Conversations with Caves: The Role of Pareidolia in the Upper Palaeolithic Figurative Art of Las Monedas and La Pasiega (Cantabria, Spain)

Izzy Wisher, Paul Pettitt & Robert Kentridge

The influence of pareidolia has often been anecdotally observed in examples of Upper Palaeolithic cave art, where topographic features of cave walls were incorporated into images. As part of a wider investigation into the visual psychology of the earliest known art, we explored three hypotheses relating to pareidolia in cases of Late Upper Palaeolithic art in Las Monedas and La Pasiega Caves (Cantabria, Spain). Deploying current research methods from visual psychology, our results support the notion that topography of cave walls played a strong role in the placement of figurative images—indicative of pareidolia influencing art making—although played a lesser role in determining whether the resulting images were relatively simple or complex. Our results also suggested that lighting conditions played little or no role in determining the form or placement of images, contrary to what has been previously assumed. We hypothesize that three ways of artist–cave interaction ('conversations') were at work in our sample caves and suggest a developmental scheme for these. We propose that these 'conversations' with caves and their surfaces may have broader implications for how we conceive of the emergence and development of art in the Palaeolithic.

Introduction

How central were psychological features deriving from our visual systems to the early evolution of human visual culture? Pareidolia—the psychological phenomenon of seeing meaningful forms in random patterns, such as perceiving faces in clouds—is a universal feature of our visual system. It is likely a consequence of the evolution of our visual system adapting to allow partial or obscured profiles of potential predators to be rapidly identified through the conferral of meaning, and hence to minimize risk (Bednarik 2017, 102; Hodgson 2003; Melcher & Bacci 2008, 351). To achieve this, our visual system constructs a complete picture despite missing visual information, thus often causing us to 'see' things that are not there as it attempts to resolve ambiguous visual cues (Frith 2007, 132; Hong *et al.* 2013, 79; Ward 2008, 18). This process has been the subject of extensive psychological study, with existing debates regarding the particular cultural mechanisms that may cause pareidolia, e.g. do modern Western people see faces relatively frequently because our visual system has evolved to treat the visual stimuli of faces as 'special' (Carmel & Bentin 2002, 25; Hong *et al.* 2013, 79; Zhou & Meng 2019, 3) or merely because we have visual expertise in face perception (Harel 2016; Joyce & Cottrell 2004, 127; Rossion *et al.* 2004, 14521; Tovée 1998, 1239)? It certainly seems that pareidolia is informed by cultural experience, through the frequent perception of everyday objects or animals (Bracci *et al.* 2019, 6514; Maranhão-Filho & Vincent 2009, 1117). Thus, one's visual familiarity with certain stimuli (particular animals, faces, or objects) may shape the visual system to perceive ambiguous or fragmented stimuli as

Cambridge Archaeological Journal Page 1 of 24
doi:10.1017/S0959774323000288 Received 12 Oct 2022; Accepted 14 Aug 2023; Revised 28 Jun 2023

being evocative of familiar forms. In modern Western societies, pareidolia frequently manifests as a propensity for perceiving faces or anthropomorphic features in objects and this ability emerges early in human development, perhaps even prenatally (Reid *et al.* 2017). This may be a consequence of—but certainly triggers—our empathetic response to visual stimuli (Correa Varella 2018; Kato & Mugitani 2015; Proverbio 2017; Zhou & Meng 2020). These psychological responses to pareidolic imagery are not limited to faces; animal-like pareidolia also elicits a response as if the person is viewing an animal in reality (Bracci *et al.* 2019). Thus, pareidolia is not merely a visual phenomenon, but can elicit visceral emotional responses too.

Previous discussions within archaeology, most notably by Hodgson (2003; 2006; 2008; 2012; 2013; 2019; Hodgson & Pettitt 2018), have provided a thorough conceptual background for how cave environments may have been conducive to triggering visual responses: either pareidolia or, more potently, *hyper-imagery*. This discussion has focused on how heightened sensory awareness and the ambiguous nature of visual stimuli, induced by the darkness of caves, would have likely caused Palaeolithic people to experience visual imagery, priming them to depict the same animals they had perceived. There has also been extensive previous discussion pertaining to the integration of the rock support and its role in determining the placement of depictions within a cave, for example with the rock used to frame depictions or add depth and dimensionality to an animal motif (Bahn 2003; Leroi-Gourhan 1971; Lorblanchet 1995; Robert 2017; Sauvet & Tosello 1998). This literature has undoubtedly contributed to understanding the role of psychological responses to evocative features of the rock support, and the morphology of the support itself, in cave-art making. However, questions remain regarding the *extent* to which pareidolia may have underpinned the making of figurative representations *in a particular cave*. The explicit focus on pareidolia within this research is intentional; the role of pareidolia in cave-art production has been conceptually discussed in previous literature, but has yet to be directly tested against examples in the archaeological record as part of a systematic and focused study. Other facets of cave-art making, such as sociocultural context, authorship and artistic skill, or sensorial elements such as tactility and acoustics, have been subject to much more extensive research, including systematic and testable studies (e.g. Fazenda *et al.* 2017; Fernández-Navarro *et al.* 2022; Jouteau *et al.* 2020; Rivero 2014; Till 2014; Waller 1993). Arguably, the role of pareidolia has not yet been understood with the same nuance. This is not intended to diminish the contribution of other facets of cave-art making. Rather, our research intends to understand the significance and role of pareidolia as one part of the complex, multifaceted process of cave-art making.

We focused on two caves in Monte Castillo (Cantabria, Spain), Las Monedas and La Pasiega, and evaluated whether, and to what extent, the making of figurative representations within them were influenced by pareidolic responses. These caves were selected due to their geographical proximity, differing chronologies (mid-Magdalenian depictions at Las Monedas, late Solutrean/early Magdalenian depictions in Gallery A at La Pasiega), and the diversity of the art between the two (i.e. depictions drawn in charcoal at Las Monedas, depictions painted in red ochre, usually using finger dots, at La Pasiega). These distinctions allowed us to investigate how pareidolia may have manifested in different chrono-cultural contexts. We developed and tested three key hypotheses, motivated by both visual psychological literature regarding the nature of pareidolic images and conceptual discussions of the conditions that may have triggered pareidolic responses in cave environments. Fieldwork observations, high-resolution photogrammetric models and virtual reality (VR) lighting simulations were used to evaluate each hypothesis. To prevent confirmation bias, all figurative depictions within Las Monedas and all figurative depictions within Gallery A of La Pasiega were evaluated. The results indicated that the extent to which pareidolia influenced the making of a particular depiction varied, and may reflect different 'conversations' occurring between the artist and the cave wall during the process of art making.

Site backgrounds

Las Monedas

Discovered in 1952, Las Monedas is attributed to the Middle/Late Magdalenian based on stylistic features subsequently confirmed by AMS radiocarbon dates of 13,766–13,248 cal. BP, 14,811–13,791 cal. BP (ibex 16) and 14,076–13,519 cal. BP (horse 20) (Amormino 2000; García-Diez *et al.* 2021; González & Balbín Behrmann 2007; González Echegaray 1952; Moure Romanillo *et al.* 1996; Múzquiz & Cabrera Valdés 2000; Ochoa 2017, and references therein; Ripoll Perelló 1972; Ruiz-Redondo *et al.* 2016). Apart from a lithic collection attributed to the Mousterian and a brief mention of an Aurignacian flint point found among remains of cave bears (Carrión Santafé & Baena Preysler 1998; Ochoa 2017, 298), the lack of

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

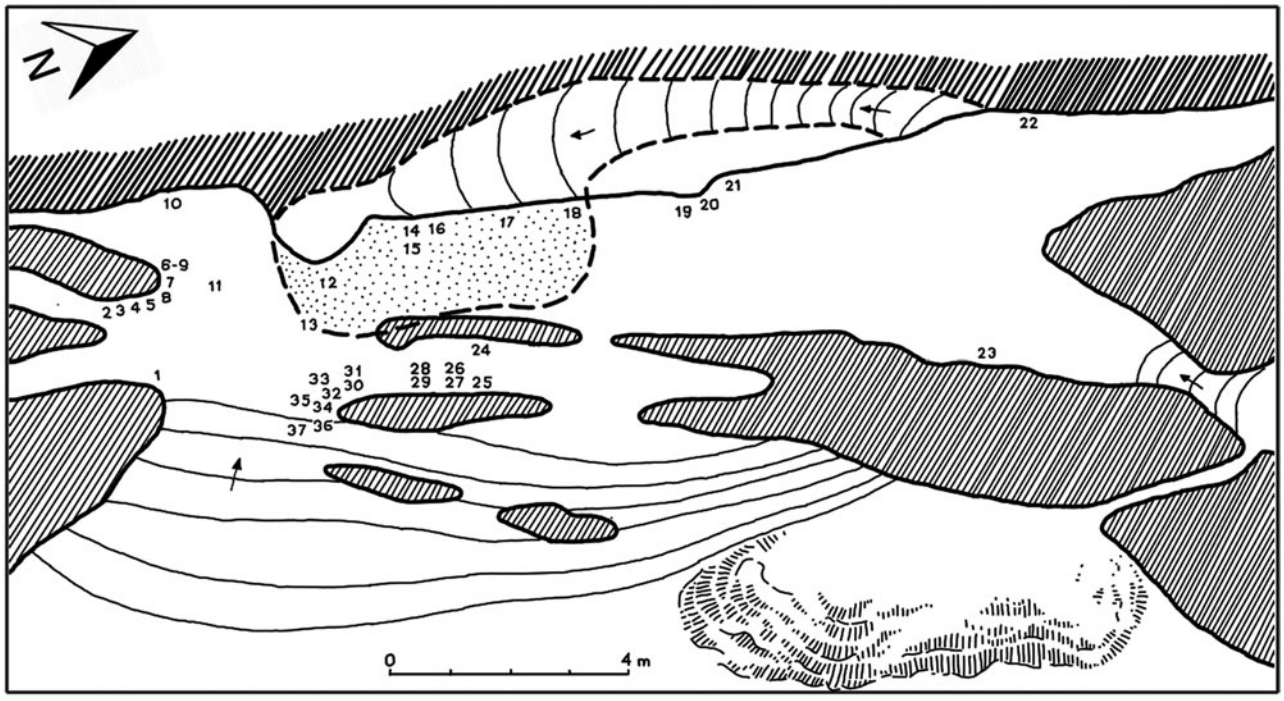

Figure 1. *Plan of the Gallery of the Paintings in Las Monedas, detailing the position of each depiction (numbers). (Digitally traced and modified after Ripoll Perello 1980.)*

materials attributable to the Magdalenian suggests that it may not have been habitually occupied when its art was created. Archaeological deposits may be present under the calcite floor in the entrance hall (García-Diez *et al.* 2021, 311) but it remains possible that, given the proximity of La Pasiega and El Castillo, and the late Upper Palaeolithic deposits in the latter (Cabrera Valdés 1984), these nearby caves were the places of residence (Ortega Martínez & Ruiz-Redondo 2018, 804).

Despite its large size, the art of Las Monedas comprises only 30 figurative and 15 non-figurative images constrained to a small area within the cave (Fig. 1). All figurative depictions appear to be superficially homogenous with the same technique and style used in all depictions, although with some subtle variation in depicting certain features of animals. Horse depictions are the most numerous (50 per cent, n=15) of the figurative representations, followed by ibex (17 per cent, n=5) and reindeer (13 per cent, n=4) (Table 1) Unusually for the Magdalenian art of northern Spain, bison depictions are rare (n=1). All depictions were drawn using a charcoal crayon, mostly detailed outlines occasionally partially infilled or with additional internal lines detailing pelage. Due to the similarities in style and technique, the constrained space of the gallery and the overlapping range of the AMS radiocarbon dates obtained from depictions 16 and 20, it is therefore likely that the art was produced by a limited number of individuals in a brief period of time (García-Diez *et al.* 2021; Ochoa 2017).

La Pasiega

Discovered in 1911 by Werner and Obermaier, the large system of La Pasiega to the east of Las Monedas contains extensive and varied depictions as well as Mousterian, Solutrean and Magdalenian archaeology, most of which is attributable to the Solutrean (e.g. Balbín-Behrmann & González-Sainz 1994; González Echagaray & Moure Romanillo 1971; González-Sainz *et al.* 2013, 106; Ochoa 2017; Ochoa *et al.* 2017, and references therein; Sainz & Balbín Behrmann 2021; Straus 1979). As originally noted in the monograph by Breuil *et al.* (1913) and systematically demonstrated by Groenen and Groenen (2019), there is an uneven distribution of images; some galleries (e.g. Gallery A) have large concentrations, others (e.g. Gallery D) comparatively few. Artistic techniques vary between galleries; ochre pigments were predominantly used throughout, but the few black depictions present concentrate in specific areas of Galleries A and C. Thematic and stylistic variability is high within and between galleries,

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

Table 1. *Summary of the figurative depictions in Las Monedas, with the numbers assigned to each depiction corresponding to the numbers in Figure 1. (Data from Ripoll Perello 1980, 24.)*

Animal depiction	Depiction number(s)	Frequency	Percentage
Horse	6; 8; 10; 11; 12; 13; 17; 20; 22; 30; 31; 33; 34; 34a; 36	15	50%
Ibex	7; 15; 16; 28; 29	5	16.7%
Reindeer	2; 3; 14; 21	4	13.3%
Indeterminate	1; 18; 35	3	10%
Bison	5	1	3.3%
Cervid	26	1	3.3%
Bear	25	1	3.3%

all of which suggests that La Pasiega's art has an extensive temporal breadth and was produced in multiple phases in which galleries formed single foci of activity, unlike the cohesive composition of Las Monedas (González-Sainz *et al.* 2013, 106).

We focused on Gallery A, due to its high number of figurative depictions that are broadly homogenous in style (primarily red ochre outline depictions produced with finger dots/smears) and form a representative sample of the art of La Pasiega, in terms of the animals represented. It is characterized by low ceilings and narrow spaces, which likely restricted the number of individuals that interacted with this space. The high frequency of depictions in Gallery A has been referred to as *horror vacui*—'fear of empty space' (García-Diez *et al.* 2018). Superimpositions are rare, further supporting the relative homogeneity of the Gallery A art and implying the depictions may have been produced over a relatively short period. As outlined in Table 2, hinds are the most frequently depicted animal, accounting for 34 per cent of the depictions, followed by horses (30 per cent), stags (14 per cent), aurochs (5 per cent), bison (4 per cent), ibex (3 per cent) and reindeer (2 per cent); indeterminate animals account for the remaining 8 per cent.

Materials and methods

Hypotheses

To determine the extent to which pareidolia may have been responsible for the form and placement of figurative depictions in the caves of Las Monedas and La Pasiega, we formulated and tested three hypotheses. First, we reasoned that if pareidolia underpinned the making of figurative depictions within these caves, then the majority of animal depictions would be scaffolded on natural topographic features of the cave wall. Pareidolic responses are triggered by evocative features that the visual system perceives as 'looking like' a meaningful form, and consequently if pareidolia was the motivation behind the placement and form of a particular animal, the depiction would naturally integrate these evocative features. This phenomenon of pareidolia motivating artistic behaviours has been previously documented, where particular forms that trigger a pareidolic response subsequently become integrated into a depiction (Lee 2016). Thus, **Hypothesis 1: The majority of figurative depictions should integrate natural topographic features of cave walls.**

Secondly, and building on Hypothesis 1, as pareidolic imagery of animals generally does not incorporate detail beyond salient outline form or the natural features that triggered the pareidolic image, we further propose that simpler depictions of animals that are incomplete in form and/or feature no additional details beyond the outline should integrate natural features. By contrast, detailed depictions, i.e. those complete in form and/or featuring internal detail such as pelage, hair, eyes, and particularly those with stylistic features consistent with other contemporaneous depictions, may thus reflect pareidolia having no or minimal influence over the form and placement of depictions. It may therefore be expected that detailed depictions are less likely to be scaffolded onto natural topographic features when compared to simple depictions. Thus, **Hypothesis 2: Simpler depictions should have a stronger relationship to natural topographic features of the cave wall than detailed depictions.**

Thirdly, to provide an explanation for why certain depictions may have been more strongly underpinned by pareidolia than others – as explored in Hypotheses 1 and 2 – the likely lighting conditions available in the Palaeolithic must be evaluated. As proposed by Hodgson (2008) and previously discussed, ambiguous visual stimuli that may be caused by fluctuating low light are conditions conducive to

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

Table 2. *Summary of the art within La Pasiega. (Data from Balbin-Behrmann and González-Sainz 1993.)*

Gallery	Total number of depictions	Animals depicted	General style	Date/stylistic attribution	Notes and additional comments
A	219 (100 figurative, 119 non-figurative)	Hind (34), Horse (30), Stag (14), Indeterminate quadruped (7), Aurochs (5), Bison (4), Ibex (3), Reindeer (2), Deer (1)	Simple outlines made mostly in red ochre, using finger dots	Solutrean to Early Magdalenian based on stylistic features of depictions	Narrow gallery deep within the cave. Accessed through Gallery B. High density of depictions
B	251 (91 figurative, 160 non-figurative)	Horse (24), Ibex (20), Indeterminate quadruped (16), Hind (11), Stag (9), Aurochs (3), Bison (2), Bovid (1), Deer (1), Carnivore (1), Bird (1), Fish (1) Anthropomorph (1)	Engraved depictions and depictions made with simple outlines in red, using finger dots	Solutrean based on stylistic features of depictions and date of occupation layers	Large chamber. Original Palaeolithic entrance to the cave. Evidence of occupation within this area of the cave. Would have received daylight
C	316 (79 figurative, 237 non-figurative)	Hind (21), Horse (16), Indeterminate quadruped (13), Bison (9) Ibex (9), Aurochs (4), Stag (3) Chamois (1) Deer (1) Mammoth (1), Anthropomorph (1)	Variety of styles including the use of engraving, red, yellow, and brown ochres and charcoal	Solutrean to Early Magdalenian based on stylistic features of depictions	Complex chamber with both open and narrow areas. High density of non-figurative motifs. Has a separate Palaeolithic entrance
D	97 (27 figurative, 70 non-figurative)	Horse (7), Hind (5), Aurochs (3), Indeterminate quadruped (3), Stag (3), Bison (3), Bovid (1), Deer (1), Ibex (1)	Engraved, with some depictions in red	Solutrean to Early Magdalenian based on stylistic features of depictions	Narrow zone that connects Gallery C to Gallery A. Few depictions that are distributed sparsely in this area

triggering pareidolic responses. By contrast, stable light conditions and brighter luminance values should be conducive to normal visual responses. This is not intended to state that pareidolia cannot occur under stable light conditions; the presence of pareidolic responses in modern contexts clearly attests to pareidolia being triggered under stable light. Instead, this hypothesis intends to explore why pareidolia may have been *more potent* in determining the form and placement of certain depictions. The topography of a particular cave wall would have influenced the interaction of light, with flatter topographies likely resulting in more stable lighting conditions, and undulating topographies therefore causing unstable and unpredictable lighting. Thus, there should be a correlation between depictions that have a strong relationship to the cave wall and unstable light conditions, and depictions with a weaker relationship to the cave wall and stable light conditions. As the topography of a particular cave wall would have influenced the distribution of illumination and hence viewing conditions, VR light simulations of 3D photogrammetry models of cave art panels were used to evaluate this hypothesis. Thus, **Hypothesis 3: There should be a correlation between unstable and low light conditions and simple depictions with a strong relationship to the cave wall, and between stable and bright light conditions and detailed depictions with a weak relationship to the cave wall.**

Fieldwork

Fieldwork was conducted by IW in Las Monedas and La Pasiega during October 2021 to allow for an initial assessment of the relationship between depictions and the topographic features of the cave wall, which was subsequently explored further through VR lighting simulations. Visual observations were made to assess the placement of depictions (e.g. visibility, integration of natural features, degree of truncation/constraint of images by the cave wall's topography), its form (e.g. taxon, internal details, completeness), and artistic techniques (i.e. method of pigment application), in addition to dimensions and orientation. Four specific categories were developed to assess the degree to which depictions related to the cave-wall topography: 1) Direct: depictions directly integrate natural features (e.g. a crack representing the dorsal line) and/or trace natural features (e.g. a dorsal line drawn over a crack); 2) Parallel: lines of the depiction have a close spatial proximity to natural features and follow their contour (e.g. a dorsal line drawn directly underneath a natural crack and follows the crack's profile); 3) Mimic: features of a depiction appear to incorporate the form of a nearby evocative topographic feature, but the

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

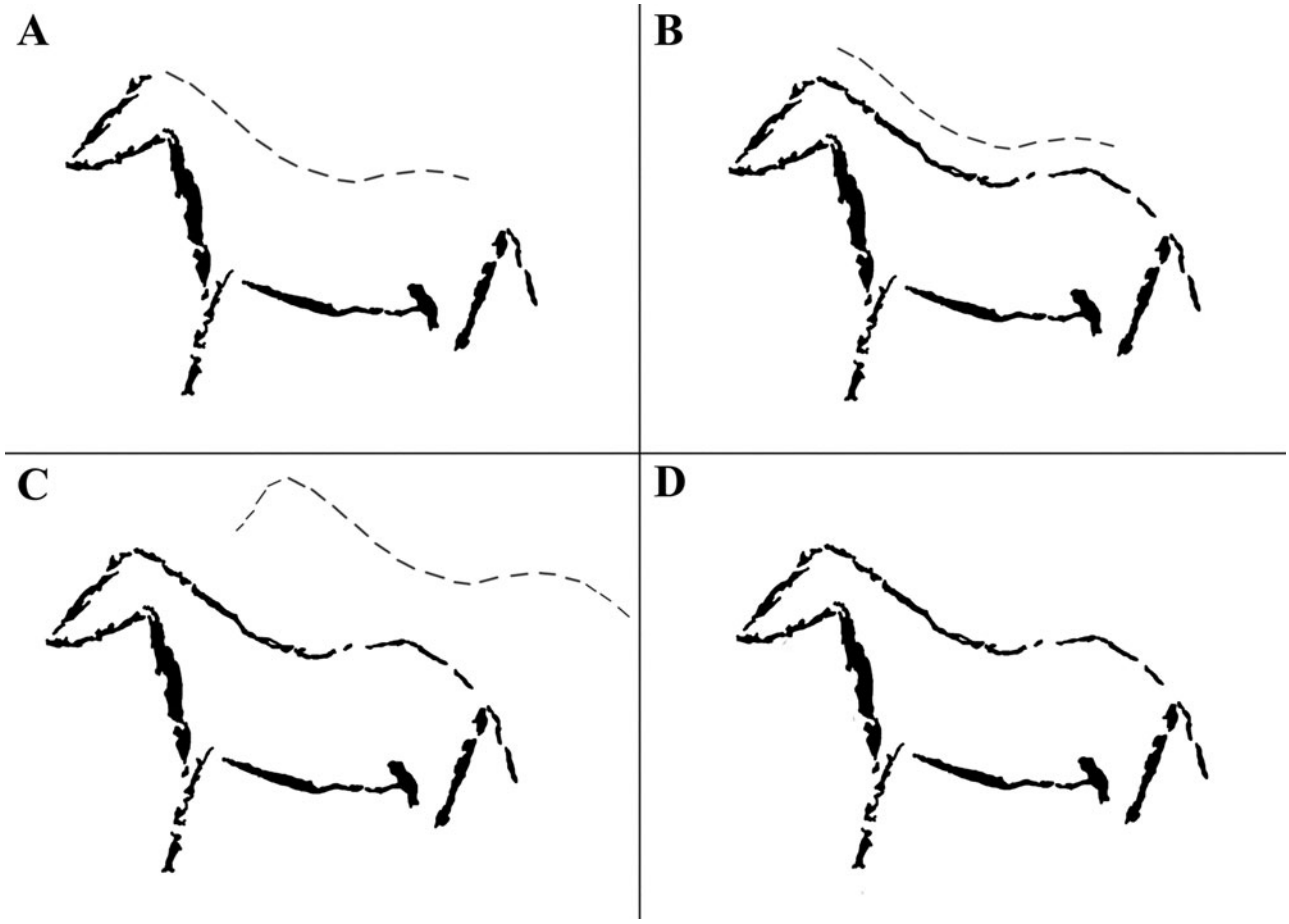

Figure 2. *Examples of the different categories of relationships between depictions and the cave wall, where in A–C the dashed line represents a natural crack.*

depiction is not drawn in parallel to this feature (e.g. a dorsal mimics the profile of a nearby crack); 4) Limited/None: there is no clear association between the depiction and the cave wall topography (Fig. 2). These categories were produced to characterize broadly different relationships to the cave wall, enabling an assessment of the extent to which depictions were influenced by topographic features. All depictions recorded were also photographed using a Nikon D3500 DSLR camera with an 18–55 mm AF-P VR lens, using cold LED light sources to illuminate the depictions and minimize the presence of shadow.

In Las Monedas, 28 out of the 30 depictions published by Ripoll Perelló (1980) were recorded (two of the indeterminate depictions could not be located). In Gallery A of La Pasiega, 65 figurative depictions were recorded, with the DStretch© plugin of ImageJ© used to facilitate the identification of faded depictions (Harman 2008). The discrepancy between the number of depictions recorded in Gallery A and those previously reported by Balbín-Behrmann and González-Sainz (1993) may be due to several factors. Some of the figurative depictions previously recorded were engraved—our study focused only on painted depictions, due to the practical limitations of recording engraved motifs using photogrammetry (Rivero *et al.* 2019). There are also several areas of Gallery A that are spatially constrained and difficult to access during fieldwork, and the area where Gallery A begins and Galleries B and D end is ambiguous and features a few isolated depictions which may have been reported as part of the depictions in Gallery A previously. In any case our study comprises 28 of 30 images for Las Monedas and 65 of 100 for Gallery A of La Pasiega.

3D modelling

To record appropriately the relationship between natural features of the cave wall and depictions, it was necessary to produce 3D models of the art that captured the topography of the cave art. 2D images are insufficient for fully capturing the dimensions

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

of the art, significantly distorting depictions and flattening their undulating topography. Consequently, Upper Palaeolithic cave-art research, and rock-art research more widely, has increasingly incorporated 2.5D (e.g. RTI) or 3D modelling (e.g. photogrammetry, TLS) techniques into traditional recording methodologies, to the extent that recording parietal art in this way is now an established approach for the analysis and preservation of the art (e.g. Díaz-Guardamino *et al.* 2015; Domingo *et al.* 2013; González-Aguilera *et al.* 2009; Lerma *et al.* 2006; 2010; Plisson & Zotkina 2015; Rivero *et al.* 2019; Ruiz López *et al.* 2019). Photogrammetric models were produced of the art panels in Las Monedas and La Pasiega based on images taken by IW and, for Las Monedas, Dr Blanca Ochoa. Images were sorted into folders for each panel, filtered for quality and imported into Agisoft Metashape using the guided image matching function to increase the likelihood of the software appropriately matching points across images. Any models that appeared to exhibit significant distortion or low confidence levels in the number of points used were omitted from the study.

VR lighting simulations

To evaluate the effect of a flickering low light source on the perception of the natural features of the cave wall, the photogrammetric models were exported as .obj files and imported into Unity, an open-source 3D gaming-development software (Fig. 3). Unity allows users to build 3D Virtual Reality environments and, notably, facilitates the manipulation of light: ambient lighting can be adjusted, and light sources can be created to emulate the warm, flickering nature of light cast from a small flame. Any 3D models within Unity receive light and cast shadows in the same way as real-world objects, allowing us to explore the real-time effects of a flickering low light source on the perception of cave-art walls.

The art of both Las Monedas and La Pasiega would have received no ambient daylight. Thus, within the VR lighting simulations, the models were illuminated only by a small, flickering light source that cast a warm light of 1850K at source, decreasing to zero at a distance of 1.25 m (diameter of 2.5 m). This is consistent with experimental observations of the lower ranges for light cast from torch technologies made from juniper or pine wood (Medina-Alcaide *et al.* 2021), likely the only woody sources available during the Older Dryas and late Solutrean–early Magdalenian, corresponding to the art of Las Monedas and La Pasiega respectively. Lower ranges were selected to provide a conservative estimate for the light available, and to accommodate for the likelihood that the torch may have been burning for some time before the art was produced; Medina-Alcaide *et al.* (2021) demonstrated light quality depletes as fuel is consumed. In Unity, light intensity does not correspond to real-world values; however, a light intensity of 0.5 was deemed suitable for the approximate light intensity produced by a small flame, particularly as this intensity increased to 0.75 and decreased to 0.25 as the light flickered: this defined our parameters. An appropriate light intensity allows for the simulation perhaps to appear more visually realistic, but the *specific* light intensity is somewhat irrelevant for determining *how* the light interacts with the surface. The light source and its distance away from the wall were kept consistent for each simulation, to allow for appropriate comparisons to be made across the simulations.

To quantify the visual effects of the VR lighting simulations, relative luminance values were calculated from still images of the simulation at the brightest and the dimmest point of flicker. Relative luminance values (RLV) weigh RGB values proportionately using the equation $Y = 0.2126R + 0.7152G + 0.0722B$, where Y is relative luminance. This reflects the sensitivities of the eye to particular wavelengths of light, i.e. a particular energy of medium wavelengths, 'green', is perceived as brighter than the same energy of longer wavelengths 'red' and similarly short wavelengths, 'blue', are perceived as dimmer than other wavelengths (Snowden *et al.* 2006, 33). This produces a value expressed as a percentage, with 100 per cent representing white (brightest) and 0 per cent representing black (darkest). By calculating the RLV at equidistant points across a surface, one can quantify the visual effects of the simulated light from a Palaeolithic torch across the topographic surface of the cave wall and create a profile for how light is interacting with this surface. This can be used to evaluate, for example, whether natural features caused high contrast in RLV, increasing their saliency and drawing visual attention, or if certain features were rendered ambiguous, reflected by low RLV. The dynamic nature of the light source adds another dimension to this, where a topographic feature may be salient in one instance but ambiguous in the next. This disparity in RLV, reflected by a large difference between RLV at the brightest and dimmest points of flicker, may have been most conducive to triggering pareidolic responses—the ambiguity and conflicting visual information would have encouraged the visual system to 'fill in' the missing information.

The Las Monedas photogrammetric models were based on lower-resolution imagery, and hence RLV was calculated at five equidistant points across a depiction. As the La Pasiega photogrammetric models

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

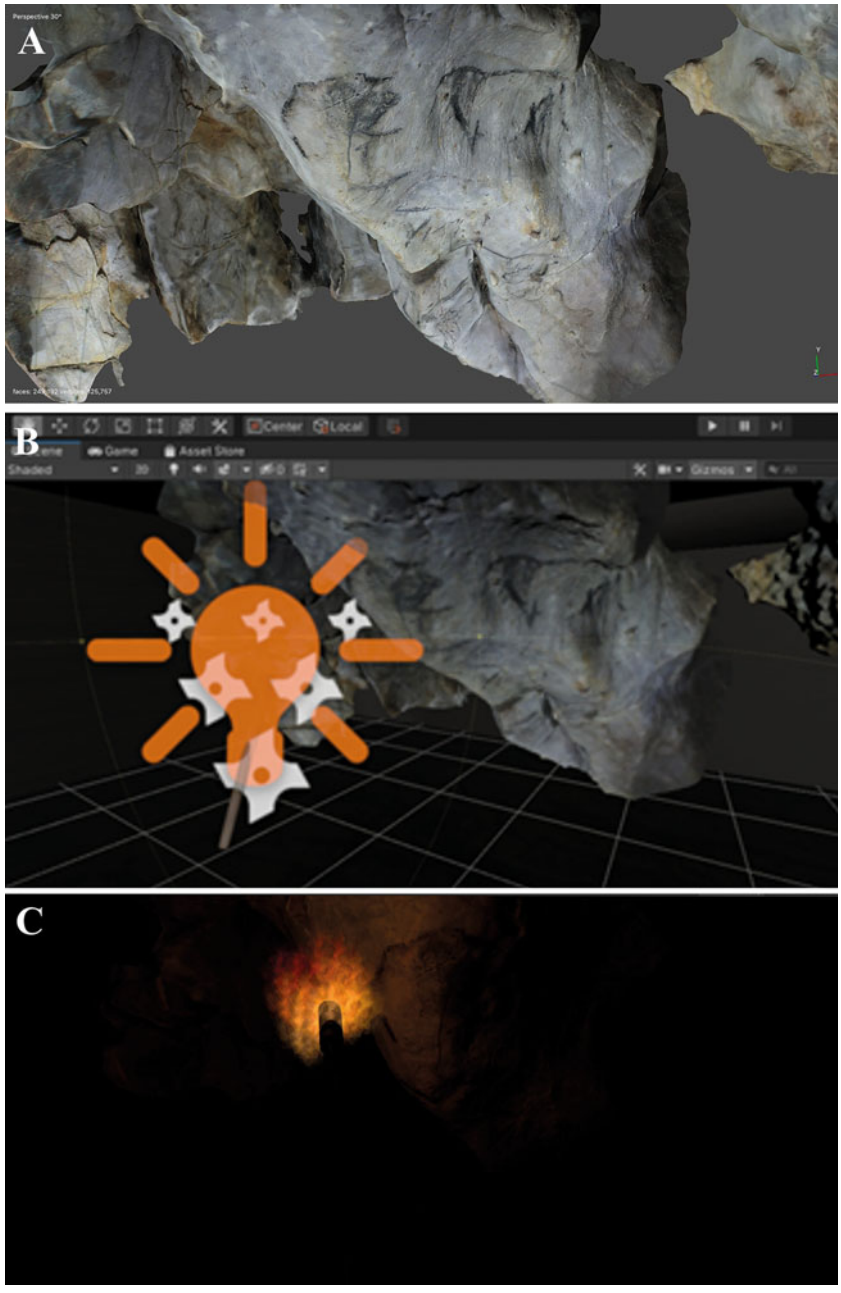

Figure 3. *Workflow for creating lighting simulations. A photogrammetry model (A) is first imported into Unity (B), where a light source that captures the properties of a Palaeolithic torch is produced (C).*

had higher resolution, RLV was calculated at specific distances across the cave wall surface: 0 cm, 5 cm, 10 cm, 20 cm, 30 cm, 40 cm and 50 cm from the source of the light. Additionally, an RLV profile was calculated for a blank white wall to provide a comparison for the profiles calculated for the cave-wall models.

Results

Las Monedas

The figurative images within Las Monedas appear to reflect a prominent influence of pareidolia within their making (Table 3). Of the figurative depictions (20/28 analysed), 71 per cent expressed a strong relationship to the natural features of the cave wall. Thirteen of these directly integrate topographic aspects of the wall into the form of the depiction (e.g. using the undulations of the cave wall to represent the back of an animal: Fig. 2A); six depictions appear to have aspects of their form running parallel to topographic features (e.g. a dorsal line being drawn close and in parallel to the curved edge of the cave wall: Fig. 2B); one depiction appears to mimic the shape of a nearby feature (e.g. the form

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

Table 3. *Summary of the results for the figurative depictions of Las Monedas. See Supplementary Information for the full VR lighting simulation results. Note that due to low–resolution models, not all of the depictions were placed in the VR lighting simulation. * refers to depictions that overlap or are spatially close, and thus experienced the same simulated lighting conditions.*

No.	Animal depicted	Relationship to cave wall	Anatomical features depicted	Style	Average RLV (overall)	RLV max. variation
2	Reindeer	Direct – head fitted to edge, chest traces/runs parallel to rock edge, intentional use of undulation to emphasise shoulder	Complete	Detailed outline with internal anatomical detail	9.3%	13.6%
3	Reindeer	Limited/none	Mostly complete, head missing	Detailed outline with internal anatomical detail	9.4%	23.1%
5	Bison	Direct – dorsal line represented by edge of cave wall	Mostly complete	Simple outline with partial infill	13.9%	29.3%
6	Horse	Direct – dorsal line and rear traces natural crack	Complete	Simple outline with partial infill	6.6%	22.7%
7*	Ibex	Direct – horns trace curvature of undulation in the cave wall	Cervico-dorsal line and front leg	Simple outline	9.3%	15.8%
8*	Horse	Direct – dorsal line traces and extends natural crack	Cervico-dorsal line	Simple outline	9.3%*	15.8%*
10	Horse?	Parallel – the cervico–dorsal line appears to be drawn in parallel to a natural crack	Complete	Simple outline	–	–
11	Horse	Parallel – legs appear to be intentionally drawn in parallel to natural cracks	Mostly complete, head missing	Simple outline	11.8%	14.5%
12	Horse	Direct – head partially traces natural crack, rear legs and tail are suggested by a natural crack	Mostly complete, rear legs and tail not depicted	Simple outline	3%	7.2%
13	Horse	Mimic – the shape of the head appears to mimic the shape of the calcite formation above	Complete	Simple outline with partial infill	9.1%	13.8%
14	Reindeer	Direct – head, eye, and chest partially trace natural cracks	Mostly complete, legs partially represented	Detailed outline with internal anatomical features represented	9.1%	18.5%
15	Caprid/ ibex	Limited/none	Complete	Simple outline	10.1%	20.0%
16	Ibex	Limited/none	Mostly complete, head missing	Simple outline	8.7%	8.8%
17	Horse	Parallel – dorsal line is drawn in parallel to contoured edge of the cave wall	Mostly complete, head missing	Simple outline	–	–
18	Indet.	Direct? – the animal appear to be drawn to emerge from a crevice, and some natural cracks may have been used to represent the ventral line	Cervico-dorsal line	Simple outline	–	–
20	Horse	Limited/none	Complete	Detailed outline with internal anatomical details	3.1%	8.6%
21	Reindeer	Direct? – Ventral line and antlers appear to be partially represented by natural cracks	Mostly complete, ventral line and front legs not depicted	Detailed outline with internal anatomical details	5.4%	10.6%
22	Horse?	Limited/none	Cervico-dorsal line	Simple outline	–	–

Continued

Table 3. *Continued*

No.	Animal depicted	Relationship to cave wall	Anatomical features depicted	Style	Average RLV (overall)	RLV max. variation
25	Bear	Direct – ventral line meets edge of the wall, natural cracks represent front les	Cervico-dorsal line	Simple outline	7.7%	11.6%
26	Cervid	Limited/none	Head	Detailed outline	11.7%	24.7%
28*	Ibex	Direct? – Appears to be positioned to make use of suggestive vertical cracks for legs	Head	Simple outline	1.7%	4.0%
29*	Ibex	Direct – front legs appear to be suggested by natural cracks	Complete	Detailed outline with internal anatomical detail	1.7%*	4.0%*
30*	Horse	Direct – dorsal line suggested by the natural edge of the cave wall.	Mostly complete, head not represented	Simple outline	6.8%	8.9%
31*	Horse	Limited/none	Complete	Simple outline	6.8%*	8.9%*
33	Horse	Parallel – dorsal line and rear follow the natural contour of the rock edge	Complete	Simple outline	15.2%	14.7%
34*	Horse	Limited/none	Complete	Detailed outline with internal anatomical detail	9.7%	28.4%
34a*	Horse	Parallel – Rear seems to run parallel to a natural crack	Complete	Simple outline	9.7%*	28.4%*
36*	Horse	Parallel – the rounded head of the horse appears to run parallel to the curved edge of the cave wall	Cervico-dorsal line	Simple outline	9.7%*	28.4%*

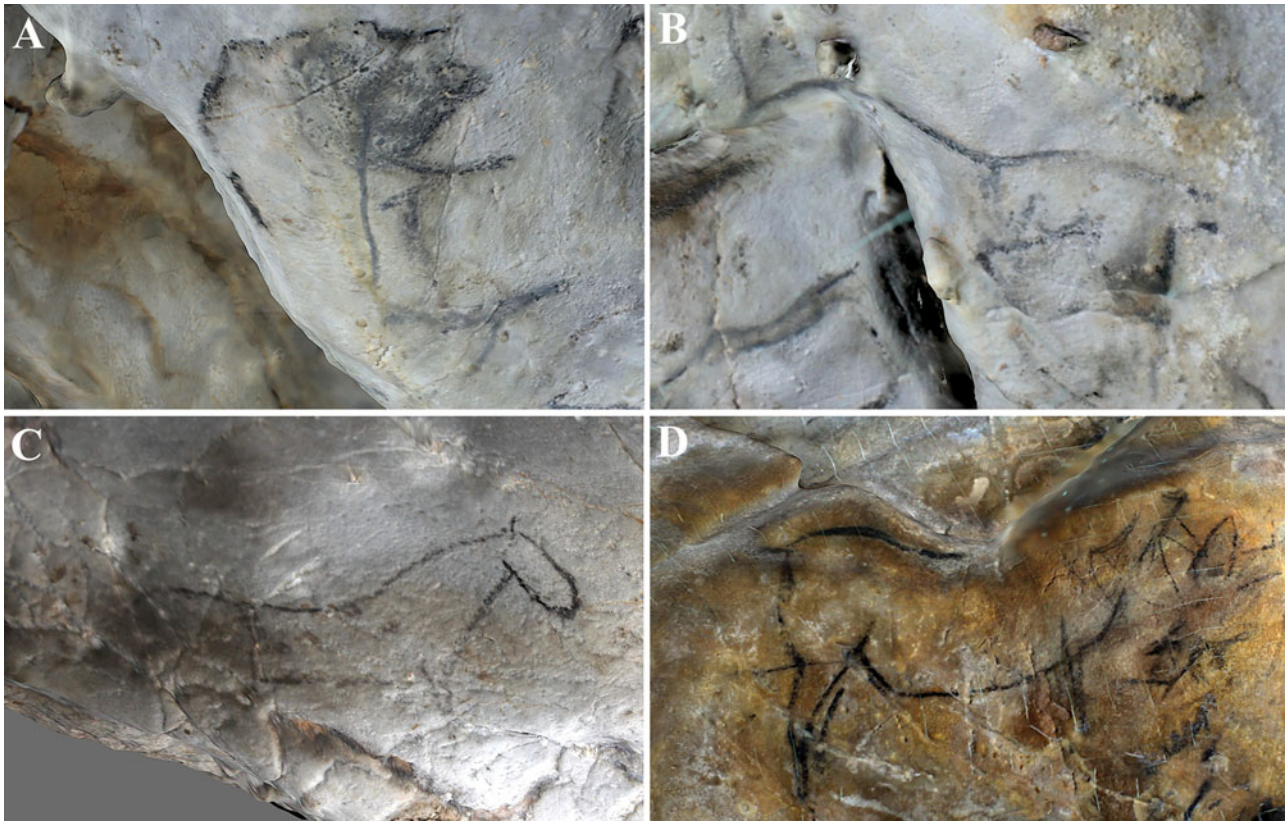

Figure 4. *Ortho-images (orthorectified image accounting for distortions in the topography of the cave wall) of depictions that are simple in style and have a strong relationship to topographic features of the cave wall from Las Monedas. (A) depiction 5; (B) depiction 8; (C) depiction 12; (D) depiction 30.*

of the depiction copies that of the natural feature, but not in parallel: Fig. 2C). These results lend support for Hypothesis 1, thus meeting the first requirement for pareidolia having influenced the making of art within this cave.

Our results also show a relationship between simple and incomplete depictions and the cave wall. Of those depictions with strong relationship to natural features on the cave wall, the vast majority (16/20 = 80 per cent; Fig. 4) are simple in style, i.e. lacking additional anatomical detail such as eyes, hair, or pelage. Equally, half of depictions with apparently limited or no relationship to the cave wall (4 out of 8 depictions) bear additional detail. This supports our Hypothesis 2, that the images that were scaffolded onto features of the cave wall should be simple in form and that those that are more detailed lack such a relationship to their supporting surfaces.

In order to compare the relationship of images to RLV results from the lighting simulations of Las Monedas we used averages of the RLV across all simulations of 8.4 per cent, as an overall average RLV, and 14.9 per cent for the average variation in RLV between the brightest and dimmest points in the simulation (see Supplementary Information for the full dataset). We used these as thresholds to evaluate our data, dividing the depictions into four categories: simple depictions with a strong relationship to features on the cave wall; simple depictions with a weak relationship to features on the cave wall; detailed depictions with a strong relationship to such features; and detailed depictions with a weak relationship to such features. Our results (Table 3) show a loose relationship between below average RLV and those images that bear a strong relationship to features of the cave wall (5 out of 13 depictions simulated = 39 per cent) when compared to the other categories. Low average RLV was recorded for only one (out of 4) of the simple depictions with a weak relationship to the cave wall; one (out of 4) of the detailed depictions with a weak relationship to the cave wall; and two (out of 4) detailed depictions with a strong relationship to the cave wall. This appears to lend some support towards Hypothesis 3, albeit weak.

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

Similarly, the relationship between simple and direct depictions and a high variation in RLV appears to not be distinct, with 46 per cent (n=6 out of 13 depictions simulated) of simplistic depictions with a direct relationship to the cave wall having a high average variation in RLV. Only one (out of 4) of the detailed depictions with a direct relationship to the cave wall also experienced a high variation in RLV. These values are comparable to the depictions with weak relationships to the cave wall; 75 per cent (n=3 out of 4 depictions simulated) of depictions which were detailed with a weak relationship and 33 per cent (n=1, out of 3 depictions simulated) of simplistic depictions with a weak relationship had high variations in RLV. This suggests that unstable light conditions were not a factor that influenced pareidolic responses. These results are therefore not consistent with Hypothesis 3, and suggest that fluctuating light conditions were not responsible for pareidolia in Las Monedas. It appears that, on balance, the particular lighting conditions experienced by artists during the making of these depictions cannot fully explain why certain depictions (i.e. simple depictions scaffolded onto natural features) appear to be heavily influenced by pareidolia, and other depictions (i.e., detailed depictions with weak relationships to the cave wall) were not. This may imply that there were additional facets to the art making process that may have informed the extent to which pareidolia influenced the form of particular depictions.

La Pasiega

The figurative depictions in La Pasiega appear to lend some support to Hypothesis 1, with the slight majority of depictions (55 per cent, n=36 out of 65 depictions) having a strong relationship to topographic features of the cave wall (Table 4; Fig. 5). Of these depictions, 32 directly integrate such features and 9 depictions (5 also directly integrate natural features) have aspects of their form which are drawn in parallel to them. This may suggest that pareidolia underpinned the making of some of these depictions, but there may be additional factors that are further influencing the making of the art.

Our results also show a relationship between simple and incomplete depictions and the cave wall, with 30 out of the 36 depictions (83 per cent) with a strong relationship to topographic features being simplistic in style. However, out of those depictions with a limited or no relationship to the cave wall (n=29), only 7 bear additional detail. This therefore does not seem to support Hypothesis 2; the level of detail of the depictions does not appear to correlate with the relationship between depictions and the cave wall. Since Hypothesis 1 is supported by the La Pasiega data, this may suggest that there are other factors influencing the form of depictions beyond pareidolic imagery. As the majority of depictions in La Pasiega are simpler in style, this may represent a cultural penchant in representing animals by only their most basic and salient outline form. Hinds in Gallery A of La Pasiega (Fig. 6), for example, are predominantly represented by only a red-dotted cervico-dorsal line—a style that is common to hinds depicted during the late Solutrean and early Magdalenian in northern Spain (the so-called 'Ramales school' of depicting hinds, observed in caves such as Covalanas, La Haza, La Garma: Apellaniz 1978; Bicho *et al.* 2007; Straus 1987; 2015).

As with the lighting simulations for Las Monedas, we used two averages for RLV with which to evaluate our data: an overall average across all simulations of 11.4 per cent; and an overall average for the variation between the brightest and dimmest points in the simulation of 18.3 per cent. Again, we divided the depictions into four categories: simple depictions with a strong relationship to features on the cave wall; simple depictions with a weak relationship to features on the cave wall; detailed depictions with a strong relationship to the cave wall; and detailed depictions with a weak relationship to such features. Not all depictions could be appropriately simulated due to low resolution in the 3D models.

There appears to be a loose relationship between simple depictions with a strong relationship to the cave wall and a low average RLV for the figurative depictions at La Pasiega, consistent with the results from Las Monedas; 52 per cent (n=11, out of 21 depictions simulated) had a low average RLV. However, within the other categories a high percentage of the depictions also experienced low average RLV: 50 per cent (n=2, out of four depictions simulated) of detailed depictions with a strong relationship to the cave wall and 67 per cent (4, out of 6 depictions simulated) of detailed depictions with a weak relationship to the cave wall had a low average RLV. By contrast, only 27 per cent (n=4, out of 15 depictions simulated) of the simple depictions with a weak relationship to the cave wall had a low average RLV. It appears, therefore, that there is no clear correlation between low light levels and the influence of pareidolia on the form of a depiction.

Similarly, the results for the variation in RLV appear to not be distinct across all categories, with approximately half of the depictions within any one category appearing to experience high variation in RLV: 48 per cent (n=10, out of 21 depictions

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

Table 4. *Summary of the results for the figurative depictions in Gallery A, La Pasiega. See supplementary information for the full results from the lighting simulations. RLV could not be calculated for depictions that were small (>10 cm), too faded to identify within the VR simulation, or had low resolution. Note that panel PA11 is situated in a spatially constrained area, and thus a 3D model could not be produced for this panel.*

Panel no.	Depiction no.	Animal depicted	Relationship to cave wall	Anatomical features depicted	Style	Average RLV (overall)	RLV max. variation
PA1	PA1.1	Hind	Direct – dorsal line traces natural crack	Cervico– dorsal line	Simple outline	12.4%	10.4%
PA2	PA2.1	Hind	Direct and parallel – ears are drawn in parallel to natural cracks, dorsal line traces natural cracks	Head and dorsal line	Simple outline	5.8%	10.9%
PA2	PA2.2	Bison	Direct – Ventral line integrates natural shape of rock, horns and head trace natural cracks.	Mostly complete – ventral line not depicted	Simple outline	9.4%	23.6%
PA2	PA2.3*	Horse	Direct – head is suggested by natural feature	Mostly complete – head is not depicted	Simple outline	12.4%	28.3%
PA2	PA2.4*	Horse	Direct – rear leg traces natural crack	Mostly complete – ventral line not depicted	Simple outline	12.4%	28.3%
PA2	PA2.5*	Stag	Direct? – Dorsal line appears to integrate natural crack	Head	Simple outline	12.4%	28.3%
PA3	PA3.1	Horse	Direct – dorsal line mapped onto natural crack	Head	Simple outline	11.1%	16.2%
PA3	PA3.2	Hind	Direct – dorsal line partially mapped onto natural crack	Dorsal line	Very simple outline	–	–
PA3	PA3.3	Stag	Direct – antlers mapped onto natural crack	Head and dorsal line	Simple outline	12.9%	35.1%
PA4	PA4.1	Stag	Direct – antlers mapped onto natural crack	Head and dorsal line	Simple outline	11.6%	15.5%
PA4	PA4.2	Horse	Limited/none	Mostly complete	Simple outline	12.9%	17.3%
PA4	PA4.3	Horse	Limited/none	Head	Detailed outline	6.5%	11.2%
PA5	PA5.1*	Hind	Limited/none	Cervico– dorsal line	Simple outline	11.7%	15.6%
PA5	PA5.2*	Hind	Direct and parallel – Part of the head is represented by a contour. Rear of the depiction runs parallel to a natural crack	Cervico– dorsal line	Simple outline	11.7%	15.6%
PA5	PA5.3	Horse	Direct? – rear leg may be represented by a natural feature	Mostly complete	Detailed outline	14.8%	23.1%
PA5	PA5.4	Horse?	Direct? – rear leg appears to be mapped onto a contoured surface	Rear leg and tail	Simple outline	10.0%	20.4%
PA5	PA5.5	Horse	Limited/none	Mostly complete	Simple outline	7.2%	5.5%
PA6	PA6.1	Horse	Limited/none	Complete	Simple outline	12.9%	15.7%
PA6	PA6.2	Hind	Direct – front legs are represented by natural cracks	Complete	Simple outline	12.3%	15.3%
PA7	PA7.1	Hind	Limited/none	Cervico– dorsal line	Simple outline	12.5%	11.3%
PA7	PA7.2	Horse	Limited/none	Head and dorsal line	Simple outline	12.5%	18.2%
PA7	PA7.3	Aurochs	Direct – head and rear mapped onto natural cracks	Complete	Simple outline	11.0%	17.3%
PA7	PA7.4	Hind	Direct – ventral line mapped onto natural crack	Complete	Simple outline	12.2%	27.7%

Continued

Table 4. *Continued*

Panel no.	Depiction no.	Animal depicted	Relationship to cave wall	Anatomical features depicted	Style	Average RLV (overall)	RLV max. variation
PA7	PA7.5	Hind	Limited/none	Head	Simple outline	12.8%	18.0%
PA7	PA7.6	Hind	Limited/none	Head, dorsal line, front leg	Simple outline	12.7%	19.3%
PA7	PA7.7	Hind	Limited/none	Head	Simple outline	12.9%	18.0%
PA7	PA7.8	Hind	Limited/none	Complete	Detailed depiction with infilling and engraved details	14.9%	21.9%
PA7	PA7.9	Hind	Limited/none	Mostly complete	Simple outline	16.3%	22.4%
PA7	PA7.10	Indet.	Limited/none	Partial head	Simple outline	–	–
PA7	PA7.11	Hind	Limited/none	Complete	Detailed infilled depiction	11.0%	12.4%
PA8	PA8.1	Stag	Limited/none	Antlers and partial dorsal line	Simple outline	20.9%	36.3%
PA8	PA8.2	Hind	Limited/none	Complete	Detailed outline with internal anatomical details	11.9%	24.7%
PA8	PA8.3	Stag	Limited/none	Head and dorsal line	Simple outline	–	–
PA9	PA9.1	Hind	Direct – front legs are mapped onto natural cracks. Rear may be represented by natural undulations in the cave wall	Head, chest and front legs	Simple outline	–	–
PA9	PA9.2	Hind	Direct and parallel – rear mapped onto a natural crack and the head is drawn in parallel to another crack.	Complete	Simple outline	–	–
PA9	PA9.3	Horse	Direct and parallel – head traces two cracks, rear runs parallel to a crack	Complete	Simple outline	–	–
PA9	PA9.4	Horse	Direct – mapped onto a suggestive contour and the tail extends a natural crack	Complete	Simple outline with infilling on the head	10.7%	19.9%
PA9	PA9.5	Aurochs	Direct? – ventral line appears to be represented by a crack	Head, chest and front legs	Detailed outline	15.3%	29.7%
PA9	PA9.6	Hind	Parallel – dorsal line of the head runs parallel to a natural crack	Complete	Simple outline	11.0%	22.3%
PA9	PA9.7	Horse	Limited/none	Mostly complete	Detailed outline	11.1%	14.5%
PA9	PA9.8	Horse	Direct – dorsal line and nostril represented by natural cracks	Head	Detailed outline	–	–
PA9	PA9.9	Aurochs?	Direct? – dorsal line appears to trace and continue natural crack	Mostly complete	Simple outline	–	–
PA10	PA10.1	Aurochs	Direct and parallel – ventral line follows and integrates the edge of the rock surface	Complete	Simple outline	11.5%	17.0%
PA10	PA10.2	Horse?	Limited/none	Neck and front leg?	Simple outline	–	–

Continued

Table 4. *Continued*

Panel no.	Depiction no.	Animal depicted	Relationship to cave wall	Anatomical features depicted	Style	Average RLV (overall)	RLV max. variation
PA10	PA10.3	Stag	Parallel – head is drawn in parallel to a natural crack	Cervico– dorsal line	Simple outline	9.4%	15.7%
PA10	PA10.4	Aurochs	Direct? – legs appear to intentionally trace natural cracks	Complete	Detailed outline with partial infill on the body	8.3%	15.2%
PA10	PA10.5	Deer	Direct? – depiction may intentionally use natural cracks to suggest antlers	Head	Simple outline	–	–
PA11	PA11.1	Ibex	Limited/none?	Mostly complete	Detailed outline	–	–
PA11	PA11.2	Ibex	Direct – dorsal line traces natural crack	Mostly complete	Detailed outline	–	–
PA11	PA11.3	Horse	Parallel – rear and front legs are drawn in parallel to natural cracks	Mostly complete	Simple outline	–	–
PA11	PA11.4	Indet.	Limited/none	Mostly complete?	Simple outline	–	–
PA12	PA12.1	Horse	Parallel – rear is drawn in parallel to a suggestive contour, front leg is drawn in parallel to a natural crack	Complete	Detailed outline	8.4%	14.3%
PA12	PA12.2	Aurochs	Limited/none	Mostly complete	Simple outline	11.0%	15.8%
PA12	PA12.3	Ibex?	Limited/none	Head, chest and front legs	Simple outline	–	–
PA12	PA12.4	Horse	Direct – front and rear legs trace suggestive contours	Mostly complete	Simple, stylised outline	7.2%	13.8%
PA12	PA12.5	Horse?	Limited/none	Head?	Simple outline	–	–
PA12	PA12.6	Horse	Direct – traces suggestive, natural contour in the cave wall surface	Head	Simple outline	8.7%	13.9%
PA12	PA12.7	Aurochs	Direct – traces a suggestive contour and the horns trace natural cracks	Head, chest and front legs	Simple outline	–	–
PA12	PA12.8	Hind	Limited/none	Mostly complete	Simple outline	–	–
PA12	PA12.9	Indet.	Direct – appears to trace a suggestive contour with the ventral line suggested by the edge of the rock surface	Rear and dorsal line	Simple outline	–	–
PA12	PA12.10	Horse	Limited/none	Head, chest and front legs	Simple outline	12.7%	22.1%
PA12	PA12.11	Hind	Direct – head traces a suggestive contour and cracks represent the neck	Head, chest and front legs	Simple outline	10.6%	24.2%
PA12	PA12.12	Hind	Limited/none	Head, chest and front legs	Simple outline	7.8%	23.1%
PA12	PA12.13	Horse	Limited/none	Head, chest and front legs	Simple outline	11.2%	19.8%
PA12	PA12.14	Horse	Limited/none	Head	Detailed outline	9.3%	22.1%

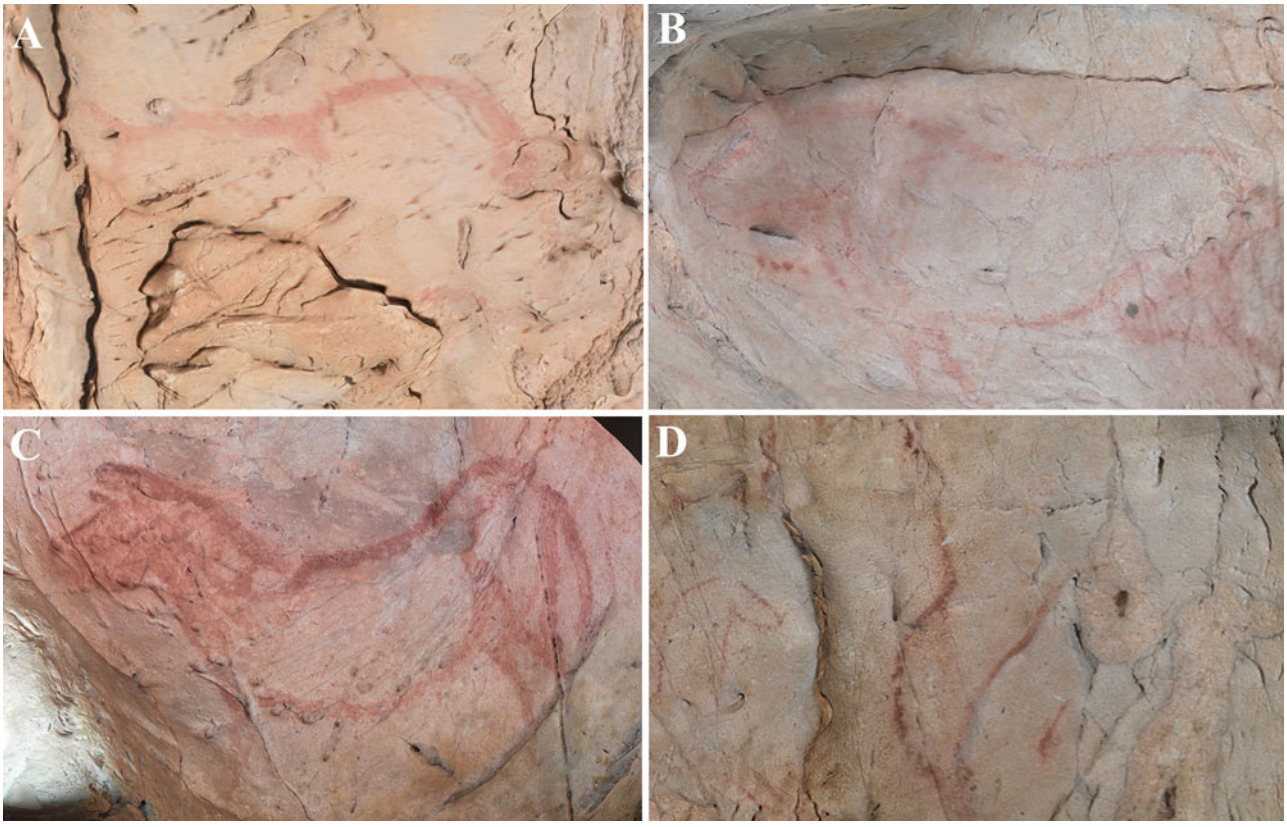

Figure 5. *Ortho-images of depictions that have a strong relationship to topographic features of the cave wall from La Pasiega. (A) depiction PA2.2; (B) depiction PA7.3; (C) depiction PA9.4; (D) depiction PA12.6.*

simulated) of simple depictions with a strong relationship to the cave wall; 40 per cent (6, out of 15 depictions simulated) of simple depictions with a weak relationship to the cave wall; 50 per cent (2, out of 4 depictions simulated) of detailed depictions with a strong relationship to the cave wall; and 50 per cent (3, out of 6 depictions simulated) of detailed depictions with a weak relationship to the cave wall, had a high variation in RLV. This clear lack of relationship between any particular category of depiction and high variation in RLV further suggests that light conditions did not influence, or at least were not the only factor to influence the extent of the role pareidolia had in the making of figurative depictions. While this certainly challenges the assertion made by Hypothesis 3, it is clear that at least some depictions appear to conform to the expectations of pareidolia having a prominent role in art making. For example, depiction PA12.6—a simple representation of a horse head in vertical orientation—directly traces evocative features of the cave wall's topography and experienced low but unstable lighting conditions in the VR simulation. By contrast, there are equally clear examples of depictions that challenge the hypotheses and appear not to have been influenced by pareidolic responses. Depiction PA8.1—a detailed, complete depiction of a hind that does not relate to topographic features of the cave wall—experienced particularly unstable lighting conditions, with a variation in RLV of 36.3 per cent, which one might expect would be associated with pareidolic responses. This alludes to a more complex relationship occurring with the extent to which pareidolia influenced the making of figurative cave art and encourages a deeper consideration of the interaction between the artist, their visual response to light diffusing across the cave wall surface and the subsequent, and perhaps sensorial, interaction with the cave wall.

Discussion and conclusion

In order to evaluate the contribution of pareidolia to the form and position of images in Las Monedas and La Pasiega Caves, we formulated three testable hypotheses and evaluated them using data generated from fieldwork, high-resolution 3D models and simulated light conditions in VR. Hypothesis 1—

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

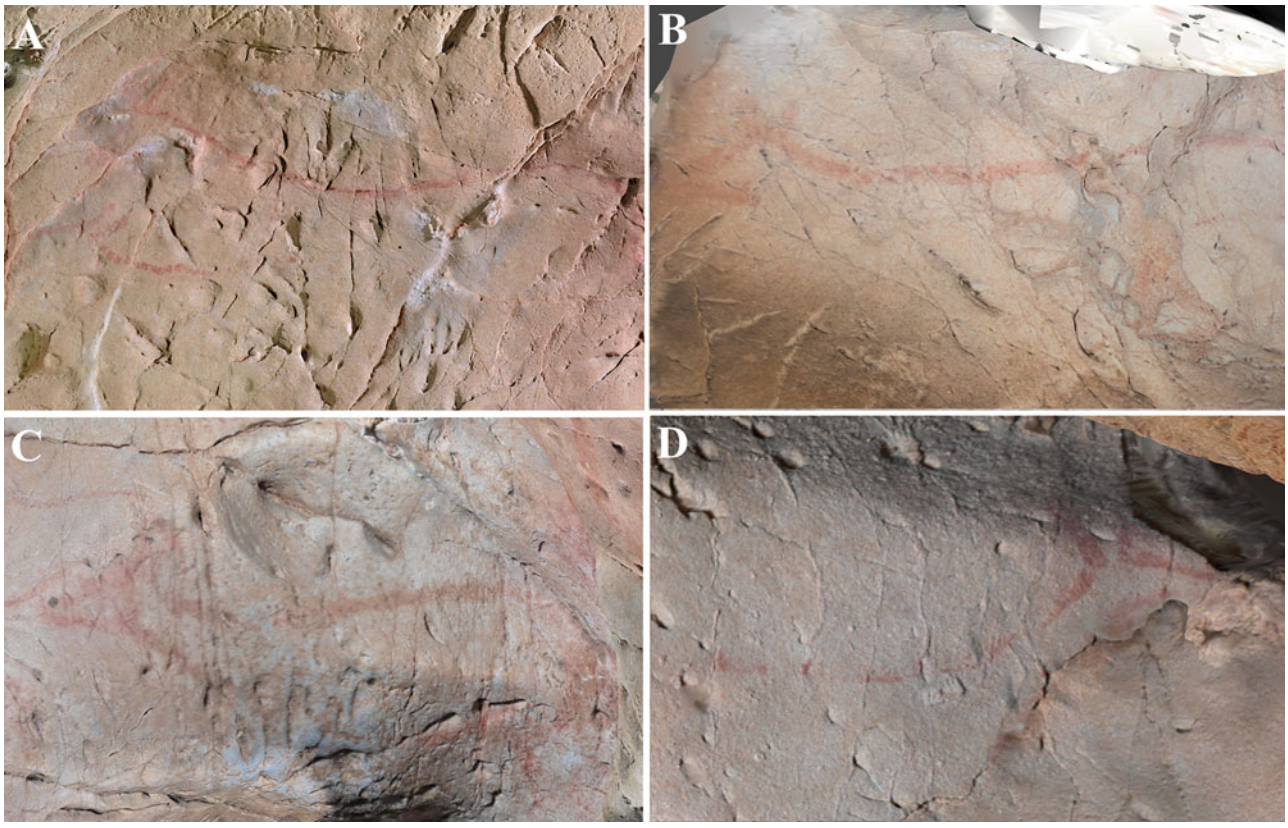

Figure 6. *Ortho-images of hind depictions depicted in similar styles from La Pasiega, but with varying relationships to the cave wall. (A) depictions PA5.1 (top) and PA5.2 (bottom); (B) depiction PA7.1; (C) depiction PA7.4; (D) depiction PA12.11. (See Table 4 for relationship to cave wall.)*

that the majority of the caves' figurative depictions should integrate natural topographic features of the caves' walls—was supported by our data, with the majority of depictions in both caves integrating the cave wall topography. Seventy-one per cent of images in Las Monedas and 55 per cent of those in La Pasiega demonstrably integrate topographic features into their outline imagery. Given the amount of available wall space that was *not* utilized for figurative depictions in both caves, but particularly for Las Monedas, this cannot have been coincidental. Rather, it suggests that the integration of wall and image was intentional, and therefore that the pareidolia evidenced in the majority of cases played an active part in the creation of animal representations in these caves. Hypothesis 2—that simpler (outline) depictions should have a stronger relationship with natural features of the caves' walls than those containing more detail—was somewhat supported by our results, albeit with some nuance within them. For both caves, the depictions that directly integrate natural features are overwhelmingly simplistic in style—80 per cent of the Las Monedas depictions and 83 per cent of the La Pasiega depictions that have a direct relationship to topographic features are simple in style. However, the absence of detail does not appear to be directly informed by this relationship; with La Pasiega, for example, 76 per cent of the depictions that have a weak relationship to the cave wall are also simple in style. The results are thus perhaps best interpreted as reflecting a *tendency* not to add detail to images placed in relationship to natural features. Perhaps this was because the incorporation of natural features *was itself* a form of detail. This may also be reflecting cultural style. For La Pasiega, hinds are often depicted by representing only the head and dorsal line of the animal, which is characteristic of hind depictions in the late Solutrean of northern Spain. Hypothesis 3, however—simple depictions with a strong relationship to the cave wall should experience low and unstable light conditions, and detailed depictions with a weak relationship to the cave wall should experience bright and stable light conditions—was not supported by the results, and we can reject it. It therefore seems that the *reason* behind pareidolia having a stronger

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

influence over certain depictions than others appears not to have any clear relationship to lighting conditions. This has pertinent implications for understanding the specific mechanisms behind pareidolia in caves, and perhaps may reflect a particular penchant for seeking out pareidolic forms in the cave surface, regardless of lighting conditions.

The results seem to indicate there was a *negotiation* occurring between the artist, the cave wall and the form of the animal depiction, with the artist responding to the topographic features of the cave wall in different ways. We thus propose three modes for conceiving of the role of pareidolic responses to cave walls in the making of figurative depictions within La Pasiega and Las Monedas:

- *Dominant*: pareidolia was the dominant factor influencing figurative depictions and thus the cave dominated a two-way conversation, with the artist adopting a more passive 'listening' role.
- *Collaborative*: the artist and cave engage in a two-way conversation in which pareidolia played a partial role in influencing the making of figurative depictions, but this occurred alongside tactile and other sensorial elements of the conversation as well as the artist's own intentions.
- *Passive*: the artist dominates a two-way conversation with the cave, with pareidolia having a minimal or negligible influence over the placement, taxon and form of figurative depictions.

This framework captures the shifting dynamics at play between different agents involved in the cave art making at Las Monedas and La Pasiega. Previous representationalist approaches to Palaeolithic art have tended to assume that only the artist was 'in control' of the creation of their art, i.e. they imposed a predetermined mental representation of the depiction onto a passive surface. In recent years, however, there has been a greater appreciation of the relational nature of art production with sensorial attributes of parietal art making, such as acoustics or tactility, and the materiality of the rock support being understood actively to have shaped this process (DeMarrais & Robb 2013; Fazenda *et al.* 2017; Jouteau *et al.* 2020; Pettitt *et al.* 2014; Sakamoto *et al.* 2020). Our results further contribute to this relational perspective of Palaeolithic art making, and invite the consideration that this was a nuanced process, with the cave having the potential to exert a strong influence over the form and placement of depictions, yet equally may also have played a quieter role. Within our two sample caves, these different roles of the cave wall within the 'conversation' of art making can be observed.

Art making in Las Monedas and La Pasiega may thus have involved several forms of 'conversations' with the cave walls, mediated through sensory responses such as pareidolia, which varied in terms of the relationship between cave, artist and concepts. This is evocative of recorded examples of art making in ethnographic contexts, for example Aboriginal Australian rock-art making being a process of allowing ancestors to speak through the rock surface, with the artist themselves perceiving their role as passive (Brady & Bradley 2014; Layton 1985; Taçon 1989) or Inuit (Aivilik) figurine making being understood as a conversation with the material and 'releasing' the trapped form (Graburn 1976), with amulets or masks within different Inuit societies also having the capacity to negotiate dialogues with animals (Hill 2013; Oosten 1992). These kinds of perspectives resonate with recent discussions of the relationality and materiality of prehistoric rock art in general (Bacelar Alves 2020; Díaz-Guardamino 2020; Valdez-Tullett 2020), often referred to as the 'ontological turn' in rock-art research (Moro Abadía & Gonzalez-Morales 2020).

For the making of figurative art at Las Monedas and La Pasiega, it seems that, at times, the artist/s assumed a subservient relationship with the cave, passively responding or deliberately seeking guidance from it as to what should be created where, reflected in examples where the topographic features of the cave wall are directly integrated and grafted together with the pigment applied by the artist. For example, several depictions from both Las Monedas (e.g. depictions 5, 6, 21, 25, 33) and La Pasiega (e.g. depictions PA2.2, PA5.4, PA7.3, PA9.6, PA12.1, PA12.11) satisfied all three hypotheses; they directly integrate natural features (Hypothesis 1), are simple in style (Hypothesis 2) and their simulated light conditions were unstable and/or low (Hypothesis 3). These depictions perhaps reflect clear examples of pareidolia motivating the theme, placement and form: pareidolia was dominant in their making.

At other times the interaction could be more balanced, utilizing a mixture of topographic, tactile, light and other elements in a two-way discussion of what to depict. This may be the case for depictions that partially satisfied our hypotheses, for example directly integrating natural features and experiencing low light but being detailed in form, or where the depiction is placed in relation to areas of shadow, rather than topographic features, as appears to be the case for depictions 8 and 25 in Las Monedas (Fig. 7). Finally, the artist/s may have adopted a more dominant stance, either overprinting the cave's contribution to the conversation with their

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

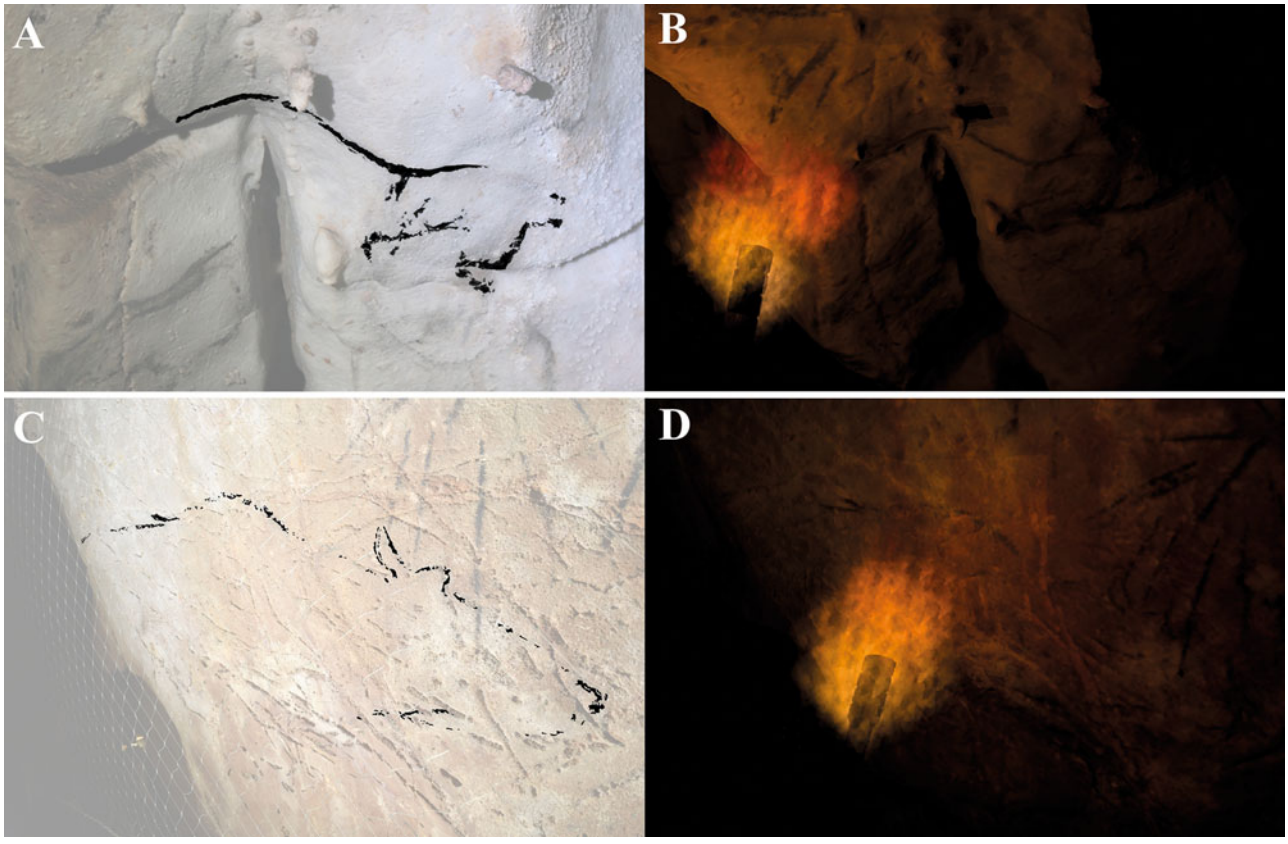

Figure 7. *Digital tracings and VR simulation images of depiction 8 (A and B) and depiction 25 (C and D) from Las Monedas. The two depictions appear to be placed in relation to natural areas of shadow, giving the impression of the animals emerging out of the darkness.*

culturally informed notions of what to depict and how to depict it, or simply treating the cave wall as a blank canvas for the creation of images contained solely in their imagination. This may be the case for examples of depictions within the two caves that do not satisfy Hypothesis 1, i.e. appear to have no relationship to the topographic features of the cave wall. These conversations thus capture the shifting tensions and multifaceted dynamics of relations occurring between artist, cave wall, light, pigment mediated through sensory responses like pareidolia.

The deeper consideration of the role of pareidolia in the making of Upper Palaeolithic figurative art has important implications for our understanding of how Palaeolithic art was created and why. In terms of our three ways for creating visual culture in caves, the earliest, non-figurative phase of art—created, it appears, both by Neanderthals (Hoffman *et al.* 2018) and early *Homo sapiens* (Pike *et al.* 2012)—can best be seen as a *collaborative* discussion. While the finger dots, spat disks and hand stencils were often (but not always) associated with concavities, convexities and fissures in the cave walls, these served as a focus of interaction and did not stimulate or constrain the form of the non-figurative creations (Pettitt 2021). Meaning was achieved through the use of the topography to 'frame' markings derived directly from the bodies of their creators.

This raises questions regarding how the ability or desire to represent 'things' emerged. If our current understanding of the chronological development of Palaeolithic visual culture is correct, it seems that figurative representation occurred after a long non-figurative phase, perhaps shortly after 40,000 BP in Europe and east Asia, and conceivably elsewhere (Aubert *et al.* 2014; Conard 2009; Floss 2018; Pettitt *et al.* 2015). As discussed by Guthrie (2005), Malafouris (2007) and Dobrez and Dobrez (2013), figurative art may have involved the first human attempt to render a three-dimensional object (i.e. an object in three dimensions moving in time) into a relatively flat, two-dimensional image. Pareidolia may have facilitated this process, resonating with

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

our *dominant* conversation category. If this were the case, seeing an animal in the evocative features of cave walls may have acted as cognitive scaffolding, allowing artists to conceive of and represent animals on a surface. In this sense, the appearance of figurative art reduced the human to a more passive role in the conversation: now, both collaborative and dominant conversations drove the creation of visual culture. Finally, perhaps as artistic behaviour became more established, artists could, should they wish, themselves determine where images were placed and the form they took, with pareidolia consequently becoming a *passive* agent. This might explain why the most detailed, realistic images and lifelike scenes develop only in the Late Upper Palaeolithic, a period in which the greater majority of Upper Palaeolithic art is found. While future research may allow for this to be robustly tested, we might envisage human art constituting first a collaborative conversation; supplemented later by a dominant conversation where pareidolia scaffolded the emergence of figurative representations; and finally a passive conversation, where images could be conceived of and imposed onto surfaces irrespective of their morphology.

Acknowledgements

We are grateful to the Gobierno de Cantabria for granting fieldwork permissions for this work and Dr Roberto Ontañon for his support in applying for permissions. We would also like to thank Dr Eduardo Palacio-Pérez for guiding IW around the Monte Castillo caves and his enthusiastic support of this research. Thanks also to Dr Blanca Ochoa for kindly providing images from her fieldwork in Las Monedas cave, and Prof. Marc Groenen for his collegiality regarding the work in La Pasiega cave. IW is grateful to the Northern Bridge DTP for financially supporting this research as part of her PhD. We would like to extend our thanks to the three anonymous reviewers and the editor for their constructive comments.

Supplementary material

For Supplementary information, please visit https://doi.org/10.1017/S0959774323000288
Supplementary videos of the VR light simulations are available upon reasonable request to the authors.

Izzy Wisher
Department of Archaeology
University of Durham
Durham DH1 3LE
UK
Email: isobel.c.wisher@durham.ac.uk

Paul Pettitt
Department of Archaeology
University of Durham
Durham DH1 3LE
UK
Email: paul.pettitt@durham.ac.uk

Robert Kentridge
Department of Psychology
University of Durham
Durham DH1 3LE
UK
Email: robert.kentridge@durham.ac.uk

References

Amormino, V., 2000. L'art paléolithique et le carbone 14 [Palaeolithic art and carbon-14). *L'Anthropologie* 104 (3), 373–81.

Apellaniz, J.M., 1978. Análisise interpretación de Ekain [Analysis and interpretation of Ekain]. *Munibe* 30, 110–50.

Aubert, M., A. Brumm, M. Ramli, *et al.*, 2014. Pleistocene cave art from Sulawesi, Indonesia. *Nature* 514, 223–7.

Bacelar Alves, L., 2020. The act of creation: tangible engagements in the making and remaking of prehistoric rock art, in *Images in the Making: Art, process, archaeology*, eds I.-M. Back Danielsson & A.M. Jones. Manchester: Manchester University Press, 168–83.

Bahn, P.G., 2003. Location, location: what can the positioning of cave and rock art reveal about Ice Age motivations?, in *Höhlenkunst und Raum: Archäologische und architektonische Perspektiven*, eds A. Pastoors & G.C. Weniger. Mettmann: Neanderthal Museum, 11–20.

Balbín-Behrmann, R. & C. González-Sainz, 1993. Nuevas investigaciones en la cueva de La Pasiega (Puente Viesgo, Cantabria) [New investigations at the Cave of La Pasiega (Puente Viesgo, Cantabria)]. *Boletin del Seminario de Estudios de Arte y Arqueologia* 59, 9–34.

Balbín-Behrmann, R. de & C. González-Sainz, 1994. Un nuevo conjunto de representaciones en el sector D.2 de La Pasiega (Puente Viesgo, Cantabria) [A new group of depictions in sector D.2 of La Pasiega (Puente Viesgo, Cantabria)], in *Homenaje al Dr. Joaquín González Echegaray*, ed. J.A. Lasheras Corruchaga. Santander: Idioma, 269–80.

Bednarik, R.G., 2017. Pareidolia and rock art interpretation. *Anthropologie* 55(1/2), 101–17.

Bicho, N., A.F. Carvalho, C. González-Sainz, J. Luis Sanchidrián, V. Villaverde & L.G. Straus, 2007. The Upper Paleolithic rock art of Iberia. *Journal of Archaeological Method and Theory* 14, 81–151.

Bracci, S., J.B. Ritchie, I. Kalfas & H.P. Op de Beeck, 2019. The ventral visual pathway represents animal appearance over animacy, unlike human behavior and

deep neural networks. *Journal of Neuroscience* 39(33), 6513–25.

Brady, L.M. & J.J. Bradley, 2014. Reconsidering regional rock art styles: exploring cultural and relational understandings in northern Australia's Gulf country. *Journal of Social Archaeology* 14(3), 361–82.

Breuil, H., H. Obermaier & H.A. del Río, 1913. *La Pasiega á Puente-Viesgo (Santander, Espagne)* [La Pasiega in Puente Viesgo (Santander, Spain)]. Paris: Institut de Paléontologie Humaine.

Cabrera Valdés, V., 1984. *El Yacimiento de La Cueva de El Castillo (Puente Viesgo, Santander)* [The stratigraphy of the Cave of El Castillo]. Madrid: Conseio Superior de Investigaciones Científicas.

Carmel, D. & S. Bentin, 2002. Domain specificity versus expertise: factors influencing distinct processing of faces. *Cognition* 83, 1–29.

Carrión Santafé, E. & Baena Preysler, J., 1998. Breves anotaciones sobre la colección musteriense de la Cueva de Las Monedas (Puente Viesgo, Cantabria), depositada en 334 el Museo Regional de Prehistoria y Arqueología de Santander [Brief notes on the Mousterian collection of the Cave of Las Monedas (Puente Viesgo, Cantabria), deposited in 334 of the Regional Museum of Prehistory and Archaeology in Santander]. *CuPAUAM: Cuadernos de Prehistoria y Arqueología* 25, 71–85.

Conard, N., 2009. A female figurine from the basal Aurignacian of Hohle Fels cave in southwestern Germany. *Nature* 459, 248–52.

Correa Varella, M.A., 2018. The biology and evolution of the three psychological tendencies to anthropomorphize biology and evolution. *Frontiers in Psychology* 9(1839), 1–21.

DeMarrais, E. & J. Robb, 2013. Art makes society: an introductory visual essay. *World Art* 3(1), 3–22.

Díaz-Guardamino, M., L. García Sanjuán, D. Wheatley & V. Rodríguez Zamora, 2015. RTI and the study of engraved rock art: a re-examination of the Iberian south-western stelae of Setefilla and Almadén de la Plata 2 (Seville, Spain). *Digital Applications in Archaeology and Cultural Heritage* 2(2–3), 41–54.

Díaz-Guardamino, M. 2020. Rock art as process: Iberian Late Bronze Age 'warrior' stelae in-the-making, in *Images in the Making: Art, process, archaeology*, eds. I.-M. Back Danielsson & A.M. Jones. Manchester: Manchester University Press, 73–89.

Dobrez, L. & P. Dobrez, 2013. Rock art animals in profile: visual recognition and the principles of canonical form. *Rock Art Research* 30(1), 75–90.

Domingo, I., V. Villaverde, E. López-Montalvo, J.L. Lerma & M. Cabrelles, 2013. Latest developments in rock art recording: towards an integral documentation of Levantine rock art sites combining 2D and 3D recording techniques. *Journal of Archaeological Science* 40(4), 1879–89.

Fazenda, B., C. Scarre, R. Till, *et al.*, 2017. Cave acoustics in prehistory: exploring the association of Palaeolithic visual motifs and acoustic response. *Journal of the Acoustical Society of America* 142, 1332–49.

Fernández-Navarro, V., E. Camarós & D. Garate, 2022. Visualizing childhood in Upper Palaeolithic societies: experimental and archaeological approach to artists' age estimation through cave art hand stencils. *Journal of Archaeological Science* 140, 105574.

Floss, H., 2018. Same as it ever was? The Aurignacian of the Swabian Jura and the origins of Palaeolithic art. *Quaternary International* 491, 21–9.

Frith, C.D., 2007. *Making Up the Mind: How the brain creates our mental world*. Oxford: Blackwell.

García-Diez, M., D. Garrido Pimentel, J. Angulo Cuesta & P.A. Fernández Vega, 2018. *Monte Castillo: The sacred mountain*. Santander: Cantabria Regional Press.

García-Diez, M., P. Smith, E. Muñoz, D. Garrido, Á. Ibero, P. López-Calle & B. Ochoa, 2021. Visiting Palaeolithic art – explorations and archaeological implications in Cueva de Las Monedas, Spain. *Oxford Journal of Archaeology* 40, 309–22.

González, J.J.A. & R. Balbín Behrmann, 2007. C14 et style: La chronologie de l'art parietal à l'heure actuelle. [C14 and style: The chronology of parietal art at present]. *L'Anthropologie* 111(4), 435–66.

González-Aguilera, D., A. Muñoz-Nieto, J. Gómez-Lahoz, J. Herrero-Pascual & G. Gutierrez-Alonso, 2009. 3D digital surveying and modelling of cave geometry: application to Paleolithic rock art. *Sensors* 9, 1108–27.

González Echegaray, J., 1952. La 'Cueva de las Monedas', nueva caverna con pinturas en la provincia de Santander [The 'Cave of Las Monedas', a new decorated cave in the province of Santander]. *Archivo Español de Arqueología* 25, 343–5.

González Echegaray, J. & J.A. Moure Romanillo, 1971. Representaciones rupestres inéditas en la Cueva de la Pasiega (Puente Viesgo, Santander) [Unpublished rock art depictions in the Cave of La Pasiega (Puente Viesgo, Santander)]. *Trabajos de Prehistoria* 28, 401.

González-Sainz, C., A. Ruiz-Redondo, D. Garate-Maidagan & E. Iriarte-Avilés, 2013. Not only Chauvet: dating Aurignacian rock art in Altxerri B Cave (northern Spain). *Journal of Human Evolution* 65(4), 457–64.

Graburn, N.H.H., 1976. Nalunaikutanga: signs and symbols in Canadian Inuit art and culture. *Polarforschung* 46, 1–11.

Groenen, M. & M.-C. Groenen, 2019. Modes of space appropriation in the decorated caves of El Castillo and La Pasiega (Puente Viesgo, Cantabria, Spain). *Journal of Archaeological Science: Reports* 28, 1–13.

Guthrie, R.D., 2005. *The Nature of Palaeolithic Art*. Chicago (IL): University of Chicago Press.

Harel, A., 2016. What is special about expertise? Visual expertise reveals the interactive nature of real-world object recognition. *Neuropsychologia* 83, 88–99.

Harman, J., 2008. Using Decorrelation Stretch to enhance rock art images. http://www.dstretch.com/AlgorithmDescription.html (accessed 5 May 2021).

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

Hill, E., 2013. Archaeology and animal persons: toward a prehistory of human-animal relations. *Environment and Society* 4(1), 117–36.

Hodgson, D., 2003. Seeing the 'unseen': fragmented cues and the implicit in Palaeolithic art. *Cambridge Archaeological Journal* 13(1), 97–106.

Hodgson, D., 2006. Altered states of consciousness and palaeoart: an alternative neurovisual explanation. *Cambridge Archaeological Journal* 16(1), 27–37.

Hodgson, D., 2008. The visual dynamics of Upper Palaeolithic cave art. *Cambridge Archaeological Journal* 18(3), 341–53.

Hodgson, D., 2012. Emanations of the mind: Upper Paleolithic art as a visual phenomenon. *Time and Mind* 5(2), 185–93.

Hodgson, D., 2013. The visual brain, perception, and depiction of animals in rock art. *Journal of Archaeology* 2013, 1–6.

Hodgson, D., 2019. *The Roots of Visual Depiction in Art: Neuroarchaeology, neuroscience and evolution*. Cambridge: Cambridge Scholars.

Hodgson, D. & P. Pettitt, 2018. The origins of iconic depictions: a falsifiable model derived from the visual science of Palaeolithic cave art and world rock art. *Cambridge Archaeological Journal* 28(4), 591–612.

Hoffmann, D.L., C.D. Standish, M. García-Diez, *et al.*, 2018. U-Th dating of carbonate crusts reveals Neandertal origin of Iberian cave art. *Science* 359, 912–15.

Hong, K., S.K. Chalup, R.A. King & M.J. Ostwald, 2013. Scene perception using pareidolia of faces and expressions of emotion, in *Proceedings of 2013 IEEE Symposium on Computational Intelligence for Creativity and Affective Computing (CICAC 2013) (Singapore 16–19 April)*, Singapore: IEEE, 79–86.

Jouteau, A., V. Fergulio, D. Lacanette, S. Carre, N. Noe & J. Jaubert, 2020. Understanding the perception and appropriation of space in Palaeolithic decorated caves: new methods and tools, with the examples of Cussac and Lascaux caves. *Rock Art Research* 37 (2), 137–54.

Joyce, C.A. & G.W. Cottrell, 2004. Solving the visual expertise mystery, in *Connectionist Models of Cognition and Perception II: Proceedings of the Eighth Neural Computation and Psychology Workshop*, eds H. Bowman & C. Labiouse. London: World Scientific, 127–36.

Kato, M. & Mugitani, R. 2015. Pareidolia in infants. *PLoS One* 10(2), 1–9.

Layton, R., 1985. The cultural context of hunter-gatherer rock art. *Man* 20(3), 434–53.

Lee, J., 2016. I see faces: popular pareidolia and the proliferation of meaning, in *Materiality and Popular Culture: The popular life of things*, eds A. Malinowska & K. Lebek. London: Routledge, 105–18.

Lerma, J.L., S. Navarro, C. Miriam & V. Villaverde, 2010. Terrestrial laser scanning and close-range photogrammetry for 3D archaeological documentation: the Upper 355 Palaeolithic Cave of Parpalló as a case study. *Journal of Archaeological Science* 37, 499–507.

Lerma, J.L., V. Villaverde, A. García & J. Cardona, 2006. Close range photogrammetry and enhanced recording of Palaeolithic rock art. *IAPRS* 36(5), 147–54.

Leroi-Gourhan, A., 1971. *Préhistoire de l'art occidental* (2nd edn). Paris: Mazenod.

Lorblanchet, M., 1995. *Les grottes ornées de la préhistoire: nouveaux regards*. Paris: Errance.

Malafouris, L., 2007. Before and beyond representation: towards an enactive conception of the Palaeolithic image, in *Image and Imagination: A global history of figurative representation*, eds C. Renfrew & I. Morley. Cambridge: McDonald Institute for Archaeological Research.

Maranhão-Filho, P. & Vincent M.B., 2009. Neuropareidolia: diagnostic clues apropos of visual illusions. *Arquivos de Neuro-Psiquiatria* 67(4), 1117–23.

Medina-Alcaide, A., D. Garate, I. Intxaurbe, *et al.*, 2021. The conquest of dark spaces: an experimental approach to lighting systems in Paleolithic caves. *PLoS One* 16(6), 1–30.

Melcher, D. & F. Bacci, 2008. The visual system as a constraint on the survival and success of specific artworks. *Spatial Vision* 21(3–5), 347–62.

Moro Abadía, O. & M.R. González Morales, 2020. Art in the making: recent developments in the study of Pleistocene and Holocene images. *Journal of Archaeological Method and Theory* 27, 439–53.

Moure Romanillo, A., C. González Sainz, F. Bernaldo de Quirós & V. Cabrera, 1996. Dataciones absolutas de pigmentos en cuevas cantábricas: Altamira, El Castillo, Chimeneas y Las Monedas [Absolute dating of pigments in the Cantabrian caves: Altamira, El Castillo, Chimeneas and Las Monedas.], in *'El Hombre Fósil' 80 años después* ['The Fossil Man' 80 years on], ed. A. Moure Romanillo. Santander: Universidad de Cantabria.

Múzquiz, M. & V. Cabrera Valdés, 2000. El arte rupestre de la cueva de Las Monedas (Puente Viesgo). Resultados preliminares de las campañas 1989–1990 [The parietal art of the cave of La Monedas (Puente Viesgo). Preliminary results of the fieldwork 1989–1990], in *Actuaciones arqueológicas en Cantabria* 1984–1999 *[Archaeological activities in Cantabria* 1984–1999*]*, eds R. Ontañón & R. Santander. Consejería de Cultura y Deporte del Gobierno de Cantabria, 145–6.

Ochoa, B., 2017. *Espacio gráfico, visibilidad y tránsito cavernario: El uso de las cavidades con arte paleolítico en la Región Cantábrica*. [Graphic space, visibility and cave transit: the use of caves with Palaeolithic art in the Cantabrian region]. (BAR International Series S2875.) Oxford: BAR Publishing.

Ochoa, B., D. Garrido-Pimentel & M. García-Diez, 2017. Looking through past records: the use of historical documents in cave art spatial studies and its

application to La Pasiega (Puente Viesgo, Cantabria, Spain). *Quaternary International* 430(A), 130–40.

Oosten, J., 1992. Representing the spirits: the masks of the Alaskan Inuit, in *Anthropology, Art, and Aesthetics*, eds J. Coote & A. Shelton. Oxford: Clarendon Press, 113–34.

Ortega Martínez, P. & A. Ruiz-Redondo, 2018. An approach for understanding site location preferences on Pas River Basin during Late Magdalenian. Landscape analysis of Las Monedas cave. *Journal of Archaeological Science: Reports* 19, 804–10.

Pettitt, P.B., 2021. The origins of human visual culture: a three-stage hypothesis from babble to concordancy to inclusivity, in *The Beef behind All Possible Pasts. The Tandem-Festschrift in Honour of Elaine Turner and Martin Street*, eds S. Gaudzinski-Windheuser & O. Jöris. (RGZM Monographien/*Propylaeum* 868.) Mainz: Römisch-Germanisches Zentralmuseum, 229–47.

Pettitt, P.B., M. Garcia-Diez, D. Hoffmann, A. Maximiano Castillejo, R. Ontanon-Peredo, A.W.G. Pike & J. Zilhao, 2015. Are hand stencils in Palaeolithic cave art older than we think? An evaluation of the existing data and their potential implications, in *Prehistoric Art as Prehistoric Culture. Studies in honour of Professor Rodrigo de Balbín-Behrmann*, eds P. Bueno-Ramirez & P. Bahn. Oxford: Archaeopress, 31–43.

Pettitt, P., A. Maximiano Castillejo, P. Arias, R. Ontañón Peredo & R. Harrison, 2014. New views on old hands: the context of stencils in El Castillo and La Garma caves (Cantabria, Spain). *Antiquity* 88, 47–63.

Pike, A.W.G., D.L. Hoffmann, M. García-Diez, *et al.*, 2012. U-series dating of Paleolithic art in 11 caves in Spain. *Science* 336(6087), 1409–13.

Plisson, H. & L.V. Zotkina, 2015. From 2D to 3D at macro- and microscopic scale in rock art studies. *Digital Applications in Archaeology and Cultural Heritage* 2(2–3), 102–19.

Proverbio, A.M., 2017. Sex differences in social cognition: the case of face processing. *Journal of Neuroscience Research* 95, 222–34.

Reid, V.M., K.J., Dunn, R.J., Young, J. Amu, T. Donovan & N. Reissland, 2017. The human fetus preferentially engages with face-like visual stimuli. *Current Biology* 27(12), 1825–8.

Ripoll Perelló, E., 1972. *La cueva de Las Monedas en Puente Viesgo (Santander). Monografías de Arte Rupestre, Arte Paleolítico. Vol. 1* [The cave of Las Monedas in Puente Viesgo (Santander). Monographs of Cave Art, Palaeolithic Art. Vol. 1]. Barcelona: Diputación Provincial de Barcelona/Wenner Gren Foundation for Anthropological Research.

Ripoll Perelló, E., 1980. *The Cave of Las Monedas in Puente Viesgo (Santander)*. (Monographs on Cave Art: Palaeolithic Art 1.) Barcelona: Diputación Provincial de Barcelona Insituto de Prehistoria y Arqueología.

Rivero, O., 2014. Vers une caractérisation du gisement magdalénien d'Isturitz (Pyrénées-Atlantiques) à travers sa production artistique [Towards a characterisation of the Magdalenian deposit of Isturitz (Pyrenees-Atlantiques) through its artistic production]. *Bulletin de la Société préhistorique française* 111 (2), 255–74.

Rivero, O., J.F. Ruiz-López, I. Intxuarbe, S. Salazar & D. Garate, 2019. On the limits of 3D capture: a new method to approach the photogrammetric recording of Palaeolithic thin incised engravings in Atxurra Cave (northern Spain). *Digital Applications in Archaeology and Cultural Heritage* 14, 1–10.

Robert, E., 2017. The role of the cave in the expression of prehistoric societies. *Quaternary International* 432(B), 59–65.

Rossion, B., C.-C. Kung & M.J. Tarr, 2004. Visual expertise with nonface objects leads to competition with the early perceptual processing of faces in the human occipitotemporal cortex. *Proceedings of the National Academy of Sciences of the USA* 101(40), 14521–6.

Ruiz López, J.F., C.T. Hoyer, A. Rebentisch, *et al.*, 2019. Tool mark analyses for the identification of palaeolithic art and modern graffiti. The case of Grottes d'Agneux in Rully (Saône-et-Loire, France). *Digital Applications in Archaeology and Cultural Heritage* 14, e00107.

Ruiz-Redondo, A., M. Cubas, D. Garate, *et al.*, 2016. Una aproximación a los últimos artistas del Paleolítico: novidades et recientes descubrimientos en La Cueva de Las Monedas (Cantabria, España) [An approach to the last Palaeolithic artists: news and recent discoveries in La Cueva de Las Monedas (Cantabria, Spain)], in *El Arte de las Sociedades Prehistóricas*, eds O. Rivero-Vilá & A. Ruiz-Redondo. Santander: Edificio Interfacultativo, 39–41.

Sainz, C.G. & R. de Balbín Behrmann, 2021. Las representaciones más antiguas de la Cueva de La Pasiega (Puente Viesgo, Cantabria): Los grabados y pinturas parietals de sector D.5 [The parietal engravings and paintings of area D.5], in *De la mano de la Prehistoria: Homenaje a Pilar Utrilla Miranda* [Hand in hand with prehistory: tribute to Pilar Utrilla Miranda], eds M. Bea, R. Domingo Martínez, C. Mazo, L. Montes & J. Rodanés. (Monografias Arqueológicas Prehistorica 57). Zaragoza: Universidad de Zaragoza, 79–95.

Sakamoto, T., P. Pettitt & R. Ontañon-Peredo, 2020. Upper Palaeolithic installation art: topography, distortion, animation and participation in the production and experience of Cantabrian cave art. *Cambridge Archaeological Journal* 30(4), 665–88.

Sauvet, G. & G. Tosello, 1998. Le mythe paléolithique de la caverne [The Palaeolithic cave myth], in *Le propre de l'homme: Psychanalyse et préhistoire* [Uniquely human: psychoanalysis and prehistory], eds F. Sacco & G. Sauvet. Lausanne: Delachaux et Niestlé, 55–90.

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press

Snowden, R., P. Thompson & T. Toscianko, 2006. *Basic Vision: An introduction to visual perception*. Oxford: Oxford University Press.

Straus, L.G., 1979. Cantabria and Vascongadas, 21,000–17,000 B.P.: toward a Solutrean settlement pattern. *Munibe San Sebastian* 31(3-4), 195–202.

Straus, L.G., 1987. The Paleolithic cave art of Vasco-Cantabrian Spain. *Oxford Journal of Archaeology* 6(2), 149–63.

Straus, L.G., 2015. Recent developments in the study of the Upper Paleolithic of Vasco-Cantabrian Spain. *Quaternary International* 364, 255–71.

Taçon, P.S.C., 1989. From the 'Dreamtime' to the present: the changing role of Aboriginal rock paintings in western Arnhem Land, Australia. *Canadian Journal of Native Studies* 9(2), 317–39.

Till, R., 2014. Sound archaeology: terminology, Palaeolithic cave art and the soundscape. *World Archaeology* 46(3), 292–304.

Tovée, M.J., 1998. Is face processing special? *Neuron* 21, 1239–42.

Valdez-Tullett, J., 2020. Connectivity and the making of Atlantic rock art, in *Images in the Making: Art, process, archaeology*, eds. I.-M. Back Danielsson & A.M. Jones. Manchester: Manchester University Press, 104–19.

Waller, S.J., 1993. Sound reflection as an explanation for the content and context of rock art. *Rock Art Research* 10, 91–101.

Ward, C.W., 2008. Duality and Perception. MSc thesis, Western Carolina University.

Zhou, L.-F. & M. Meng, 2020. Do you see the 'face'? Individual differences in face pareidolia. *Journal of Pacific Rim Psychology* 14, 1–8.

Author biographies

Izzy Wisher recently completed her PhD at Durham University on the visual psychology of Upper Palaeolithic figurative cave art in northern Spain and is currently a postdoctoral research fellow on the ERC project 'eSYMb: The Evolution of Early Symbolic Behaviour'. Her research focuses on using interdisciplinary methods with the cognitive sciences to test hypotheses related to the making of early art.

Paul Pettitt is Professor of Palaeolithic Archaeology at Durham University. His research interests focus on the Neanderthals and early *Homo sapiens* in Europe, specifically the origins and early evolution of Palaeolithic art and the development of human treatment of the dead.

Robert Kentridge is a Professor of Visual Psychology at Durham University. His work focuses on understanding the relationship between visual perception, visual attention, and consciousness. He is involved in a number of interdisciplinary projects, collaborating with philosophers and archaeologists alike.

https://doi.org/10.1017/S0959774323000288 Published online by Cambridge University Press