0.012) *t*(8) = 1.11, p =<.47
Pictures vs 3D prints	*Pictures* (*M* = 0.048, *SD* = 0.011), *3D prints* (*M* = 0.033, *SD* = 0.006) *t(8)* = 3.2, p =<.18
3D vs Touch	*3D* (*M* = 0.035, *SD* = 0.012), *Touch* (*M* = 0.044, *SD* = 0.018), *t(8)* = 1.95, p =<.3
3D vs Look	*3D* (*M* = 0.035, *SD* = 0.012), *Look* (*M* = 0.042, *SD* = 0.005), *t(8)* = 6.53, p =<.08
3D vs 3D prints	*3D* (*M* = 0.035, *SD* = 0.012), *3D prints* (*M* = 0.033, *SD* = 0.006) *t(8)* =2.88, p =<.2
Look vs Touch	*Look* (*M* = 0.042, *SD* = 0.005), *Touch* (*M* = 0.044, *SD* = 0.018) *t(8)* =7.88, p =<.06

Look vs 3D prints	*Look* (*M* = 0.042, *SD* = 0.005), *3D prints* (*M* = 0.033, *SD* = 0.006) *t(8)* =2.27, p =<.26
Touch vs 3D prints	*Touch* (*M* = 0.044, *SD* = 0.018), *3D prints* (*M* = 0.033, *SD* = 0.006) *t(8)* =5.63, p =<.09

Similarly, statistical analysis comparing the ratio of expressions of doubts produced by students in the five scenarios revealed no significant differences between the groups (table 25).

Table. 25. T-test showing no significant difference between students in the 3D scenario and those in the other scenarios.

Scenarios	**Results of t-test**
3D vs Pictures	*3D* (*M* = 0.059, *SD* = 0.012), *Pictures* (*M* = 0.05, *SD* = 0.014) *t(8)* = 1, p = <.5
3D vs Look	*3D* (*M* = 0.059, *SD* = 0.012), *Look* (*M* = 0.053, *SD* = 0.028) *t(8)* = 5.59, p = <.09
3D vs Touch	*3D* (*M* = 0.059, *SD* = 0.012), *Touch* (*M* = 0.053, *SD* = 0.026) *t(8)* = 4.67, p = <.1
3D vs 3D prints	*3D* (*M* = 0.059, *SD* = 0.012), *3D prints* (*M* = 0.059, *SD* = 0.012) *t(8)* = 1, p =<.5
Look vs Pictures	*Look* (*M* = 0.053, *SD* = 0.028), *Pictures* (*M* = 0.05, *SD* = 0.014) *t(8)* = 5.58, p =<.09
Look vs Touch	*Look* (*M* = 0.053, *SD* = 0.028), *Touch* (*M* = 0.053, *SD* = 0.026) *t(8)* = 1.2, p =<.44
Look vs 3D prints	*Look* (*M* = 0.053, *SD* = 0.028), *3D prints* (*M* = 0.059, *SD* = 0.012) *t(8)* = 5.6, p =<.09
Touch vs Pictures	*Touch* (*M* = 0.053, *SD* = 0.026), *Pictures* (*M* = 0.05, *SD* = 0.014) *t(8)* = 4.67, p = <.1
Touch vs 3D prints	*Touch* (*M* = 0.053, *SD* = 0.026), *3D prints* (*M* = 0.059, *SD* = 0.012) *t(8)* = 4.68, p =<.1
Pictures vs 3D prints	*Pictures* (*M* = 0.05, *SD* = 0.014), *3D prints* (*M* = 0.059, *SD* = 0.012) *t(8)* = 1, p =<.5

These findings suggest that the media used to visualize the artifacts do not affect the use of expressions of doubts, at least from a quantitative perspective. As evident in the following qualitative analysis, however, the way these expressions of doubts were used seemed to vary in each scenario (figs. 36, 37).

Examination of all available interviews to see when participants used expressions of doubts revealed that archaeologists use modal auxiliaries, mental phrases, and hedges to elaborate on the function of the artifacts, regardless of the given media scenario. This finding is not a surprise since, as previously stated, determining the function of an object is an interpretative process that inevitably produces doubt, especially when the object is presented out of context. Comparison of each scenario showed some differences: archaeologists in the *Pictures* scenario use the highest percentage of verbal expressions of doubt when talking about function than the other scenarios.

Verbal expressions of doubt were also used when elaborating on the techniques and technologies of the manufacturing process. For instance, a few participants focused on the knapping technique used to make the projectile point or tried to find physical clues such as ridges inside the hollow interior of the pot that could help them to understand if the pot was made using a wheel. Archaeologists in the *Touch* scenario used a much higher percentage of verbal expressions of doubt than the other participants.

In addition, modal auxiliaries, mental phrases, and hedges were used to describe physical characteristics of the objects, with differences between the media used.

With regard to material, archaeologists in the *Pictures*, *Look*, and *3D scenarios* showed a similar percentage of uncertainty, which ranged from 11.1% and 13.9%. The percentage of verbal expressions of doubt used by *3D prints* and *Touch* participants differed considerably from *Pictures*, *Look* and *3D* (*3D prints*: 22%; *Touch*: 5.5%). With respect to the prints, this finding reinforces the idea that the powder used for the 3D prints makes it difficult even for professionals to describe the original material of the artifact. Participants in the *Touch* scenario seemed more confident about the material of the artifact and utilized verbal expressions of doubt only when guessing the specific type of material used to make the object. For instance, when describing the projectile point, a few archaeologists defined this as a lithic object and then outlined the variety of raw material (e.g., churt, cryptocrystalline rock, etc.).

With regard to texture, the percentage of verbal expressions of doubt was quite low in all categories, although the *3D* and *3D print* scenarios had slightly higher percentages that the other scenarios. When compared to previously observations about the number of times participants mentioned the texture of the artifacts), this finding suggests that the number of expressions of doubt used by *3D* participants was directly proportional to their level of interest in *texture*, or even more to the point, it seems directly proportional to the capacity of the 3D medium to afford the quality of *texture* even with a level of uncertainty. The quality of texture seemed also well afforded in the *3D prints* scenario, which involved the sense of touch. Nonetheless, as noted above with respect to innate qualities, archaeologists were skeptical of this media and questioned the level of accuracy of the copy. This skepticism was mirrored by the use of verbal expressions of doubt.

Modals, mental phrases, and hedges were minimally used to talk about size with qualitative differences. While in the *Touch* and *Look* scenario, verbal expressions of doubts were utilized in the cases in which participants postulated measures in centimeters for the objects, in the *Pictures* and *3D* scenarios these expressions showed participants' uncertainty about the approximate size of the objects. Verbal expressions of doubt for size were almost absent (i.e., just one modal auxiliary) in the *3D prints* scenario, but this finding reflects the lack of observations made of this quality.

With regard to *shape,* the level of uncertainty was somewhat similar in all scenarios—ranging from 3.5% to 7.5%—with the *Pictures* scenario having the lowest percentage and the *3D prints* the highest. As previously explained, the level of uncertainty was often linked with the difficulties encountered in describing the Buddhist ritual object, but varied slightly with different scenarios. For instance, archaeologists in the *3D* scenario found it difficult to discern the hollowness of the pot, and similarly, archaeologists in the *3D prints* scenario criticized the reproduction of the interior part of the pot, which was considered somewhat inaccurate and artificial (i.e., a fake).

Verbal expressions of doubt were nearly absent when considering the category of *weight*. This finding mirrors the result reported in Chapter 5.1.2, since *weight* was almost never mentioned by participants in this experiment. Only a few archaeologists in the *Touch* scenario, who had a tactile experience with original artifact, considered *weight* and simulated the act of weighing the artifact in his/her hand and then hypothesized the actual weight of the object using either a modal auxiliary, mental phrase, or hedge.

Examination of the verbal expressions of doubt used when talking about *color*, revleaed that the *Touch* and *3D prints* scenarios showed similar percentages, which are higher than the percentage in the other scenarios. A qualitative analysis shows that while these expressions were used in the *Touch* scenario when describing specific details of color variation (e.g., details that would require the use of a microscope, as expressed by some professionals), archaeologists in the *3D prints* scenario used these expressions when trying to discern the general color pattern of an object. In other words, even if participants in the *Touch* and *3D prints* scenarios produced the same number of expressions of doubt, the level of uncertainty in discerning the color of an object was higher in the *3D prints* scenario.

Finally, some discussion of the descriptor *other* is warranted. This descriptor groups a variety of expressions of doubt used to talk about details that were not specifically related to the description of the object or its function. For instance, *other* includes all the times an archaeologist expressed an idea regarding the original or depositional context of the artifact or tried to remember some information previously read in the caption (these were the majority). *Other* also included all auxiliaries, mental phrases, and hedges used by archaeologists to express their doubts about the medium they were utilizing; this mainly happened for *3D* and *3D prints*.

Fig. 37 shows a quite different trend for students. Students used the highest percentage of expressions of uncertainty (between approximately 50 and 80%) when talking about function. Thereafter, in all scenarios the highest percentage of modal auxiliaries, mental phrases, and hedges were used for the category *other*. The *Touch* scenario presented a homogeneous distribution percentage of expressions of uncertainty about all other categories, with a higher percentage with respect to the size. Conversely, the *Look* scenario had only expressions of uncertainty for *material*, and the *Pictures* scenario only had such expressions for *material*, *shape*, and *size*. Participants in the 3D scenario used expressions of uncertainty to describe texture, material, manufacturing, shape, size, and color, but *material* and *shape* had slightly higher percentages than the other characteristics. Similarly, *3D* participants used expressions of uncertainty while talking about *manufacturing*, *size*, *shape*, *material*, and *texture*, with higher percentages of doubt for *size* and *shape*.

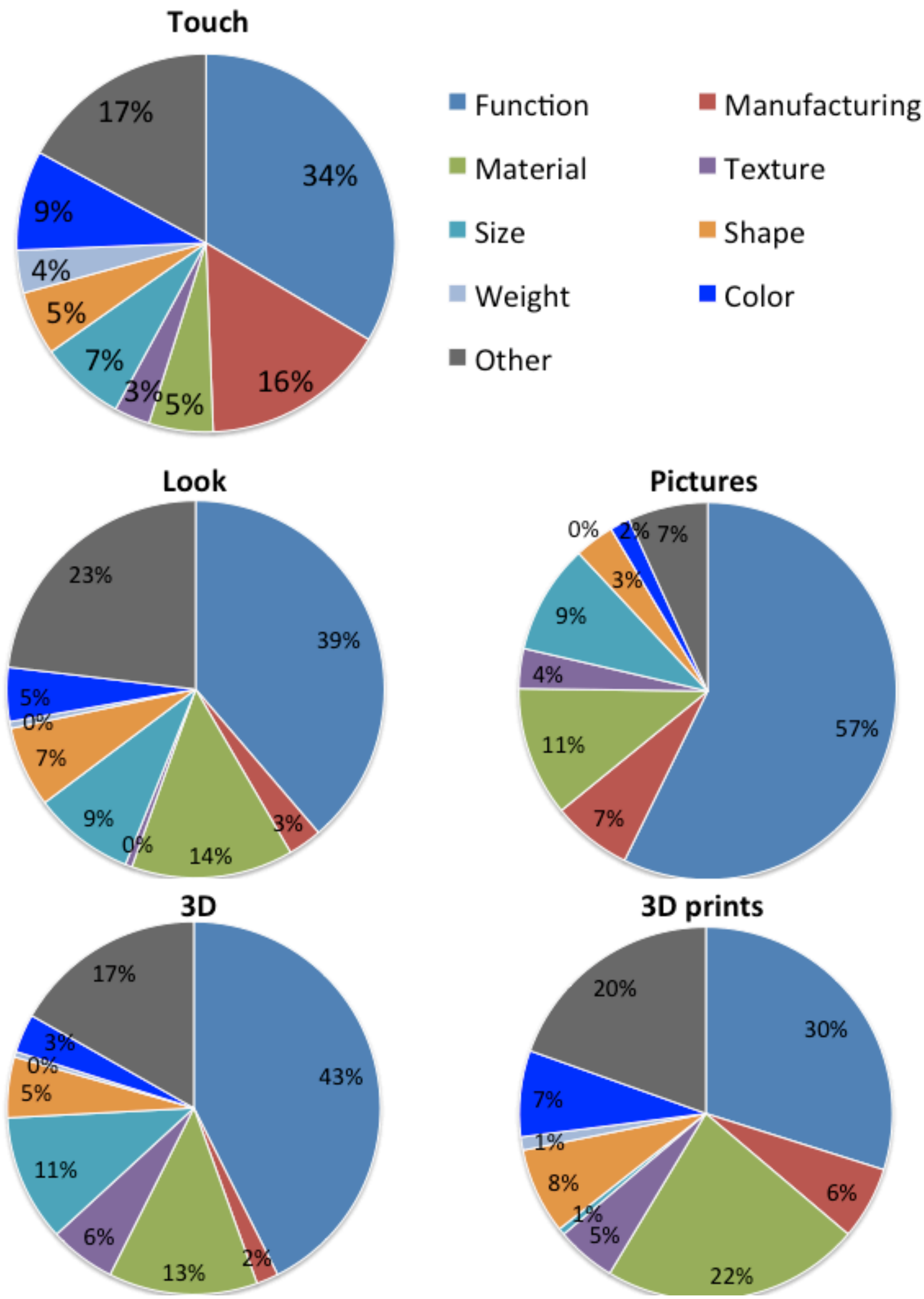


Figure 36. Percentage of expressions of doubt utilized by archaeologists to describe physical characteristics of the objects.

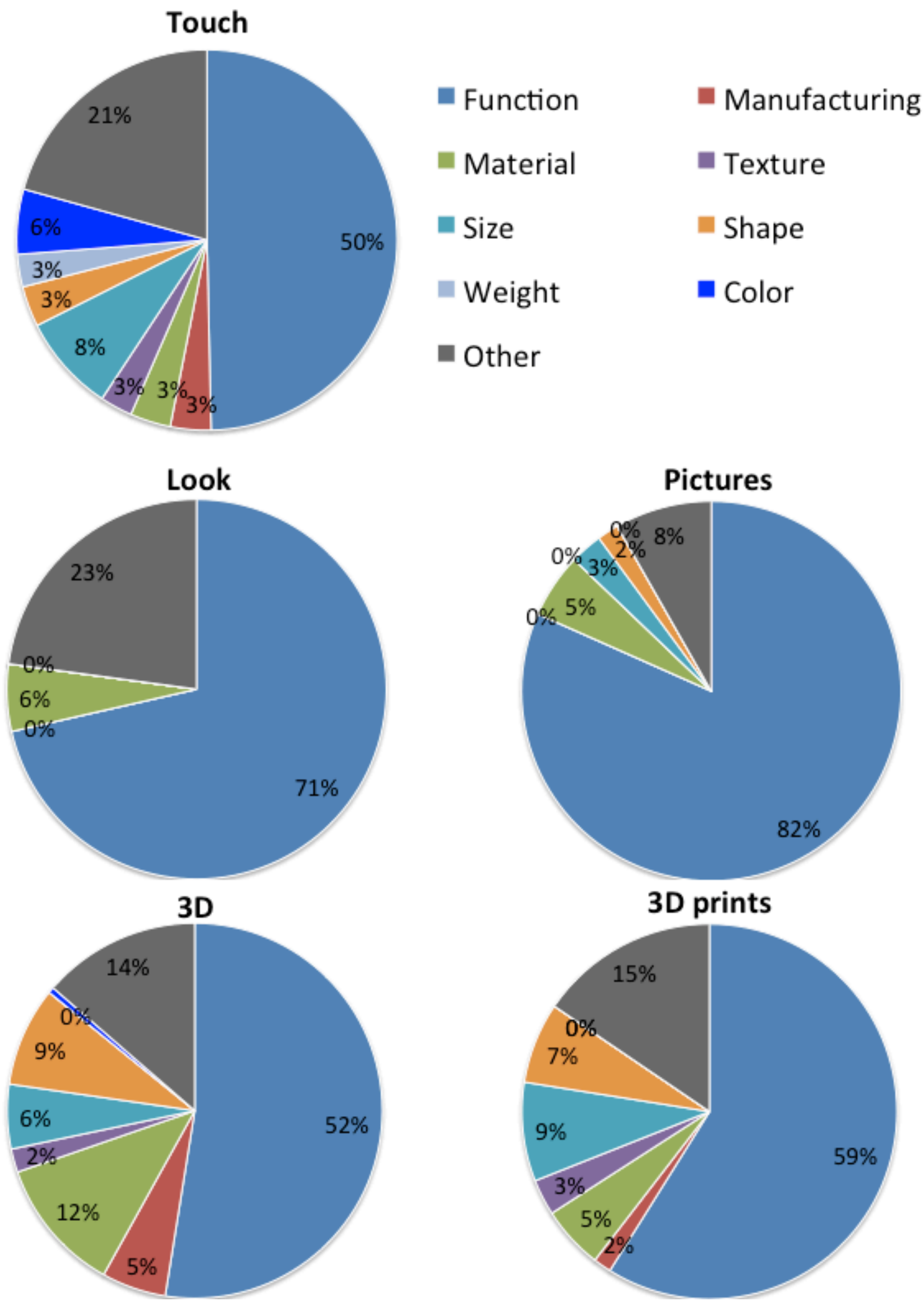


Figure 37. Percentage of expressions of doubt utilized by students to describe physical characteristics of the objects.

In conclusion, the *Pictures* and *Look* scenarios had the fewest expressions of uncertainty when describing physical characteristics of the object. What do these findings tell us? Perhaps the students in the *Look* and *Pictures* scenarios were more confident when describing objects than all other students. If we compare these data with what was previously observed with regard to the number of words used to describe objects and how many times students described the innate qualities of an artifact, cross-comparisons suggest a different explanation. That is, the small number of expressions of uncertainty corresponds to a low level of concern or engagement with an artifact, at least for which concerns their describing their specific physical characteristics.

5.4. Analysis of gestures. How beat and iconic gestures facilitate the experience with ancient artifacts.

As described in Chapter 4, scholars studying gesture still debate the definition of gestures (see Goodwin 2003: 229-330), but often make a distinction between beat gestures and iconic gestures. Beat gestures are brief, rhythmic hand movements that facilitate lexical access (see Krauss 1998) without conveying any particular semantic information. For instance, when describing an artifact a participant might try to recall information read in a book and, while struggling to recall it, produce a quick gesture (e.g., shaking one hand) to help her remember.

In contrast, iconic co-speech gestures are spontaneous body movements produced in coordination with speaking that do convey visual-spatial information about the topic of discourse (McNeill 2007). For instance, while describing the function of the grinding stone, one might say: "It was used to grind something like corn," and while speaking, make a gesture depicting the action of grinding corn with the stone.

Analysis for the current study compared archaeologists and students to see how many times they used both beat and iconic gestures. This included an in-depth qualitative analysis of the iconic gestures to see in which specific part of the discourse they were used.

No significant difference was found between archaeologists and students in the mean number of beat gestures used by these two groups (Archaeologists M = 6.1, SD = 9.47; Students M = 6.43, SD = 13.57), with $t(38)=2.05$, p =<.06. The difference was significant, however, when the mean number of iconic gestures was examined (Archaeologists *M* = 4.5, *SD* = 4.61; Students *M* = 2.18, *SD* = 2.93), with *t*(38)=2.48, p =<.03. The data showed that while students used fewer iconic gestures than archaeologists, they used a higher—although not significantly higher—number of beat gestures, which seems to suggest that the difficulty experienced while describing an artifact was eased by using beat gestures as facilitators for lexical access.

Examination of the mean number of total gestures (i.e., both beat and iconic gestures; see fig. 38) used in the different scenarios revealed that both archaeologists and students in the *Look* scenario used the fewest gestures (*M* = 27.65, *SD* = 1.28), while participants in the *3D* scenario used the largest number of gestures (*M* = 2.12, *SD* = 23.03), with a significant difference between *look* and *3D* scenarios, with *t*(8) = 323.19, p =<.0001.

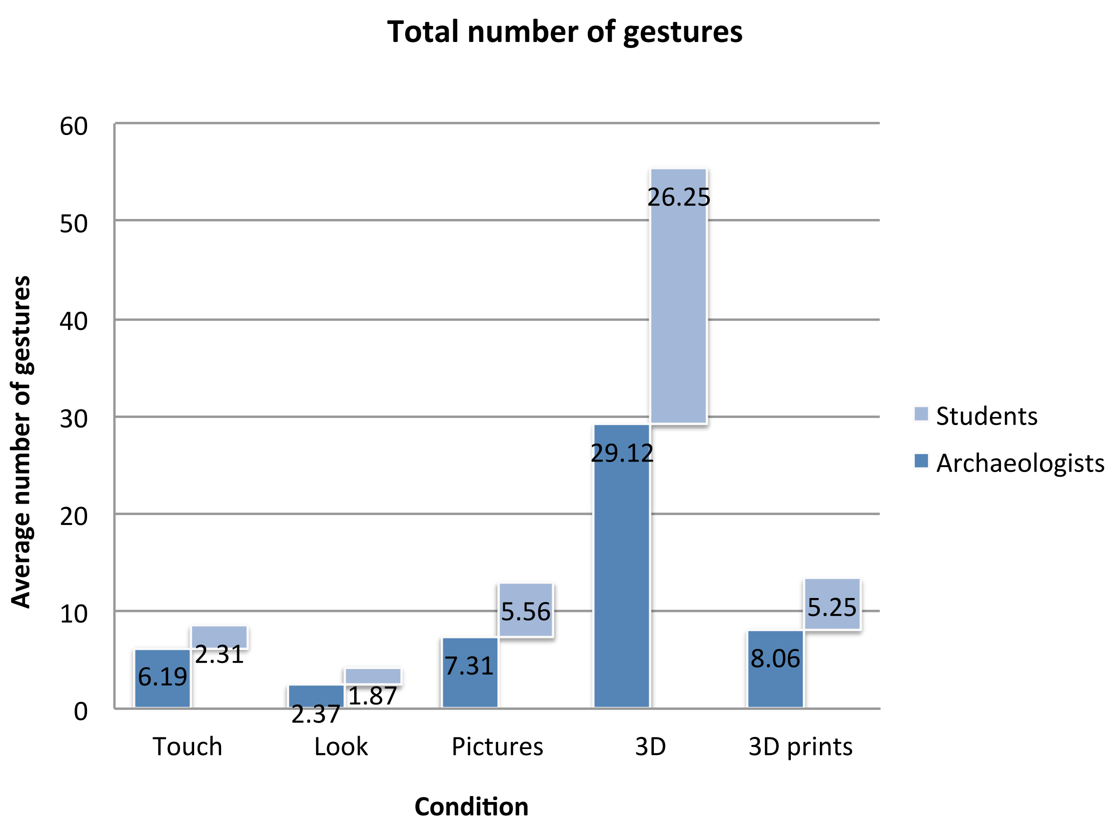


Figure 38. Total mean number of gestures used by archaeologists and students while talking about the artifacts (the graph combines beat and iconic gestures).

Further, comparison of the total mean number of gestures used by archaeologists in the *3D* scenario and the total mean number of gestures used in the other scenarios revealed that even though gestures were more common in the *3D* scenario (*M* = 29.06, *SD* = 14.58),this difference was significant only between *3D* and *Look* scenarios (*M* = 2.37, *SD* = 1.42), with *t(8)* = 105.45, p =<.001. The differences reported below are, in fact, not significant (table 26).

Table 26. T-tests showing no statistical significance between archaeologists in the *3D* scenario and archaeologists in other scenarios.

Scenarios	**Results of t-tests**
3D vs *Touch*	(*3D M* = 29.06, *SD* = 14.58; *Touch M* = 6.19, *SD* = 7.91) *t(8)* = 3.39, p =<.2;
*3*D vs *Pictures*	(*3D M* = 29.06, *SD* = 14.58; *Pictures M* = 7.31; *SD* = 5.73) *t(8)* = 6.47, p =<.08;
3D vs *3D prints*	(*3D M* = 29.06, *SD* = 14.58; *3D prints M* = 8.06, *SD* = 10.45) *t(8)* = 1.94, p =<.3.

Conversely, comparison of the total number of gestures used by archaeologists in the *Look* scenario (*M* = 2.37, *SD* = 1.42) and the number used in other scenarios revealed signficant differences. Differences were significant between *Look* and *3D prints* (*Look M* = 2.37, *SD* = 1.42; *3D prints M* = 8.06, *SD* = 10.45), with *t(8)* = 54.22, p =<.004; between Look and *Touch* (*Look M* = 2.37, *SD* = 1.42; *Touch M* = 6.19, *SD* = 7.91),with *t(8)* = 31.06, p =<.009; and between the *Look* and *Pictures* (*Look M* = 2.37, *SD* = 1.42; *Pictures M* = 7.31, *SD* = 5.73), with *t(8)* = 16.3, p =<.02. These findings suggest that the display cases might inhibit archaeologists' gesture production and make them less likely to express information about the objects using their body.

An opposite trend was evident in the students' responses. Differences between students in the *3D* scenario and students in all other scenarios were all significant; that is, students used a much greater number of gestures in the *3D* when compared to all other scenarios. This difference was significant between *3D* and *Touch* (*3D M* = 26.25, *SD* = 29.05; *Touch M* = 2.31, *SD* = 1.5), with *t(8)* = 373.15, p =<.0002. This result is not surprising because participants holding original objects had, in theory, less mobility, since their hands were engaged in object manipulation. The same observation was made with respect to the difference between *3D* and *3D prints* (*M* = 5.25, *SD* = 7.1), with *t(8)* = 16.74, p =<.02. More surprising was the difference between both *3D* and *pictures* (*M* = 5.56, *SD* = 2.48), with *t(8)* = 136.83, p =<.001; and between *3D* and *Look* (*M* = 1.87, *SD* = 1.07), with *t(8)* = 739.92, p =<.0001. It is important to note, however, that some of the participants in the *Pictures* scenario preferred to hold the pictures while describing them, thereby behaving similar to those who manipulated original artifacts and 3D prints (i.e., their hands were engaged in other activities and that might explain the difference with 3D), participants in the *Look* scenarios were free to move their hands just like 3D participants, so the difference between these two categories is particularly reliable.

Comparison of *Look* (*M* = 1.87, *SD* = 1.07) and the other scenarios for the students revealed significant differences only with *3D* (as just shown) and *3D prints* (*M* = 5.25, *SD* = 7.1), with *t(8)* = 44.19, p =<.005. All other comparisons in fact, were not statistically significant (table 27).

Table 27. T-tests showing no statistical significance between students in the *Look* scenario and students in other scenarios.

Scenarios	Results of t-tests
Look vs *Touch*	(*Look M* = 1.87, *SD* = 1.07; *Touch M* = 2.31, *SD* = 1.5) *t(8)* = 1.98, p =<.29;
Look vs *Pictures*	(*Look M* = 1.87, *SD* = 1.07; *Pictures M* = 5.56, *SD* = 2.48) *t(8)* = 5.41, p =<.1.

Examination of beat and iconic gestures separately revealed that archaeologists used a significantly larger number of beat gestures in the *3D* scenario (*M* = 20.93, *SD* = 11.31) than in all other scenarios (see fig. 39). This finding was especially significant when comparing *3D* and *Look* (*3D M* = 20.93, *SD* = 11.31; *Look M* = 0.62, *SD* = 0.28), with *t(8)* = 1638.55, p =<.0001. Statistical analysis also revealed significant differences between *3D* and *Touch* (*3D M* = 20.93, *SD* = 11.31; *Touch M* = 2.68, *SD* = 3.53), with *t(8)* = 10.28, p =<.04. Comparisons between *3D* and *Pictures* showed a difference (*3D M* = 20.93, *SD* = 11.31; *Pictures M* = 3.62, *SD* = 3.7), with *t(8)* = 9.38, p =<.049. but, comparisons between *3D* and *3D prints* found no significant difference (*3D M* = 20.93, *SD* = 11.31; *3D prints M* = 2.65, *SD* = 3.84), with *t(8)* = 8.67, p =<.05. This finding is interesting, since it suggests that the act of holding an object does not prevent an individual from performing beat gestures if they need to, thus indicating the importance of these gestures for lexical access or to recall information that is archived on our mind.

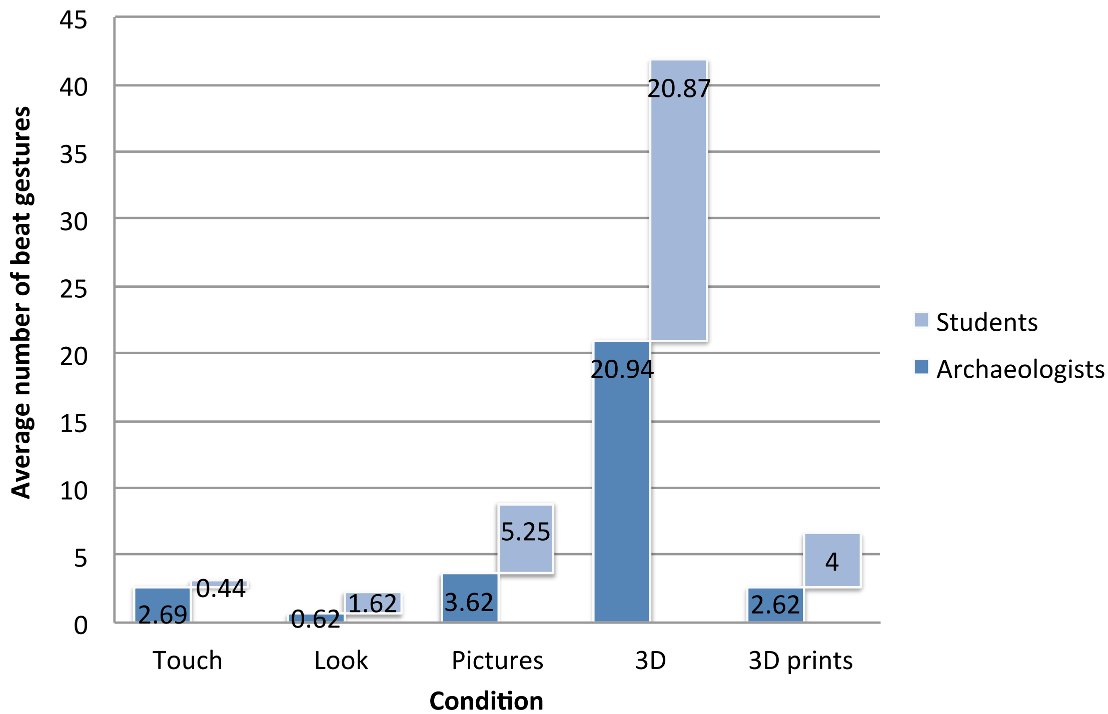


Figure 39. Mean number of beat gestures used by students and archaeologists to talk about the artifacts.

With respect to students, a pattern fairly similar to that of archaeologists observed. Students in the *3D* scenario used significantly more beat gestures (M = 20.87, SD = 24.51) than their peers interacting with artifacts through other forms. This difference was reliable when comparing *3D* and *Touch* (M = 0.44, SD = 0.51), with $t(8)$ = 2294.6, p =<.0001; *3D* and *Look* (M = 1.62, SD = 0.8) $t(8)$ = 937.44, p =<.0001, *3D* and *Pictures* (M = 5.25, SD = 2.04), with $t(8)$ = 144.49, p =<.00; and *3D* and *3D prints* (M = 4, SD = 6.35), with $t(8)$ = 14.89, p =<.03.

As discussed previously, students in the *3D* scenario produced more beat gestures than their peers in the *Look* scenario. This difference was also significant when comparing *Look* and *Pictures* (*Look M* = 1.62, *SD* = 0.8; *Pictures M* = 5.25, *SD* = 2.04), with *t(8)* = 6.49, p =<.008, and *Look* and *3D prints* (*Look M* = 1.62, *SD* = 0.8; *3D prints M* = 4, *SD* = 6.35), with *t(8)* = 62.98, p =<.003. Conversely, no significant differences were found between *Look* and *Touch* (*Touch M* = 0.44, *SD* = 0.51), with *t(8)* = 2.45, p =<.2.

As already observed with archaeologists, these findings seem to suggest that window cases also inhibit students' bodily expression.

Examination of the number of iconic gestures performed by archaeologists revealed that *3D* was again the scenario eliciting the greatest gesture production (*M* = 8.12, *SD* = 3.5), while the *Look* scenario led to fewer gestures (*M* = 1.75, *SD* = 1.33; see table 28, fig. 39).

Unlike what was observed with beat gestures, comparisons between 3D and the other scenarios revealed no significant differences (table 28).

Table 28. T-tests with no statistical difference in the number of iconic gestures produced by archaeologists in the 3D scenario compared to other scenarios.

Scenario	Results of t-test
3D vs *Touch*	(*3D M* = 8.12, *SD* = 3.5; *Touch M* = 3.5, *SD* = 4.4) *t(8)* = 1.59, p =<.3;
3D vs *Look*	(*3D M* = 8.12, *SD* = 3.5; *Look M* = 1.75, *SD* = 1.33) *t(8)* = 6.82, p =<.07;
3D vs *Pictures*	(*3D M* = 8.12, *SD* = 3.5; *Pictures M* = 3.69, *SD* = 2.26) *t(8)* = 2.38, p =<.2;
3D vs *3D prints*	(*3D M* = 8.12, *SD* = 3.5; *3D prints M* = 5.44, *SD* = 6.7) *t(8)* = 3.68, p =<.1;

Similarly, even if the Look scenario seemed to lead to the fewest iconic gestures, this difference was significant on when comparing *Look* and *Touch* (*Look M* = 1.75, *SD* = 1.33; *Touch M* = 3.5, *SD* = 4.4), with *t*(8) = 10.86, p =<.04, and *Look* and *3D prints* (*Look M* = 1.75, *SD* = 1.33; *3D prints M* = 5.44, *SD* = 6.7), with *t*(8) = 25.11, p =<.01. As already discussed, there was no significant difference between *Look* and *3D*, while s *look* and *Pictures* (*Look M* = 1.75, *SD* = 1.33; *Pictures M* = 3.68, *SD* = 2.26), with *t*(8) = 2.87, p =<.2.

Examination of the number of iconic gestures students used in the various scenarios showed that *3D* was the scenario with the highest number of words (*M* = 5.37, *SD* = 4.96), and comparisons with the other scenarios revealed that the difference were either significant or nearly significant (fig. 40, table 29).

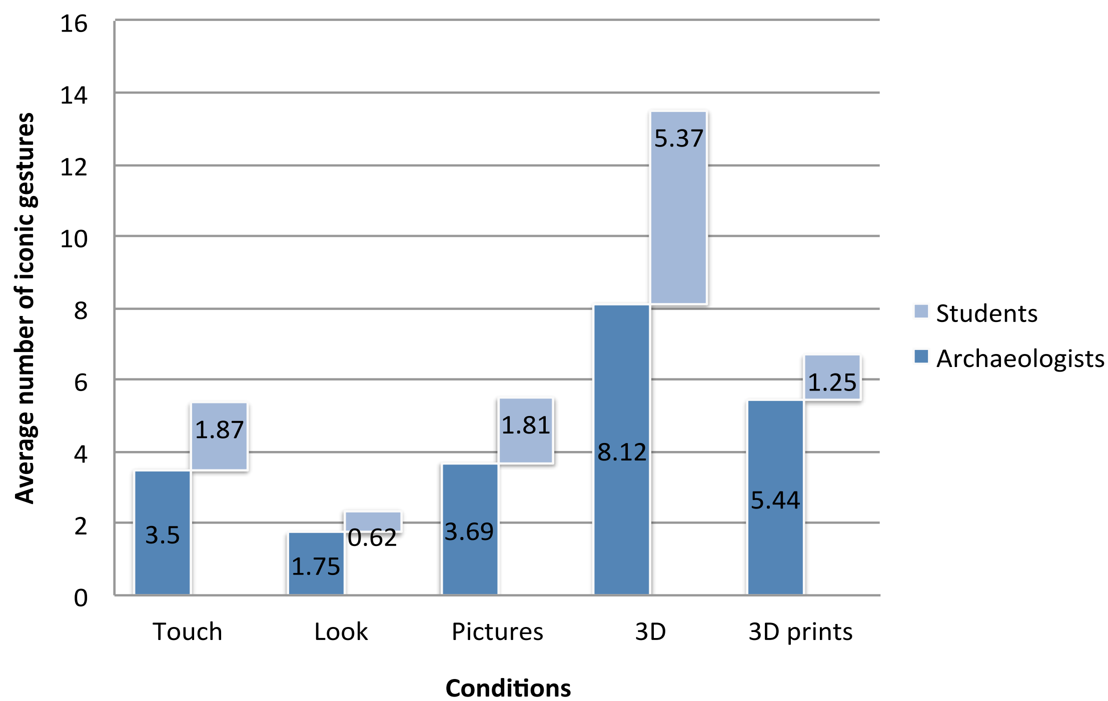


Figure 40. Mean number of iconic gestures used by students and archaeologists to talk about the artifacts.

Table 29. T-tests performed to compare the number of iconic gestures produced by students in the 3D scenario to the number produced by students in the other scenarios.

Scenario	Results of t-test
3D vs *Touch*	(*3D M* = 5.37, *SD* = 4.96; *Touch M* = 1.87, *SD* = 1.61) *t(8)* = 9.53 p =<.048;
3D vs *Look*	(*3D M* = 5.37, *SD* = 4.96; *Look M* = 0.62, *SD* = 0.65) *t(8)* = 58.26, p =<.004;

3D vs *Pictures*	(*3D* $M = 5.37$, $SD = 4.96$; *Pictures* $M = 1.81$, $SD = 0.9$) $t(8) = 31$, p =<.009;
3D vs *3D prints*	(*3D* $M = 5.37$, $SD = 4.96$; *3D prints* $M = 1.25$, $SD = 0.9$) $t(8) = 30.25$, p =<.01.

Conversely, even though the *Look* scenario led to the fewest iconic gestures, the tests revealed that there was significant difference between this and the *3D* scenario (see above), but no significant differences with all other scenarios (table 30).

Table 30. T-tests with no statistical difference in the number of iconic gestures produced by students in the *Look* scenario compared to other scenarios.

Scenario	Results of t-test
Look vs *Touch*	(*Look* $M = 0.62$, $SD = 0.65$; *Touch* $M = 1.87$, $SD = 1.61$) $t(8) = 2.45$, p =<.08;
Look vs *Pictures*	(*Look* $M = 0.62$, $SD = 0.65$; *Pictures* $M = 1.81$, $SD = 0.9$) $t(8) = 1.88$, p =<.3;
Look vs *3D prints*	(*Look* $M = 0.62$, $SD = 0.65$; *3D prints* $M = 1.25$, $SD = 0.9$) $t(8) = 1.93$, p =<.3.

To see how media influences the production of gestures, the number of beat and iconic gestures performed in each scenario were also examined. This analysis revealed that archaeologists in the *3D* scenario produced significantly more beat than iconic gestures (Iconic M=8.12, beat M=20.94), with $t(8) = 10.54$, p =<.04 (fig. 41). The ratio of iconic to beat gestures was reversed in all other scenarios (i.e., the number of iconic gestures was higher than that of beat gestures). In this case, however, the results were significant only in the *Look* scenario (table 31).

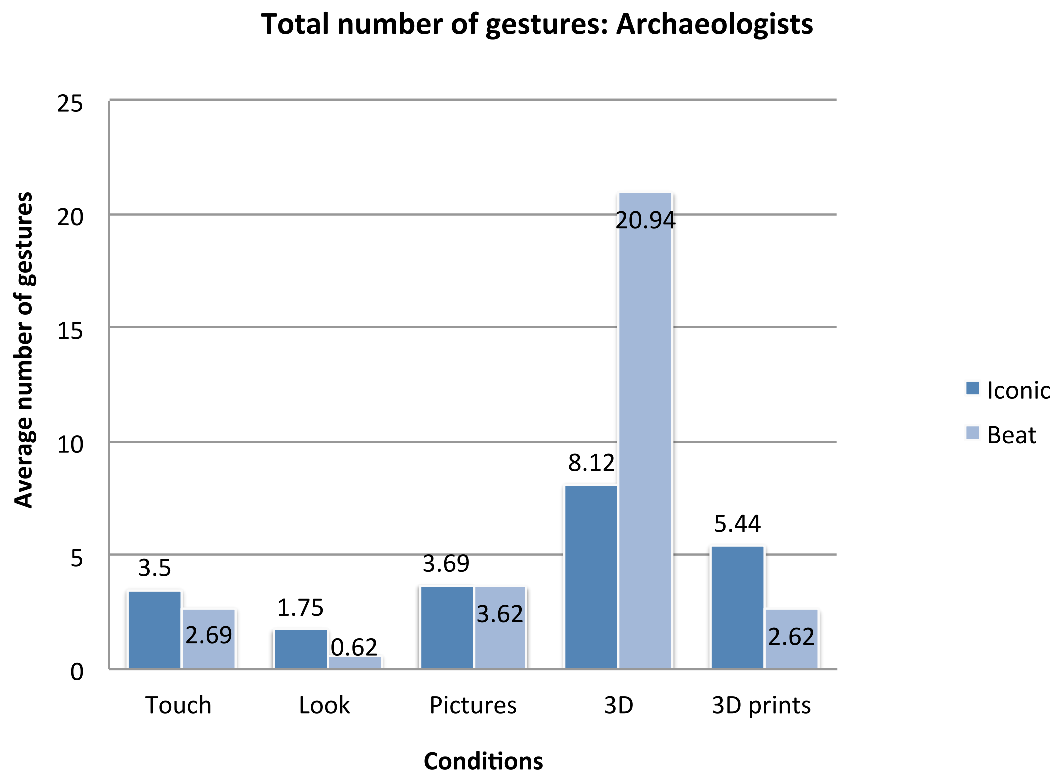


Figure 41. Beat and iconic gestures used by archaeologists while talking about the artifacts.

Table 31. Comparison between the number of beat gestures and that of iconic gestures performed by archaeologists in the various conditions.

Scenario	Results of t-test
Touch	(iconic M = 3.5, beat M = 2.69) t(8) = 1.55, p = <.4;
Look	(iconic M = 1.75, beat M = 0.62) $t(8)$ = 22.8, p = <.01;
Pictures	(Iconic M = 3.69, beat M = 3.62) $t(8)$ = 2.67, p = <.2;
3D prints	(Iconic M = 5.44, beat M = 2.62) $t(8)$ = 3.03, p = <.2.

Students produced more beat than iconic gestures in all categories, with the exception of the *Touch* scenario, wherein the ratio of gestures was reversed (fig. 42). The difference between beat and iconic gestures was significant only in the *Touch*, *3D* and *3D prints* scenario (table 32).

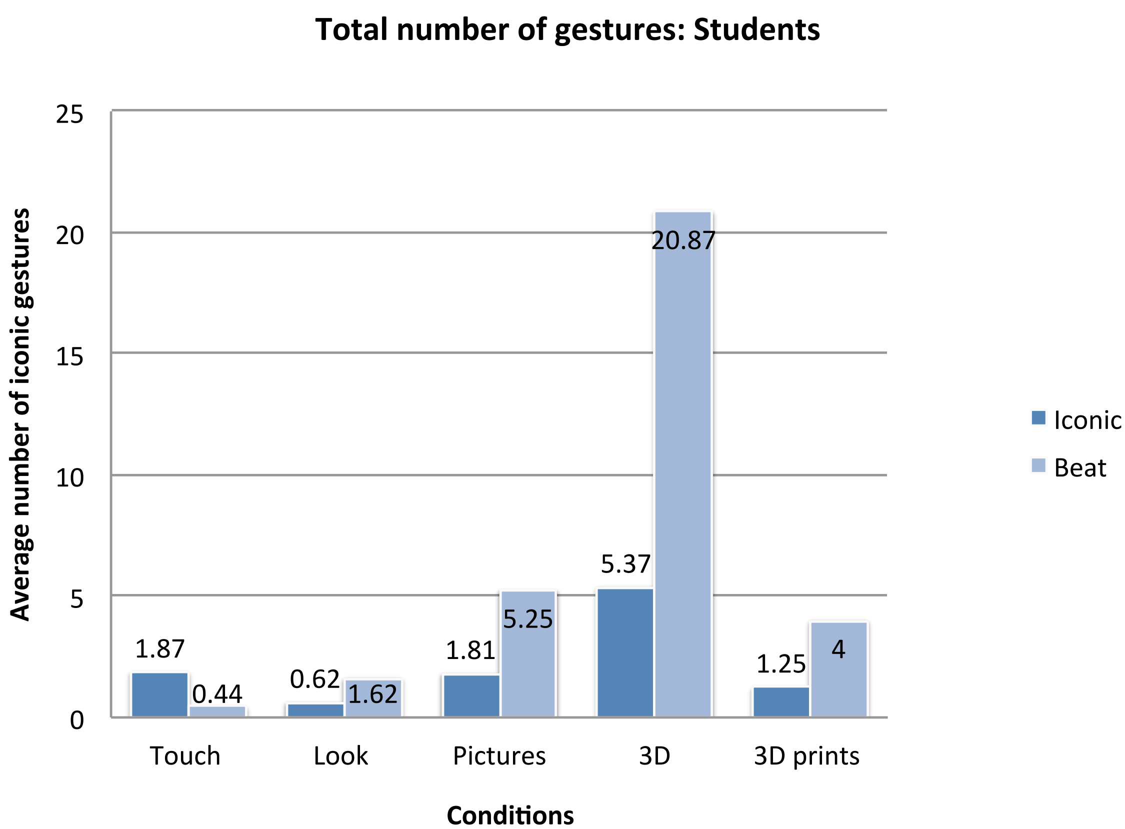


Figure 42. Beat and iconic gestures used by students while talking about the artifacts.

Table 32. Comparison between the number of beat gestures and that of iconic gestures performed by students in the various conditions.

Scenario	Results of t-test
Touch	(iconic M = 1.87, beat M = 0.43) t(8) = 9.85, p =<.046;
Look	(iconic M = 0.62, beat M = 1.62) t(8) = 1.52, p =<.4;

Pictures	(iconic M = 1.81, beat M = 5.25) $t(8)$ = 5.24, p =<.1;
3D	(iconic M = 5.37, beat M = 20.87) $t(8)$ = 24.43, p = <.01;
3D prints	(iconic M=1.25, beat M=4) $t(8)$ = 49.65, p = <.005.

Subsequently, types of iconic gestures used by participants while describing the artifacts were classified. Such gestures were found to mainly be used to describe motion. Iconic gestures conveying motion were frequently used to talk about the function of an object. For instance, while talking about the 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 the grinding stone, some participants mimicked the circular motion performed by people to grind seeds or other vegetal foods (fig. 43). A variety of iconic gestures also helped to describe the function of the Buddhist object (see fig. 31 in paragraph 3.1.).

Participants often used gestures while talking about how the artifact 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. As noted above, iconic gestures were also used to define the shape of an object and/or stress elements of shape described using FM phrase (fig. 44). In the case of the pot, an object missing part of the lip and handle, gestures helped to stress the shape of the missing parts. In one case, a participant stressed color variation of an object by using the FM "it goes from brown and right here is grey," then moved his finger to describe a linear path following the color variation. Some participants performed iconic gestures while talking about *texture* and *material* of an object. Iconic gestures also helped some people imagine the size of an object, especially in those cases in which it was difficult to determine object scale (fig. 45; see also fig. 27 in chapter 4).

Figure 43. Participant simulating the motion of grinding food with a mono.

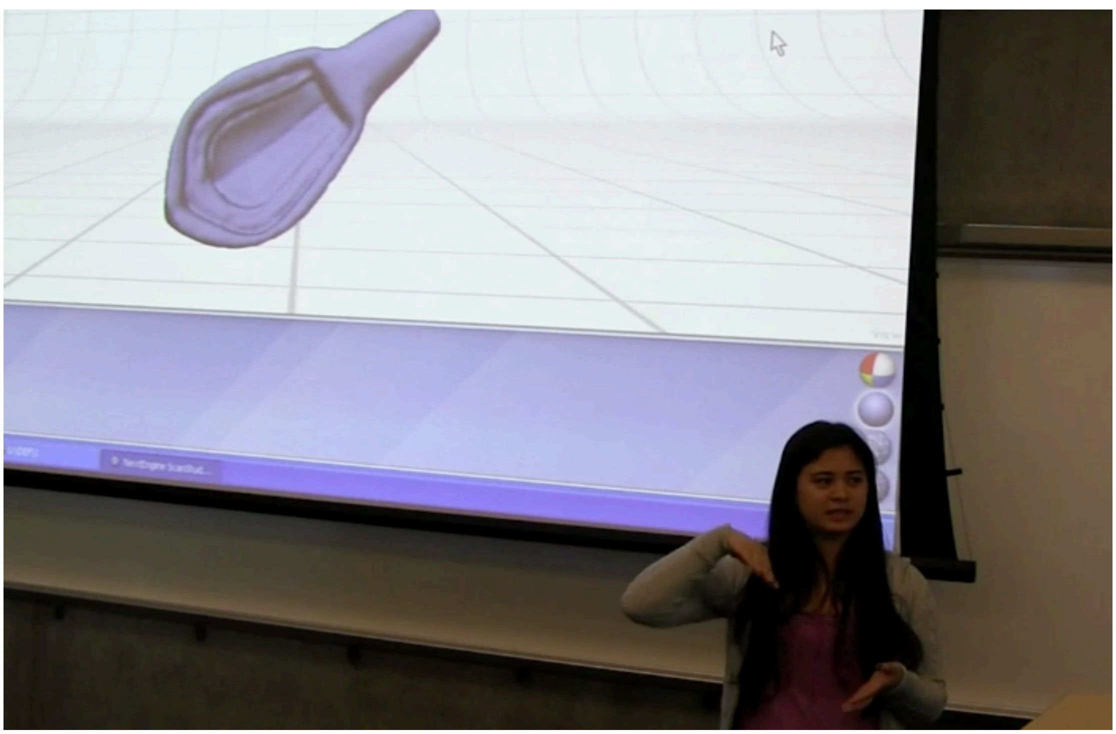


Figure 44. Iconic gestures used to describe the groves of the Buddhist object.

Figure 45. Archaeologist trying to figure out the size of the pot through gestures.

As previously noted with respect to how people described the size of an artifact, these gestures are usually associated with an adjective. For instance: "it is/should be this big." In the *Touch* scenario, to measure an object a few participants simulated a ruler, moving fingers through 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 (see fig. 31 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 such devices. Finally, some participants (in other than the *Touch* scenario) also simulated touching an artifact indicating their frustration over the lack of a tactile experience with the object.

Similar to the analysis of words and expressions of uncertainty used to describe objects and guess their function in the past, figures 46 and 47 show how gestures used to describe an artifact were distributed differently based on the medium used.

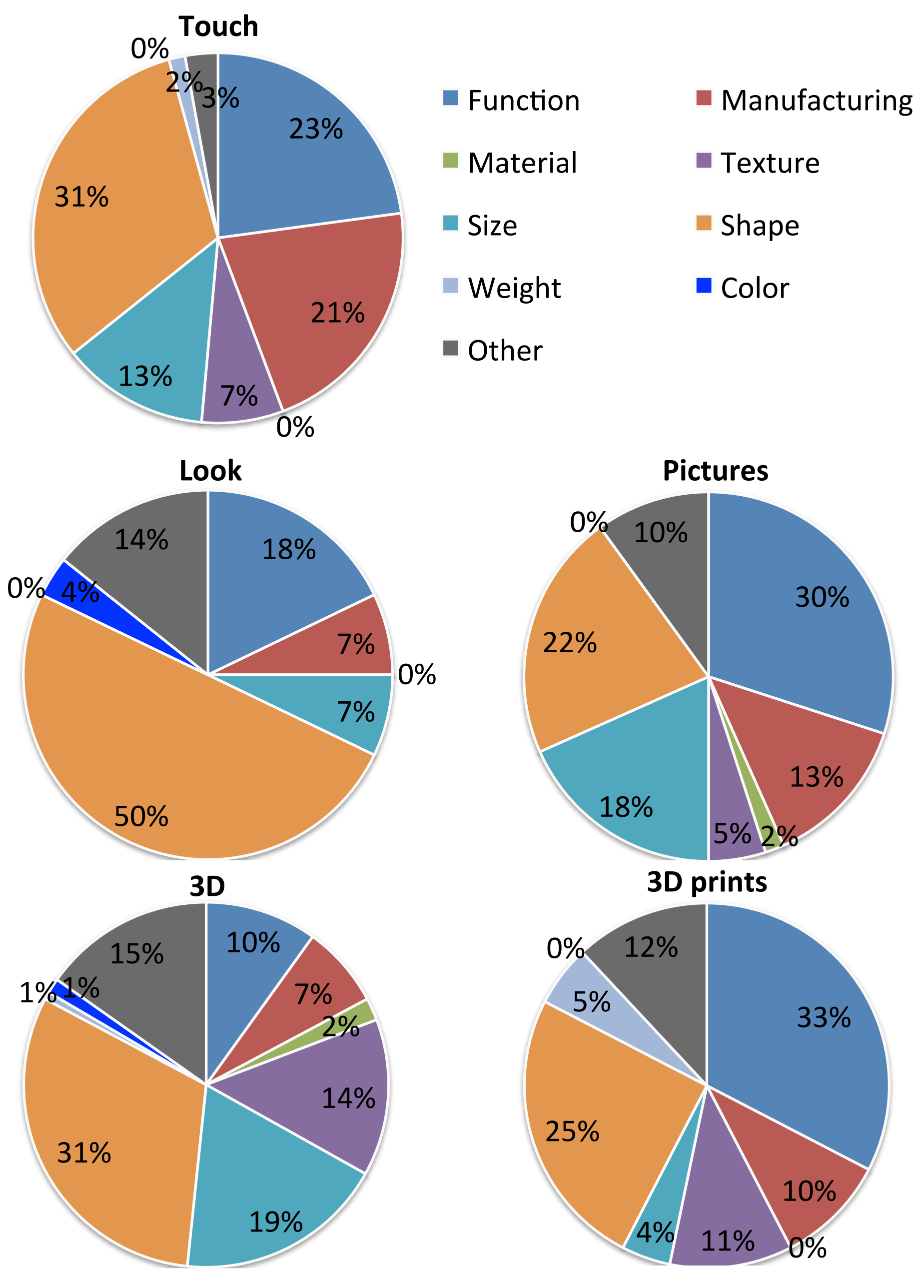


Figure 46. Percentage of gestures produced by archaeologists in each scenario.

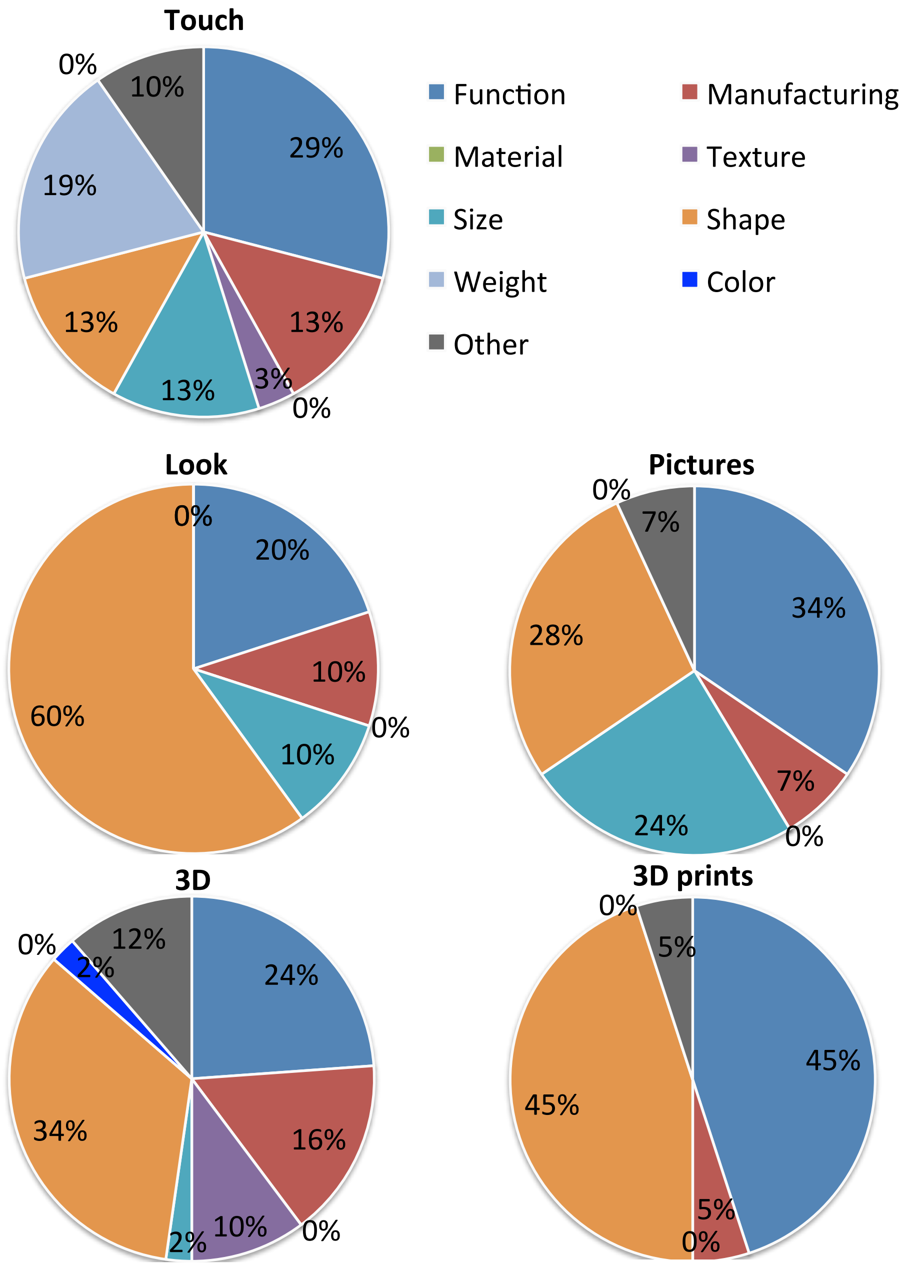


Figure 47. Percentage of gestures produced by students in each scenario.

While there was certain homogeneity in the use of gestures in the *Touch* scenario, both student and archaeologist participants in the *Look* scenario used the most gestures to describe *shape* (archaeologists: 50%; students: 60%). In the *Pictures* scenario, both archaeologists and students used the most gestures to mimic the function of the objects (archaeologists: 30%; students: 34%), but also to show particular attention on the *size*, indicating that the graphic scale provided on the photo is not sufficient when attempting to understand the actual size of an object. Archaeologists in the *3D* scenario used most of their gestures (19%) to describe *size* rather than other scenarios. Interestingly, archaeologists and students in the *3D* scenario used similar numbers of gestures to simulate the texture of objects (archaeologists: 14 %; students: 10%); specifically, these gestures simulate hand movements one would make while touching real-life-objects in order to perceive their texture. Archaeologists also simulated texture by means of gestures in the *3D print* scenario, while students did not perform these type of gestures. In particular, it should be emphasized that students in the *3D print* scenario focused almost exclusively on *shape* and *function* when using body language.

5.5. Observing participants' interaction with the medium: insights into the experience with artifacts

A few additional observations regarding how participants in the experiment interacted with the given media are in order. A tactile experience with a real-life artifact is, in fact, a full sensorial experience that included touching, seeing, and even smelling an artifact. For instance, more than one student in the Touch scenario pointed out that some of the artifacts (i.e., Buddhist object and pot) smelled old. Participants also heard the sound that the artifact produced when it was knocked or thumped (which is something participants do especially with the pot—and they even potentially predicted what the object would taste like.

These sensorial experiences have important psychological implications, if we consider that people were aware they were dealing with ancient artifacts were. In fact, as described this chapter, those individuals not in the fields of archaeology and heritage often showed a sense of excitement when left alone in a room with ancient artifact, and; Being allowed to touch these artifacts made this experiment a very unique experience for these participants, and gave then the opportunity to emotionally connect with the objects. The opportunity to touch artifacts that were part of a collection disappointed some archaeologists; for example: "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…" (#29, projectile point). In the *Touch* scenario, both students and archaeologists seemed very comfortable to talk while interacting with the artifacts. They held and carefully manipulated each object for the entire length of their speech, pointing to specific parts while they described them and used gestures to help with the discourse.

In contrast to what was observed in the *Touch* scenario, both students and archaeologists in the *Look* scenario seemed more uncomfortable during their interaction with the objects, which were located in display cases. These participants looked at the objects and often leaned their head close to the cases to visually examine specific details that could help them describe the objects, but at the same time, they tried to keep their hands far from the case. In some instances, participants put their hands behind their back; at other times, they rested their hands on the table. Some participants shyly touched cases with their fingertips and then quickly retracted them. These observations mirror the findings regarding gestures, since participants in the *Look* scenario used a very low number of bodily gestures.

As described in the introduction to this chapter (5.1), participants in the *Pictures* scenario were free to either talk while holding the pictures or leave the pictures on the table. Most of these participants preferred to hold the picture while talking. This allowed them to point to specific parts while describing the object, but did not prevent them from moving and using gestures to facilitate their discourse. The experience of these participants thus became a tactile interaction with the pictures, which mimic, in a sense, what would happen if the participants had real-life artifacts in their hands.

Participants in the *3D* scenario could interact with 3D replicas of artifacts through the mouse. As described in Chapter 4, participants were allowed to virtually manipulate (e.g., rotate, zoom in and out, etc.) the artifact before describing it. They were asked to try not to touch the mouse while talking, but they were allowed to use the mouse to point to parts of the object while talking, if needed. Observing the videos, it seemed that most of these participants found it difficult not to touch the mouse. Their interaction with the mouse seemed to simulate a tactile experience with the artifact. This might explain why they used the most gestures of all participants: perhaps the use of gestures compensated for the lack of interaction with the digital artifacts. Another explanation for the high number of gestures could be that gestures—specifically beat gestures—were utilized to fill the gap between participant physicality and the "virtuality" or "digitality" of the 3D replicas. This connection between the physical and the digital world does not seem an obstacle to an engaging experience with the artifacts. On the contrary, even if critical of the medium, participants seemed to recognize some benefit in the software capabilities, as previously explained. Moreover, they often showed excitement for the 3D medium, emotionally connecting with the 3D artifacts. This is especially true for students, but was also observed in archaeologist interactions.

Finally, *3D print* participants interacted with 3D prints as they would with real-life objects. Nonetheless, while archaeologists spent a considerable amount of time manipulating these prints to find cues that could help them understand how similar the copy was to the original artifact, students seemed less engaged. It may be that for students knowing these objects were fake representations prevented them from making a psychological or emotional connection with objects presented in this medium.

Another observation concerns the Buddhist ritual object. As mentioned several times in this and the previous chapter, this ritual object was likely used in Buddhist ceremonies as a niche for Buddha or related figurines.

[no new paragraph] When the default orientation of this object on the table was set, this position reflected my understanding of the function of the object. That is, tt was located "upright," with the handle (lower part) close to the edge of the table (i.e., proximal end toward the study participant) and the niche (upper part) away from the edge (i.e., distal end away from the study participant). This default position seemed ideal and was unconsciously driven by *function*. The same orientation was adopted for the picture of this object and any time the object was visualized as the 3D digital replica on a computer screen (fig. 48).

Interestingly, almost all archaeologists, after interacting with this object through the selected media, replaced the object in the original orientation, exactly the way they initially found it. Only two of the 20 archaeologists (one in the *Pictures*, one in the *Touch* scenario) replaced the object back horizontally, that is, with both lower (proximal) and upper (distal) parts parallel to the edge of the table. In contrast, eight of the 20 students (40%) did not respect the default position and replaced the object horizontally (figs. 49, 50).

The difference between students and archaeologists with regard to object placement after interaction was statistically significant: X^2 $(1, N = 40) = 4.8$, $p = 0.03$. One possible explanation for this observation relates to the discourse on discipline-specific training already discussed in this chapter. It is possible that archaeologists replaced the object precisely as it was found because they are trained to respect the orientation and location of an object, since these are aspects of *provenience,* which is often linked to the concepts of *context*, *interpretation* of data and *preservation*. Conversely, students are not trained in archaeology and likely do not consider moving an object an issue that could endanger an artifacts; thus they placed the Buddhist object back at their discretion. It is possible that the participants who freely decided to place the object horizontally did so because they were unconsciously driven by their interpretation of this object's *function*. In fact, all participants who replaced the object horizontally thought this could be used as a scoop and it was easier for them to place it back in a way that represented their idea regarding the *function* of the object more closely. There was not a predictable relationship between final object placement and how participants understood function.

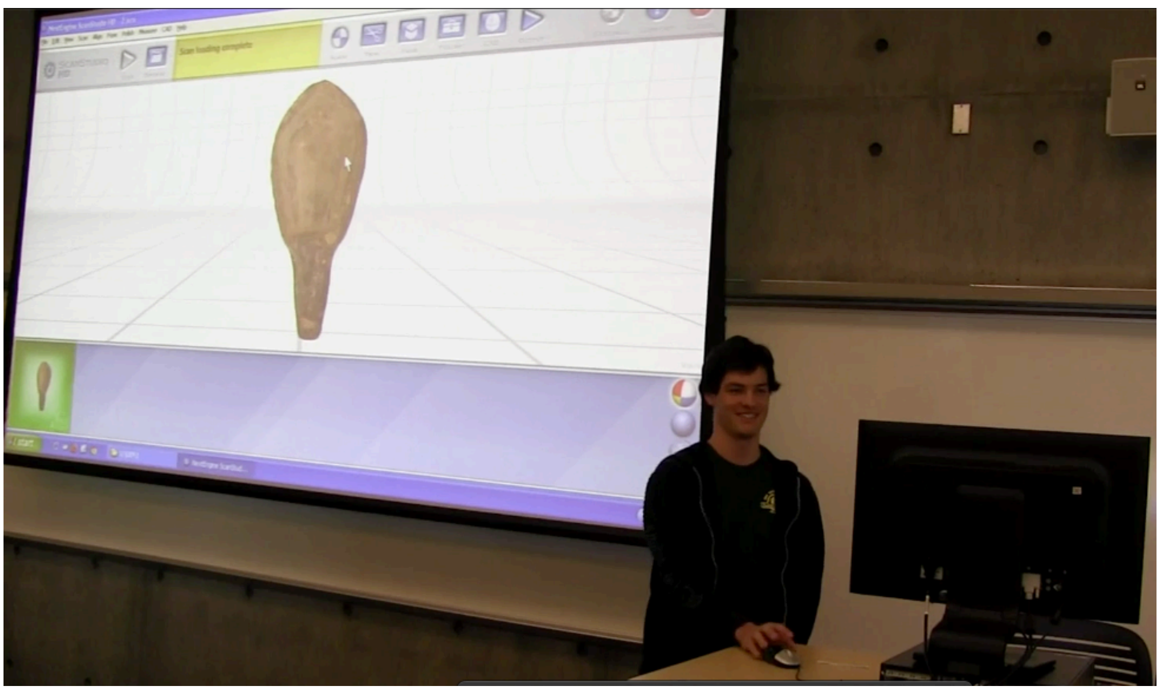


Figure 48. Default upright position of the Buddhist object on a computer screen.

Figure 49. Student participant replacing the picture of the Buddhist object horizontally.

Figure 50. Student participant replacing the 3D print of the Buddhist object horizontally.

5.6. Conclusions

These experiments were conducted to investigate how modality of presentation influences participant understanding of artifacts. Specifically, how do people interact with, understand, and describe objects differently when such objects are presented in five unique scenarios: tactile experience with authentic artifacts, visual experience with authentic artifacts, 2D pictures, 3D digital reconstructions, 3D prints. In the study, participants—both professionals in the field of archaeology and students—were asked to describe ancient artifacts in detail while alone in front of a video camera.

Results of this research reinforce the notion that people do *think* with objects, and that manipulation is a critical component of this engagement with artifacts. Yet people interacting with artifacts in other media states were able to compensate for the absence of tactile experience and acquire a sense of distinctive physical characteristics that were crucial for determining object function.

Comparisons between archaeologists and students reveal how differently such individuals engage with artifacts. Archaeologists were usually able to *describe* the objects first (i.e., describe what they saw), and then provide their *hypothesis* (or interpretation) regarding possible function of an artifact in the past. When describing artifacts, archaeologists obviously drew on a set of specific scientific terms they learned through discipline-specific training. This training requires them to thoroughly describe the physical characteristics of artifacts to then classify, date, and interpret the function/role of an artifact in the past. Discipline-specific training also evidently influences archaeologists' interpretation of *function*, since this interpretation is guided by the importance of certain characteristics of the artifact relative to other characteristics.

Undergraduate students who participated in the experiment usually centered their discussion on the function of the artifact, and preferred to describe only specific characteristics of the object that could help them with the interpretation of its function. In other words, even if never trained as an archaeologist, a student was able to form one or more hypothesis about an object's function(s) and validate their hypotheses by referring to specific details observed on the artifact. As a result, most of the students were very engaged during the interviews and enjoyed participating in the experiment.

While statistical analysis revealed significant differences between students and archaeologists in the number of words used to describe an artifact, the data also showed that various scenarios influenced the number of words used to describe an artifact. Archaeologists used the fewest words to describe an artifact in the *Pictures* scenario; students used the fewest words when describing pictures and objects exhibited in a display case. Qualitative analysis helped clarify this finding, and suggests that the number of descriptive words used is in direct proportion to the challenge experienced when describing certain characteristics of an object, although the data also show strong engagement with the media used.

Examining how both students and archaeologists described individual characteristics of the objects reveals that the tactile experience invites people to more in-depth analysis of such characteristics. In addition, this analysis shows that when people cannot discern certain physical characteristics of an object, they rely on other physical clues that help them describe the object, showing how the simple task of *describing-an-object* becomes more of an interpretation process for those individuals who could not touch the artifact.

It is obvious that experiencing artifacts through media other than the tactile experience with the original entails certain limits, but it is a also significant that a number of participants in the *3D* group stressed the importance of multi-visualizations (i.e., object with or without original colors) to comprehend some traits they could not grasp otherwise; for instance, textural information is a detail highly associated with tactile experience. Texture cues can help participants successfully determine both object material and function. In the case of the grinding stone, people often look at signs of wear to determine its function. For many participants, determination of the Buddhist object's material was only possible through the use of texture.

With regard to shape, both students and archaeologists interacting with 3D replicas mentioned and described the shape of the object more consistently and frequently than those in other experimental scenarios. As noted earlier, the shape of 3D digital replicas can be difficult to recognize when color information is applied to the model. For this reason, the visualization of 3D models with no colors applied may be crucial for recognizing *shape* information. The importance of removing original colors from the 3D models was highlighted by several participants, but this observation was usually only made following interaction with the second, or sometimes even the third, 3D model they encountered. This observation is not trivial, since it indicates that 3D model users needed experience to understand the tool and fully benefit from the 3D model medium.

Direct perception of innate physical qualities of artifacts can be very effective for discussion of object function in the past, but such perception can also be misleading at times. For instance, the handle and concavity of the Buddhist object are strong direct affordances that often lead participants in the experiment to believe this was a spoon or scoop.

In the absence of direct perception or when such perception is hard to achieve (or not *relational* and/or *transparent*, in Knappett's [2004:46] words), users search their personal knowledge to describe an object on the basis of the categories in their mind. This pre-knowledge (i.e., *indirect perception*) is so strong in their minds that it not only influences the answer, but gives the less critical user (i.e., the students) a great certainty of their response. This has been dissed Erik Mazur, a physicist at Harvard, who studied violin strings and sound to show that prior knowledge interferes with learning core concepts (Mazur 1997).

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 in conjunction with fictive motion to describe details of *shape*. Iconic gestures also help people figure out the size of an object.

As noted above, when people describe objects they also produce beat gestures, which do not convey any particular meaning. Study participants who interacted with digital 3D objects produced a significantly higher number of beat gestures. Following Krauss (1998), who argued that beat gestures facilitate lexical access, it appears that the high number of beat gestures reflect a certain insecurity in describing an artifact. Nonetheless, the experiments revealed no significant difference between 3D and the other scenarios in the number of expressions of doubt used while describing an artifact. Another possible explanation of the high production of beat gestures in the 3D scenario could be that beat gestures helped participants compensate for the lack of a tactile experience. It is worth remembering 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 well indicate that participants recognized a difference, a frame, between the physical and the virtual world and tried to fill this gap using gestures. The use of gestures may have helped participants have a more embodied experience with an artifact.

Conversely, participants looking at artifacts in display cases used the fewest gestures and were particularly inhibited by the cases. This suggests that the cases represented both a physical and a psychological barrier that prevented individuals from having a completely engaging experience with an artifact.

Chapter six: Conclusions

Three-dimensionality of the simulacrum - why would the simulacrum with three dimensions be closer to the real than the one with two dimensions? It claims to be, but paradoxically, it has the opposite effect: to render us sensitive to the fourth dimension as a hidden truth, a secret dimension of everything, which suddenly takes on all the force of evidence.
(Baudrillard, Jean, *Simulacra and Simulations*)

The idea behind this doctoral work was inspired by intersections between material culture and cognition theories. Its experimental design was motivated by the following claim: "Things possess their own nonverbal qualities and are involved in their own material and historical processes that cannot be disclosed unless we explore their integrity *qua* things" (Olsen 2010: 173; see chapter 2). To explore object's integrity *qua* things, I asked people to experience some artifacts out of context, so that the only cues to determine these objects' "meaning" in the past were their physical properties. In other words, following Gibson (1979), I was interested in seeing if direct perception of material qualities alone could lead to the understanding of artifacts' function in the past.

The results of this doctoral research reinforces the idea that people do *think* with objects (Demarrais *et al.* 2004; Malafouris & Renfrew 2010). Participants who described the objects without touching them reproduced stereotypical iconic gestures (i.e. to show how to use the objects) as if they were actually touching the item. Physical interaction is more crucial for professionals, though, who are accustomed to a tactile experience with ancient artifacts and cannot even hide their frustration with not touching the artifacts.

These results also show that 3D virtual copies cannot reproduce the sense of innate qualities of objects (i.e., density, weight, etc.) yet. This is because even though computer scientists have designed devices able to reproduce the feel of a physical contact with objects and the perception of tactile stimuli (i.e. Hoffman 1998; Jeonghun *et al.* 2003), we are still far from a quasi-real sensorial experience:

> To meet the deepest needs of *people* virtual environments must move beyond the purely visual to include the tangible. The need is driven by the very nature of thinking. As we improve our understanding of the way thought reaches out to include material objects we control, it is apparent that *people* rely on playing with the material artifacts *discovered* to deepen their understanding. Nothing, in principle, prevents future virtual environments from supporting this material engagement of digital versions of artifacts. But, there is much that remains to be understood about how to realize this material engagement, both at a technological and a cognitive level. [Kirsh 2010:124, emphasis original].

In the absence of a tactile experience with real-life artifacts, participants utilizing other media were still able to grasp physical properties of objects, but the perception of these qualities was affected by the medium. Three-dimensional technologies, unlike other media (e.g., 2D images) have the potential to provide people with augmented visualization strategies that help them to negotiate the lack of tactile experience with artifacts and even the absence of authentic objects. Three-dimensional replicas enhance perception of texture more than other media, for instance, thanks to the possibility of removing original colors (i.e., *texture*) from the 3D digital model on the computer screen. In this case the multi-visual experience (i.e., *texture*, *mesh*, *wireframe*, *point cloud*) allowed people to grasp the materiality of the objects' textures and have a quasi-tactile experience.

This experiment also demonstrated that *direct* perception does guide and/or influence the interpretation of the artifact's use in the past, but it is often mediated by *indirect* perception, since people rely on mental representations to make sense of their direct perception of certain physical properties of the objects. We observed this process with the Buddhist object, for instance, when the affordance of the handle and the concavity of its upper part suggested a daily use of the object as spoon or scoop. As argued by Knappett (2004: 46) when *direct* perception is not *transparent*, we mainly rely on pre-knowledge to describe physical properties and/or to provide hypotheses on the function of an artifact. In other words, participants in the experiment often rely on their personal experience with the world not only to interpret the function of the artifacts, when these are unfamiliar to them, but also to describe certain characteristics of the artifacts, when the affordance is not *transparent* and *relational*.

Following the phenomenology of Husserl, it seems clear how meaningful experience with artifacts belongs to the *lifeworld* and the everyday manner in which we live our lives, whether we are professionals or not. These research observations seem to reinforce phenomenological perspectives of Husserl and Marlau-Ponty (discussed in chapter 2; Merlau-Ponty 1962; Husserls 1970a; 1970b), showing how meaning is not something that we come across when encountering objects; in other words meaning is not just produced or constructed by us. Meaning seems, instead, to be a compromise between *direct* perception of material culture, which varies based on the medium we use for the experience, and our pre-knowledge of the *lifeworld*, shaped by previous experience. Our research finding combined with previous research (Mazur 1997; Di Giuseppantonio 2010; Di Giuseppantonio et al. 2012) also shows that pre-knowledge can be particularly misleading, when it comes to interpretation of the artifacts. This suggests that we should find some strategies to make *direct* perception of specific aspects of the artifacts more *transparent* and *relational* to the user.

A solution to this dilemma comes from a paper by Elizabeth Grant and Michael Spivey (2003). The paper, aimed at eye-tracking visual attention during diagram-based problem solving, showed that particular fixation patterns correlate with success in solving problems. Given this correlation between attention to a particular diagram feature and problem-solving insight, they investigated participants' cognitive sensitivity to perceptual changes in a diagram feature and found that perceptually highlighting the critical diagram component, identified through eye tracking, significantly increased the frequency of correct solutions. This study suggests that environmentally controlled perceptual properties can guide attention and eye movements in ways that assist in developing problem-solving insights that dramatically improve reasoning. If we apply this finding to our study, 3D reproductions combined with specific augmented reality strategies could help with emphasizing specific properties of the artifacts and enrich interpretation of their meaning in the past. In this way *direct* perception will reduce the effect of background knowledge; however, interpretation will also become *mediated*, reducing the freedom of *observer-observed* relationships. Another solution could be to simply leave the objects and their reproduction as they are, stressing the importance of multiple, multivocal narratives created by the observers while they experience artifacts through different media. In this way, the past becomes a polysemous process which takes into account the *now* and *here* of the experience and the *medium* through which we experience it.

With this work we also wanted to stress the importance of materiality (i.e., material qualities of the world) and understand how people perceive artifacts when they experience them virtually. If we accept the notion that a person is an *organism-in-its-environment* (which includes artifacts, as part of the environment; Ingold 2000:172) and the environment is material, what happens when we ask people to interact with object in a virtual form? Do these people feel they are part of the virtual environment, or excluded from it?

The analysis of gestures helps with answering these questions. Participants who could not touch authentic objects or 3D prints produced the highest number of gestures. This finding reinforces the idea that people think with the objects through manipulation; moreover, in absence of a tactile experience with ancient artifacts, manipulation is simulated with gestures and the experience with artifacts from *tactile* becomes *embodied*.

When people interacted with 3D digital objects, they produced a higher number of beat gestures than they do when interacting with other media. The number of beat gestures seems correlated to people's perception of the virtual environment; that is, people recognize a gap between their material essence and the *virtuality* of the artifacts. This gap is filled with beat gestures that compensate for the lack of a material experience with the artifacts.

To specify, our experiment required participants to describe 3D objects displayed on a computer screen. It was not an immersive experience with the artifacts, which we would have replicated if we inserted our objects in an immersive environment, such as the Power Wall, or C.A.V.E. systems (see chapter 3).

The fact that participants in the 3D condition produced a far greater number of beat gestures while describing the objects seems to indicate that the screen was conceived as a *frame* between the material and the digital. What is a frame? Kant defines it *parergon* (Kant 1952: 85), a hybrid of outside and inside. For Kant the frame can be defined *parergon* especially when it is beautifully decorated to "recommend the panting to our attention by its attraction" (63-64). Derrida defines a frame an *edge* between inside and outside, which can be both inclusive and exclusive. Gregory Bateson (1972) clarifies the latter definition, specifying that a frame is not only physical but can also psychological:

> We assume that the psychological frame has some degree of real existence. In many instances the frame is consciously recognized and even represented in vocabulary (186).
>
> Rather the actual physical frame is, we believe, added by human beings to physical pictures because these human beings operate more easily in a universe in which some of their psychological characteristics are externalized…
>
> (a) Psychological frames are exclusive, i.e., by including certain messages (or meaningful actions) within a frame, certain other messages are excluded.
>
> (b) Psychological frames are inclusive, i.e., by excluding certain messages certain others are included. The frame around a picture, if we consider this frame as a message intended to order or organize the perception of the viewer, says, "Attend to what is within and do not attend to what is outside."
>
> (c) Psychological frames are related to what we have called "premises". The picture frame tells the viewer that he is not to use the same sort of thinking in interpreting the picture that he might use in interpreting the wallpaper outside the frame.
>
> (d) …a frame is metacommunicative. Any message, which either explicitly or implicitly defines a frame, ipso facto gives the receiver instructions or aids in his attempt to understand the messages included within the frame. (186-188).

Following Bateson and Derrida we can conclude that the non-immersive experience with 3D digital artifacts is *exclusive*, because it separates the material world from its digital representation, but also *inclusive*, since it produces interaction, engagement and excitement for the medium (as shown in the previous chapter).

Differing from what was observed with 3D digital copies, we found that participants in the *Look* scenario (i.e., participants looking at the artifacts exhibited in a window-case) used the fewest amount of words and their movements seemed constrained by the presence of showcases. Showcases seemed to represent a barrier that affected the experience with real-life artifacts. The objects were viewed as distant objects from the past that needed to be protected, and this situation created a social distance between observer and observant. How can we eliminate this social distance? Tactile experience with 3D prints could compensate with the lack of a tactile experience with real-life artifacts. However, we should not forget to specify that these prints are not authentic copies of the original, since they cannot replicate important properties such as weight, texture and shape.

The current work is preliminary and many intriguing questions remain. What may be influences (ethnicity, gender, education, socio-economic background) in varying perceptions of authenticity in relation to objects, virtual and real? And importantly, how might these results vary across cultures? It would also be interesting to explore how people with particular affiliation with tangible heritage interact with both authentic objects and their reproductions in different media states.

Another interesting aspect will be to explore how people interact with objects inserted in immersive systems, such as the Power Wall, to see to what extent these systems facilitate perception, simulating a tactile experience with the artifacts (fig. 51).

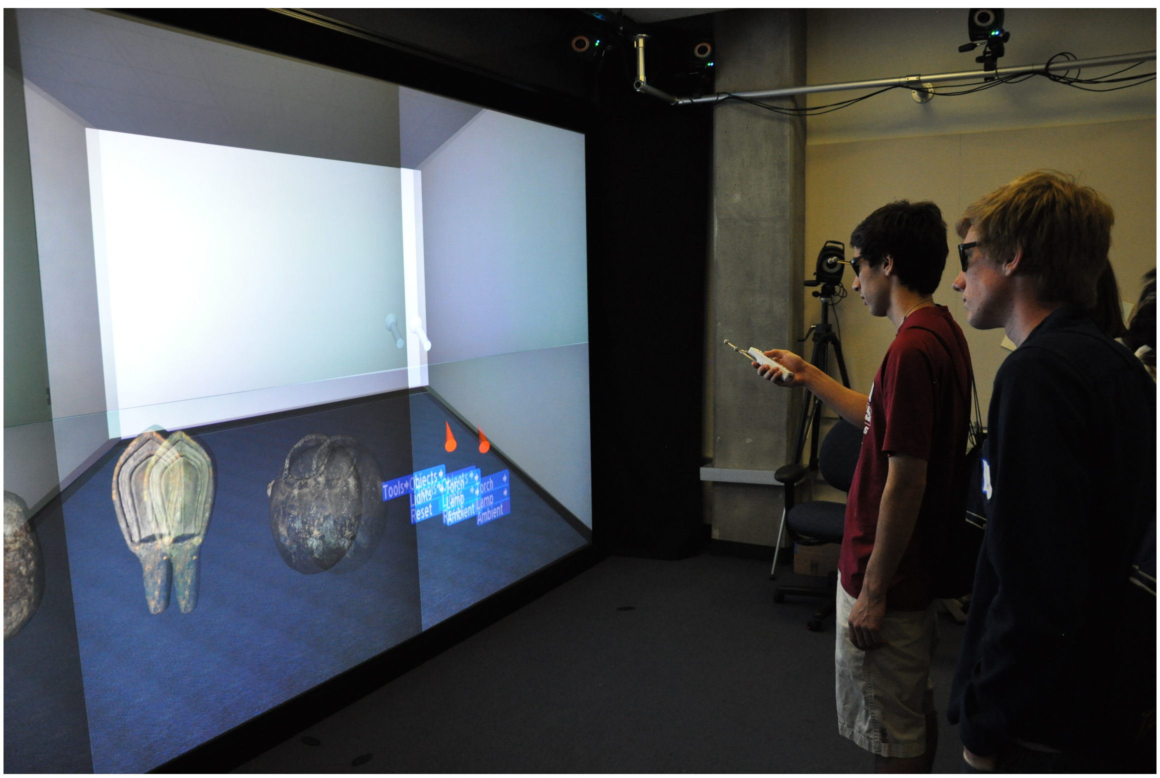


Figure 51. Artifacts exploration in the Power Wall.

As explained, this research presented objects out of their context and showed how, in certain cases, when participants found it difficult to guess the former function of an object, they attempted to associate the object to other objects present during the experiment. The inter-object associations helped them describe and interpret the objects under analysis. Further analysis will help to clarify how context functions as gateway between people of the present and objects from the past. Does the presentation of objects in-context help people to overcome the absence of authentic objects?

Future research should also address how different media enhance affect and emotions for artifacts and the past. Our experiment revealed how people feel various emotions touching the artifacts. Emotions connected people to the objects, but also to some of their past memories. What happens to our emotions with objects when these objects are presented in modalities other than the tactile experience? How do people emotionally cope with inauthentic artifacts? Some scholars argue that when an object becomes digital, it loses evocative power. Susan Yee, architect workings at Le Corbusier archive in Paris, gives her perspective on the topic stating that when objects become digital they lose their evocative power (2007: 30-37). To explain her argument she draws on her personal experience with Le Corbusier's work and explains that her most emotional moment of intimacy with this work was when she could touch the overall plan drawing for the unbuilt Palace. She was emotionally moved and felt close to Le Corbusier, as she walked around the drawing. These emotions disappeared when Yee was shown Le Corbusier's digital archive. She looked at these digital scans and, even though she was aware of the importance of the digital archive for public access and mass consumption of Le Corbusier's work, she had the feeling that her intimacy with the author and his process of projecting the Palace of the Soviets was lost: "The new Le Corbusier digital database did things for me. It allowed me to do things that I could not do before. I could search it, manipulate it, copy it, save it, share it. But what did it to me? It made the drawings feel anonymous. I felt no connection to the digital drawings on the screen, no sense of the architect who drew it" (34).

This quote invites us to think about a dilemma embedded in the production of digital heritage; that is, can digital heritage be as touching and evocative as its physical authentic counterpart?

Looking ahead to future interdisciplinary or multidisciplinary works concerned with the use of new technologies in heritage studies and development of the research presented in this manuscript, two approaches commonly used for interdisciplinary studies—which is important to discuss and problematize in this chapter—are proposed:

1. The first approach is to train individual researchers in the interdisciplinary perspective. Scientists possessing a strong background in both heritage studies and cognitive science fields can formulate more appropriate theories to address issues related to digital preservation and communication of the archaeological record. Some scholars (Friedenberg and Silverman 2006: 440) argue that this solution has some limitations, since scientific practice requires a high degree of specificity and focus, and researchers should acquire a high level training in multiple alternative disciplines.
2. A second approach is interdisciplinary cooperation, which sees a team of investigators from different disciplines working together on a common project. This solution seems the most practiced today, and generated findings unlikely to have been obtained by departments and programs operating autonomously. This second solution requires integration across discipline-specific methodologies. It has, however some limitations too, which deal with the very nature of inter- and multi-disciplinary collaborations. For instance, for scholars with a narrow discipline-specific background, it might be difficult to generate research questions that cross the boundaries of their discipline.

One solution to overcome the limitations of the previous two approaches would be to combine a strong discipline-specific training with basic knowledge on theories and methodologies of other disciplines (e.g., cognitive science) and then start interdisciplinary collaborations. This approach allows to overcoming the limitations of a discipline-specific focus, as well as increasing critical awareness in favor of a genuine interdisciplinary approach. Moreover, it fastens research design and data analysis, since all stakeholders involved in the study can easily problematize findings and interact to assess the original research design. The latter approach was adopted for this study and generated results that can be applied to different disciplines, giving space to the development of new research questions and theories.

In conclusion, the results reported in the last chapter are preliminary, but they have implications for research on a variety of topics: first, they help with clarifying how narratives on material heritage are constructed, defining heritage as a multivocal process that challenges traditional subject-object empirical logics; second, these results shed light on the relation between gestures and fictive motion, contributing to studies on embodiment and the conceptualization of space. They have also set the stage for future research on the link between objects perception and new media. In addition, this study hopes to become a useful instrument to assess future projects with artifacts on display. For instance, detecting the type of gestures used to describe the artifacts could improve 3D virtual storytelling and make the experience with artifacts more inclusive (fig. 52, 53).

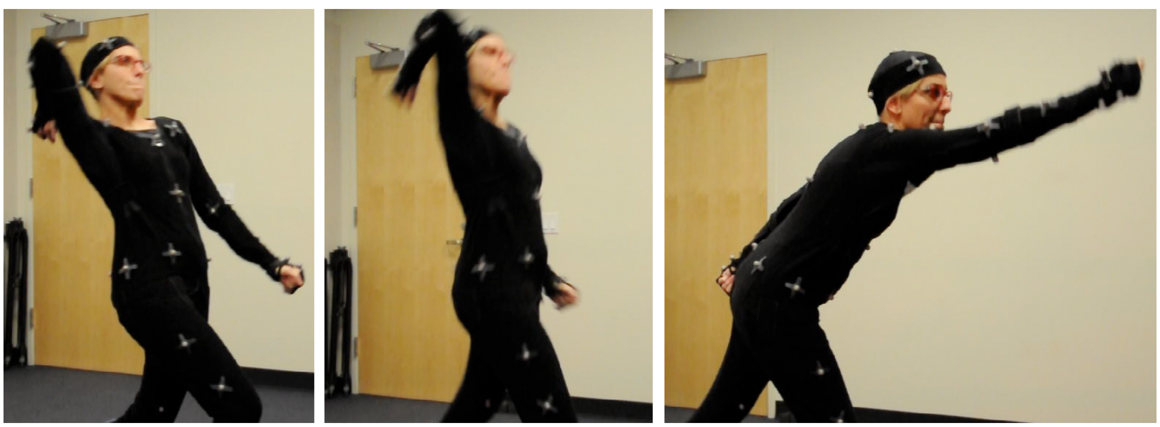


Figure 52. Motion caption for virtual storytelling. Explaining how to use the projectile point.

Through empirical analysis and a strong epistemological foundation, this research contributes to the following theoretical debates:

1. It influences the interdisciplinary study of material culture from the past, which emerged in the 1980s and developed from museum-based studies of "technology'" and "primitive art" during the late nineteenth century related to the

idea of relationships between the "social"/"cultural" and the "material."

2. It helps to clarify how people deal with the inauthentic (i.e., absence of original artifacts).

3. In a broader theoretical perspective, this research clarifies how people think with things; this is the first time somebody study has focused on the relationship between people and *object-from-the-past*. The combined study of gestures and speech (which is also in its experimental stage in cognitive and information science) helps to clarify to what extent body and mind concur to the thinking process, contributing to the ongoing debate between scholars supporting either Cartesian and Embodied Cognition theories.

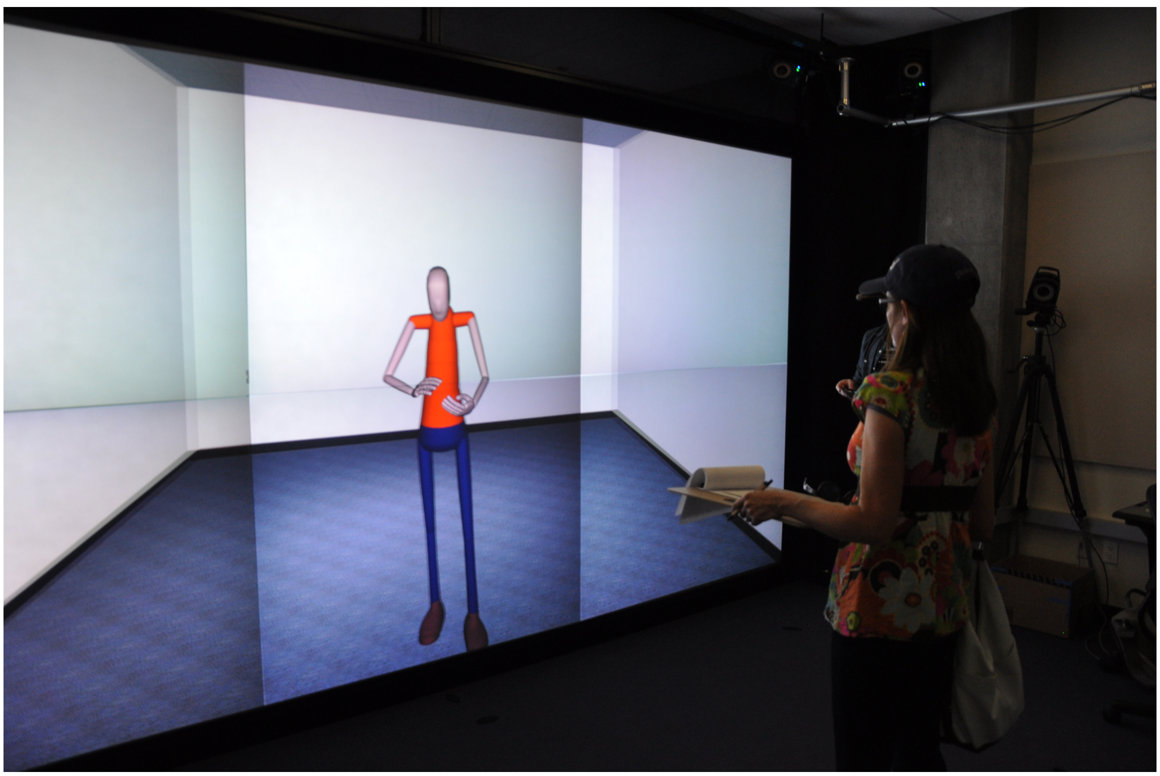


Figure 52. Three-dimensional virtual storytelling. Avatar reproducing the motion people perform while using a grinding stone.

More specifically, results of the research allow technological advancement in the following sectors:

1. *Museums:* this research will allow curators to (re)think their collections and how their objects are showcased for any public community. Results of this study will also help museum curators to sensibly select technologies and media based on the objects to be displayed.
2. *Heritage management:* results of this research will help heritage management specialists to design 3D digital preservation projects, considering how 3D technologies affect the interpretation of the archaeological record and how different artifacts necessitate different 3D preservation strategies.
3. *Archaeology*: the possibility of sharing 3D reproductions of the archaeological record with scholars worldwide represents a revolutionary change in archaeology. In the last few years, 3D digital collections of artifacts have significantly increased. Since 3D reproduction of artifacts can affect the perception of the real-life objects, results of this research will provide archaeologists with an instrument to think about high-quality metadata to accompany each 3D reconstructed object. These metadata will include annotations of meaningful parts or attributes of an object that are supported, emphasized, or made more difficult to understand through the 3D model.

At the present moment, the hope is that this interdisciplinary research will boost future studies aimed at understanding how human-objects interact and enhance best practices for preservation and presentation of cultural heritage.

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