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Now you see me. An assessment of the visual recognition and control of individuals in archaeological landscapes

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Abstract

Visibility analysis has become extremely popular in landscape-oriented archaeology in recent decades and has become even more widespread with the popularization of GIS tools, which have multiplied the ways in which visual perception can be analysed and digitally modelled. Visibility has been used as a proxy for different archaeological approaches, from the analysis of subjective perception to the assessment of strategic control. While interest has most often been focused on how objects, features and sites are perceived, there has also been an interest in how visual control is exerted from archaeological sites or other places in the landscape. Within the latter approaches, the distances at which visual control can be exercised have usually been determined in a more or less arbitrary manner, without a clear and empirically informed reference on how things and, especially, people can be observed and recognized differently at a distance. In this paper, we present the results of a field experiment carried out to measure the distances at which individuals can be spotted, recognized and identified with the naked eye in favourable conditions. Based on these results, we introduce the concept of Individual Distance Viewshed (IDV) as a GIS-based representation of visual control. This will serve as a reference to better qualify potential visibility in landscape analysis. Finally, we illustrate the applicability of this approach with a case study which explores the relationship between visual control and mobility during the Iron Age in the NW of the Iberian Peninsula.

Keywords

Visibility; Landscape; Visual control; Perception; Distance; GIS; Viewshed; Iron Age; NW Iberian Peninsula

1. Introduction

Over the last 20 years, the analysis of visibility has become a recurrent topic in landscape archaeology. The progressive development of digital tools, and more specifically GIS, has given this area a significant boost and has produced an abundant body of literature which includes both theoretical and methodological proposals, along with a plethora of case studies (e.g. Brughmans, et al., 2014, Lake and Ortega, 2013, Lake, et al., 1998, Lake and Woodman, 2003, Llobera, et al., 2010, Mayoral Herrera, et al., 2017a, Paliou, 2013, van Leusen, 1999, Wheatley and Gillings, 2000). As has been analysed in greater detail elsewhere (Gillings, 2012, Lake and Woodman, 2003, Llobera, 2012, among others), the advent of digital modelling was seen with suspicion, and was even strongly criticized, by those concerned with an explicitly-phenomenological approach, in which observation and direct experience in the field were considered as the only reliable approaches to perception. For these people, digital modelling was necessarily biased by a cartographic, from-above and non-humanistic perspective. Indeed, the first attempts to model visibility in digital environments were actually largely restricted by a simplistic, binary determination of what can be potentially visible and not visible.

Recently, the development of more nuanced proposals for the digital exploration of visual landscapes, from a more humanistic perspective, has helped to take the discussion to a different level (Gillings, 2009, Gillings, 2012, Llobera, 2001, Llobera, 2007, Llobera, et al., 2010, Wernke, et al., 2017). These authors, among others, argue that, when embedded within a more robust and sensitive theoretical framework, and relying on more sophisticated technical skills, digital tools provide an opportunity to approach the human experience of visual perception in the landscape in a replicable and quantifiable way (Llobera, 2012). This can be exemplified by the emergence of concepts such as *visualscapes* (Llobera, 2003), *visual affordances* (Gillings, 2009), *viewshed*

fragmentation and *visual horizons* (Lake and Ortega, 2013), *viewerships* (Bernardini, et al., 2013) or *visibility fields* (Eve and Crema, 2014), all of which go beyond the somehow restrictive notions of line-of-sight and viewshed.

In order to fully reconcile visual experience in the field and digital modelling, some issues which are yet to be addressed are those related with the consideration of visual acuity and the actual capacity of the human eye to distinguish objects and features in the landscape, a particularly relevant issue in archaeology. The study carried out by Ogburn (2006), elaborating on previous proposals (Fisher, 1994), provided a reference to estimate the effect of distance in the observation of any given static object, considering its size. This has proved useful when one is interested in exploring human perception *over* objects, features and places (used for instance in Bernardini, et al., 2013, Gillings, 2009, Gillings, 2015, Kantner and Hobgood, 2016). However, in other cases the interest in visibility is more related with issues of *visual control* exerted *from* features or archaeological sites.

Visual control can be defined in different ways, but the use of the concept in most archaeological studies refers to the recognition and characterization of individuals, or groups of individuals, in the landscape. Although it may be pertinent to many other archaeological contexts, visual control has largely been argued, be it explicitly or implicitly, to be one possible key factor in the selection of settlement location in many archaeological contexts, especially those in which fortification played a major role (e.g. Keeley, et al., 2007). In fact, viewsheds have been used as proxies for the measurement of the effective defensibility of archaeological settlements (Loots, et al., 1999, Martindale and Supernant, 2009, Parcero-Oubiña, 2013, Sakaguchi, et al., 2010) or larger polities (Canosa-Betés, 2016, Zhu, et al., 2017), or as key elements in analysing specific conflict events such as sieges (Rubio-Campillo, et al., 2015) or battlefields (Nolan, 2009). In a similar vein, visual control

has been used as a key element in the analysis of conquest strategies and the domination of complex polities (Acuto, et al., 2012, Kosiba and Bauer, 2013).

Within these approaches, quite often the distances at which visual control can be exercised have either been dismissed or determined more or less arbitrarily, without a clear and empirically informed reference on how things and, especially, people can be observed and recognized differently at a distance. It seems reasonable to think that effective visual control (especially in strategic terms) should only be argued for those areas located within the limits of human vision. A question then arises: what are the distances at which people can be spotted in the landscape? This simple question involves a couple of nuances. What do we mean by spotting? Under what conditions?

In this paper, we will present the results of a field experiment aimed at answering these questions by determining the maximum distances at which, under good conditions, different aspects of an individual can be perceived in the landscape with the naked eye. Subsequently, we present a proposal that discusses the use of these field results within GIS environments, resulting in the proposal of an Individual Distance Viewshed (IDV), a viewshed aimed at the characterization of potential visual control over individuals. The paper ends with a case study which applies the proposal in order to explore the relationship between visual control and mobility during the Iron Age in the NW Iberian Peninsula.

2. Visual perception and distance

The analysis of mutual visibility between sites and their surroundings has been one of the most common uses of GIS-based visual modelling approaches in archaeology (e.g. Kantner and Hobgood, 2016, Wright, et al., 2014 to quote just a couple of recent examples). In addition to these problem-oriented works, other authors have discussed different issues involved in the GIS-based analysis of visual perception and, in particular, how well GIS can represent *if* and *how* things can actually be seen on the ground (Kormann and Lock, 2013, Nutsford, et al., 2015, Zamora Merchán, 2006). Most of these proposals share a common criticism of the restricted way in which standard digital viewsheds represent visibility, as undifferentiated binary models of potentially visible/non-visible areas, disregarding any other variable which might affect actual perception.

Among the variables affecting visual perception, distance is perhaps the most remarkable. Although it is not necessarily the most influential, it is indeed the most persistent and universal. While others, such as atmospheric conditions, are occasional or erratic, distance is inherently attached to the location of things. Consequently, when analysing the influence of visibility and visual control in the selection of archaeological site locations, it makes sense to consider distance as the most critical factor. In fact, the effect of distance in visibility has long been acknowledged, and certain solutions have been proposed to incorporate it into GIS-based calculations. The use of *fuzzy viewsheds* has been especially popular in this regard. A fuzzy viewshed relies on distance decay functions to illustrate the degree to which a cell in a raster surface is visible (Fisher, 1994). This concept has been used in archaeology to propose different indexes of visual certainty (Lake and Ortega, 2013, Lake, et al., 1998, Lake and Woodman, 2003, Llobera, 2001, Llobera, 2003, Llobera, et al., 2010, Paliou, 2013, Wheatley and Gillings, 2000). Coupled with the proposal developed by Higuchi (1983), Wheatley and Gillings (2000) proposed a method for the definition

of three “visibility zones” (foreground, middle ground and background), not necessarily based on distance but on any other variable of preference. Some years later, M. Llobera (2007) proposed a more refined characterization of these three visibility zones for the specific case of the analysis of the visual perception of barrows in the landscape. His proposal was based on the visual angle occupied by a barrow at each location with reference to the comparative size of an individual or a group of people. As a result, he did not define absolute distances but rather angles relative to the field of view of the observer.

The above-mentioned work by Ogburn (2006) is perhaps the best known attempt in archaeology to develop an index of visibility-distance of universal applicability, consisting of a “fuzzy viewshed approach, modified to account for target size”. Based on a consideration of the psychophysical and environmental limits of human vision, it proposed “a method for assessing how far individual objects could have been seen within past landscapes”. The method provides useful guidelines for calculating the maximum distance at which any object of a given size can be visually recognized. However, it does have certain limitations when the interest is not only in determining if something can or cannot be visible, but also in further exploring how perception and recognition changes with distance. In addition, targets are deemed to be static, something which, again, does not apply when dealing with people moving across the landscape. The proposal considers the possibility of using *fuzzy values* to differentiate between the specific characteristics of targets, but the values to be assigned remain relatively undefined, “based on knowledge of local environmental conditions and physical properties of the target and its setting” (Ogburn, 2006).

Working from a different basis, authors interested in a phenomenological approach to archaeological landscapes have also stressed the impact of distance, among other variables, on visibility, although they have explored it via direct observation in the field (e.g. Van Dyke, 2008). As has been acknowledged, the study by Hamilton, et al. (2006) is among the few attempts to bring

sound methodological discipline and repeatability to those subject-centred observations. These authors were interested not only in visibility but also in other forms of sensory experience, such as sound. As far as visibility is concerned, their proposal is focused on certain specific forms of visual engagement: the perception of the different parts of the body and the specific kinds of communication they allow. Among other results, they suggest some distances at which different parts of the human body can be distinctly perceived. However, their objective is primarily to explore the potential for gestural communication, rather than a more general assessment of how different dimensions of an individual can be observed and perceived at a distance.

Mathematical modelling and field observation are, then, two different approaches to one similar objective. Some attempts have shown that it is possible to reconcile both perspectives, albeit still with a focus on exploring visibility and perception at medium to long distances, starting at best at the distance of detection of people (Rennell, 2012) and extending to the general visual structure of the landscape (Llobera, 2007) – from ca. 1.5 to 20 km. Although there is no doubt that most visual communication takes place at much shorter distances, to the best of our knowledge there is still a lack of references on how visual perception changes at such distances.

3. Materials and methods

3.1 Qualities of visual control

Our experiment was aimed at defining the maximum distances at which, under favourable conditions (as shall be detailed below), different dimensions of the visual recognition of a person can be obtained. In other words, our aim was to find an empirical reference of the distances at which different forms of effective visual control can be exerted over human individuals and associated features (clothes, objects/accessories and human traits). This makes it necessary to distinguish between the different properties of an element that can be perceived (colour, shape and texture) and how these properties can be observed at different distances. Combining these ideas, we have differentiated between three levels of visual resolution:

1. Detection: when something first enters the visual field and its presence is discernible against the background and other things around it. In our case, when an individual is visible for the first time or when the clothes and objects he/she is carrying are first noticed.
2. Recognition: when the basic characteristics of a visible element are discernible. In our case, this means different things: at its most basic level, it means that an individual is at a distance at which the observer can notice that he/she is a human and nothing else. However, at a more detailed level, by recognition we also mean the gradual perception of certain characteristics of the individual: the shape and predominant colour of the clothes and other accessories, the approximate colour of his/her hair and skin (dark or light), his/her complexion, etc.

3. Identification: when the specific details of the elements (specific colour, shape and texture) can be described. In the case of a person, his/her attire and accessories can be described with precision and one specific person and one specific element (garment, accessory, etc.) can be clearly distinguished from any other. In our case, this means that we can clearly see an individual's peculiarities and personal traits, the pattern of his/her clothes and the details of the objects he/she may be carrying.

These three levels of visual resolution express different types of potential control. At the most basic level, visual control is exercised merely by being aware of someone's presence and being able to follow his/her movements in the landscape. However, a different type of control can be exerted when we are able to identify certain characteristics of that person; his/her attitude, age, gender and even his/her identity and intentions as expressed in the clothes he/she is wearing, what objects he /she is carrying, etc. This is especially relevant if we consider how "by means of dress, ornamentation, body modification, posture, gesture, and representation, an individual has the ability to 'put on a social skin', allowing self-identification as a member of a larger or different social or interest group" (Fisher and Loren, 2003: 225).

The objective of our experiment was, then, to obtain a series of *maximum threshold distances* at which different forms of visual control can be exerted over individuals in the landscape. By maximum distances, we mean that the field observation was carried out in favourable conditions, as will be detailed in the following section. By different forms of visual control, we mean the appreciation of different characteristics of an individual with the naked eye, as shall also be described below. As our interest is to explore the effect of distance in visual perception, we have sought to minimize the effect of other variables in order to determine distances at which changes in visual perception are noticeable.

3.2 Designing the field experiment

In the previous section the different nuances of visual control that we are interested in analysing have been described. To address them, a simple field experiment was conducted which consisted of recording the distances at which a target individual became visible from an observation point. To qualify the ways in which the individual “became visible”, a table with different aspects of visual appreciation was used to guide the documentation of the observations in the field (Table 1). As mentioned above, besides the basic question of the visual detection of a person, we were particularly interested in a qualitative assessment of the changes in the perception of the target individual. For this reason, we decided to include some specific details regarding both the attire and the physical characteristics of the target. The visual appreciation of these details was first considered at the basic binary level of visible/non-visible but was also further characterized in terms of recognition and identification.

As we were interested in obtaining a reference for maximum distances, when selecting an area to carry out the experiment it was important for the conditions of the environment to be as unrestrictive as possible. Thus, preference was given to areas in which neither vegetation nor topographic features might act as visual barriers.

One further factor was taken into consideration when selecting the scenario for the field experiment: the effect of the texture of the landscape. In effect, contrast is a highly influential factor in visibility, and the quality of the land cover is expected to substantially modify the possibilities of spotting and identifying specific elements against a background. In order to explore the possible influence of this factor, we decided to carry out our field experiment in two different types of landscape: a bare-earth area and a landscape with vegetation.

Level of visual resolution

		Detection	Recognition	Identification
<i>Person</i>		yes/no	Identified as a human being	
<i>Clothing</i>	general	yes/no		
	separate ¹	yes/no	Predominant colour and shape of the different parts of the attire	Detailed description
<i>Accessories</i>	Hat	yes/no	Predominant colour, general shape (cap, wide-brimmed, etc.)	Detailed description
	Walking stick	yes/no	General shape, long/short	Detailed description
	Bracelet	yes/no	Predominant colour, general shape, material	Detailed description
<i>Bodily features</i>	Limbs	yes/no	Position and movement, light/dark, strong/thin, etc.	
	Hair		Light/dark, long/short, loose/pinned-back	Detailed description
	Facial hair		Light/dark, beard/moustache/sideburns	Detailed description

Table 1. Framework for recording the results of observations in the field: levels of visual resolution and criteria used for their definition

¹ By “separate” we refer to the distinct detection of the main elements of which the clothing is composed (top/shirt – trousers/skirt).

Figure 1. Location of the two areas selected for the field experiment: Barbanza (1) and Carnota (2)

Based on these propositions, two areas were selected (Figure 1). The first was an area of scrubland, with gentle topographic changes, in the Barbanza mountain range in Galicia (NW Spain) (Figure 2). The observation point was located in an elevated position from which almost complete visibility was available up to ca. 3.5 km, a distance at which it was already clear that a person cannot be detected (Rennell, 2012).

Figure 2. The area in Barbanza, as seen from the observation point

The second area was Carnota, also in Galicia (Figure 3), a very long beach with more than 6 km of continuous sand. The observation point was located in an elevated position, from which complete visibility towards the north was available for more than 6 km.

Figure 3. The area in Carnota, as seen from the observation point

In both areas the field observations were repeated 7 times (14 observations in total). Slight changes in weather conditions took place between observations (Table 2), although in all cases foggy, rainy or very cloudy days were avoided.

Small changes were also made in the clothing and accessories worn by the target individuals, although a similar basic appearance was always maintained (Figure 4, Figure 5). Three different individuals, with similar physical characteristics, took turns as targets. Their attire was differently configured for each scenario, in order to maximize its potential visibility (using clothes and complements of contrasting colours against the background), but without relying on elements, materials and textures of uncommon qualities. In some cases, different variants of an element were used (for instance, hats) in order to check the extent to which changes in colour, shape or texture implied different distances of visual detection.

<i>Observation</i>	<i>Area</i>	<i>Land cover</i>	<i>Start time</i>	<i>Weather conditions</i>
<i>B1</i>	Barbanza	scrubland	13.00	Sunny
<i>B2</i>	Barbanza	scrubland	11.30	Partly cloudy
<i>B3</i>	Barbanza	scrubland	13.00	Mostly sunny
<i>B4</i>	Barbanza	scrubland	11.30	Mostly sunny
<i>B5</i>	Barbanza	scrubland	13.00	Mostly sunny
<i>B6</i>	Barbanza	scrubland	11.30	Partly cloudy
<i>B7</i>	Barbanza	scrubland	13.00	Partly cloudy
<i>C1</i>	Carnota	beach	13.00	Sunny, misty
<i>C2</i>	Carnota	beach	11.30	Sunny
<i>C3</i>	Carnota	beach	13.00	Sunny
<i>C4</i>	Carnota	beach	11.30	Sunny
<i>C5</i>	Carnota	beach	13.00	Sunny, misty
<i>C6</i>	Carnota	beach	11.30	Sunny
<i>C7</i>	Carnota	beach	13.00	Partly cloudy, misty

Table 2. Conditions of the observations in both scenarios

In the first area (Barbanza), the target person was dressed in light colours to improve contrast against the terrain (Figure 4), while on the beach at Carnota darker colours were chosen for the same reason (Figure 5). In both cases, the target individuals were bearded (either naturally or with an artificial beard) and both carried accessories of different sizes and relevance (hat/cap, walking stick and bracelet).

Figure 4. Elements of the attire and physical features of the target individual in the first area
(Barbanza)

Figure 5. Elements of the attire and physical features of the target individual in the second area (Carnota)

Two further factors were taken into consideration. Firstly, in both cases the target was located to the north of the observation point, thereby ensuring that illumination was optimal at all times and the shadow of the individual was projected towards his/her back. Secondly, the observations in the field were conducted in good to optimal weather conditions (during the spring/summer and around high noon, to minimize the effect of shadows).

Two people were needed to conduct our experiment: an observer and a target. The equipment used were a pair of walkie-talkies to allow communication between the observer and the target

and a GPS-equipped handheld collector that was used by the target to store the exact position of any changes in visibility as noticed by the observer.

Prior to the carrying out of the field observations, a GIS viewshed calculation was performed in each area from the respective observation points, using a LiDAR-derived 1 m resolution DEM. The results of these calculations were copied into the handheld collector used by the target, in order to make sure that she was keeping track within the theoretical viewshed of the observation point. Although this was unnecessary in the beach scenario, in the Barbanza area, despite the selection of the best possible observation point, some spots that were hidden to the observer still remained. Aided by that information, she stood on a starting point located within a theoretical line of sight from the observation point but where, due to the distance, she was not actually visible (a minimum distance of 2.5 - 3 linear km from the observation point was selected). Then she started walking towards the observation point. Guided by the template summarized in Table 1, the observer informed the target of any changes in how she was being viewed, and the target recorded the exact position with her GPS.

Finally, it should be mentioned that the observer was not the same individual on all occasions. Although the methodology for recording field observations was explicitly designed so that subjective biases were strongly minimized, as described above (documenting only what is and what is not visible, and not how the target is subjectively perceived), this was further guaranteed by having two people acting together as observers in some cases.

4. Results: visual perception and distance

The main results of the field observations in both scenarios are summarized in Table 3 and Table 4 (the complete results are available in the Supplementary Materials section). An initial form of detection occurs at different distances in both scenarios (Figure 6). Contrast against the background favours a slightly earlier detection on the beach (2,538 m., maximum distance) than on scrubland (2,095 m.). At such distances, the individual is just detected as a tiny point in the distance, whose presence is only noticed due to his/her changing position. This range of distances coincides well with the theoretically calculated distance at which an object the size of a human being will subtend a 1' visual arc (Ogburn, 2006: 410, Table 1).

		<i>Level of visual control</i>		
		<i>Detection</i>	<i>Recognition</i>	<i>Identification</i>
<i>Person</i>		2095	958	
<i>Clothing</i>	general	762		
	separate	581	416	29
<i>Accessories</i>	Hat	502	214	29
	Walking stick	287	88	29
	Bracelet	103	28	
<i>Bodily features</i>	Limbs	658	197	
	Hair		225	29
	Facial hair		91	28

Table 3. Results of field observations in scenario 1 (scrubland): maximum distances at which different levels of visual resolution were possible, considering the combination of criteria described in Table 1 (distances in m.)

Level of visual control

		<i>Detection</i>	<i>Recognition</i>	<i>Identification</i>
<i>Person</i>		2538	1246	
<i>Clothing</i>	general	798		
	separate	583	454	69
<i>Accessories</i>	Hat	321	186	58
	Walking stick	321	86	31
	Bracelet	122	36	
<i>Bodily features</i>	Limbs	982	228	
	Hair		137	36
	Facial hair		99	36

Table 4. Results of field observations in scenario 2 (beach): maximum distances at which different levels of visual resolution were possible, considering the combination of criteria described in Table 1 (distances in m.)

A more significant level of resolution occurs at ca. 1250-960 m., depending on the scenario, at which point it is possible to notice that the form of the moving entity corresponds to a human walking. This second distance corresponds better with our definition of recognition (see section 3.1. Qualities of visual control). As is to be expected, some consistent differences exist between the two scenarios (Figure 6), which can easily be attributed to the higher contrast of the bare earth (beach) background.

Figure 6. Results of field observations in both scenarios: distances of first detection and recognition

Of course, it is absolutely impossible to characterize with any detail the individual at such distances. This only begins to occur at much closer distances. The first distinguishable characteristics of the individual are the presence of clothes and the limbs, the former thanks to their colour and the latter thanks to their movement. Both characteristics are initially recognized at ca. 800 m., but it is only at ca. 600 m. that the distinct parts of the attire (shirt-trousers) begin to be perceived (Figure 7).

Figure 7. Results of field observations in both scenarios: detection distances of certain specific basic elements of the individual

As the person approaches the observer, both the clothes and limbs become progressively easier to recognize, but it is only at ca. 400-150 m. that they become fully recognizable. At approximately 400-300 m the basic forms of the clothing (long or short sleeves, long or short trousers/skirt) are recognized. Between 300-150 m the presence of smaller accessories (walking stick) is detected, the specific position and movement of the limbs is perceived, and the basic characteristics of the hat are recognized (Figure 8).

Figure 8. Results of field observations in both scenarios: detection and recognition distances of certain detailed traits of the individual

Finally, a detailed characterization of the physical features of the individual and his/her clothes and accessories only occurs at a much closer distance (around 60-30 m). At such close distances, even minor changes in the specific visual qualities of the elements to be identified (especially clothing) might have an effect on the relative distance at which they become evident. This can explain the higher variability in the distances of identification of clothes and hat shown in Figure 9, which can be attributed to changes in the attire of the target individuals on different days (see Figure 5).

Figure 9. Results of field observations in both scenarios: distances of identification

5. Discussion

5.1 Distance thresholds in visual perception

Following the results of the field experiment, it is clear that a steady progression in the forms of visual recognition across distance exists. By considering all the results together, and bearing in mind that we are interested in defining the maximum distances at which changes in visual perception occur, we can suggest the existence of a few discrete thresholds which signal significant changes in how an individual can be visually detected and recognized in the landscape. Considering the different visual contrast of the background, different thresholds values can be offered for each context (the following distances are rounded-up numbers based on the field observations):

- 2550-2100 m. (depending on the scenario) is the maximum distance for the **first detection** of the presence of an individual as a differentiated entity in the landscape, mainly due to his/her changing position. However, at this distance it is not possible to establish if that entity is a human or any other moving being. This maximum distance is longer on the beach than on the scrubland (Figure 6).
- 1250-975 m. (depending again on the background) is the maximum distance at which it is possible to recognize an individual as a human being (**human recognition**) by distinguishing the basic shape of his/her anatomy (upright position, limbs) and the idiosyncrasies of human movement. The field observations are consistent and, again, the maximum distances are longer on the beach than on the scrubland (Figure 6).
- 600 m. This threshold refers to the possibility of beginning to recognize some elements that allow an initial **basic recognition of the individual** to be made as far as his/her

identity and behaviour are concerned. The distance at which this occurs is a little more difficult to establish with certainty, since there is a soft progression in the perception of the first details of the individual. The results suggest that at ca. 800 m. the first basic details of the individual begin to be perceived (he/she is dressed, his/her limbs are noticeable in some cases), but it is only at ca. 600 m. that more details are noticeable, namely the different elements of clothing and the movement of the limbs are detectable in all cases.

- At ca. 225 m. certain detailed characteristics of a visible person are discernible that allow him/her to be recognized in more detail (**detailed individual recognition**). In our case, this means that we can perceive all the following characteristics: the position and detailed movement of the limbs, the use of a walking stick, the shape and colour of accessories (hat), the predominant colour of the hair.
- Finally, from 60 m. it is possible to begin to identify most of the specific, individual details of the person, his/her attire and accessories, and to distinguish between one specific person and one specific element (garment, accessory, etc.) and another (**identification**).

These results may be directly of use as a reference for any approach to the study of visual control. But beyond that, these values can easily be used to produce a qualitative viewshed with any GIS software. A simple way to do this is to use these results as discrete distance intervals which represent qualitative changes in the forms of detection, recognition and identification of an individual in the landscape. Combining these distance intervals with a standard binary viewshed will produce the result shown in Figure 10, which can be described as an Individual Distance Viewshed (IDV): the visible area from a given location that falls within a distance where the presence of a human being can be perceived and recognized in different ways. Although still a potential viewshed, as it is based on the maximum distances at which it is possible to detect,

recognize or identify an individual, it gives a more nuanced representation of the chances of visual control in a specific environment and over a specific type of target. Among other applications, it can provide a more balanced assessment of the actual possibilities of visual control exercised from different places of interest in a landscape.

Figure 10. Individual Distance Viewshed (IDV), for the areas of Carnota (left) and Barbanza (right). The meaning of the labels assigned to the intervals is described in the text

5.2 *Comparison with other references*

Strictly speaking, the results obtained in our experiments are only valid for the specific conditions in which they were conducted. As pointed out above, we attempted to select two complementary scenarios with the best possible conditions (in terms of atmospheric and landscape) in order to obtain the maximum possible distance at which the different types of visual control considered

could be exerted. To the best of our knowledge, no other similar experiments exist which might enable a comparison and an external validation of our results. We were only able to find some external references in field manuals for military use, which, although not directly equivalent, provide at least a comparable framework.

The manuals providing the most useful data are those about the 19th century, a time in which infantry was still the main unit of combat. Nosworthy (1995), for instance, indicates that it is possible to recognize, with the naked eye and in good weather conditions, an enemy army at 2,000 m. At 1,200 m. it is possible to distinguish between cavalry and infantry, although the movement of individuals is only discernible at 600 m. The ranges offered by Griffiths (1869) are rather similar: an army is discernible at 1,300 yards (1,554 m.), cavalry from infantry and the movement of the army as a whole at 1,300 yards (1,188 m.), and the movements of an advanced individual are discernible at 1,000 yards (914 m.).

A better term of comparison is offered by other references related to the identification of specific characteristics (clothing) of an approaching army. Griffiths (1869) indicates that belts and light-coloured trousers can be perceived at 700 yards (640 m.), and the particular signs of the uniform of a general are discernible at 500 yards (457 m.). Other authors affirm that between 200-250 yards (188-223 m.) all parts of a body are discernible, the details of a uniform are sufficiently distinguishable and it is possible to distinguish between officers and soldiers (Hughes, 1997). These references are very similar to the distances we have obtained for basic and detailed recognition (Figure 10) and they are coincident in indicating ca. 200 m. as the distance at which intensive visual recognition of a person is possible.

5.3 *A fuzzy approach*

An IDV as described above has both the benefit and drawback of simplifying a complex phenomenon, by representing a progressive quality (changes in visual perception) via a limited number of discrete intervals. This may be useful and helpful in certain research contexts, but it could also be seen as an oversimplification. It seems logical to ask whether a better approach might be the use of a fuzzy viewshed. As we have described in section 2, Ogburn (2006) provided a reference for the assessment of changes in the visual perception of any object according to its size. Figure 11 shows the results of a target size-sensitive fuzzy viewshed calculated for scenario 2 (beach) using the default parameters suggested by Ogburn (2006), along the lines established by Fisher (1994)². When exploring how well this represents the results of our field observations, two issues must be highlighted. Firstly, a required parameter for the calculation of fuzzy viewsheds is to determine the distance representing the limit of the foreground from the viewpoint (variable b1 in Fisher (1994)), the region of very high clarity around the observer, within which atmospheric extinction is negligible. Within that distance, then, no visual decay is assumed to take place, implying a fuzzy membership value of 1; Fisher himself proposed using a distance of 1 km., with the assumption that the foreground zone extends to roughly 1 km. If this is also assumed in our case, the effect is that most of the changes documented in the visual detection and recognition of the individual are simply not represented: all but one of the changes fall within the area of “perfect vision” around the observer. Although this might be correct in terms of acuity of vision,

² This calculation was made with the ArcGIS toolbox developed by Gianmarco Alberti, available at: https://www.researchgate.net/publication/320490670_Fuzzy_Viewshed_ArcGIS_toolbox

when applied to the perception of an individual it produces an oversimplified representation of actual perception on the ground.

Figure 11. Target size-sensitive fuzzy viewshed for the area of Carnota, calculated according to the parameters suggested by Ogburn (2006). Fuzzy membership is shown in discrete intervals for clarity

Furthermore, there is a second question to be raised in relation with the archaeological applicability of these fuzzy viewsheds: how can the values of fuzzy membership be interpreted? What are the implications of that fuzziness? It is undoubtedly true that a fuzzy viewshed provides a much more nuanced approach to visual perception than a binary viewshed, but the question is; what is the qualitative meaning of the quantitative values (0 to 1) that fuzzy membership provides?

Drawing from the results of our observations, a bespoke fuzzy approach can be developed in which not only the size of the (human) target is considered, but also the changes in how that human target is perceived as distance changes. In particular, we propose the use of the critical distance intervals documented in the field observations as reference values for a linear distribution of fuzzy membership values (Table 5).

<i>Interval</i>	<i>Max. distance (bare earth area)</i>	<i>Max. distance (area with vegetation)</i>	<i>Fuzzy membership</i>
<i>Identification</i>	60	60	1
<i>Detailed recognition</i>	225	225	0.75 – 0.99
<i>Basic recognition</i>	600	600	0.5 - 0.75
<i>Human recognition</i>	1250	975	0.25 - 0.5
<i>First detection</i>	2550	2100	0.1 - 0.25
<i>Beyond detection</i>	>2550	>2100	0 – 0.1

Table 5. Suggested assignation of values of fuzzy membership to the critical distance intervals documented in the field observations (distances in m.)

This approach makes it possible to combine the advantages of both the use of a fuzzy logic (where changes happen progressively) and the existence of reference values that provide a qualitative meaning to the quantitative weighting of fuzzy membership. A Fuzzy Individual Distance Viewshed (F-IDV) is the result of applying that approach (Figure 12). Although the background data are the same as in Figure 10, in this case the values follow a gradual scale 0-1 (shown here in discrete intervals), produced by linear interpolation using the values described in Table 5.

Figure 12. Example of Fuzzy Individual Distance Viewshed (F-IDV). Fuzzy membership is shown in discrete intervals for clarity, using the same colour palette as in Figure 11

6. Case study. Visual control and mobility in the Iron Age in the NW Iberian Peninsula

To illustrate the applicability of those results in an archaeological context, we will briefly present a case study that deals with the relationship between visual control and mobility in the location of a group of Iron Age settlements in the NW Iberian Peninsula (Figure 13). We have chosen a large portion of the middle sector of the River Ulla, one of the most important rivers in the region which currently forms the boundary between the provinces of A Coruña and Pontevedra. Within the ca. 78 km represented in Figure 13, the river can, at present, be crossed in 9 different places (not including the recently built motorway and railway bridges). The origin of at least 5 of those 9 bridges can be traced back to the Middle Ages or before, thanks to either architectonic remains, documentary sources or both (Ferreira Priegue, 1988). In a previous study, a GIS-based analysis suggested that the location of those 5 bridges corresponds to primary nodes in the main natural corridors of communication in the Middle Ages, and at least some of them would also have played a primary role in the regional network of Roman roads (Fábrega-Álvarez and Parcero-Oubiña, 2007, Parcero Oubiña and Fábrega-Álvarez, 2010). Furthermore, the same study also suggested that there may have been a direct relationship between Iron Age settlements in the area and the control of these crossings. The suggestion was based on the observation that most of the Iron Age hillforts located in the immediate vicinity of the River Ulla are clustered around these 5 crossings. More specifically, 6 out of the 7 Iron Age hillforts located in the immediate vicinity (15 min. walking distance) of the River Ulla were located in the immediate vicinity of one of these 5 bridges (Fábrega-Álvarez and Parcero-Oubiña, 2007, figure 9).

This case study aims to assess to what extent choosing a location which allowed for effective visual control of these strategic river crossings might have been a relevant factor in the Iron Age and, if so, what consequences can be drawn from this.

Figure 13. Location of the study area in the NW Iberian Peninsula. Distribution of Iron Age settlements around the middle section of the River Ulla. Location of the historically-documented river crossings: 1-Pontecesures, 2-Pontevea, 3-Ponte Sarandón, 4-Ponte Ulla, 5-Ponte Ledesma

Two basic datasets were used in our analysis. Firstly, a DEM was used for calculating the viewsheds, using topography as the only barrier. Although land cover can also affect visibility, we did not consider it in our analysis for two main reasons: (1) it is a property that simply cannot be

properly known for the period of interest and (2) it can be relatively easily modified, so we assumed that it was not a structural factor in the locational decisions at this level. Topography was represented via a LiDAR-derived DEM with a 5x5 m pixel size, produced by the Spanish National Geographic Institute within the PNOA project.

Secondly, the location of the Iron Age hillforts was taken from the database of our institution, which stores data gathered during the course of multiple fieldwork projects carried out over the last 30 years. The location and delimitation of the sites was double-checked with other archaeological inventories available and further refined with the aid of remote sensing tools such as modern and historical aerial images and LiDAR data (Figure 14).

Figure 14. An example of one of the Iron Age hillforts in the study area, as seen in different aerial images and visualizations of the LiDAR data. Credits: (1) - OrtoPNOA-H 1956-57 CC-BY

4.0 scne.es; (2) - FotoPNOA 2016 CC-BY 4.0 scne.es; (3 to 6) - LiDAR-PNOA 2015 CC-BY 4.0
scne.es; (3 to 6) processed with Lidar Relief Visualization Toolbox (Zakšek, et al., 2011)

The size and scale of the settlements used in our analysis mean that, at the resolution used, all of them occupy hundreds of pixels (Figure 14). Using one single point to represent each settlement in the viewshed calculation implies a simplification that would lead to incorrect results. To prevent this problem, we first delimited the perimeter of each single settlement and created a point layer with points regularly spaced within that perimeter, so that they completely covered the full extension of the site. The calculation of the viewsheds was performed as a cumulative viewshed of all the points included within the perimeter of each site. The IDVs were calculated using a binary reclassification of those cumulative viewsheds (1 = visible from any position on the settlement, 0 = not visible from anywhere on the settlement).

To ease the process of analysis, and considering that we are only interested in exploring the relationship between the hillforts and the river, out of the 126 sites shown in Figure 13, we only analysed those located within a 5 km buffer from the river ($n=67$), a distance that is far beyond the potential limits of visual control. The IDVs were calculated using the results of the field observations in Barbanza, since the study area better corresponds with that type of landscape.

Given the high density of hillforts, and their typical location in prominent places, when taken together, their maximum potential visual control over the area is extremely high (Figure 15-A): 86.4% of the area within a 5 km buffer from the River Ulla (545 km^2) is potentially visible from at least 1 site. Or, to put it other way, only 13.6% of the area is definitely occluded from the hillforts taken as a whole. A large part of the course of the River Ulla is also easily visible from them, although to a lesser degree (64.4 % of the 78.5 km of river length) due to the existence of some sectors towards the east where the river runs between steep slopes.

As should be expected from what is known about the settlement patterns of the Iron Age hillforts in this region, potential visual control is extremely intense. But this situation may be different if we focus specifically on the possibility of effective visual control over human beings. Figure 15-B shows potential visibility from the hillforts within the maximum distance of human detection (2,100 m.). All five historical bridges are located within the range of visual detection from one (bridges 3 and 4), two (bridge 5) or even 4 sites (bridges 1 and 2). Despite the logical reduction in visual coverage over the whole study area (now 46.4 %), the map shows how the sectors around the bridges are among those with a greater convergence and more continuous visibility. We will return to this point later.

Figure 15. Visual control from the hillforts over the River Ulla: A) potential viewshed of all the hillforts in the study area; B) Multiple IDVs: distance of First Detection (2,100 m.); C) Multiple

IDVs: distance of Human Recognition (975 m.); D) Multiple IDVs: distance of Basic Individual Recognition (600 m.)

Before that, we can move to a different level of visual resolution, one which we have called Human Recognition. At this distance (975 m., Figure 15-C), only 19.2% of the whole area can be controlled from any site, but again the map seems to show that the areas close to bridges 1, 2, 4 and 5 are among those with a more convergent and continuous degree of control. Two of the bridges (3 and 4) are no longer visible from any hillfort (although bridge 4 is extremely close to a visually controlled area), but one (5) is still visible from one hillfort and the other two (1 and 2) from two sites.

Visual control over these bridges still persists if we move to the resolution that we have called Basic Individual Recognition, at which it is possible to begin recognizing certain elements which allow a first, basic characterization of the individual to be made in terms of his/her identity and behaviour (600 m., Figure 15-D): bridges 1, 2 and 5 are still under the visual control of some hillforts at that close distance.

The convergence of visual control from different hillforts seems to reinforce the likely importance of these places. We have already suggested that the areas around the historical bridges showed a higher juxtaposition of visual control, but this is more clearly visible in Figure 16. Here we can see how, except around bridge 3, there is a frequent overlap of viewsheds not only at the distance of simple Detection, but also in terms of Human Recognition, Basic Individual Recognition and, even in some cases, Detailed Individual Recognition. This only occurs in some other scattered places in the area but, quite significantly, not over other portions of the river.

Figure 16. Convergence of visual control (areas controlled from more than one single site) at different distances across the study area

Indeed, the idea that the locations of the historical bridges were places of especially relevant visual control can be further explored by checking what portions of the course of the River Ulla fall within the more detailed levels of visual control from the hillforts. In this case, we found it useful to accumulate the Fuzzy IDV calculated from all the hillforts and to extract, for each part of the river, the maximum value of fuzziness (as described in the section entitled A fuzzy approach). The results (Figure 17) show that, although a large part of the river falls within the potential viewshed of any of the sites (as we have seen), most of these potentially visible parts are beyond the distance of first detection ($>2,100$ m.). In fact, the only continuous sectors of the river that are

visually controlled at the level of Human or Basic Individual Recognition are located around or next to historical bridges 1, 2, 4 and 5 (apart from some isolated spots towards the east).

Figure 17. Maximum value of the accumulated Fuzzy IDV over the course of the River Ulla

These results even relativize the fact that the specific location of bridge 4 is beyond the range of any of those intervals, since a large portion of the river near to it, starting just a few hundred meters upstream, is continuously controlled. Indeed, this is an important point that should be highlighted: to our view, the relevant question is not so much whether the bridges themselves are visible or not, but if their location points to places along the course of the river that have historically acted as crossing points. The exact location of the existing bridges, built at best in the Roman period, is the result of specific historical conjunctures that do not necessarily apply to the case of the Iron Age. A good way to illustrate this is by extracting IDV indexes that help to understand the results quantitatively (Table 6). Table 6 shows two complementary indexes: the

portion of the area which is within the ranges of either First detection or Human recognition and the number of hillforts from which that control is exerted. These indexes are calculated not only for the current extension of the bridges themselves but also, beyond that, for the surrounding areas within buffer distances of 100, 300 and 500 m. The indexes clearly show that bridges 1, 2 and 5 are located in places of extremely high and concurrent visual control from the hillforts: more than 95% of the area at any buffer distance considered is visible at the distance of First detection, and more than 85% at the distance of Human recognition in all three cases. The table also shows that, in effect, bridge 3 is out of any type of visual control for the hillforts. Bridge 4 is a particular case: although the bridge itself is only marginally controlled, things are slightly different if we focus on the surrounding area: almost 50% of the 100 m. buffer is within visual First detection, more than 60% of the 300 m. buffer and almost 75% of the 500 m. buffer. Although the figures are not as conclusive as in the cases of bridges 1, 2 and 5, we believe that visual control can also be argued for this case if we put the focus not so much on the exact location of the bridge but, on a larger scale, on the site on which the bridge was built along the river.

FIRST DETECTION

<i>Bridge n°.</i>	<i>Name</i>	<i>Bridge</i>		<i>100 m. buffer</i>		<i>300 m. buffer</i>		<i>500 m. buffer</i>	
		from	% area	from	% area	from	% area	from	% area
1	Pontecesures	4	100.00	4	97.59	4	99.03	4	98.70
2	Pontevea	4	95.91	4	99.73	4	99.67	4	99.38
3	P. Sarandón	1	0	1	0	1	7.92	1	16.86
4	P. Ulla	1	42.71	2	41.95	2	61.02	2	74.66
5	P. Ledesma	2	97.42	3	99.32	3	99.64	4	99.52

HUMAN RECOGNITION

<i>Bridge n°.</i>	<i>Name</i>	<i>Bridge</i>		<i>100 m. buffer</i>		<i>300 m. buffer</i>		<i>500 m. buffer</i>	
		from	% area	from	% area	from	% area	from	% area
1	Pontecesures	2	90.67	2	91.83	2	94.26	2	85.81
2	Pontevea	2	93.38	3	93.26	3	93.60	3	91.40
3	P. Sarandón	0	0	0	0	0	7.92	0	16.86
4	P. Ulla	0	0	0	0	1	4.20	1	13.54
5	P. Ledesma	1	97.42	1	97.89	2	92.18	2	87.86

Table 6. Indexes of multiple IDVs over the five bridges. The table shows, for each bridge, the number of hillforts from which different forms of visual control are exerted and the % of the area that is controlled from at least one hillfort. Indexes are shown for the exact extension of the bridges, as preserved today, and for the surrounding areas of 100, 300 and 500 m., and for the distances of Detection and Human Recognition

7. Discussion

Our analysis suggests that the association between Iron Age hillforts and historical bridges is, indeed, not just a matter of physical proximity, but also of visual control. The Iron Age hillforts show a strong preference for visually controlling just a few areas of the course of the River Ulla, and they coincide with the sectors where those historical bridges were located (with the exception of bridge 3). Apart from some isolated exceptions, the only sections of the course of the river where the presence of people moving could be detected and recognized from the hillforts coincide with the areas where these bridges would later be built. As with many other spatial correlations, the question of significance and non-randomness may fairly be raised: is it possible that there is no particularity in the location of these hillforts when compared with other random points in the area? In fact, there are some other hillforts in the area from which the river is visible, and a few which are quite close to the river, but the combination of visibility and proximity only occurs around four of the five historical bridges. Quite possibly, there could be many other random points where both requirements (proximity to and visibility over the river) are met, but the question is that there are no other hillforts in the area that match them. To our view, this is what makes these locations significant.

Figure 18. Total IDV calculated for the course of the River Ulla. Values correspond to the extension of the surrounding areas from which the river can be visible within distances of First detection (2100 m.) and Human recognition (975 m.)

In order to reinforce this argument, we have envisaged a method to check to what extent the location of the historical bridges correspond with places along the river that are naturally more open to visual control, something which may weaken the correlations identified in our analysis. Instead of an approach based on a set of random points, as is common practice, we have chosen what we believe to be a more robust method: we have calculated a “total IDV” towards the River Ulla to determine what portions of the river are naturally more visible at the different distances of visual control used here (First detection, Human recognition, etc.). For this purpose, a layer of 50 m. regularly-spaced points along the river was created (n=1978 points) and the IDV towards all those points was individually calculated. The results, summarized in Figure 18, show that most of the five bridges (all except bridge 5) are actually located in places with only average topographic

conditions for good visual control. Since the spatial resolution of Figure 18 might not be good enough to grasp the details, Figure 19 summarizes these data in two histograms for the distances of First detection and Human recognition. In order to allow a fair comparison, and considering our previous discussion about the issue of the scale, we have located the bridges in the histogram by extracting the median of the IDV values of the river at 100 m. around each bridge. Here, the heterogeneous visual affordances of the bridges become evident: while bridge 5 does indeed occupy a position along the river where visual control is naturally easy, the other four are located in positions with only average values.

To our understanding, this provides additional evidence to argue that visual trends of control exerted from the hillforts do not correspond with the properties of the local topography and that there is a significance in the link between hillforts and river crossings.

Figure 19. Histograms showing the distribution of the values of the Total IDV for the River Ulla (visible positions of the river within detection distance from n Has. around) for the distances of First Detection and Human Recognition. The darker columns highlight the intervals corresponding to the values of the position of the five bridges (measured as the median of the points at 100 m. around the bridge)

As far as the interpretation of these correlations is concerned, there are two chronological problems which must be discussed. The first one is less problematic: although the oldest dates known for those bridges are from the Roman period or the Middle Ages, their importance in our analysis is based on the results of a previous study suggesting that they occupied primary nodes in the development of the historical mobility network in the area (Fábrega-Álvarez and Parcero-Oubiña, 2007, Parcero Oubiña and Fábrega-Álvarez, 2010). In other words, these bridges occupy the best natural positions for crossing the River Ulla and for enabling mobility on a regional scale. It is the relevance of their position which makes them useful for our purpose.

Secondly, we do not possess data regarding the specific chronology of these hillforts within the Iron Age. While it may be the case that they were in use at the same time, this is *a priori* quite unlikely. However, alternative, and interesting, interpretations can be proposed for any of these possible scenarios. Assuming that all the hillforts around the bridges were contemporary, this would indicate the existence of a remarkable interest in exercising visual control over these locations at one specific moment in time, either in terms of competition among the sites, or in terms of cooperation between them and in opposition to any external agent. Within the regional Iron Age, such a density of settlement could only be expected to exist in the Later Iron Age and during the first decades of the Roman period, when the possible emergence of supra-local political entities has been suggested (González García, 2011, González García, 2017). If this were the case, control of the river crossings would acquire an immediate strategic significance.

However, it is more likely that these hillforts were not in use at the same time. In such a case, these results can be interpreted as the outcome of a cumulative process, in which the interest in controlling mobility across these locations would have persisted through time. The higher convergence observed around some of them might suggest that the importance of these locations was more enduring, perhaps as an effect of a more relevant role in articulating mobility in the

region. Indeed, bridges 1 and 4 (Pontecesures and Ponte Ulla) are today the most important for movement across the area, being part of the major roads that join Santiago de Compostela with two other provincial capitals (Pontevedra and Ourense, respectively). Furthermore, both coincide with two of the main historical pilgrimage roads to Santiago (the so-called Portuguese and Via de la Plata routes). This primary importance since at least the Middle Ages is shared by bridges 2 and 5 (Pontevea and Ponte Ledesma). Figure 20 summarizes Elisa Ferreira's proposal about medieval roads in the area (Ferreira Priegue, 1988), based largely on the use of documentary sources, where bridges 1, 2, 4 and 5 are all located along the main roads crossing the area. However, bridge 3 occupies only a secondary position both in the modern and medieval patterns of mobility across this region. This secondary position provides a good argument to explain why this is the only example where no visual control has been detected in our analysis: one might hypothesize that the secondary role of this bridge in historical times corresponds with a lesser historical depth. In any case, this question might be clarified by future work exploring the relationship between sites, paths and potential mobility in this area (as in Fonte, et al., 2017, Güimil-Fariña and Parcero-Oubiña, 2015, Herzog, 2017, Llobera, 2015).

Figure 20. Medieval road and settlement network in the study area, according to Ferreira Priegue (1988)

Without taking distance into consideration, it could be argued that visual control was extended over most of the river and the surrounding areas. Although in abstract terms this might be true (Figure 15), in fact, the actual possibility of monitoring and controlling the movement of people is restricted to certain specific areas, with the location of the bridges being remarkably important in that respect.

8. Conclusions

Visual perception remains a common topic in landscape-oriented archaeological analysis. GIS tools have had, on the one hand, the great benefit of giving easy access to the exploration of potential forms of visibility in the landscape in relation to many archaeological questions of a different nature and theoretical inspiration, from subjective perception to positive, strategic visual control. However, as has been widely discussed, they have also brought about the risk of becoming “black boxes” (Kvamme, 2018, Mayoral Herrera, et al., 2017b) the outcomes of which are still quite often seen with suspicion by many colleagues, especially from the point of view of their (often) dubious capacity of accurately modelling human perception in the landscape. The availability of high-resolution tools and data currently constitutes an essential contribution to an increasing relevance of digital means in archaeological research (Opitz and Limp, 2015). Nevertheless, at the same time, there is still the need to keep building bridges between digital modelling and human experience. This paper has been an attempt to make a contribution in this regard, by exploring the extent to which visual control can be effectively exerted over individual human beings moving across the landscape. We have explored the effect of linear distance in that specific type of visual perception and proposed different possible ways to make use of our field observations. The results shown here can easily be used to calculate Individual Distance Viewsheds (IDV)³, either as discrete intervals or as a fuzzy progression, which may be helpful tools to assess questions related to the

³ A Toolbox for automatic IDV calculation in ArcGIS is provided as supplementary material.

role of visual control in multiple archaeological contexts. The example shown in the case study illustrates the usefulness of using informed references to qualify visual control.

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10. References cited

Acuto, F.A., Troncoso, A., Ferrari, A., 2012. Recognising strategies for conquered territories: a case study from the Inka North Calchaquí Valley, *Antiquity* 86, 1141-1154.

Bernardini, W., Barnash, A., Kumler, M., Wong, M., 2013. Quantifying visual prominence in social landscapes, *Journal of Archaeological Science* 40, 3946-3954.

Brughmans, T., Keay, S., Earl, G., 2014. Introducing exponential random graph models for visibility networks, *Journal of Archaeological Science* 49, 442-454.

Canosa-Betés, J., 2016. Border surveillance: Testing the territorial control of the Andalusian defense network in center-south Iberia through GIS, *Journal of Archaeological Science: Reports* 9, 416-426.

Eve, S.J., Crema, E.R., 2014. A house with a view? Multi-model inference, visibility fields, and point process analysis of a Bronze Age settlement on Leskernick Hill (Cornwall, UK), *Journal of Archaeological Science* 43, 267-277.

Fábrega-Álvarez, P., Parcerro-Oubiña, C., 2007. Proposals for an archaeological analysis of pathways and movement, *Archaeologia e Calcoratori* 18, 121-140.

Ferreira Priegue, E., 1988. *Los caminos medievales de Galicia*, Ourense.

Fisher, G., Loren, D.D., 2003. Introduction, *Cambridge Archaeological Journal* 13, 225-230.

Fisher, P.F., 1994. Probable and fuzzy models of the viewshed operation, in: Worboys, M.F. (Ed.), *Innovation in GIS, selected papers from the First National Conference on GIS Research UK*, Taylor & Francis, pp. 161-175.

Fonte, J., Parcerro-Oubiña, C., Costa-García, J.M., 2017. A GIS-based analysis of the rationale behind Roman roads. The case of the so-called via XVII (NW Iberian Peninsula), *Mediterranean Archaeology and Archaeometry* 17, 163-189.

Gillings, M., 2009. Visual Affordance, Landscape, and the Megaliths of Alderney, *Oxford Journal of Archaeology* 28, 335–356.

Gillings, M., 2012. Landscape Phenomenology, GIS and the Role of Affordance, *Journal of Archaeological Method and Theory* 19, 601-611.

Gillings, M., 2015. Mapping invisibility: GIS approaches to the analysis of hiding and seclusion, *Journal of Archaeological Science* 62, 1-14.

González García, F.J., 2011. From Cultural Contact to Conquest: Rome and the Creation of a Tribal Zone in the North-Western Iberian Peninsula, *Greece and Rome* 58, 184-194.

González García, F.J., 2017. Exploring Alternative Pathways to Social Complexity in the European Iron Age: The Northwestern Iberian Peninsula as a Case Study, *Cambridge Archaeological Journal* 27, 295-311.

Griffiths, F.A., 1869. *The Artillerist's Manual and British Soldier's Companion*, W.H. Allen, Londres.

Güimil-Fariña, A., Parcero-Oubiña, C., 2015. "Dotting the joins": a non-reconstructive use of Least Cost Paths to approach ancient roads. The case of the Roman roads in the NW Iberian Peninsula, *Journal of Archaeological Science* 54, 31-44.

Hamilton, S., Whitehouse, R., Brown, K., Combes, P., Herring, E., Thomas, M.S., 2006. Phenomenology in Practice: Towards a p Methodology for a 'Subjective' Approach, *European Journal of Archaeology* 9, 31-71.

Herzog, I., 2017. Reconstructing Pre-Industrial Long Distance Roads in a Hilly Region in Germany, Based on Historical and Archaeological Data, *Studies in Digital Heritage* 1, 19.

Higuchi, T., 1983. *Visual and Spatial Structure of landscapes*, MIT, Massachussets.

Hughes, B.P., 1997. *Firepower. Weapons effectiveness on the Battlefield, 1630-1850*, Da Capo Press, London.

Kantner, J., Hobgood, R., 2016. A GIS-based viewshed analysis of Chacoan tower kivas in the US Southwest: were they for seeing or to be seen?, *Antiquity* 90, 1302-1317.

Keeley, L.H., Fontana, M., Quick, R., 2007. Baffles and Bastions: The Universal Features of Fortifications, *Journal of Archaeological Research* 15, 55-95.

Kormann, M., Lock, G., 2013. Exploring the effects of curvature and refraction on GIS-based visibility studies, in: Earl, G., Sly, T., Chrysanthi, A., Murrieta-Flores, P., Papadopoulos, C., Romanowska, I., Wheatley, D. (Eds.), *Archaeology in the Digital Era. Computer Applications and Quantitative Methods in Archaeology 2012* (Southampton, UK, March 26-30, 2012), Amsterdam University Press, Amsterdam, pp. 428-437.

Kosiba, S., Bauer, A., 2013. Mapping the Political Landscape: Toward a GIS Analysis of Environmental and Social Difference, *Journal of Archaeological Method and Theory* 20, 61-101.

Kvamme, K., 2018. Getting Around the Black Box: Teaching (Geophysical) Data Processing through GIS, *Journal of Computer Applications in Archaeology* 1, 74–87.

Lake, M., Ortega, D., 2013. Compute-Intensive GIS Visibility Analysis of the Settings of Prehistoric Stone Circles, in: Bevan, A., Lake, M. (Eds.), *Computational Approaches to Archaeological Spaces*, Left Coast Press, Walnut Creek, pp. 213-243.

Lake, M.W., Woodman, P.E., Mithen, S.J., 1998. Tailoring GIS Software for Archaeological Applications: An Example Concerning Viewshed Analysis, *Journal of Archaeological Science* 25, 27-38.

Lake, M.W., Woodman, P.E., 2003. Visibility Studies in Archaeology: A Review and Case Study, *Environment and Planning B: Planning and Design* 30, 689-707.

Llobera, M., 2001. Building Past Landscape Perception With GIS: Understanding Topographic Prominence, *Journal of Archaeological Science* 28, 1005-1014.

Llobera, M., 2003. Extending GIS based analysis: the concept of visualscape, *International Journal of Geographic Information Science* 17, 25-48.

Llobera, M., 2007. Reconstructing visual landscapes, *World Archaeology* 39, 51-69.

Llobera, M., Wheatley, D., Steele, J., Cox, S., Parchment, O., 2010. Calculating the inherent visual structure of a landscape (total viewshed) using high-throughput computing, in: Niccolucci, F.,

Hermon, S. (Eds.), *Beyond the artifact: digital interpretation of the past*, CAA 04, Archaeolingua, Budapest, pp. 146-151.

Llobera, M., 2012. Life on a Pixel: Challenges in the Development of Digital Methods Within an "Interpretive" Landscape Archaeology Framework, *Journal of Archaeological Method and Theory* 19, 495-509.

Llobera, M., 2015. Working the Digital: Some Thoughts from Landscape Archaeology, in: Chapman, R., Wylie, A. (Eds.), *Material Evidence. Learning from Archaeological Practice*, Routledge, Oxon, pp. 173-188.

Loots, L., Nackaerts, K., Waelkens, M., 1999. Fuzzy Viewshed Analysis of the Hellenistic City Defence System at Sagalassos, Turkey, in: Dingwall, L., Exon, S., Gaffney, V., Laflin, S., Leusen, M.v. (Eds.), *Archaeology in the Age of the Internet. CAA97. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 25th Anniversary Conference*, University of Birmingham, April 1997 Archaeopress, Oxford.

Martindale, A., Supernant, K., 2009. Quantifying the defensiveness of defended sites on the Northwest Coast of North America, *Journal of Anthropological Archaeology* 28, 191-204.

Mayoral Herrera, V., Parceró-Oubiña, C., Fábrega-Álvarez, P., 2017a. *Archaeology and Geomatics. Harvesting 10 years of training in the Iberian Peninsula (2006-2015)*, Sidestone Press, Amsterdam.

Mayoral Herrera, V., Parceró-Oubiña, C., Fábrega-Álvarez, P., 2017b. Unboxing the black box. Some reflections after ten years of teaching geospatial technologies to archaeologists, in: Mayoral Herrera, V., Parceró-Oubiña, C., Fábrega-Álvarez, P. (Eds.), *Archaeology and Geomatics. Harvesting 10 years of training in the Iberian Peninsula (2006-2015)*, Sidestone Press, Amsterdam, pp. 9-20.

Nolan, T.J., 2009. Geographic Information Science as a Method of Integrating History and Archaeology for Battlefield Interpretation, *Journal of Conflict Archaeology* 5, 81-104.

Nosworthy, B., 1995. *Battle tactics of Napoleon and his enemies*, Constable, London.

Nutsford, D., Reitsma, F., Pearson, A.L., Kingham, S., 2015. Personalising the viewshed: Visibility analysis from the human perspective, *Applied Geography* 62, 1-7.

Ogburn, D.E., 2006. Assessing the level of visibility of cultural objects in past landscapes, *Journal of Archaeological Science* 33, 405-413.

Opitz, R., Limp, F., 2015. Recent Developments in HDSM for Archaeology: Implications for Practice and Theory, *Annual Review of Anthropology* 44.

Paliou, E., 2013. Reconsidering the Concept of Visualscape: Recent Advances in Three-Dimensional Visibility Analysis, in: Bevan, A., Lake, M. (Eds.), *Computational Approaches to Archaeological Spaces*, Left Coast Press, Walnut Creek, pp. 243-263.

Parcero-Oubiña, C., 2013. Midiendo decisiones locacionales. Una aproximación a la evaluación de la defensibilidad efectiva de sitios arqueológicos fortificados, *Comechingonia Revista de Arqueología* 17, 57-82.

Parcero Oubiña, C., Fábrega-Álvarez, P., 2010. Una arqueología del movimiento: modelización de la evolución histórica del tránsito entre el Deza y Santiago, in: Martínez, P.P., Boado, F.C. (Eds.), *Reconstruyendo la historia de la comarca de Ulla-Deza (Galicia, España)*. Escenarios arqueológicos del pasado, CSIC, Santiago de Compostela, pp. 145-157.

Rennell, R., 2012. Landscape, Experience and GIS: Exploring the Potential for Methodological Dialogue, *Journal of Archaeological Method and Theory* 19, 510-525.

Rubio-Campillo, X., Cardona, F.X.H., Yubero-Gómez, M., 2015. The Spatiotemporal Model of an 18th-Century City Siege, *Social Science Computer Review* 33, 749-765.

Sakaguchi, T., Morin, J., Dickie, R., 2010. Defensibility of large prehistoric sites in the Mid-Fraser region on the Canadian Plateau, *Journal of Archaeological Science* 37, 1171-1185.

Van Dyke, R.M., 2008. Visual Perception in Chaco Canyon, New Mexico: some Phenomenological Observations, in: Jorge, V.O., Thomas, J. (Eds.), *Archaeology and the Politics of Vision in a Post-Modern Context*, Cambridge Scholars Publishing, Cambridge, pp. 278-291.

van Leusen, M., 1999. Viewshed and cost surface analysis using GIS (cartographic modelling in a cell-based GIS II, *New Techniques for Old Times*. CAA98 Computer Applications and Quantitative

Methods in Archaeology: Proceedings of the 26th Conference, Barcelona 1998, Oxford, pp. 215-223.

Wernke, S.A., Kohut, L.E., Traslaviña, A., 2017. A GIS of affordances: Movement and visibility at a planned colonial town in highland Peru, *Journal of Archaeological Science* 84, 22-39.

Wheatley, D., Gillings, M., 2000. Vision, Perception, and GIS: developing enriched approaches to the study of archaeological visibility, in: Lock, G. (Ed.), *Beyond the Map: Archaeology and spatial technologies*, IOS Press, Amsterdam, pp. 1-27.

Wright, D.K., MacEachern, S., Lee, J., 2014. Analysis of Feature Intervisibility and Cumulative Visibility Using GIS, Bayesian and Spatial Statistics: A Study from the Mandara Mountains, Northern Cameroon, *PLoS ONE* 9.

Zakšek, K., Oštir, K., Kokalj, Ž., 2011. Sky-View Factor as a Relief Visualization Technique, *Remote Sensing* 3, 398-415.

Zamora Merchán, M., 2006. Visibilidad y SIG en Arqueología: mucho más que ceros y unos, in: Grau Mira, I. (Ed.), *La Aplicación de los SIG en la Arqueología del Paisaje*, Universidad de Alicante, Alicante, pp. 41-54.

Zhu, J., Nie, Y., Gao, H., Liu, F., Yu, L., 2017. GIS-Based Visibility Network and Defensibility Model to Reconstruct Defensive System of the Han Dynasty in Central Xinjiang, China, *ISPRS International Journal of Geo-Information* 6, 247.