Gazed Pottery: an Archaeometric-Cognitive Approach to Material Culture Visuality

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Highlights

Eye-tracking analysis tests the impact of material culture on perceptual processes.
Visual behavior reacts distinctively to different material cultures as shown by the differential visual responses provoked by prehistoric pottery from distinct periods.
Eye-tracking of prehistoric pottery allows to identify the oculomotor responses produced by distinct ceramic styles.
Visual behavior is imposed by the material shape of the object in a way that is consistent with the cultural style.
Eye-tracking of prehistoric ceramics underpins the material engagement of visual cognition.
Future possibilities of eye-tracking analysis as an archaeometric technique for cognitive Archaeology.

Graphical abstract

Abstract

This paper presents a study of visual perception through the application of eye-tracking of prehistoric ceramics. The study is a feasible methodology to understand the agency of material culture through quantitative techniques, which allows for the analyses of possible relationships between visual behavior, material culture and social complexity. In particular, the horizontality of gaze is shown to be associated with pottery from early periods and its verticality increases in pottery materials from later, more complex societies. These, and other results, confirm that differential patterns of visual response by observers are determined by the material characteristics of each ceramic style. Implications for improved interpretation of archaeological phenomena are discussed including the possibilities of new applications for heritage valuing. Therefore, eye-tracking analysis appears to be a powerful and profitable archaeometric technique.

Keywords


(1) Research problem: towards an Archaeology of Visuality

Visuality, even if we take into account the criticisms levelled against ocularcentrism (Levin, 1993), is a central issue for humans and for research. What we see, how we see it, how we are seen by others, how we react to what we see or when we are seen, form a fundamental facet of mankind’s relationship with the world, with things and with other beings. Important aspects such as the self, the social identity, the community, the built environment or symbolic meaning are all related to the visuality because, one way or the other, all the visible is symbolic (Criado-Boado, 1993; Criado-Boado, 1995). Understanding the arrangement and social meaning of e.g. architecture, urban settings, the landscape, or bodily practices (adornments or tattoos), requires us to carry out different sorts of visibility analyses. But do we really understand everything that “visibility” implies as a social, symbolic and cognitive process? Do we know if there is an inextricable yet accountable relationship between these processes? Do we even know how material culture affects or even produces visuality?

Cognitive studies in the humanities, cognitive archaeology, and before all of this, philosophy and phenomenology, have approached issues of visuality and perception, and have produced a significant body of knowledge on the topic. However, these studies often answer these questions in the best tradition of the humanities, in an essentially reflexive and speculative way. They offer sensible interpretations based on applying the consequences derived from the most advanced results of cognitive sciences to archaeological and anthropological case studies. But in
many cases they are not accompanied with data or methodological tools that can be used to construct any type of “evidence” (a cutting edge of the archaeological method, as argued by Chapman and Wyllie, 2015). Archaeometry, on the other hand, can make a major contribution by a “more integrated approach” (Martlew et al., 2008; Torrence et al., 2015) and linking archaeological approaches to the social dimension (a “social archaeometry”, Jones, 2004; Martinon, 2008, echoed by a recent symposium Thinking Archaeological Science held in Stanford University in May 20141). Our approach, drawing on this renewed archaeometric agenda, intends to supplement the archaeological sciences by facilitating their engagement with the social and cognitive domains of human reality.

Cognitive archaeology and anthropology have shown that large shifts in historical or ethnographic societies have provoked major changes in terms of perception and cognition (Malafouris, 2013), something that has also been accounted for art historic styles by cognitive sciences (Graham et al., 2010). However, the divide between disciplines and historic or archaeological periods, whose study demands specific know-how, has made it difficult to provide an accurate account of the shape and rationale of the interaction between social, stylistic and cognitive changes. For example, a main problem for dealing with this sort of research is to produce reliable data in order to consider cognitive issues in the past. To attain this, in the present study a synergic alliance between archaeology and neuroscience (Renfrew et al., 2009) was undertaken. Following the science-orientated revolution in Archaeology (Kristiansen, 2014), we bring together scientific methodologies and techniques in order to explore the very possibility of providing archaeometric data to sustain cognitive research. We combine this with reflective, interpretive research: phenomenology with a critical use of technology. In doing so, we intend to overcome simplistic theoretical divides and look for a new positive synthesis of systems to produce new knowledge.

Our purpose here, then, is to examine the gaze from the perspective of material culture based on eye-tracking analysis (ETA). The fundamental research questions are: Is there any chance to approach the visuality of material culture from an archaeometric perspective? If such, how could an Archaeometric-Cognitive Approach to Material Culture enhance our Knowledge of Visual Perception? And thus, what can we learn about material culture, the processes of materialization, human life and the Mind itself? (DeMarrais, 2005; Renfrew and Malafouris, 2010). These issues have been studied mostly in relation with Human evolution, in the very long-term (e.g. Haidle, 2010; Haidle et al., 2015). This paper aims to address them in more recent chronologies and with a dynamic and innovative way, as anticipated in Wells (2012), by using solid data and applying a new set of rigorous methodologies. These then will contribute to implement the “spatial turn” (Earley-Spadoni, 2017) on archaeological visual analyses, overcoming either the overly descriptive and insufficiently transparent phenomenological approaches (Bernardini et al., 2013) or the GIS quantitative approaches to the effects of perception (Paliou et al., 2011; Eve et al., 2014) with a proper study of the perception itself. The first results of this research were recently presented in Criado-Boado et al. 2019; here we wish to deep in the methodologic and technical issues of this research to foster the adoption of eye-tracking in archaeometric research.

(2) Theoretical remarks and working hypothesis on visual responses to materiality

Over the last 30 years, archaeology has changed as a result of the intertwining of the archaeometric tendency with the new heritage politics and theoretical debate. Theoretical developments which for many years were focused on the polarisation between processual archaeology and post-processual archaeology, have now overcome the most dogmatic aspects
of this confrontation making it possible to integrate contributions from both fields in positive approaches. Thus, at the same time as they gradually lose their specific identities, an emerging paradigm gradually begins to take shape (Kristiansen, 2014). This new disciplinary consensus is supported by the greater degree of reflexivity embedded in archaeological practice (as in other disciplines from the humanities, mainly owing to a renewed impetus from the philosophy, theory and history of science), this being one of the best legacies of post-processualism (Criado-Boado, 2016). This consensus embraces the fact that research has to be based on rigorous methodologies and solid data, as a result of the development of archaeological sciences and processualism. A positive combination of both traditions, could open a renewed road to objectivity, that is much needed today to contest current trends in fake science and alternative rights (González-Ruibal et al., 2018).

These developments, fostered by an interdisciplinary debate with philosophy, anthropology and other social sciences, have balanced out the emphasis in epistemology and representationalism towards an object-oriented perspective, leading to a growing interest in material cultural studies (Brown, 2004), new thing-theory (Boivin, 2008; Alberti et al., 2011) and social ontology (Ihde, 2002; Gosden, 2008) emphasizing that, as Olsen et al. (2012) puts it, “archaeology is first and foremost a concern with everyday things”. This synthesis and its respective problems can be clearly confirmed in recent developments in the field of cognitive archaeology (Renfrew, 2010). As this synthesis refers to a processual genealogy, it deals with research problems that post-processualism has partly forgotten or ruled out: it seeks out a large, evolutionary perspective, capable of systematically accounting for characteristics of humanity and human live. The effect is that now we can encompass an integrated approach to the human engagement with material culture, and to the interaction between material culture and technology with the evolution of the human species and its capacities (Mithen, 1996; Thornton, 2012).

These insights have focused on the agency of material culture as a new research priority: how it operates, which effects it produces, and what its relationship with other agents is like (Knappett, 2005). This points out the physical world, not as an external setting of human history, but instead as a medium that interacts with the social and individual histories. Agency is meant as the basic capacity that organisms have for actualizing changes in their environment (Johannsen, 2012). So material agency is not an isomorphic extension of human agency (Heidegger, 1994; Malafouris, 2013) but it is “active in the manner of objects” (Gosden, 2001). Objects, then, have a function for humans that goes beyond being an instrument, unless “instrument” was understood as something that is embodied in humanity itself, and through which this modifies its environment: the hammer for the carpenter, the biface for the hominin (Knappett and Malafouris, 2008), or the basket for its maker (Ingold, 2011), could be considered so intimate and embodied as a stick for the blind person (Merleau-Ponty, 1945) or a prosthesis in a person with a disability.

Overcoming reductionist models based of duality brain/body or mind/brain, neurosciences now assert that the brain and the body are extended in the instruments and therefore extend into the world (Dunbar, Gamble and Gowlett, 2010). However, these topics, when approached by the Humanities, are often dealt with from a pure narrative, qualitative, speculative research. Either the new thing-theorists or onticologists (Bryant et al., 2011) or, quite paradoxically, the processual-cognitive partisans (Renfrew, 1994) often lack empirical method and data (Thornton, 2012: 2036).

Considering that material culture is something that embodies human action and materializes human mind, identifying the relationships between mind, world and matter becomes possible through the cognitive mechanisms of perception, and particularly visual perception. Visual perception does not occur mainly in the retina, but in the brain involving high level cognitive functions (such as context, abstractions, concept formation, linguistic meanings, memory, Bar 2004, Geisler 2008). A question to be raised here is to what extent the outside (the visual stimuli) interacts with the visual cognition. Our strategy is to pay attention to visual perception and to
analyse its cognitive mechanisms by concentrating on visual stimuli and their changes. This can be feasibly sought from material culture and material images, which at the same time allow one to introduce the history and social dimension of the study of the visual process. Visual perception is not disembodied (Braidotti, 2006) but embodied and enactive (Noë, 2004) and combined with emotion, memory, and motion (Bagnall, 2003; Thrift, 2004; Hutchins, 2010; Jones, 2005, Stafford, 2001). It speaks for the entanglement of humans, things and the world (as stated by Hodder, 2012), and bridges culture, biology and matter. The transitive engagement of visual perception with a world of objects has been remarked upon in different domains; for example, critical museology posits the existence of a two-way interrelationship between the person who observes, and the object that is being observed (Bagnall, 2003; Thrift, 2004). This is because the statistics of the world that influence/affect human perception do not only include the natural world, but also embrace the artificial (Graham et al., 2010). As a result, the way of looking is a powerful proxy of testing hypotheses about the visual statistics of the world.

To put in other words, our intention here is to solve the Sapiens Paradox (Renfrew et al., 2008: 1935) by finding the “tracer” that Malafouris (2013) wisely demands for demonstrating the material engagement of mind. A good tracer in our view is the behaviour of visual exploration, which through oculomotor movements links the gaze of the external world with the visual part of the brain (Figure A). This can be easily studied with techniques and equipment to perform an eye-tracking analysis (ETA). As will be shown, this sort of approach to visual perception is feasible in archaeology. This approach investigates the fundamentals of visual perception in relation to its cognitive nature. The working hypothesis we will review is that the physical features of a material object predefine the way the object will be explored by the observer. The key point is that not only the more informative parts of an object attract a greater number of visual visitings, but also that the shape of the object drives the visual behaviour to such extent that this can be predicted from the materiality itself. Visual behaviour (ie. eye movements) is the cognitive response to external stimuli: materiality imposes a movement trend and visual cognition reacts driving an oculomotor feedback. Hence, the analysis of visual movements by ETA data would allow us to observe the effect of materiality in the perceptual-cognitive processes. We can learn about the pattern of the material culture, but also about the capacities and functions of cognition.

(3) Materials and methods: eye-tracking of archaeological material culture

We performed an exhaustive study of one specific domain of material culture (ceramics) to explore the visual and perceptual reactions of humans to material culture, encompassing a series of pots from diverse prehistoric contexts, involving the analysis of information about these materialities together with analyses of visual responses of observers, and including a vast number of experimental subjects (far from what is usual in cognitive or psychological experiments). Our experiment took place on materials from Galician (NW Iberia) prehistory and protohistory.

The main limitation of ETA is the impossibility of presenting a wide range of objects to the volunteers because effects of fatigue, adaptation and lack of attention (a maximum of 30-40 images/experiment is recommended), it was critical to select a sampling of representative pots for each periods. Fifteen pots were chosen, each three representing the formal variety of the five main ceramic styles from the prehistory of Galicia in the NW Iberian Peninsula during the Mid Neolithic, Late Neolithic (Prieto-Martínez, 2017), Early Bronze Age (ie. Bell Beaker pottery, Prieto-Martínez, 2009), Middle Iron Age and Late Iron Age (González-Ruibal, 2004) (Figure B.1/B.5).
Pots spread for a long period of time, from 4000 BP -0, embracing a significant time span ranging from the middle stages of the Neolithic (Megalithism) through to the end of protohistory, and covering a variety of socio-cultural forms from simple communities based on the house and the family which are relatively egalitarian and building communitarian (Whitehouse et al., 2014), through to social formations based on hierarchisation, ranked societies, warri orship, aristocracy and finally complex proto-states social formations (Table A, see Parcero and Criado, 2013).

The pots replicas were made using a process which in itself was an experimental archaeology project (see Supplementary material). For operational reasons, instead of carrying out the analysis using physical pieces, high resolution photos were presented on a computer controlled monitor. This may look surprising to those who are not experts in ETA techniques and the study of visual perception, who in principle could think that the observation of an image and the process of decontextualisation that the analysis itself provokes, would invalidate the data obtained. However, specialists in ETA know that this does not affect the quality of the data. Even though to record normal observation conditions and to account for the differences of seeing material culture (3D objects) and 2D images (as paintings, drawings or monitor images) is desirable, what at first has to be studied is the dynamic of visual exploration. Thus, a good starting point is to work with on-screen images, as most ETA does: whatever is lost by altering the “natural” observation conditions is recovered by having greater control over the data.

Eye- tracking is a recent technique that has not been sufficiently exploited in many fields. It was refined by Yarbus (1965-1967), following early research from before the Second World War. This methodology was abandoned when psychology replaced its interest in mentalist issues (such as perception or attention) by a behavioural approach, then replaced at the end of the 1960s by cognitivism. Its use did not become widespread until the mid-1990s; more than 90% of the ETA publications correspond to the last 25 years, which is thought to be too recent to allow for adaptation by Archaeology. This, and due to the lack of consistent research questions, prevented ETA from being used in archaeological or material culture studies. Actually we just know a single paper on ETA applied to archaeologists (Tokitsu, 2004) and it was done with the purpose of realizing the differences between skilled experts and novices while observing pottery, but the research orientation is totally different of what informs our approach here. ETA is becoming increasingly important, with an exponential growth in its applications, helped by its robustness (see Holmqvist et al., 2011) and the availability of more versatile, powerful and economical equipment. Nowadays, ETA is being rapidly implemented in many different domains and in diverse hardware (including smartphones) to promote a friendly interaction between the user and the machine. Numerous studies have applied the use of ETA to artistic paintings, starting with Buswell (1935), the first systematic study using ETA in the world of art. It was then widely used in art by psychology (eg. Kapoula et al., 2010; Segev et al., 2014). Nevertheless, the main focus of this research has always been on studying the mechanisms of visual perception, and not learning about art or material culture in itself, or about their relationship with humans and the mind.

Eyes are never quiet. The phases of real immobility, which are called fixations, last on average 330-180 ms (Rayner et al., 2007). Even during fixations the eyes are in movement. There are four types of eye movements: saccades, micro-saccades, drifts and tremors. Saccades and micro-saccades are rapid eye movements, from one fixation to another, through which the eyes identify points of focus. The drifts are very slight movements to tune the fixation. The tremors, on the other hand, are a constant flicker, 3-4 Hz speed, which prevents the world from fading into view by adaptation of the photoreceptors. The processing of visual signal mainly occurs during long fixations on points of interest. The information of visual perception is obtained during the fixation and simultaneously other regions of interest are identified to be straightaway explored. During saccades, the brain does not process visual information.
In this ETA study, we analyzed saccades and drift. Saccades can follow any direction and adopt any length. The quantitative analysis of saccades is a superb way to characterize the visual exploration of an image by observers. The analysis of the distribution of the saccades' angles is a powerful tool to reconstruct the visual exploration and allows comparisons between observers and images. Drifts were also considered in this research but we concluded that they are primarily a movement to predefine the fixation: since the results from their analysis fitted well with those provided by the saccadic movements and did not provide further substantial information, this paper is based mainly on saccades, and further information on drifts are provided as Supplementary Material.

More common saccades angles in free-viewing tasks are distributed around the horizontal or vertical axes, both in natural and fractal images (Foulsham et al., 2010). Preliminary results of the present study, confirmed that depending on the image, saccades close to horizontal (0° or 180°) or close to vertical (90° or 270°) angles prevail. This shows that a good procedure to compare images is the rate between horizontal (angle between 45° and -45° with respect to horizontal) and vertical (45° and -45° with respect to horizontal) saccades. To study this, we defined a V-index (Vi), ie. a verticalization index of saccades and drifts that expresses the rate between vertical and horizontal saccades. Its formula is \(Vi = (W*NSV-H*NSH)/(W*NSV+H*NSV)\), H being the height of the screen in pixels, W its width, NHS is the total number of horizontal saccades, and NSV total number of vertical saccades. The formula was sized to the dimension of the screen, as stated by Lau et al., 2001; (further details in Supplementary Material).

Eye movements were collected using an Eyelink II (SR Research Ltd., Osgoode, Ontario, Canada) 500 Hz eye tracker. It records both eyes independently, at a sample frequency of 500 Hz. Each sample/measurement includes the spatial position of the centre of the gaze (recorded in X-Y coordinates) and the pupil size. The saccade velocity is inferred from the shift of positions over time. Based on this, analyses were carried out in order to determine: saccade directions; saccade velocity; fixation duration; average distance of fixations to the center; probability, range, amplitude, and peak velocity of horizontal and vertical saccades; landing of first saccade; latency, amplitude, and peak velocity of first saccade; pupil diameter; heating maps (mapping of eye visit distributions on pots); micro-saccades; and several parameters of drifts (ie. slow eye movements). A great amount of information was generated which facilitated complex analysis. Differences in terms of gender, age and sample population were taken into account for all of the variables (see Supplementary material). The presentation of stimuli and coordination between the registration system and the presentation system was implemented in MATLAB based on the Psychotoolbox and the specific toolbox for Eyelink. Data were processed with nonparametrics statistics, in particular with the Kruskal and Wallis test.

Besides ETA, we employed some other techniques to analyse visual images of material culture, including the density and the complexity of visual information by means of maps of visual saliency (Itti, 2007), and of height-to-width aspect ratio (AR), the data of which were processed using MATLAB.

The study involved four different experiments and 99 subjects in total (average age 34, age range 23-59) who carried out 124 different tests (25 people repeated Experiment 4 as a part of the experimental strategy), as a result of which we finally had 117 valid tests.

In the first experiment (E1 in this paper, code Ex14061 –this code identifies the raw data of the experiment, available on the open access repository Digital.CSIC), a series of six pots were presented in two consecutive batches, the first by free viewing (FE) and the second by directed observation (DO) through questions about the pot that were asked to the observer before presenting the image. Each piece belonged to a five different ceramic style plus one distractor and was viewed for 30 seconds. The pieces were presented to each subject in a random order to prevent any bias in the results. In the second experiment (E2, code Ex14062), a series of black
and white drawings of the same pots were presented in order to avoid the usual differences between images due to their distinct luminance (i.e. the amount of light emitted by an object or surface or, more precisely, a photometric measure of the luminous intensity per unit area of light travelling in a given direction). Such circumstances could affect the pattern of eye movements and especially the pupil response, as well as their saliency. In the third experiment (E3, Ex14071), photographs of the same pieces were shown, but this time replacing the front view with perspective views, making it possible to see the relief and shape of each piece more clearly, and changing the position of the decoration; (Figure B).

Finally, after first processing and interpreting the results of tests E1 to E3, we designed the fourth experiment (E4, code Ex14091) to completely change the observation conditions in order to force to a maximum the results obtained in the previous experiments. The observation time was reduced to 15 seconds and a total of 40 drawings were presented, belonging into 8 different series (Figure C): one included the five pots of the previous experiments (the undecorated pot was not used in this experiment); the other two included five new pots from the same periods. This was done with the aim of confirming whether they produced the same visual response as E1-E3. Another five were variations in the conditions in which the pots of the first series were presented, what was a way to check under very different situations to what extent the materiality of each decorative style determines the pattern of visual observation (as we had seen in E1, E2 and E3) even if we totally altered the position or location of the decoration on the pot; also the decorations and shapes were exchanged, eliminating the decoration from the body of the pot in order to see if the visual exploration pattern is influenced by the shape of the pot itself, and we even laid the pots on their side, to test whether the sense of visual exploration of the pot and its decoration remains the same if the position of the pot was changed.

A total of 68 subjects took part in E1, seven of whom had to be excluded from the analysis due to the recording conditions. The sampling was gender balanced. The mean age of the remaining 61 subjects was 36 (range of 15–58). The subjects conformed 5 different sample populations based on their degree of expertise in the experiment: a first group consisting of 13 people who had a high degree of specific knowledge and were aware of the working hypotheses, all of whom belong to the primary institution (Incipit) for this research (mean age: 40); a second group of 12 people had a high degree of specific knowledge (archaeologists) since they knew the material but were not familiar with the working hypotheses (mean age: 34); a third group was comprised of 11 specialists in the production of ceramic items (mean age: 49); and finally a group consisting of 25 persons of the general public had no specific familiarity of the pottery or the working hypotheses (mean age: 30).

A total of 10 subjects took part in E2 (mean age 32), and 10 subjects in E3 (mean age: 37). Finally, in E4 a total of 36 people took part, of whom 25 had already taken part in the previous experiments (mean age: 34), but none of them were members of the Incipit and they were unaware of the project.

(4) Results: different pottery styles provoke distinct visual behaviours

The analysis of E1 showed that the task (FE or DO) did not affect the visual exploration, asthe outcomes were practically the same (Figure D1), and implies that providing background information on the pots (DO) did not affect the ETA results. The results of E2, revealed that visual reaction did not change substantially either observing photos or drawings (Figure D2). We also confirmed that the visual behaviour in 30” tests was consistent with this in the first 15”.

Therefore, we can avoid noise and simplify the experimental process by reducing the time of observation, which allowed to increase the number of images to be presented. Therefore, in
forthcoming experiments we decided to mostly use drawings. Next, E3 showed that the visual exploration of the image when observed frontally or with a 3D effect were virtually the same (Figure D3). Even though the eyes movements become adapted to this change in the position of the object, the results show that the subjects were still looking at the same points and following the general trend of the decoration.

Altogether our analyses show a clear trend of increasing Vi through chronological time for all the experiments. There are no gender (Figure E1) or age (Figure E2) differences. Moreover, all the sampling populations display similar Vi values. A minor exception is the “non-expert” group, which presents smoother fluctuations than the three “experts” groups (Incipit members, archaeologists and potters) (Figure F). This implies that the non-experts are less reactive to the materials (Fig. A.6). Experts’ Vi shows a strong increment when observing the bell beaker (pot 3), while non-experts’ visual pattern is not so disruptive as it is for the experts. This could be because of the awareness of experts about the significant vertical differences that bell beaker decoration contains despite of its homogeneous appearance. Non-experts probably assume that bell beaker decoration adopts a repetitive pattern.

Further on, we estimated to what extent the visual behaviour for each pot could be determined by the general form of the pot and the range of its decorated belt. For this we analysed the aspect ratio of each pot, using the formula AR = (V-H)/(H+V). Bronze Age and Iron Age pots (3, 4 and 5) display an AR (in form as much as in decoration) that is more vertical than Neolithic pots. The comparison between AR and Vi show that expert groups mainly focus their attention on the decoration, while the non-expert groups gaze the pot more freely and following its salience, either caused by the decoration or by the texture and colour of the pot (Fig. A.17).

To contrast these results, we analysed the visual exploration patterns of the pots during E4, where the original pots were artificially modified (Figure C). The consequence of this experiment was that the decoration, supplemented by the form of the pot, imposed the pattern on the visual response to any observer. In other words, this confirmed that the material characteristics affect the visual behaviour. For instance, the comparison of the Vi of the series undecorated and the decorated (original) series, shows that the presence of the decoration reinforces the Vi (Fig. A.10). That is, decoration enforces horizontal exploration in pots 1 and 2, and vertical exploration in pots 3, 4 and 5. The exchange between forms and decorations (Fig. A.11) confirms the effect of the latter on the visual exploration of the pots. Thus the incorporation of pot 5 decoration (from the Late Iron Age) on pot 1 (Middle Neolithic, a pot whose AR and morphology presents the most horizontal Vi pattern), transforms its Vi in vertical. The same occurs when decoration of pot 4 (Middle Iron Age) is transferred to pot 2 (Late Neolithic). Respectively, the transference of the decoration of pot 1 (MN) to pot 3 (a bell beaker with a totally vertical Vi), horizontalizes this pot, and the same occurs when decoration 2 is incorporated in pot 5 (Late Iron Age). Meanwhile the transference of bell beaker decoration of pot 3 to pot 4 (MIA), reverts its Vi in the highest one. Finally, the Vi of the “laid” series (Fig. A.15) show that a horizontal decoration is transformed in a vertical one when the pot is placed on its side, while the vertical decorations trend to become more horizontal.

(5) Conclusions: from the order of human materiality to the human engagement with technology

Our primary observation is that, obviously, the decorated regions are significantly more visited than the non-decorated regions, and that the decoration arranges and orientates the visual exploration (Figure G). Due to the novelty of this thematic, there are few reference studies with which we can compare this. Some studies carried out for marketing purposes on the visual exploration of jam jars (Piqueras-Fiszman et al., 2013) indicates that the visual reaction when
looking at them is mainly punctual, focusing on the items of relevant information that are given priority on each type of container (i.e. the photograph of the jam, or the original fruit, or the trademark). This is actually the basic principle of the studies of visual salience (Itti et al., 1998). In spite of this, the decoration of archaeological pots forces the gaze to shift towards exploring the body of the pot and comprehend it in the double sense of understanding and apprehending; (this was also stated by Tokitsu, 2004, but never considered in certain detail).

There are general consequences that arise from these results. Primarily, these indicate that through time there are significant changes in how visual perception operates. Our pots show a gradual transition from a visual behaviour in which firstly predominated a simple horizontal gaze and then a more robust horizontal-linear gaze, to another in which gaze becomes gradually vertical and finally hierarchized. These ways of looking at material culture are compatible with the ways of gazing that are used in other human phenomena and codes, from architecture to the social landscape. Bradley’s *Idea of Order* (2012), especially his emphasis on Neolithic circular arrangements, are supported in the light of these data; the same occurs with Ingold (2007) or other works (Criado-Boado, 2014 and 2000, recently confirmed by Llobera, 2015). These changes through material styles correlate with social complexity, and with the main features of each socio-cultural formation, in the sense that, whenever a society becomes more complex, a bigger verticalization of the visual patterns of its objects come into existence. According to our pots, horizontal visual exploration predominates in social formations with limited levels of complexity, while vertical exploration predominates in contexts marked by social complexity and ranking.

But leaving apart implications in terms of prehistoric sociology, this research points towards the agency of material culture and highlights new aspects that allow for a better understanding of its shape, role and meaning. A good example of this is Bell Beaker pottery, whose specific nature marking the transition between the Neolithic and Bronze ages (Kristiansen, 2014) is reinforced with perception studies which show that the bell beaker marks the changeover point from the fundamentally horizontal pattern of exploration for pots 1 and 2 towards the vertical pattern of pots 4 and 5, although the bell beaker is clearly different from the latter, in which the upward and downward eye movements are balanced. The Bell Beaker casserole (pot no. 3.2) is an excellent example of this effect, because, in spite of having a form with an AR that reinforces its horizontality (without decoration this form would be seen with a predominant horizontal gaze), the incorporation of beaker decorations forces a vertical visuality of the pot.

Visual heatmaps of eye fixations (Figure G) are highly intuitive and simple ways to illustrate the differences between different objects in terms of visuality. However, they do not tell us anything else. Actually, when ETA is reduced to indicate what parts of an object are mostly frequented, a large amount of information is lost. Heat maps tell a lot about the areas of the object that are seen but nothing about how the object is seen, what the visual behaviour is. This has been the main focus of attention of this research. It shows how a simple technique as the Vi enables the characterization of patterns of eye movements imposed by distinct styles of material culture.

(6) Further discussion

Presentism could be considered an inevitable limitation of this experiment since we are submitting prehistoric material to present day Galician people. For this reason, future research should undertake some wider dimensions, not only to do multicultural cross-studies, but also to access the multisensorial dimension of how perceptions are experienced. The understanding of perception is incomplete without taking into account the fact that our worldly experience is created through the body and shaped by our actions, combining our different senses and reflexes towards the exterior world. The idea of *action in perception* (Noë, 2004; Mitchell, 2005)
becomes the key for an Enactive Neuroscience of Perception (Varela et al., 1991), which is not only devoted to measure the cognitive and body reactions to visual perception, but is also in seeing how these interact with gestural exploration. Techniques of neuroimaging that allows to search for the “bell beaker neuron” so much as there is a “Jennifer Aniston’s neuron” (Quian Quiroga et al., 2005), will be so profitable as widening the objects to analyse, including historical paintings so much as architectural settings; to realize the differences between seeing a 2D image, a 3D object, or an object-in-context, is also needed.

Farther on, if these methodologies do not allow for the accounting of the original contexts in which material culture was created and used, then this approach can at least offer clear consequences about how the agency of things operates today, and which perceptual mechanisms trigger interactions with archaeological heritage. This can then be used to guide our relationship with heritage. What we today call “heritage” is a function of the social value added to specific cultural objects, the result of a categorization made in the present day (Criado-Boado et al., 2015). Thus, an account of how heritage is perceived by the public is required to know its social values and capabilities. Our approach to the cognitive dimension of material culture could permit on understanding of the subjective reactions produced when seeing heritage artefacts and images, when interacting with originals, replicas or ersatz. In this way, the study of the visual perception of objects would provide many practical applications for analysing the present day role of heritage in our societies and people relations to heritage assets, either objects, buildings or even cultural landscapes. This opens broader perspectives for, and new applications from, the study of material agency of objects through ETA.

The results of this study are also instructive and profitable for the immediate future. It has been calculated that by 2020 there will be 100,000 million sensors throughout the whole world capturing information of all kinds and processing it digitally, connected together and therefore functioning as a vast, extended human brain (Rifkin, 2014). If this is the scenario that awaits us, then it is for the best that archaeological studies of material culture contribute to the building of an awareness of this reality. Other disciplines could also contribute to such understandings, but cognitive research on material culture can fold historic time to contribute to these matters. Robots and cyborgs will require this kind of research to learn how to behave.

This research makes contributions of great importance to archaeology and other disciplines, such as the comprehension of material culture, the social history of thought, and the visual cognition studies. The visual response of experimental subjects provides meaningful insights on how the agency of material culture operates and how the mind is engaged with the materiality. The approach we outlined to this topic avoids to hint that there is an imbalance between (subjective) theoretical reasoning and (objective) data interpretation. Altogether we can preview in the short term an expansion of eye-tracking analysis of archaeological material culture. This study opens a new line of research in the short term. The techniques are already available, and they are neither costly nor complicated. They are capable of offering new insights into material culture studies, providing results that are of great importance for a wide range of fields, from the humanities and social sciences through to the “hard” sciences. ETA to characterize visual behaviour is a new archaeometric facility to use in archaeological science.

**Acknowledgements**

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This research was funded by the Spanish Ministry of Economics and Competitiveness, Program Consolider-Ingenio 2010, as part of the “Research Program on Technologies for conservation and valorization of Cultural Heritage” (CSD2007-00058). Work in the laboratory of LMM was supported by the Spanish Ministry of Economy and Competitiveness (Grant BFU2014-58776-r), co-financed by the European Regional Development Fund (ERDF), and the Severo Ochoa Program for Centers of Excellence in R&D (SEV-2013-0317). We took the title “gazed pottery” from the post that John Ankers published when an image of our first paper on this topic in Scientific Reports was posted in the web of the London Institute of Medical Sciences as “biomedical picture of the day” (http://bpod.mrc.ac.uk/archive/2019/4/10); we credit John Ankers for this fortunate motto.

Appendixes
*Appendices in Supplementary data

Appendix A: Eye movement analysis. A document with further information about the analysis of eye movements of prehistoric pottery performed in this study. It includes supplementary information on the experiments, extra nineteen graphics and statistical analyses [JAS_Material-culture-visuality_Appendix-A (6847 words, 24 pages)].

Appendix B: A document providing detailed information on the process to replicate and produce the pots used in Experiment 1. It also includes the formal variety of each pottery style in comparison with the selected pots for the study [JAS_Material-culture-visuality_Appendix-B (1440 words, 10 pages)].

The datasets of the experiments, together with more detailed information about them, are freely accessible on the open access institutional repository of CSIC https://digital.csic.es/ (see particular links in Appendix A).

References


Criado-Boado, F., 2016. Tangled between paradigms in the neo-baroque era. Archaeological Dialogues. 23(2), 152-158.


Artwork and Tables with Captions

Figures

Figure A. The visual perception is the result of a process in the brain which decodes the electromagnetic signals from the world, including eye movements, the filtering introduced by the retinal mosaics, and the specific processing performed by a hierarchy of different brain nuclei and cortical areas.

Figure B. Panel B1: Map with the location of the archaeological sites of the studied pots. Panel B2: Images presented in Experiments E1, E2 and E3.

Figure C. Images presented in Experiment 4 (E4). The fifteen original pots are labelled as 1.1., 1.2..., where the first digit is the archaeological period. Series artificially modified to check changes in visual response, are labelled to facilitate the identification of their analytical results.

Figure D. Results confirm that Vertical Index (Vi) is closely related to the chronology. Panel D1 shows the Vi tested in E1 and E4; saccades display in both a stronger effect than drifts, as explained in the text. The way of looking at the pots does not change depending on the task; free viewing and directed observations gave substantially the same results in E1 (Panel D2). The comparison of Vi of Experiment E1 and E2 show that there are not significant differences between looking at photos or drawings of the same pots (Panel D3). Experiment E4 shows that eye movements generally follow the sense of the decoration even if we change the position of the pot, as demonstrated by Vi of original pots (series X.1) and Vi of series Rs5 (Panel D4).

Figure E. Analysis of Vi in Experiment E1 did not find any relevant differences in terms of gender (Panel E1) or age (Panel E2).

Figure F. Comparing the eye behaviour of the different expert groups in Experiment E1 allows to confirm that Vi does not change significantly depending on the knowledge of the material (Panel F1) and degree of expertise by observers. Comparing experts as a whole (archaeologists, potters and subjects who had previous knowledge of this research) with non-experts (Panel F2), shows that the experts are more influenced by the orientation of the decoration than the non-experts, in the sense that their Vi is lower when looking a decoration that is highly horizontal (pot 2) and higher when looking a vertical decoration (pot 3).

Figure G. Heat maps of aggregated fixations for all the experimental subjects clearly show that gaze concentrates attention in those areas of the pot with more visual information, either on photos (from E1) or drawings (from E4). But it is even more important to realize that the dominant direction of the saccades (ie. how each pot is actually visually explored by observes) changes depending on the decorative style.
Figure B
Figure C

<table>
<thead>
<tr>
<th>Original archaeological pots</th>
<th>Diverse analytical modifications of series X.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>Rdi Rdi Rdi</td>
<td>Rsi Rsi Rsi Rsi Rsi Rsi Rsi</td>
</tr>
</tbody>
</table>

Figure D

Panel D1

<table>
<thead>
<tr>
<th>Drift</th>
<th>Secolide</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Panel D2 (data)

Panel D3

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Panel D4

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
**Tables**

Table A. The socio-cultural scenario of our empirical sampling; see Parcero et al. (2013) for a discussion of the social context and through time dynamics embedded in these chronological stages.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Settlement</th>
<th>Location</th>
<th>Form</th>
<th>Mobility</th>
<th>Violence</th>
<th>Degree</th>
<th>Main strategies and tactics</th>
<th>Production</th>
<th>Environmental impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before 6500 BCE</td>
<td>Upland</td>
<td>Campos</td>
<td>Fixed</td>
<td>Absent</td>
<td>Null</td>
<td>Absent</td>
<td>Inherited, Centening, Horticulture</td>
<td>Null</td>
<td>Absent</td>
</tr>
<tr>
<td>6500 – 6000 BCE</td>
<td>Upland</td>
<td>Campos</td>
<td>Important</td>
<td>Present</td>
<td>Present</td>
<td>High</td>
<td>Collective, Agricultural</td>
<td>Very low</td>
<td>Absent</td>
</tr>
<tr>
<td>5500 – 4300 BCE</td>
<td>Valley</td>
<td>Villages</td>
<td>Low</td>
<td>Present</td>
<td>Present</td>
<td>Individual</td>
<td>Follow agriculture</td>
<td>Big</td>
<td>Increasing</td>
</tr>
<tr>
<td>4300 – 3900 BCE</td>
<td>Upland</td>
<td>Small</td>
<td>Important</td>
<td>Present</td>
<td>Present</td>
<td>Present</td>
<td>Stockbreeding, Follow agriculture</td>
<td>Low</td>
<td>Decrease</td>
</tr>
<tr>
<td>3900 – 3600 BCE</td>
<td>Lowland</td>
<td>“Pequeno”</td>
<td>Low</td>
<td>Absent</td>
<td>Null</td>
<td>Present</td>
<td>Follow agriculture</td>
<td>Very high</td>
<td>Increase</td>
</tr>
<tr>
<td>3600 – 3300 BCE</td>
<td>Upland</td>
<td>Small</td>
<td>Fixed</td>
<td>Present</td>
<td>Present</td>
<td>Present</td>
<td>Follow agriculture</td>
<td>Low</td>
<td>Increase</td>
</tr>
<tr>
<td>3300 – 2900 BCE</td>
<td>Lowland</td>
<td>Small</td>
<td>Fixed</td>
<td>Present</td>
<td>Present</td>
<td>Present</td>
<td>Inheritance, Agricultural</td>
<td>Big</td>
<td>Increase</td>
</tr>
<tr>
<td>2900 – 2500 BCE</td>
<td>Lowland</td>
<td>Small</td>
<td>Fixed</td>
<td>Present</td>
<td>Present</td>
<td>Present</td>
<td>Inheritance, Agricultural</td>
<td>Very high</td>
<td>Increase</td>
</tr>
</tbody>
</table>

*Note: The table above includes data from various periods, highlighting changes in settlement location, form, mobility, violence, and strategies/tactics. The environmental impact trends are shown in the last column.*
Appendix A: Analysis of Eye movements show differential visual responses provoked by prehistoric pottery from distinct periods

Performance of the experiments

The experimental process involved a considerable amount of effort, approximately 2,660 hours (of a team with 10 people) from May 2014 to October 2014, plus 99 volunteers who devoted a total of around 220 hours.

The volunteers taking part in the ETA were carefully recorded but with full warranties of preserving their identity. Contextual data recorded data were age, place of origin and main characteristics (place of residence, education, training, professional activity, language, social identity, etc.).

The study included four different experiments:

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Short reference in this paper</th>
<th>Code of the Experiment</th>
<th>Link to dataset and further details</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Experiment</td>
<td>E1 EXP_14061</td>
<td></td>
<td><a href="http://hdl.handle.net/10261/153984">http://hdl.handle.net/10261/153984</a></td>
</tr>
<tr>
<td>Second Experiment</td>
<td>E2 EXP_14062</td>
<td></td>
<td><a href="http://hdl.handle.net/10261/153984">http://hdl.handle.net/10261/153984</a></td>
</tr>
<tr>
<td>Third Experiment</td>
<td>E3 EXP_14071</td>
<td></td>
<td><a href="http://hdl.handle.net/10261/153984">http://hdl.handle.net/10261/153984</a></td>
</tr>
<tr>
<td>Fourth Experiment</td>
<td>E4 EXP_14091</td>
<td></td>
<td><a href="http://hdl.handle.net/10261/153984">http://hdl.handle.net/10261/153984</a></td>
</tr>
</tbody>
</table>
These experiments involved 99 subjects in total (average age 34, age range 23-59) who carried out 124 different tests (25 people repeated Experiment 4 as a part of the experimental strategy). A total of 68 experimental subjects took part in E1, 7 of who had to be excluded from the analysis due to the recording conditions (the 2 young children, 3 people due to the recording conditions and 2 for other reasons, including one of the authors –FCB). The mean age of the remaining 61 subjects was 36, with a range of 15–58 years. The subjects conformed 5 groups (different sample populations) based on their degree of familiarity with the pieces and working hypotheses: a first group consisting of 13 people who had a high degree of specific knowledge and all of the whom were aware of the working hypotheses and the aims of the project, and members of the same research institute where the research was carried on (6 men and 7 women; mean age: 40; range: 29 - 45); a second group of 12 people with a high degree of specific knowledge (archaeologists) but who were not familiar with the working hypotheses (7 men and 5 women; mean age: 34, range: 22-57); a third group of 11 specialists in the production of ceramic items (6 men and 5 women; mean age: 49, range: 31-58), including the three artisans who did the replicas of the pots (their results fit very well into the same trend as the others); a group consisting of 25 members of the general public with no specific familiarity of the pottery or the working hypotheses (10 men and 15 women; mean age: 30, range 22-50); and finally, a study group was put together of 3 teenage girls (15, 15 and 17), that gave interesting results but were discarded because lack of statistical significance.

In E2 (black and white drawings), a total of 10 subjects took part, 1 man and 9 women; mean age 32; range 22-44; one of them was excluded in the analysis due to the recording conditions (9 valid trials). A total of 10 subjects took part in E3 (3D): 5 men and 5 women; mean age: 37; range: 25-54; two of them were excluded due to the recording conditions (8 valid trials).

Finally, in E4 (new series) a total of 36 people took part, of whom 25 had already taken part in the previous experiments but none of them were members of the Incipit and them they were unaware of the project: 18 men and 18 women, mean age: 34, range: 23-59. Three people were excluded due to the recording conditions (33 valid trials).

Comment on eye movement analysis

By simply observing the scan-path or visits map of an image it is immediately obvious that each image has intrinsic characteristics that will determine the way in which that particular image is going to be explored by an observer. Even when each observer might follow its own exploring strategies, at the end the most informative regions will be visited by almost every possible observer. Thus it is relatively easy to deduce which regions of a particular image would be receiving more visual exploratory visits. Indeed, it is also possible to have an intuitive idea of the direction in which such exploration may occur; that is, the characteristics of the materiality allow for a reasonable conjecture on how this materiality is going to be explored. However, all this knowledge turns out to be useless when trying to study the images quantitatively to allow for an objective comparison of some images against others.

Comment on distribution of angles and saccades

Visual processing occurs during the so-called fixation periods (FPS), while the gaze is relatively stable in the regions of interest (ROIs). The information that is going to prompt for visual
perception is extracted during the FPSs where the ROIs next to be explored are also identified. The movement between fixations is discrete and it is called saccade. The saccades are abrupt gaze displacements in any direction and of variable amplitude. The characterization and quantification of saccades is a practical way of studying the way in which a certain image is explored. The distribution of saccade angles provides us with a first measure on how a particular image was explored therefore allowing for an immediate comparison.

H/V ratio: distribution of the horizontal and vertical components in saccades, drifts and standard deviation

In free observation tasks the most common angles for the saccades are around the vertical and horizontal axis both of natural and fractal images (Foulsham T & Kinstone A; 2010). This pattern is also found for the images used in this work (Fig. 1). Saccades with and angle between 45º and -45º with respect to the horizontal are considered as horizontal saccades. Similarly those saccades with angles between 45º and -45º with respect to the horizontal are considered as vertical saccades. The same angle classification was applied to the drifts, in this case considering the angle formed between the final coordinate of the previous saccade and the initial one of the next saccade. To calculate these ratios we used the following formula:

\[ V_i = \frac{(W*NVS-H*NHS)}{(W*NVS+H*NVS)} \]

Where H is the screen height in pixels; W is the screen wide in pixels; NHS is the number of horizontal saccades; and NVS is the number of vertical saccades.

The normalization regarding the screen dimensions seemed convenient to ease comparison with other screens and its based in the one used by Lau and col. (Lau WC, Goonetilleke RS & Shih HM; 2001). The drifts were also analyzed in a discrete way following the same formula.

In addition to the discrete quantification based on saccades and drifts, the scanning path was also studied in a continuous way by considering the SD in both X and Y axes. For this last analysis and equivalent formula was used:

\[ V_i (sd) = \frac{(W*SDY - H*SDX)}{(W*SDY+H*SDX)} \]

Where SDY and SDX are the standard deviations in the vertical and horizontal axes respectively.

V index in relation with the chronology (Experiments 1 and 4)

The proposed chronological sequence (Fig. 1) is composed of 5 discrete periods of the archaeological register: Initial Neolithic (first row), Final Neolithic (second row), Initial Bronze (third row), Iron 2 (fourth row) and Iron 3 (fifth row). In the Exp1 we used Lateral pictures of a reconstructed pot of each the periods mentioned before. In the Exp4 we used lateral drawings of 15 original pieces (Fig1), 3 of each period, this experiment also included drawings of the 5 pieces used in Exp1; in addition 5 new series of variations of these pieces were included totalizing 40 images. Each of which was presented for a period of 15 seconds to the observers.

A clear effect of the chronology is observed both in experiments 1 (Exp1) and 4 (Exp4) as the ANOVAs show (Figs. 2, 3, 4). A clear trend towards verticality is observed as we advance in the chronological series. This pattern was observed so well in the experiment with pictures as in the
one with drawings. Remarkably this trend is maintained in Exp4 despite the fact that the new pieces incorporated allow for a great heterogeneity in some of the periods (Fig. 3). The period 3 is particularly striking as the Bell-beaker pot are of extreme verticality which makes them stand out well above expectations. This supposes a great step when comparing with pieces of the period 2; in fact, it shows even higher values than the consecutive period 4. This abrupt rupture is found only for the vases as the pot shows values in between those of periods 2 and 4.

Another relevant aspect to consider is the differences between the results for the original series (Rdi) between the experiments 1 and 4 (Fig. 4). Even when both series show an almost parallel behavior, there is a gap of 0.19 Vi points between the results obtained with the original pictures (Exp1) and those obtained with drawings (Exp4), these last showing lower values, which means that horizontal exploration is more dominant in Exp4 than in Exp1, this is so for the 5 pots of the study.

Effect of the grade of knowledge of the material (Exp1)

After discarding some of the subjects for poor recording conditions the remaining sample in Exp1 was composed of 63 subjects. These were distributed taking in consideration their grade of familiarity with the experimental material and the research hypotheses. The first group was composed of professionals which were aware of the approach, work hypothesis and the aims of this projects (N=13). The second group was composed by archaeologists familiar with the used ceramics (N=12). The third group is composed by ceramists (N=11). Additionally there was a group of non-experts unfamiliar with any of the topics of the research (N=24). There was also an exploratory sample of 3 teenagers not considered for further analysis due to its heterogeneity and small size.

When observing the Vi variation calculated for the standard deviation in the X and Y axes for the different periods and groups it’s noticed that all the groups show very similar values (Fig. 5). The Vi of the 3 groups shows a very similar pattern with regards to its evolution: a very soft decrease between 1 and 2; followed by a sharp increase between 2 and 3; then a clear decrease between 3 and 4; and lastly a great increase between 4 and 5. The non-expert group shows a similar behavior but with softer oscillations.

These little differences increase when decomposing the analysis in saccades and drifts, in such a way that the evolution of the verticality shows more clear differences between the non-expert group and the different groups of experts (Fig. 6A). The Vi index of the three experts groups shows the same behavior for saccades that when analyzing SDs: a very soft decrease between 1 and 2; followed by a sharp increase between 2 and 3; then a clear decrease between 3 and 4; and lastly a great increase between 4 and 5. However the non-expert group does not show such clear oscillations and the Vi increases between all periods (notice that for SD soft decrements were observed between period 1 and 2 and 3 and 4). For further saccades analysis all three experts groups were considered together (Fig. 6B).

The drifts present a totally different pattern characterized by horizontal displacements (Fig. 7). Thus the averages for all groups and periods are below 0. The group 1 (Incipit) shows the most conspicuous behavior by retaining the characteristic zigzag evolution also present in the saccades and SD studies. Among the other groups, there are almost no differences between the groups 2 and 3 (archaeologists and ceramists) and the non-expert group show and slightly different behavior characterized again by softer oscillations. Despite the extreme horizontality of all the periods and groups it is also worth mentioning that the chronology effect is maintained for the drifts as well. This kind of evidences is important, because even when remaining cautious,
we can to a certain degree assimilate the behavior of the experts with the one expected for the “natives” (the people who originally made and used the pieces) as, contrary to the standard population, the experts have a greater grade of knowledge and familiarity with the pieces which for example, might allow them to make conjectures or contextual derivations, identify them at first sight, know where to look to localize the relevance and singularity of each individual piece, etc.

Effect of the aspect ratio of the pieces and the decoration (Exp 1 and Exp 4)

All the series present a greater grade of verticality in its aspect ratio as we get closer to period 5. However, there is also a clear similarity between the results obtained in both Exp1 and Exp4 and aspect ratio (AR) of the decorated band (Fig. 8). This suggests that the decorated band is the key element in determining how vertical our exploration of a certain piece is. A second aspect of crucial importance is the AR of the whole piece; in fact, for some of the pieces the AR of the whole piece might be even more relevant than that of the decorated band. As we advance in the series, the AR of the shapes presents a uniform tendency towards verticality; this is only so for the particular pieces of our experiments. When comparing with the whole archaeological register this trend seems not to be maintained. This trend is also present for the AR of the decorated bands (actually, Decorated band AR could be an interesting factor to study in the archaeological record) with the only exception of the Bell Beakers pots where the whole piece is decorated in what turns out to be an abrupt rupture in an otherwise progressive trend.

The AR of both shapes and decoration presents a similar trend towards more verticality in the most modern pieces. However, some little differences could allow us to distinguish between observers. In this regard it is very interesting that in Exp1 the subjects of the non-expert group show an exploratory behavior characterized by an almost constant increase in Vi, in fact if we consider saccades only there are no decrements (Fig. 6B), this is what can be expected when exploring a piece uniformly in all of its dimensions. On the contrary, the groups of experts present an exploratory behavior in which its Vi values change more abruptly between periods, thus reflecting more closely the characteristic decorated band AR discontinuities which are particularly clear for periods 3 and 5 (fig. 6B).

These differences would be coherent with the experts focusing more in the decoration and thus reflecting the constrains imposed by the decorated band boundaries in its Vi values. On the other hand, the non-experts would explore the piece in a more anarchic way, maybe even following irregular saliences not imposed by the decoration; as a result their exploratory behavior might be restrained by the outer limits of the piece rather than by the decoration.

This interpretation seems to be reinforced by the results obtained in Exp4 with the drawings (Fig. 8). When comparing the results obtained in Exp4 (with an entirely non-expert population) with the results of Exp1, the pattern shows the acute discontinuities observed for the expert group rather than the most progressive pattern observed for the non-expert (Fig. 9).

The simplicity induced by the drawings significantly reduces irrelevant saliencies, this simplification may work in the same way that the selective attention of the experts filtering out the non-decorated regions.
Decoration effect (Exp4)

In addition to the original series (Rdi) of 5 pieces, we used 5 more series with drawings representing variations of this original series. In the Rs1 the decoration was removed and the drawings represented just the external shape of the pieces; in the Rs2 series the decoration was interchanged between the different pieces of the series; in the RS3 the decoration was painted in the lower part of the pieces; the Rs4 presented the decoration also in the lower half but the direction of the motifs was inverted as well; finally, the Rs5 series showed the original pieces but inclined 90°.

Except for the comparison between the series Rdi and Rs5, in all other the comparisons made the ANOVA showed a principal effect of the chronology, which is fully coherent with the importance of the AR for the Vi that was commented before. This effect is observed for both saccades and drifts. However it is of greater magnitude for saccades and presents interesting variations between the different pieces and series, for these reasons we have conducted a more detailed analysis for the saccades than for the drifts.

Void shapes. When comparing the Rdi and Rs1 series (Fig. 10) we can observe how both of them maintain the trend shown previously where the Vi rises as we advance across the chronological series. It is also very clear an effect of the decoration that provokes a clear increase in Vi in the periods 3 (3Rdi) and 5 (5Rdi). The decoration also enhanced the horizontal exploration particularly of piece 1 (1Rdi) but also of piece 2 (2Rdi). In this Fig. 10 it can be observed that the drifts behave in a relatively parallel way when compared with the saccades. The saccades show in the undecorated pieces a progressive and parallel Vi, yet still, higher than its corresponding AR.

Interchanged Decoration. These decoration effects are also very conspicuous when the decoration is interchanged between the different pieces of the series (Fi. 11). When comparing the Rdi series with the Rs2, it can be observed how by superposing the decoration of the period 2 over the shape of period 5 we can induce a clear decrement in Vi values when compared with the original piece 5, perhaps even more remarkable is the fact that this change cannot be attributed to the AR of the new decoration since both decorated bands have the same AR. Additionally, the decorated band of period 1 reduces dramatically the Vi values for the period 3 piece. On the other hand, the decoration of periods 5 and 4 increases de Vi values of the pieces of periods 1 and 2 respectively. Finally the Bell Beaker decoration (period 3) evokes a very clear Vi increase over piece 4 shape. All this changes were statistically significant, what gives a clear idea of the big importance of the decoration in determining the way the whole piece is observed. Of particular interest is the result obtained for the superposition of decoration 2 over shape 5, as it compellingly shows that it is not only the decoration band AR but also the motifs within it which determine the Vi values, that is the way we look at a particular piece.

The previous trends are also clear in the comparison between series Rs1 and Rs2 (Fig. 12). Again we can see the absolute relevance of the decoration in modulating the Vi values induced by the outer shape of the pieces. In all the cases we observe how the decoration drags the Vi value of the shape towards that of the piece whose decoration is being used. Again all these differences are statistically significant, with the only exception of the period 1 piece with the decoration of period 5, but it is worth pointing out that in this case de difference in the display surface induces a very dramatic change in the original decoration dimensions and scales.

Decoration in the lower part. We also see some little differences between series Rdi and Rs3 (Fig. 13), in general it seems that Rs3 has a similar behavior than Rs1. This would indicate that for the decoration to be fully effective it is important to be disposed in the upper (and more salient) part of the piece. However, in the pieces 1 and 4 the decoration in the lower part shows its full potential.
**Inverted decoration.** Overall series Rs3 and Rs4 seem no to present big differences (Fig. 14), this impression is statistically consistent as there are no significant differences between both series. In spite of this, some tendencies can be pointed out. For period 1 by eliminating the discontinuities in the horizontal bands the Vi gets more vertical and gets to values in between those of Rdi or Rs3 and the more vertical ones obtained for Rs1. Oppositely, for Fig. 2 the inversion of the decoration on Rs4 with respect to Rs3 reduces verticality and drags de Vi values very close to those of the original piece. Similarly for periods 4 and 5 it seems that de inversion of the decoration on Rs4 with respect to Rs3 has the effect of slightly increasing Vi values.

**90º Inclination.** Finally, when comparing Rdi and Rs5 series (Fig. 15) we see how the variations in the orientation of the pieces provoke totally opposite effects in the pieces of the first two periods for both drifts and saccades. The differences in the other 3 periods are more complex to infer but it is very likely that in all 5 cases the determining factor affecting the Vi of the inclined pieces is the AR of the decorated band.

**Figures**

**Fig. A.1: E4: set of images and directions of their saccades**

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Fig. 1. Pieces and distribution of angles in Exp4. We showed 40 images of pieces corresponding to 5 discrete periods of the archaeological register: Initial Neolithic (first row), Final Neolithic (second row), Initial Bronze (third row), Iron 2 (fourth row) and Iron 3 (fifth row). The total number of series was eight of which three were original series (three first columns) and the other five were modifications of one of the original series (the one used in the 3 experiments).
The 5 factors ANOVA (periods from 1 to 5) shows significant differences for the chronological variable for both drifts ($F(4,62) = 9.458, p<0.000$) and saccades ($F(4,62) = 68.213, p<0.000$).

We did an analysis of variance (ANOVA) of 5 (Chronology) by 3 (series) with repeated measures in both factors. For the drifts we found a main effect for the factor chronology ($F(4,32) = 11.57, p<0.000$): the Vi
shows higher values as we advance in the chronological sequence. We also found a significant interaction between both factors (F(8,32) = 4.155, p<0.001): which implies homogeneity variation between the pieces of the different periods.

We also found a main effect of the factor chronology for the saccades F(4,32) = 37.542 p<0.000: the Vi shows higher values as we advance in the chronological sequence. There is also a main effect for the factor series, which implies that the pieces were not homogenous for the parameter under scope (F(2,32) = 6.82, p<0.002). The interaction between both factors was also significant (F(8,32) = 7.321, p<0.000): this indicates that for the saccades there is also a significant heterogeneity between the pieces included in each period. The period three deserves special attention as it clearly breaks the trend imposed by the chronological sequence. Consequently, unlike for the rest of the periods compared, the Student’s t-test for the comparison between periods three and four results in a positive significant value (t(32)= -2.997, p<0.005).

No significant differences appear when considering possible gender differences (F(2,32) = 0.002, p<0.967) or between veterans (those who had already taken part in one experiment and were familiar with par of the pieces and proceedings) and new subjects (F(2,32) = 0.332, p<0.569).

Fig. A.4: Similarities and dissimilarites between E1 (photos) and E4 (draws)

Fig. 4. Average of Vi evolution in Exp1 and Exp4. It shows how both follow parallel trends, with a clear effect of the chronology (F(4,95) = 77.983, p<0.000) but with a clear difference between both series (F(2,95) = 31.917, p<0.000). When this difference is quantified we obtain that Vi is on average 0.19 points lower (more horizontal) in Exp4 that in Exp1.
Fig. A.5. E1: Vi as function of expertise

Fig. 5. Evolution of SD Vi for the different periods and groups. When considering the different population groups (excluding the group of 3 teenagers), the ANOVA for the SD in Exp1 shows a main effect of the chronology \((F(4,62) = 200.351\ p<0.000)\) as well as an interaction between chronology and group (Chronology*group: \(F(4,62) = 2.446\ p<0.009)\).

The graphics show the variation of the Vi values of the expertise subgroups for the different pots, the first graphic shows the average Vi index, the second graphics shows a normalized average of the Vi index ranking of the different measures taken for each subgroup and pot.

Kruskall-Wallis: For a 3 degrees of freedom and \(\alpha\) value of 0.05 we should expect a \(\chi^2\) value over 7.815 which is only reached for pots 2 and 3. For the pot 1 \(\chi^2(3, \ N = 60) = 3.965, p = 0.265\); pot 2 \(\chi^2(3, \ N = 60) = 11.239, p =0.011\); pot 3 \(\chi^2(3, \ N = 60) = 9.789, p =0.020\); pot 4 \(\chi^2(3, \ N = 60) = 3.240, p =0.356\); pot 5 \(\chi^2(3, \ N = 60) = 3.876, p =0.275\).

When analyzing in detail the results of the two pots where the significant differences were found we see that for the pot 2, we have significant differences between the groups 1 (Incipit) and 2 (Archaeologists) \(\chi^2(1, \ N = 25) = 4.503, p = 0.034\); 1 and 4 (non-expert) \(\chi^2(1, \ N = 37) = 8.294, p = 0.004\) and 3 (ceramists) and 4 \(\chi^2(1, \ N = 35) = 4.623, p =0.032\).

For the pot 3 we have significant differences between the groups 2 and 3 \(\chi^2(1, \ N = 23) = 4.253, p = 0.039\); as well as between the groups 2 and 4 \(\chi^2(1, \ N = 36) = 7.390, p = 0.007\).
When considering the different population groups (excluding the group of 3 teenagers), the ANOVA for the saccades in Exp1 shows a main effect of the chronology ($F(4, 62) = 74.772, p < 0.000$) as well as an interaction between chronology and group ($Chronology*group: F(4, 62) = 2.517, p < 0.006$).
When considering the different population groups (excluding the group of 3 teenagers), the ANOVA for the drifts in Exp1 shows a main effect of the chronology ($F(4,62) = 9.963\ p<0.000$) as well as an interaction between chronology and group ($\text{Chronology}^*\text{group}: F(12,62) = 1.922\ p<0.045$).
Fig. A.8. E1 and E4: Effect of pieces and decoration AR

The graphic shows the values of Vi for the original series in Exp1 (Exp1 Vi), Exp4 (Exp4 Vi), the void series in Exp4 (Rs1) and the AR values of the pieces (Exp4 AR) and decorated band (DecoExp4) measured for Exp4 but undistinguishable from the values of Exp1.

Fig. 8. Exp1 and Exp4: Effect of pieces and decoration AR on Vi. The graphic shows the values of Vi for the original series in Exp1 (Exp1 Vi), Exp4 (Exp4 Vi), the void series in Exp4 (Rs1) and the AR values of the pieces (Exp4 AR) and decorated band (DecoExp4) measured for Exp4 but undistinguishable from the values of Exp1.
Fig. 9. Attention as a filter for saliencies: $Vi$ for saccades in Exp1 (experts and non-experts) and Exp4.

The graphic shows the $Vi$ values for saccades of the expert (Exp1 expert) and non-expert (Exp1 non-expert) groups in Exp1, additionally the $Vi$ for the original series in Exp4 is also shown, note that to ease comparison of the $Vi$ evolution in the different periods, 0.19 points have been added to the Exp4 actual values as such is the average difference between Exp1 and Exp4 values.
Fig. 10. Effect of decoration: original vs void shapes (Rdi vs Rs1). The Vi of the Rdi original series (blue) is compared with the Rs1 undecorated series (green) of both drifts and saccades. For the drifts it is detected a main effect of the chronology ($F(4,32) = 7.794, p<0.000$).

In the case of the saccades, a main effect of the chronology is also detected ($F(4,32) = 24.647, p<0.000$), but also an interaction between the variables of series and chronology ($F(4,32) = 6.236, p<0.000$).
**Fig. A.11. E4: Effect of decoration: Interchanging decoration (Rdi vs Rs2)**

**Fig. 11. Effect of decoration: Interchanging decoration (Rdi vs Rs2).** The Vi of the original Rdi series (blue) is compared with the Rs2 series (green) where the decoration is interchanged between different pieces, the piece 1 incorporated period 5 decoration (Late Iron Age) over pot 1 shape (Middle Neolithic); the piece 2 incorporated the decoration 4 (Middle Iron Age) to the pot 2 (Late Neolithic); the piece 3 incorporated the decoration 1 (Middle Neolithic) to the pot 3 (Bell Beaker); the piece 4 incorporated the decoration 3 (Beaker) to the pot 4 (Middle Iron Age); and the piece 5 incorporated the decoration 2 (Late Neolithic) to the pot 5 (Late Iron Age).

Both drifts and saccades are considered.

For the drifts it is detected a main effect of the chronology (F(4,32) = 8.346, p<0.000).

In the case of the saccades, a main effect of the chronology is also detected (F(4,32) = 24.647, p<0.000), but also an interaction between the variables of series and chronology (F(4,32) = 6.236, p<0.000). This interaction stresses the importance of the decoration in whether we look more or less vertically at a certain piece. In all the pieces the new decoration drags the Vi of the shape closer to that of the decoration’s piece of origin. Additionally in all the cases the differences between the original and the newly decorated pieces are statistically significant.

When the decoration of period 5 is added to the shape of piece 1 the Vi gets 0.15 more vertical (from -0.32 to -0.17), t(32)=-2.4, p<0.022. In period 2 the addition of period 4 decoration increases the Vi from -0.29 to -0.07 (t(32)=-4.36, p<0.000). In period 3 the substitution of the original decoration with that of period 1 evokes a clear reduction in Vi from 0.24 to -0.27 (t(32)=3.78, p<0.001). In period 4, the decoration of period 3 induces a change from -0.07 to 0.1 (t(32)=3.05, p<0.005). In period 5, the decoration of period 2 induces a change from 0.19 to -0.13 (t(32)=4.69, p<0.000).
**Fig. A.12. E4: Effect of decoration: interaction between shape and decoration (Rs1 vs Rs2)**

For the drifts it is detected a main effect of the chronology ($F(4,32) = 3.073, p<0.022$). In the case of the saccades, a main effect of the chronology is also detected ($F(4,32) = 10.718, p<0.000$), but also an interaction between the variables of series and chronology ($F(4,32) = 8.927, p<0.000$). In the period 2 the piece with the decoration corresponding to period 4 has a Vi value of -0.07 and whereas the Vi of the undecorated shape falls to a statistically significant lower value of -0.20, $t(32)=-2.93, p<0.006$. In period 3 the piece with period 1 decoration has Vi value of -0.27 and whereas the Vi of the undecorated shape is -0.15, this difference is marginally significant statistically ($t(32)=-1.312, p<0.065$). In period 4 the values are -0.07 for the undecorated shape and 0.1 when period 3 decoration is added, this difference is statistically significant ($t(32)=3.27, p<0.003$). In period 5, the decoration of period 2 induces a change from 0.07 in the undecorated shape to -0.13 when period 2 decoration is added, again this difference is statistically significant ($t(32)=4.42, p<0.000$).

**Fig. 12. Effect of decoration: interaction between shape and decoration (Rs1 vs Rs2).** The Vi of the undecorated Rs1 series (blue) is compared with the Rs2 series (green) where the decoration is interchanged between different pieces, the piece 1 incorporated period 5 decoration (Late Iron Age) over pot 1 shape (Middle Neolithic); the piece 2 incorporated the decoration 4 (Middle Iron Age) to the pot 2 (Late Neolithic); the piece 3 incorporated the decoration 1 (Middle Neolithic) to the pot 3 (Bell Beaker); the piece 4 incorporated the decoration 3 (Beaker) to the pot 4 (Middle Iron Age); and the piece 5 incorporated the decoration 2 (Late Neolithic) to the pot 5 (Late Iron Age). Both drifts and saccades are considered.
For the drifts it is detected a main effect of the chronology \( (F(4,32) = 9.065, p<0.000) \).

In the case of the saccades, a main effect of the chronology is also detected \( (F(4,32) = 28.259, p<0.000) \), but also an interaction between the variables of series and chronology \( (F(4,32) = 4.36, p<0.003) \). In the piece of period 3, by limiting the decoration to the lower part we obtain a Vi value of -0.12 significantly lower than the original value of 0.024 \( (t(32)=2.53, p<0.017) \). In the period 4 the original value of -0.074 with the decoration changes to a value of 0.016, this difference is marginally significant \( (t(32)=-1.94 p<0.061) \). In the piece of period 5, by moving the decoration to the lower part we obtain a Vi variation from 0.19 in the original piece to 0.04 in the piece with the decoration in the lower part \( (t(32)=2.846, p<0.008) \).
Fig. A.14. E4: Effect of decoration: Inversion of decoration in the lower part (Rs3 vs Rs4)

The Vi of the Rs3 series (blue) with the decoration in the lower part is compared with the Rs4 series (green) which has the decoration relocated to the lower part of the pieces as well, but where the motifs of the decorated bands are inverted as well. Both drifts and saccades are considered.

For the drifts it is detected a main effect of the chronology ($F(4,32) = 5.071$, $p<0.001$).

In the case of the saccades, a main effect of the chronology is also detected ($F(4,32) = 28.515$, $p<0.000$), however there are only minor differences between both series ($F(2,32) = 3.531$, $p<0.069$)
Fig. A.15. E4: Effect of decoration: orientation effect (Rdi vs Rs5)

![Graph showing the effect of decoration on orientation](image)

The Vi of the Rdi original series (blue) is compared with the Rs5 series (green) where the pieces are inclined 90° (laid down). Both drifts and saccades are considered. Both drifts and saccades are considered.

For the drifts it is detected a main effect of the chronology ($F(4,32) = 5.071, p<0.001$). A clear interaction between chronology and series is also to be observed ($F(4,32) = 12.331, p<0.000$). In period 1 ($t(32)=-6.785 p<0.000$) and 2 ($t(32)=-4.945 p<0.000$) both series are clearly apart from each other however in the last 3 periods they are almost indistinguishable.

In the case of the saccades, a main effect of the chronology is also detected ($F(4,32) = 6.168, p<0.000$), as well as a series effect ($F(1,32) = 38.210, p<0.000$). Additionally there is a clear interaction between chronology and series ($F(4,32) = 43,125, p<0.000$). In period 1 ($t(32)=-11.942 p<0.000$) and 2 ($t(32)=-10,611 p<0,000$) both series are clearly apart from each other however in the last 3 periods they intercross each other, they get inverted in period 3 ($t(32)=1.915 p<0.064$), to intercross again in period 4 ($t(32)=-2.876 p<0.007$) and again in period 5 ($t(32)=1.786 p<0.083$). Despite the several intercrossing both series do not really merge at any point.

Fig. A.16 E1: Gender differences

We found no significant differences between the Vi values of males and females for any of the stimuli used.
The graphics show the variation of the Vi values of males and females for the different pots, the first graphic shows the average Vi index, the second graphs shows a normalized average of the Vi index ranking of the different measures taken for both males and females for each pot.

For a 1 degree of freedom and α value of 0.05 we should expect a χ² value over 3.841 which is not reached for any of the pots displayed. For the pot 1 \( \chi^2(1, N = 60) = 0.204, p = 0.652 \); pot 2 \( \chi^2(1, N = 60) = 2.673, p = 0.102 \); pot 3 \( \chi^2(1, N = 60) = 0.603, p = 0.437 \); pot 4 \( \chi^2(1, N = 60) = 0.11, p = 0.739 \); pot 5 \( \chi^2(1, N = 60) = 1.832, p = 0.176 \).

**Fig. A.17 E1: Experts vs non-experts**

We found significant differences between experts and non-experts for the images of the pots 2 and 3.

The graphics show the variation of the Vi values of experts and non-experts for the different pots, the first graphic shows the average Vi index, the second graphs shows a normalized average of the Vi index ranking of the different measures taken for both experts and non-experts for each pot.

For a 1 degree of freedom and α value of 0.05 we should expect a χ² value over 3.841 which is only reached for pots 2 and 3. For the pot 1 \( \chi^2(1, N = 60) = 0.295, p = 0.587 \); pot 2 \( \chi^2(1, N = 60) = 6.467, p = 0.011 \); pot 3 \( \chi^2(1, N = 60) = 5.507, p = 0.019 \); pot 4 \( \chi^2(1, N = 60) = 1.230, p = 0.267 \); pot 5 \( \chi^2(1, N = 60) = 2.463, p = 0.117 \).

**Fig. A.18 E1: Expertise subgroups**

We found significant differences among the different expertise classes for the images of the pots 2 and 3.
The graphics show the variation of the $Vi$ values of the expertise subgroups for the different pots, the first graphic shows the average $Vi$ index, the second graphs shows a normalized average of the $Vi$ index ranking of the different measures taken for each subgroup and pot. The $Vi$ data is based on SD variation in both vertical and horizontal axes.

For a 3 degrees of freedom and $\alpha$ value of 0.05 we should expect a $\chi^2$ value over 7.815 which is only reached for pots 2 and 3. For the pot 1 $\chi^2(3, N = 60) = 3.965$, $p = 0.265$; pot 2 $\chi^2(3, N = 60) = 11.239$, $p = 0.011$; pot 3 $\chi^2(3, N = 60) = 9.789$, $p = 0.020$; pot 4 $\chi^2(3, N = 60) = 3.240$, $p = 0.356$; pot 5 $\chi^2(3, N = 60) = 3.876$, $p = 0.275$.

When analyzing in detail the results of the two pots where the significant differences were found we see that for the pot 2, we have significant differences between the groups 1 (Incipit) and 2 (Archaeologists) $\chi^2(1, N = 25) = 4.503$, $p = 0.034$; 1 and 4 (non-expert) $\chi^2(1, N = 37) = 8.294$, $p = 0.004$ and 3 (ceramists) and 4 $\chi^2(1, N = 35) = 4.623$, $p = 0.032$.

For the pot 3 we have significant differences between the groups 2 and 3 $\chi^2(1, N = 23) = 4.253$, $p = 0.039$; as well as between the groups 2 and 4 $\chi^2(1, N = 36) = 7.390$, $p = 0.007$.

**Fig. A.19 E1: Age groups**

We found no significant differences between the $Vi$ values of the 3 age groups established for any of the stimuli used.

The graphics show the variation of the $Vi$ values the 3 groups of age (between 20 and 31, between 30 and 41 and over 40) for the different pots, the first graphic shows the average $Vi$ index, the second graphs shows a normalized average of the $Vi$ index ranking of the different measures taken for the different age groups in each pot.

For a 2 degree of freedom and $\alpha$ value of 0.05 we should expect a $\chi^2$ value over 5.991 which is not reached for any of the pot images used as stimuli. For the pot 1 $\chi^2(2, N = 60) = 3.722$, $p$
References:


Appendix B: Archaeological context of the experimental pots and their replication

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\section*{Introduction}

This Appendix provides detailed information on the process to replicate and produce the pots used in Experiment 1. It also includes the formal variety of each pottery style in comparison with the selected pots for the study.

Two replicas of each of the five selected pots were made: an exact replica of the prehistoric pot, and a “fake pot”. In this research the first series was used. The series of fake pots has not been used because it was done to test the perceptual reaction of different people to an archaeological “original” material, which will involve measuring emotional responses and other tests that were not done now.

\section*{Choice of the archaeological pieces to study}

Five pieces of pottery of archaeological origin of different contexts and times are selected. It was intended to reproduce with the maximum level of detail the original pieces, in forms, textures, finishes, type of decoration and color. From each of the pieces are made two replicas, one of them is to reproduce a false original, with the formal irregularities, incomplete conservation and fragmentation characteristic of the archaeological ceramics, the intention is that it can be confused with a piece original. The other replica that is made of each original piece, is made the most geometric with a continuous decoration, which can be clearly identified with a replica. In the case of the bell-shaped vessel, a third replica is made where the white paste that is characteristic of this type of objects is inserted into the decorated part.

1) Pottery sherd from Mámoa 3 de Parxubeira, A Coruña (Middle Neolithic)
2) Bowl from *Penha* style, from the open air settlement of Vinha de Soutilha, Chaves, Portugal (Late Neolithic)

3) Bell Beaker from barrow no. 242, Veiga de Vilavella, As Pontes, A Coruña (Early Bronze Age)

4) Pottery sherd of a *Castros Culture* style bowl of Castro de Punta de Muiño do Vento, Pontevedra (Middle Iron Age, s. IV-II a.C)

5) Pottery sherd of a *Castros Culture* jar, *Toralla type*, from Castro Grande de Neixón, Boiro, A Coruña (Late Iron Age, s. IV-II a.C)

Below information is provided about the formal variety of each pottery style in comparison with the selected pots for the study.

Figure B.1-B.5: ceramic typology of Middle Neolithic, Late Neolithic, Early Bronze Age, Middle Iron Age and Late Iron Age pottery in Galicia, (after Prieto, Ruibal et al.).

**Formal variety of each pottery style in comparison with the selected pots for the study**

**Formal variety of pottery style 1 (Middle Neolithic) in comparison with the analyzed pot (no. 1)**
Formal variety of pottery style 2 (Late Neolithic) in comparison with the analyzed pot (no. 2)
Formal variety of pottery style 3 (Bell Beaker) in comparison with the analyzed pot (no. 3)
Formal variety of pottery style 4 (Middle Iron Age) in comparison with the analyzed pot (no. 4)
Formal variety of pottery style 1 (Late Iron Age) in comparison with the analyzed pot (no. 5)

Manufacture of the ersatzs, an experimental process

To make the replicas of the Neolithic vessel and the pot and jar of castros culture we start with hypothetical reconstructions, since only a fragment of the original pieces is preserved.

To make the replicas two types of mud are used, of native origin. All the replicas are made by manual modeling, using the churros technique, only the slow lathe is used to finish the pieces of the Iron Age.

Once all the replicas have been made and the drying process is finished, the retorts in which a final reddish and uniform color (pot and jar of castros culture) are sought are simulated in an electric oven. The maximum cooking temperature for these pieces is 980°C. To obtain an irregular cooking that contributed to give an appearance more similar to the original the rest of pieces are cooked in a bonfire of wood.

In the case of Penha style replicas, a reduction cooking is performed and the result obtained in terms of color and texture is very similar to that of the original piece. In the Neolithic replicates an oxidizing cooking is done and the smoky and irregular appearance of the coloring is also very satisfactory.
After cooking a final treatment is given in the wood oven to the pieces cooked in the electric oven to create a smoked effect in the Neolithic retort, and in the carafe and pot. In the case of castros culture replicas, manganese oxide is previously applied to the surface and then introduced into the furnace in order for the oxide to penetrate the pores of the ceramic. In the case of the bell-shaped replica 3B, the decoration is filled with a white paste (ceramichrome, mineral spirit, white MS19).

**Breaking and restoring of the fake original pieces**

It is exceptional that ceramic vessels of archaeological origin are whole or that they do not appear fractured. For this reason to make the false originals we decided to cause the pieces to break and then restore them as would be done with the archaeological objects. To cause an abrasion on the outer surface of the ceramics we buried them in mud and after two or three days we caused the containers to break.

The adhesion of the fragments is done starting from the base of the container and ending at the edge. At the time of gluing the oldest false originals, the Neolithic and the rock type, we try to make the existing deformation in the pieces be appreciated and even more marked in the restored piece. In the “castros cultures” and Bell Beaker pieces we try to ensure that the deformation in the edge diameter and profiles is the minimum as it happens in the original pieces.

In each of the pieces some fragments that are not included in the paste are eliminated. It was about giving a complete finish but where the elements of the decoration were appreciated in a discontinuous way and for that we removed some fragments especially from the decorated area of the containers.

Once the adhesion is completed, we reintegrate the faults, the holes left by the fragments removed. For the reintegration of the faults we use Araldit Madera of two components that is modeled to fill the holes and also to reinforce the fracture lines in the case of the Neolithic vessel and the rock type. The reintegration is finished with a smooth finish.
Original selected pieces

Modeling the clay

Firing the pots
Refitting the fake original

Final result: replic (1R) and fake original (1O) of the Parxubeira Neolithic Pot
Final result: replic (2R) and fake original (2O) of the Late Neolithic Penha style pot

Final result: fake original (3O), replic (3R) and painted replic (3B) of the Bell Beaker Pot

Final result: replic (4R) and fake original (4O) of the Castros Culture pot
Final result: replic (SR) and fake original (SO) of the Castros Culture jar

1 http://web.stanford.edu/dept/archaeology/cgi-bin/drupal/thinkingarchscience/