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Measuring the Complexity of Past Social Systems: a Task Analysis Approach to the Study of Late Prehistoric Monumentality in Iberia

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Abstract
In this paper, we explore the heuristic potential of a set of ideas about the structural and functional complexity of systems, proposed in the 1990s by theoretical biologist Daniel McShea. In particular, we focus on the structural aspects of the complexity exhibited by social systems organized into low- and intermediate-level functional units (*i.e.*, groups and teams). To address this subject, we describe a methodology suited for measuring the complexity in the organization of work in such systems, which is primarily based on hierarchical task analysis. With this methodology, we approach a concrete case study: the construction of megalithic monuments in late prehistoric Iberia (*ca.* 3800–1800 BC). On the basis of the analysis of the three best documented, most structurally, and functionally complex monuments built within each of the three periods under study (Late Neolithic, Copper Age, and Early Bronze Age), we found that there was a trend towards less complexity in work organization related to monument building from the Late Neolithic to the Early Bronze Age. We discuss the importance of these results in light of the existing models of social complexity in European Later Prehistory, concluding that a more balanced view of social processes would be obtained if we look at complexity as a property of every different social system integrated into the whole society, and not as an exclusive property of the latter.

Keywords Structural and functional complexity · Social systems · Work organization · Task analysis · Megalithic monuments · Iberian Late Prehistory

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Introduction

Many years ago, prominent evolutionary biologist Edward O. Wilson told science writer Roger Lewin "It is not difficult to recognize complexity […]. The difficulty comes in how you measure it" (Lewin 1999, 136). In this short sentence, Wilson brought up two major problems in the study of complexity: its recognition and its measurement. While seemingly optimistic about the former, he expressed great concern about the latter. In this paper, we start from the idea that, at least as regards social complexity and the way it is addressed in archaeology, both aspects are still problematic and deserve further exploration.

In our disciplinary field, the study of social complexity has a long history, dating back to the end of the nineteenth century (Chick 1997; Denton 1998, 2004). Since its earliest expressions, it has been approached with a clear evolutionary interest (Chick 1997), mostly framed in terms of major cultural and social achievements like the rise of civilization, urbanism, and the emergence of new forms of integration, authority, and control (Patterson 2007; Fowles 2018; for examples prior to 1960 see, among others, Adams 1960a, b; Childe 1925, 1942, 1951; Steward 1949, 1955).

In the 1960s, interest in the archaeological study of social complexity spread, primarily as a consequence of the growing influence of neoevolutionism, cultural ecology, and the American "new archaeology," particularly by the latter's focus on social organization and cultural process (for a thorough discussion see, among others, Chapman 2003; Fowles 2018; Longacre 2000; Lyman 2007; Rothman 2004; Spencer 1990). On this basis, and with the subsequent incorporation of a perspective derived from historical materialism (Chapman 2003; Kohl 1981), a particular view on social complexity crystallized in the last decades of the twentieth century that is still influential in the field. Among the most prominent and pervasive features of such a view are as follows: (1) the understanding of complexity as a phenomenon that appears at some point in the evolution of particular societies (*i.e.*, the notion of "emergent complexity"; *e.g.*, Arnold 1996; Chapman 1990; Cioffi-Revilla 2014; Fitzhugh 2003; Furholt *et al.* 2020; Hanks and Linduff 2009; Johnson 1982; Price and Feinman 1995; Rakita 2009; Read 2002; Sassaman 2014; White 2013; Zedeño *et al.* 2014); (2) the view of complexity as a quality or state characterizing whole societies—expressed in phrases like "complex societies" or "complex social systems"—(*e.g.*, Dabbaghian and Mago 2014; DeMarrais and Earle 2017; Gumerman 1997; Hideg 2004; Kushner 1969; Nescolarde-Selva *et al.* 2015, 2017; Richerson and Boyd 1999; Tainter 1988); (3) the understanding of social complexity primarily from a top-down perspective, based on the preferential analysis of aspects related to social and economic inequality, rank, and power (*e.g.*, Ames 2007; Dallos 2013; Earle 1997; Earle and Johnson 2000; Kohler and Smith 2018; Paynter 1989; Price and Feinman 1995, 2010; Renfrew and Shennan 1982; Ross and Steadman 2017).

Over the past 25 years, key aspects of the above view on social complexity have been subject, from different perspectives, to both internal and external criticism and reformulation (*e.g.*, Barrientos 2004; Barton 2014; Chapman 2003; Crumley 1995; DeMarrais and Earle 2017; Fitzhugh 2003; Furholt *et al.* 2020; Kohring 2011; Kohring and Wynne-Jones 2007; McGuire and Saitta 1996; McIntosh 1999). As a result, different approaches to the problem of social complexity currently coexist, influenced by ideas from disciplinary fields as diverse as political economy, sociology, computer science, complex systems theory, evolutionary ecology, theoretical/evolutionary biology, philosophy of biology, and evolutionary anthropology.

Complexity is, first and foremost, a matter of perspective or framing (Stewart 2001), and how social complexity is measured largely depends on how it is understood and defined. Most contemporary archaeological approaches focus on its "emergence" or its spatial or temporal patterns of variation and are based on indicators or variables that imply high-level inferences. For example, differentiation and integration—two key concepts in models of social complexity (*e.g.*, Adams 1960a, b; Fitzhugh 2002, 2003; Johnson 1982; Cohen 1985)—have been proposed to be measured with reference to different dimensions like demography, social inequality, economic intensification, craft specialization, and political strategy (Drennan *et al.* 2010; Porčić 2012). The factors or variables used for this purpose cover a wide spectrum that includes co-residential group size, coordinated land-use patterns, exchange, and patterned variation in things like tool assemblages and activity locations (*e.g.*, Fitzhugh 2003; Porčić 2012). The specification of many of these measures relies on rather long inferential chains, incorporating generalizations and assumptions that are not directly linked to original observational data.

In this context, our purpose in this paper is to suggest ways to expand the framework for complexity recognition and measuring in a more empirically grounded way. For this, we start from a set of principles that can be summarized as follows: (1) complexity is not an exclusive property of particular human societies (*i.e.*, those having large and dense populations, horizontal or vertical hierarchical organization, deep institutionalized inequalities in terms of access to resources and power, multiple social and economic roles implying specialization and division of labor, large stable settlements, *etc.*; Barton 2014; Callhoun 2002; Dallos 2013; Darvill 2008), but a quality of all animal societies because all of them are examples of natural (as opposed to artificial) complex adaptive systems or CAS[1] (in the sense of Gell-Mann 1994, 17) (*e.g.*, Barrientos 2004; Barton 2014; Bernabeu Aubán *et al.* 2013; Bonabeau 1998; Eidelson 1997; Ullah *et al.* 2015); (2) complexity is a composite and decomposable phenomenon that varies across different dimensions and scales (Heylighen 1999; McShea 1996a, b, 1997; Simon 1962); (3) complexity is not a threshold characteristic, but a scalar one (Fitzhugh 2003; Kohring 2011) susceptible of being measured on a more or less continuous way (Heylighen 1999; McShea 1991, 1996a, 1997); (4) there is not a single form of system complexity but multiple variants or types, differentiated according to well-specified parameters (McShea 1996a, b, 1997); (5) each system, defined on a specific scale, can be—with respect to any other system—more complex in one or more dimensions and less complex in other(s) (McShea 1996a, b, 1997); (6) there is no "naturally" privileged dimension in or scale at which the complexity of a system can be assessed (McShea 1996a).

In light of these principles, it may be argued that mainstream archaeological approaches to social complexity have addressed only partial aspects of the phenomenon

[1] A system can be defined as "an interconected set of elements that is coherently organized in a way that achieves something" (Meadows 2008, 11); a system "consist of three kinds of things: *elements*, *interconnections*, and a *function* or *purpose*" (Meadows 2008, 11; italics in the original). Complex adaptive systems or CAS, on the other hand, are open systems that are "dynamic in space, time, organization, and membership and which are characterized by information transmission and processing that allow them to adjust to changing external and internal conditions." (Barton 2014, 306). A CAS can be either a computer-based system or a natural one, like a living organism or a society of organisms (Barton 2014, 307; Gell-Mann 1994, 17).

and that much remains to be known in order to allow its recognition and measuring. In this paper, as part of a larger investigation into different aspects of social complexity from the perspective mentioned above (Barrientos 2004, 2011), we will focus on the structural complexity of work organization[2] in past social systems. We are interested in this aspect because it allows us to turn our gaze on the phenomenon of social complexity at the most basic level, that of small- or intermediate-scale social systems (*e.g.*, groups, teams) that behave as functional units[3] within larger systems (*e.g.*, large organizations, entire societies). This turn in focus would contribute to a better understanding of the relationships (*e.g.*, correlation, independence) between degrees of structural complexity measured at different organizational levels.

In relation to this, the aim of this paper is threefold. First, to present a general interpretative framework of structural complexity in social systems inspired by ideas formulated in the 1990s and early 2000s by theoretical biologist Daniel McShea. Second, to present a method for measuring aspects of the structural complexity of work organization in small- and intermediate-scale social systems, which is based on hierarchical task analysis. Third, to apply this methodology to the analysis of a specific archaeological case study: large-scale monumentality in Iberian Late Prehistory. We expect that this exercise will help clarify a number of relevant issues, thus encouraging further explorations on the subject.

General Interpretative Framework

The Structural Complexity of Work Organization in Social Systems

There is not a unique way to define what a social system is (*e.g.*, Ackoff and Gharajedaghi 1996; Berrien 1968; Bredemeier and Stephenson 1962; Bridgeforth 2005; Homans 1974; Katz and Kahn 1966; Laszlo *et al*. 1974; Parsons 1951; Parsons *et al*. 1961). Despite conceptual differences, there is a general consensus that the components of a social system are variously interacting individual agents operating in a specific environment (persons, kinship units, corporate groups, *etc.*) (*cf.* Luhmann 1995). A minimum yet useful definition of a social system would be one that considers it as a set of agents bound together by a set of relations, with the latter creating an overall state of interdependence between agents in a way that the actions and states of one somehow influence the actions and states of the others (Jervis 1998; Systems Innovation 2016). Defined in this simple way, social systems of any scale (*e.g.*,

[2] We prefer the term "work organization" to the more widely used, and more theoretically laden, "labor organization". It can be argued that in Marxian thinking, the concept of work—a highly polysemic word (Frayssé 2014)—is applicable to any society; it is understood as a "process in which humans in social relations make use of technologies in order to transform nature, culture and society" (Fuchs and Sevignani 2013, 240). Labor, on the other hand, is "a necessarily alienated form of work, in which humans do not control and own the means and results of production" (Fuchs and Sevignani 2013, 240). While work is an anthropological quality of individual and collective activities satisfying human needs, labor is a historical form of work organization particularly typical of class societies (Fuchs and Sevignani 2013, 287; *cf.* Arendt 1998).

[3] A function is "a process that transforms inputs into outputs." (Mobus and Kalton 2015, 113). Some systems (*i.e.*, those aimed at accomplishing some purpose) can be understood as functional units to the extent that they are composed of a set of elements integrated and organized to perform the same function or a set of closely related functions.

families, companies, networks, communities, entire societies) are amenable to description using the conceptual tools and vocabulary introduced by theoretical biologist Daniel McShea to understand systems complexity from a structural[4] point of view (McShea 1996a, b, 1997).

The complexity of a social system can be characterized in terms of the agents that compose it (object complexity) or in terms of the relationships (connections) that can be established between such agents (process complexity). In turn, agents or their interrelationships can be organized either in a nonhierarchical or in a hierarchical way (nonhierarchical and hierarchical complexity, respectively). Finally, the agents of a social system or their interconnections can be characterized by the degree of differentiation in their quantity and quality (differentiational complexity) or by the degree of irregularity or heterogeneity in their arrangement (configurational complexity). Differentiation/configuration, nonhierarchy/hierarchy, object/process constitute three nested (from top to bottom) dichotomies, whose combination produces at least eight different forms of structural social complexity (Fig. 1; for detailed explanations of each type, see McShea 1996a, b).

A key point is that, in principle at least, the degree of complexity of a social system *relative*[5] to that of another social system varies along the different dimensions specified by the three fundamental dichotomies previously mentioned; *e.g.*, a given system can be more complex than another in terms of differentiational hierarchical object complexity (DHOC) but less complex in terms of configurational nonhierarchical process complexity (CNPC). Similarly, along the same dimension, a system can be more or less complex than another in a way that can be measured in reference to some well-specified scale (McShea 1996a, b).

Social systems with any kind of structural complexity can manifest various degrees of both functionality (*i.e.*, the ability to perform any of a set of actions contributing to a larger action) and functional complexity (*i.e.*, the number of functions a system is able to perform; McShea 2000, 641). In this sense, social systems can behave as functional units as long as they are capable of accomplishing one or many specified purposes. Human social systems can also act as functional units within larger systems.[6] In this case, some social systems can be assimilated to the more general structural concept of "part," which is a system or subsystem that is both internally integrated and isolated from its surroundings (McShea 2000, 647; McShea and Venit 2001, 262) (Fig. 2). Integration refers to the existence of interactions between system components producing correlations in the behavior of such components, while isolation refers to the

[4] In this context, the noun "structure" refers to the arrangement or organization of interrelated components (objects and relations) in a particular system (Bunge 2004, 188); the adjective "structural", in turn, makes reference simply to aspects of system structure without any allusion to theories or approaches bearing that name within the humanities and social sciences (*e.g.* philosophy, linguistics, anthropology; see, among others Bastide 1962; Bourdieu 1977; Giddens 1979; Lévi-Strauss 1963).

[5] To the extent that complexity varies along different dimensions and scales, its appraisal or measurement is always relative within a definite universe of comparison, *i.e.*, no system is *per se* complex, but only in comparison with another or others along a particular dimension or set of dimensions and in their respective scales.

[6] Although this has not been studied yet, it is plausible that social systems with certain types of structural complexity possess greater functional capacity in certain contexts and less in others; functional complexity, in turn, would be exclusively linked to higher degrees of differentiational hierarchical/non-hierarchical object complexity (McShea 2000).

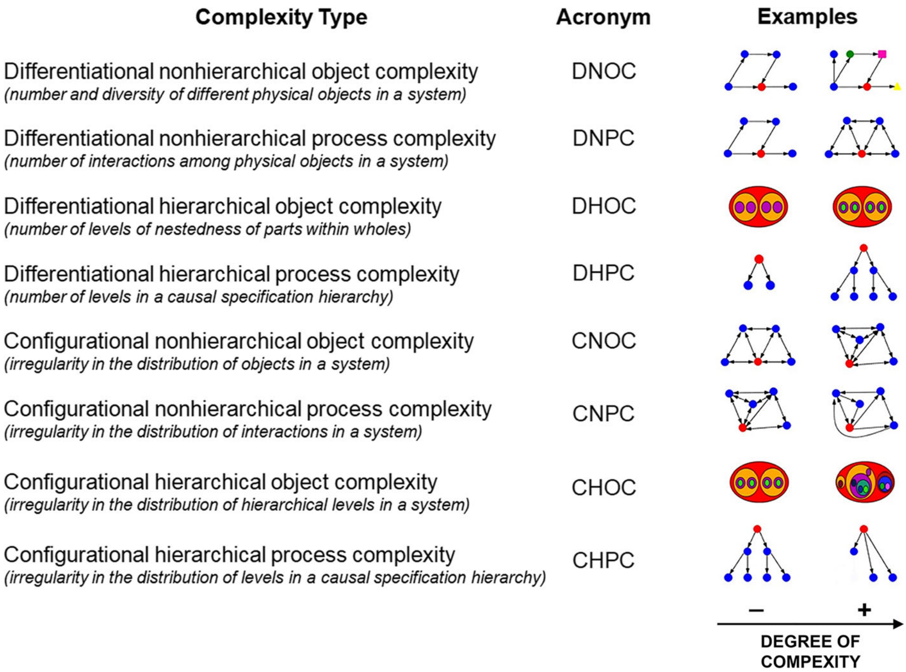

Fig. 1 Diferent types of structural system complexity (modeled after McShea 1996a, b, 1997; drawing by Gustavo Barrientos)

decrease (or cessation) of integration (McShea 2000, 647; McShea and Venit 2001, 262). Both integration and isolation, which in many functional systems are not expected to be complete or total, tend to vary continuously so the degree to which a system of any scale constitutes a part of a larger system, or behaves as such, also tends to vary continuously over time and space (McShea 2000, 648, 651; McShea and Venit 2001, 262).

The extent to which a system is (or behaves as) a part or a functional unit is time-dependent, since the degree of integration can vary over time. Therefore, a given system can be a part in one moment and not in another (*cf.* McShea 2000, 648) (Fig. 2). To exemplify this, we can consider the social systems involved in the construction and use of a building, say a medieval church. In this case, we can differentiate the system of builders (architects, foremen, and stonemasons) from the system of users (clergy and parishioners). It is clear that both systems can be made up of the same members or of totally or partially different members. As stated above, the functional units or parts may not be constant and its components may, at another time, be part of a different functional unit; in our example, the builders—or at least some of them—could also be the parishioners attending religious services in the finished church.

In functional units organized to perform a given job or task, between the two extreme organizational levels—*i.e.*, those represented by the individual and the whole society—there are intermediate levels like those corresponding to the group and the team (Wildman *et al.* 2012). A group can be considered as a collection of two or more individuals who coordinate their efforts to perform some activity, exhibiting a general pattern of activity that results from the aggregate behaviors of their individual members

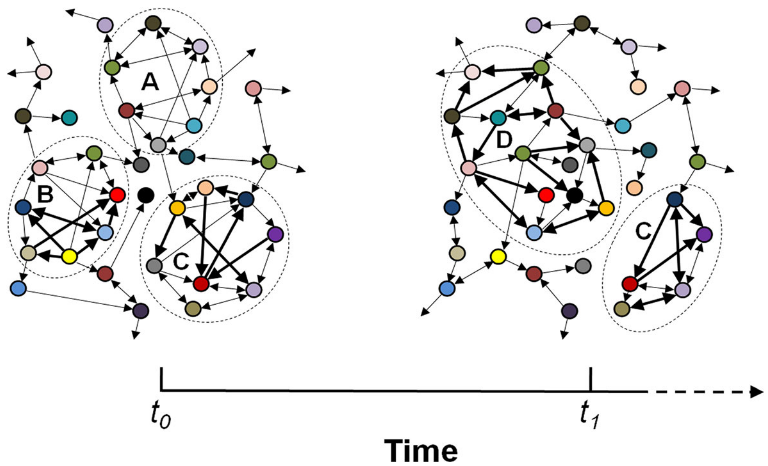

Fig. 2 Temporal variation in the number and configuration of parts within a system. Small circles represent entities and the arrows the interactions among them. The thickness of arrows denotes the strength or intensity of the interactions. Parts (A, B, C, D) are surrounded by large dashed ellipses (modeled after McShea 2000; drawing by Gustavo Barrientos)

(Paris *et al.* 1999). A team, on the other hand, is a distinguishable set of two or more individuals, each with a specific role or function, that interact dynamically, coordinately, and interpedently towards a common goal (Paris *et al.* 1999; Salas *et al.* 1992). Both groups and teams have some degree of isolation (as we saw, one of the conditions that a part must fulfill as a functional unit in McShea's model), but teams manifest a greater degree of integration than groups. Both types of units have a limited lifespan membership (Paris *et al.* 1999; Salas *et al.* 1992; Wildman *et al.* 2012), which is consistent with the idea of time-dependency of part individuation stated above (Fig. 2).

In terms of structural complexity, teams are internally more differentiated than groups (*i.e.*, have a higher degree of differentiational nonhierarchical object complexity or DNOC) not because they are necessarily composed by a higher number of members but because they have internal division of work. At the same time, as teams have a greater degree of integration than groups, they have a higher degree of process complexity than groups, particularly of the nonhierarchical type (DNPC). Both types of functional units have, at least, two hierarchical levels in a causal specification hierarchy (*i.e.*, the one occupied by the person[s] who issue the orders or instructions and those who execute them), although the teams—depending on the complexity of the task(s) they must execute—may have more than two levels (*i.e.*, may have a higher degree of DHPC).

A Task Analysis Perspective on the Structural Complexity of Work Organization

The disciplinary field that contributed the most to the study of social organization at the individual, group, and team levels has been human factors and ergonomics. Etymologically the science of work, ergonomics is an applied discipline that emerged as a differentiated field after World War II in the context of investigations concerning the role of humans in systems of different degrees of complexity (Salvendy 2012, xv). One major theme in ergonomics is the design and organization of jobs and tasks (Bedny and

Karwowski 2004; Clot 2009; Dugdale *et al.* 2000; Hollnagel 2012; Luczak *et al.* 2012), the latter understood as more or less discrete sets of operations, functions, or activities implemented to achieve a goal (Hollnagel 2012; Kirwan and Ainsworth 1992). Human tasks, which range from primarily physical, involving high levels of muscular work, to primarily cognitive, entailing a great deal of creative effort (Grandjean 1986; Karwowski 1992; Luczak *et al.* 1999), can be accomplished by individuals, groups, and/or teams.

A proxy measure of the complexity of intermediate-level social systems is the hierarchical structure of the tasks (*i.e.*, the nesting of tasks within tasks) performed by functional units of different sizes and degrees of differentiation and/or configuration (Anderson *et al.* 2001, 644). The approach devised by Anderson *et al.* (2001) to tackle the problem of hierarchical structure of tasks[7] is based on the breaking down of tasks into their individual components or subtasks, an operation akin to that of hierarchical task analysis (Hollnagel 2012; Salvendy 2012; Shepherd 2001; Stanton *et al.* 2005).

Anderson *et al.* (2001) defined four categories of tasks and subtasks (see also Anderson and Franks 2001), each with a different degree of complexity:

(a) *Individual:* tasks that can, or can only, be satisfactorily performed by an individual (Anderson *et al.* 2001, 644); when individuals work in a parallel-series arrangement (Oster and Wilson 1978), *i.e.*, with each worker tackling its own task simultaneously, this may entail some coordination among workers but, unlike groups, such cooperation and coordination is not crucial for successful task completion and, thus, it is still an individual task (Anderson *et al.* 2001, 644);
(b) *Group:* tasks that require many individuals working together, concurrently, without division of work (*i.e.*, each individual performs the same task) (Anderson *et al.* 2001, 644);
(c) *Team:* task that requires two or more different subtasks to be performed concurrently for successful task completion (Anderson and Franks 2001), *i.e.*, team tasks require the cooperation of many individuals to complete a task successfully, and there is a necessary division of work (Anderson *et al.* 2001, 645);
(d) *Partitioned:* task that split into a number of sequential subtasks and material is passed from one worker to another (Jeanne 1986; Ratnieks and Anderson 1999); partitioned tasks require multiple individuals and undoubtedly involve some differences in work contribution; often the initial stage of a partitioned task involves collection of a resource, intermediate stages usually involve transport and final stages the processing, storage, or use of the material (Anderson *et al.* 2001, 645). As it is shown in Fig. 3, team and partitioned tasks may contain individual, group, team, and partitioned subtasks or sub-subtasks.

[7] Although the methodology of Anderson *et al.* (2001) was designed to account for the complexity in activity patterns of ants, organisms with social structures based on partially different principles to those of humans (for an analysis of such differences, see Bowles and Gintis 2003; Keller and Reeve 1999), there is no reason to deny its relevance for the study of human social systems. In this regard, it is important to highlight the fact that in the study of eusocial insects, the ergonomic perspective—originally developed for the study of human work—has been widely used since the late 1960s to discuss different aspects of work organization at different levels (*e.g.* Fewell *et al.* 2009; Gordon 2002; Oster and Wilson 1978; Traniello and Robson 2016; Wilson 1968).

Individual tasks would have a low degree of complexity, group tasks a medium degree, and team and partitioned tasks a high degree of complexity (Anderson *et al.* 2001, 648). These authors assign one point of complexity to individual tasks or subtasks, two points to group tasks or subtasks, and three points to team and partitioned tasks or subtasks, reflecting the level of complexity to which each type of task or subtask was assigned (Anderson *et al.* 2001, 648). Then, they add all partial scores to obtain a score of overall complexity for each case, which allows quantitative comparison between different cases on an interval scale (Anderson *et al.* 2001, 648). The rationale for this is the intuition that a task composed of several different types of subtask seems more complex than one with no subtask distinction, that a team in which the members are groups is more complex than one in which they are individuals and so on. To the extent that tasks of different hierarchical levels (*i.e.*, tasks, subtasks, sub-subtasks) and degree of complexity (*i.e.*, low, medium, and high) are nested, their systematic study allows measuring the degree of complexity of the social system that executes them. This approach to the functioning and organizational complexity of social systems considers tasks not based upon their function but upon their structure, particularly hierarchical structure (Anderson *et al.* 2001). For this reason, it can be said that it is functional in terms of its ultimate aim but structural in terms of its immediate focus.

To illustrate the above, we can consider the example in Fig. 3, in which the same task—the supply of lithic raw materials for a stone building—is represented, but in two different contexts. In the first one, the selected rock occurs in an outcrop, providing large volume pieces, while in the second one, the rock is available in the form of small- and medium-sized blocks scattered over the ground surface. In the first example, the task is a partitioned one, to the extent that it can be split into at least three sequential subtasks (*i.e.*, quarrying, transporting, and stockpiling), with the material passing from one or more workers to other workers. In turn, these subtasks can be potentially broken down into sub-subtasks, as in the case of transporting. The diverse subtasks or sub-subtasks may be individual, group, team, or partitioned. In the second example, only subtasks can be identified (*i.e.*, collecting, transporting, and stockpiling), all of them individual or group without division of work. Although the main task involves sequential steps, it does not qualify as partitioned but only as group task. Consequently, the degree of hierarchical complexity in the first example is greater than in the second one in terms of both the number of hierarchical levels (three vs. two) and the total complexity of the task (15 points vs. 6.5 points, where 1.5 is assigned to an individual/group task, subtask, or sub-subtask).

Archaeological Approach to Task Analysis

Defined in a simple way, task analysis is the examination and description of each step involved in completing a task or job. Unlike a typical task analysis, which is primarily based on the observation and description of a socio-technical system[8] in action (Gillan 2012), an archaeological task analysis is necessarily based on a sort of reverse

[8] A socio-technical system (Emery and Trist 1960) is a system that involves "a complex interaction between humans, machines, and the environmental aspects of the work system." (Baxter and Sommerville 2011, 5). As such, it comprises at least a social and a technical system, each one with its own needs, that interact in a way that, for all practical purposes, makes them part of a single, integrated system (Whitworth 2009).

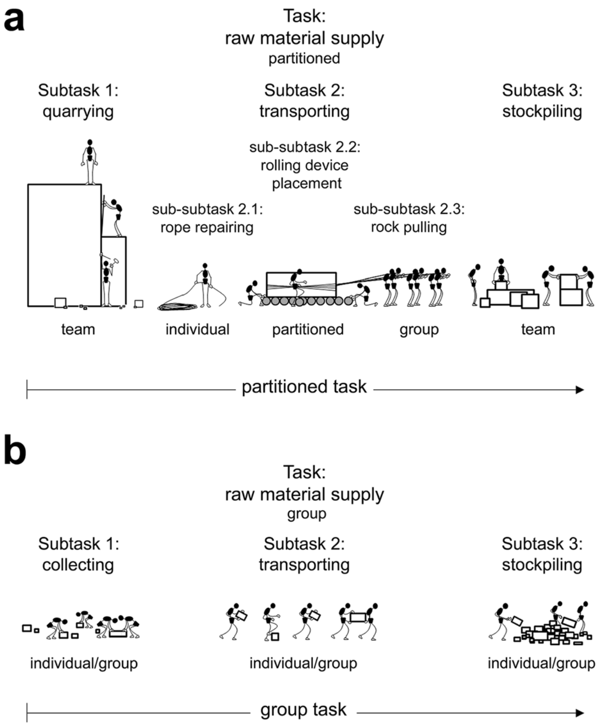

Fig. 3 Exemplification of the relationships between the four task types described in the text (*i.e.*, individual, group, team, and partitioned; Anderson *et al.* 2001). Team and partitioned tasks (*e.g.*, supply of rocks to build a structure) may contain individual, group, team, and partitioned subtasks or sub-subtasks (drawing by Gustavo Barrientos)

engineering (Messler 2013) of the preserved remains of either a past socio-technical system (*e.g.*, tools, machines) or of their products (*e.g.*, buildings, road networks; henceforth RPSTS). The study of such remains can supply valuable information about the structural and/or functional complexity of past social systems, provided we have the adequate inferential tools to turn observations into the desired knowledge.

The physical, virtual, or mental disassembling of a structure (*e.g.*, a monument) allows for the analysis of the size, shape, and composition of its constituent parts and of the order in which such parts have been assembled (Shelley 1996). This information, along with that derived from the study of its spatial location, ideally permits to infer the sequence of actions carried out for the building of the structure, as well as the tasks and subtasks performed and their respective degree of complexity (*i.e.*, if they were individual, group, team, or partitioned).

The kind of inferences referred to above has to be based on a combination of observation, educated guess, logic, some engineering principles, and rather cursory and unsystematic information about task organization in contemporary (mostly experimental) contexts and those of the ethnographic past (*e.g.*, Adams 2007; Atkinson 1956, 1961; Lipo *et al.* 2013; Midgley 2008; Mohen and Scarre 2002; Müller 1990; Osenton 2001; Van Tilburg 1995; Van Tilburg and Ralston 2005; Villalobos García 2016; Webster 1991). In relation to the latter, there is still no coherent body of controlled observations—in ethnoarchaeological, experimental, or simulative settings—about the relationships between human actions organized into tasks and particular features of human-made structures. In the words of Binford (1981), what we are currently lacking in relation to this problem is the development of middle-range research aimed at systematically investigating the linkages between the archaeological record and the actions that likely produced it, in order to give probabilistic support to our inferential arguments, particularly in the face of the problem of equifinality (Atici 2006; Crema 2018; Premo 2010; Sullivan 2007; Van Reybrouck 2012).

The lack of a more solid knowledge about the linkages between task-oriented and task-organized behavior and their archaeologically recoverable material correlates (*e.g.*, RPSTS) affects, above all, the reliability of breaking down tasks into subtasks and, particularly, subtasks into sub-subtasks. In Fig. 3a, for instance, at least three hierarchical levels of tasks can be recognized, namely those composed by the main task (supply of lithic raw materials for the construction of a megalithic monument), subtasks (quarrying, transporting, and stockpiling of large stones), and sub-subtasks (rope making and repairing, rolling device placement, and stone pulling, which are part of the second subtask, *i.e.*, transporting). In a specific archaeological case, it can confidently be inferred that the large stones that make up a megalithic monument have been transported from somewhere else if no appropriate rock sources were available in its immediate surroundings. One can establish, by provenance studies, the most probable raw material source and then investigate it for evidence of quarrying. However, in the present state of our knowledge, it is impossible, in most cases, to infer the way in which the stones have been transported to the site of the monument. This occurs because there are multiple alternative methods for transporting megaliths (Fig. 4) and there are no adequate inferential means to determine, with a high degree of probability, which of these methods was chosen in a specific case (in fact, this has long been a subject of speculation, experiment, and controversy in prehistoric studies; Harris 2018; Parker Pearson *et al*. 2015; Parry 2000).[9]

If the aim of a study is to evaluate differences in the degree of hierarchical complexity at the level of the tasks involved in the construction of one or more structures, the difficulty of knowing the likely nature of the subtasks or sub-subtasks into which a main task may be decomposed, pose problems for the analysis. For example, the five transport methods depicted in Fig. 4 and described in Table 1 imply a different number and complexity degree of sub-subtasks. Accordingly, the subtask "transporting" will obtain a quite different complexity score depending on the transport method used in each case: the lowest in the case of method *a* (group subtask not admitting further meaningful decomposition) and the highest in the case of method *e* (team subtask, decomposable in at least one partitioned sub-subtask, "rolling device placement," and one group sub-subtask, "stone pulling," the former in turn susceptible to being broken down further into group sub-subtasks, "roller extraction," "roller transportation," and "roller placement").

Based on the above, it is advisable to differentiate only two hierarchical levels or at most three (main task, subtasks, and sub-subtasks), in the latter case only if the body of knowledge regarding the relationships between human behavior and its material

[9] Ethnographic and experimental data show that method *a* described in Fig. 4 would be appropriate for stones of relatively low volume and low weight, while method *b* would only be feasible in the case of massive broad-based stones. However, more information is required to assign a high degree of probability to these correspondences.

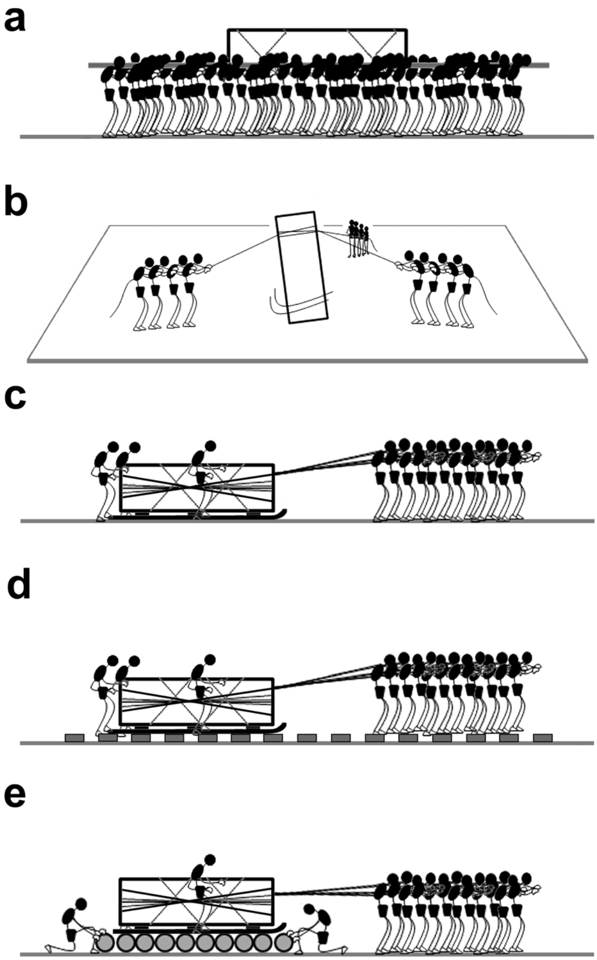

Fig. 4 Schematic representation of megalith transport methods using human muscle power and different technical devices. See the text and Table 1 for further description of each method (drawing by Gustavo Barrientos)

correlates is sufficiently detailed for the analyzed task. A general outline of the proposed methodology, which will be applied to the analysis of a specific case study in the next section of this paper, is represented in Fig. 5.

A Task Analysis-Based Approach to the Study of Iberian Megalithic Monumentality

A Brief Introduction to Megalithic Monumentality and Inferred Sociopolitical Organization in Iberian Late Prehistory

The case study analyzed in this paper is that of late prehistoric monumentality in Iberia, which requires an introduction by way of conceptual definition. By monumentality, we

Table 1 Megalith transport methods using human muscle power and different technical devices. The order is the same as Fig. 4

Transport method	Source of information	Cases and bibliographic sources
a) Carried on shoulders, lashed to a timber lattice or litter	Ethnographic accounts	Zemi Naga (Nagaland, India; Graham Bower 1952); Lotha Naga (Nagaland, India; Hutton 1929); highlanders of northern India (Lewis 1873)
b) "Walking" in an upright position, with the center of mass inclined in the direction of movement, pulled and held by at least three ropes	Experimental test	transport of an Easter Island's moai replica (Lipo *et al.* 2013)
c) Pulled by ropes or vines, lashed to a wooden sledge that slide over the ground surface	Ethnographic accounts	Zemi Naga (Nagaland, India; Graham Bower 1952), Angami Naga (Nagaland, India; Dewar 1966; Naga News 2017a); Konyak Naga (Nagaland, India; Naga News 2017b), Memi Naga (Manipur, India; Hutton 1921)
d) Pulled by ropes or vines, lashed to a wooden sledge that slide over a timber slipway	Ethnographic accounts	Niha (South Nias, Indonesia; Schröder 1917); Kodi speaking peoples (West Sumba, Indonesia; Adams 2007; Hoskins 1986)
e) Pulled by ropes or vines, lashed to wooden sledges that slide over a series of loose wooden rollers	Practical engineering applications; multiple experimental replications;	Transfer of the Vatican obelisk (Fontana 1590); transport of an Assyrian winged-bull statue (Layard 1853); for experiments, see literature cited in Harris (2018)

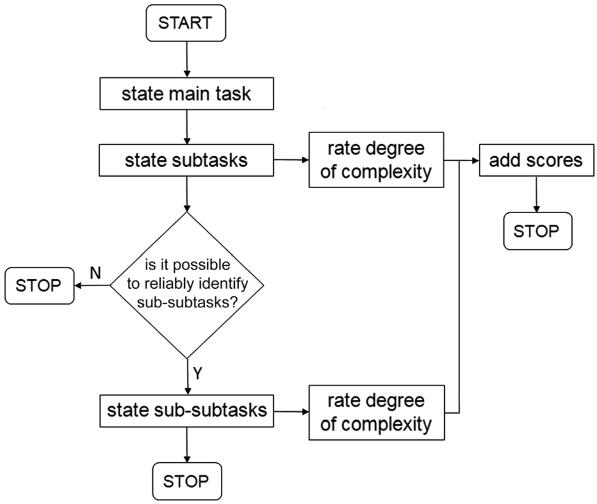

Fig. 5 Outline of the methodology implemented for tasks analysis and complexity degree assessment (drawing by Gustavo Barrientos)

understand the social practice of using material means (wood, stone, earth, *etc.*) to commemorate places of special cultural significance. In the Old World, monuments became increasingly widespread since the Neolithic, usually in the form of durable, large-sized, and conspicuous structures frequently associated with a multitude of social practices (including funerals, feasts, gatherings, pilgrimages, *etc.*).

In Europe, Late Prehistoric monuments included a wide range of types, such as wooden structures and sculptures, earthworks (ditched enclosures, mounds, platforms, *hypogea*, and others), and stone monuments like megalithic architectures of various descriptions. Here, we understand a "megalith" as a special type of monument consisting of one or more large-sized stones arranged in a particular way. Megaliths usually involve very large stones (often carefully dressed but also in a more or less natural state) weighing several hundred kilograms, or even tons. There is no agreed standard threshold in the literature to define what a "large" stone is, but here, we will implicitly accept as such any stone weighing over one hundred kilograms (a stone that, for all practical purposes, requires co-operation for its movement and/or placement as part of a monument). As we will see below, monuments usually referred to as "megalithic" include stones of widely varying sizes.

In Iberia, Late Prehistory is the long period of time between the beginning of the Neolithic, around 5500 BC, and the gradual integration of this region into the socio-cultural sphere of the Phoenician and Greek city-states that began to found colonies in the western Mediterranean from *ca.* 850 BC onwards. The *ca.* 4600 years that elapsed between those two processes are divided into three main periods, namely Neolithic (*ca.* 5500–3200 BC), Copper Age (*ca.* 3200–2200 BC), and Bronze Age (*ca.* 2200–850 BC). Overall, it witnessed major processes of gradual sedentarization, development of the productive economy, increase of long-distance contact, and the occurrence of a suit of sociopolitical changes usually understood to have led to "increased social complexity."

In general terms, social organization in Iberian Late Prehistory is a matter of debate and there is no unanimously accepted interpretation to account for it. This is largely due to the limitations of the available empirical evidence, which is generally too scarce and imprecise to allow for a clear-cut definition of the patterns of demographic, economic, and social organization, the extent of social inequality or the form of power institutions (see discussion in García Sanjuán and Díaz del Río 2006; García Sanjuán and Murillo-Barroso 2013). However, it is widely accepted that over the long period between the late 5th millennium cal BC (when large-scale monumentality in the form of ditched enclosures and megaliths became a consolidated phenomenon), and the incorporation of Iberia into the colonial orbit of the eastern Mediterranean city-states, Iberian societies experienced a process of demographic growth, the appearance of larger and more internally differentiated settlements, increases in investment dedicated to monumentality, greater social inequality, and growing conflict between groups. However, these processes were not linear and continuous but punctuated. In fact, there seems to have existed an important degree of discontinuity, with cycles of growth and collapse, in addition to an important interregional variability (for a recent overview, see contributions in Cruz-Berrocal *et al.* 2013).

It can be said that the appearance of ditched enclosures and megalithic monuments at the end of the 5th millennium BC (coinciding with the final "push" of the neolithization process of the European continent, leading to the expansion of the farming way of life to its northernmost regions, namely the British Isles and Scandinavia), reflects the consolidation of a dynamics of growing social aggregation. This was likely marked by greater productive efficiency and surplus accumulation, bigger communities, and by the competitive environment that both factors fostered in the sociopolitical realm, which found its primary expression in the sphere of the ritual and the symbolic. There is considerable agreement that ditched enclosures and megalithic monuments became arenas for the staging of practices linked to the aggregation and interaction of communities (Díaz del Río 2004, 2011). Such practices made possible a greater fluidity in the exchange of raw materials, information, and knowledge, while at the same time, they laid the basis for the appearance of intensifying institutions in the political/economic arena (such as, for example, Big Man) (García Sanjuán *et al*. 2018a, 2019).

These dynamics gained momentum at the beginning of the Copper Age (*ca.* 3200–2200 BC), with the appearance of walled enclosures (interpreted as fortified settlements by some), the development of copper metallurgy, and an intensification of the flow of exotic raw materials, including ivory from African and Asian elephants, high-quality flint, amber, rock crystal, cinnabar, ostrich eggshell, *etc.* The funerary record of the early 3rd millennium BC in some regions, especially the lower Guadalquivir valley in southwestern Spain, reveals the emergence of powerful kinship units and/or corporate groups with privileged access to highly valuable exotic materials (García Sanjuán *et al.* 2018a, 2018b, 2019). According to some interpretations, the social system emerging in this region would have been of a state-like nature (Nocete Calvo 2001; Nocete Calvo *et al*. 2008), although the evidence on which this vision is based is questionable (García Sanjuán and Murillo-Barroso 2013). The social position of the Copper Age elites seems to have been quite unstable, given the probable absence of hereditary transmission of wealth, reflected in the absence of infant burials with valuable grave goods (Cintas-Peña *et al*. 2018) and in the alternation of cycles of increase and decrease in elite influence or power (García Sanjuán *et al*. 2018c). In fact, in the twenty-fourth century BC, there was a profound crisis of the Copper Age social system, leading to the end of the construction of ditched enclosures and megalithic monuments that had dominated the social landscape in the two preceding millennia. Quite possibly, the collapse of the Copper Age social system was marked by the effects of a period of greater aridity caused by the so-called 4.2 ky BP event, which seems to have had a considerable effect across the Mediterranean and the Near East (Blanco-González *et al*. 2018; Lespez *et al.* 2016; Hinz *et al*. 2019).

With the beginning of the Bronze Age (*ca.* 2200–850 BC) the Late Neolithic and Copper Age social systems underwent a profound transformation. The practices of aggregation and competition that had led to the construction of ditched enclosures and large megaliths ceased to exist. In the last two centuries of the 3rd millennium, a very different settlement pattern became widespread, characterized by hilltop villages furnished with major infrastructure such as terraces and walls. In terms of burial practices, the construction of megaliths seems to have been abandoned and replaced by individual inhumations in small containers (like cists or "*covachas*," *i.e.*, small rock-cut cavities), although many old megaliths and hypogea were still used, which suggests an important degree of ideological connection with the past. In some regions "megalithic cists" were built to echo the architecture of the old age. In many of the individual burials of the Early Bronze Age, grave goods included weapons made of metal (arsenical copper) such as daggers, halberds, or even swords, revealing the appearance of a fairly widespread "warrior" ethos, something already foreshadowed in certain Late Copper Age Bell-Beaker tombs. All this suggests that from *ca.* 2200 BC onwards, and as a result of the disintegration of the Copper Age social system based largely on intergroup cooperation and the limitation of competition to the ritual and symbolic sphere, relations between communities acquired a more conflictive character, with a growing presence of violence and a marked warrior ideology that distinguished an elite group from the rest of society.

In this context, it is relevant to assess whether the inferred trend towards an increase in sociopolitical complexity at the level of the whole social systems corresponds to a similar trend at the level of lower-level systems, particularly those involved in the construction of objects of high social and symbolic value such as megalithic monuments.[10] In this regard, it is noteworthy that some authors have proposed that a positive correlation would exist between the scale and sophistication of architectural structures and the organizational complexity of the society that built them (*e.g.*, Atkinson 1961; Renfrew 1973, 1982; see Barrett and Boyd 2019; Osborne 2014; Webster 1991). To examine this from the perspective of the theoretical and methodological approach presented in the preceding sections, we have chosen three stone constructions that are representative of the largest investments in work and energy made in the sphere of monumentality for each of those three periods in Iberia (Fig. 6).

The Monuments

Menga Dolmen (Late Neolithic, Built *ca.* 3800–3400 BC)

As mentioned above, in Iberia, the creation of stone monuments took off in the Late Neolithic (between c. 4200 and 3200 BC), when the megalithic phenomenon became widespread and some of the most magnificent of these monuments were built. At that time, megaliths consisted mainly of simple chambers, sometimes internally sub-divided into various spaces by jambs or portals. These chambers were erected with blocks of stone weighing several tons that were dressed forming a lintel-based architecture. One of the best examples of the megalithic architecture of this period is Menga, a dolmen[11] located in Antequera (Malaga) and part of a larger site that in July 2016 was included in the UNESCO World Heritage List. This site includes two other major megaliths (the Viera dolmen and El Romeral tholos) and two natural formations closely associated with the genesis and history of these three constructions, and which had a great cultural, social, and ideological significance in their biographies: La Peña de los Enamorados, a limestone massif whose silhouette closely resembles that of a human head facing

[10] The mains reason for using megaliths as a means of comparison for work organization and, indirectly, social complexity in Late Prehistoric Iberia is that, unlike other types of monuments, which are more period-specific, they were built and used throughout the whole period under study. Megaliths of various types and descriptions were built in the Neolithic, Copper Age and Bronze Age. The same cannot be said about other monument types, such as for example ditched enclosures.

[11] A dolmen is a megalithic construction presenting one or more inner spaces (usually referred to as "chambers" or "niches") delimited in various ways (jambs, portals, corridors, *etc.*) and built by means of large stones forming lintels. Dolmens are often (but not always) covered by a mound or tumulus made of stone, earth or a combination of both.

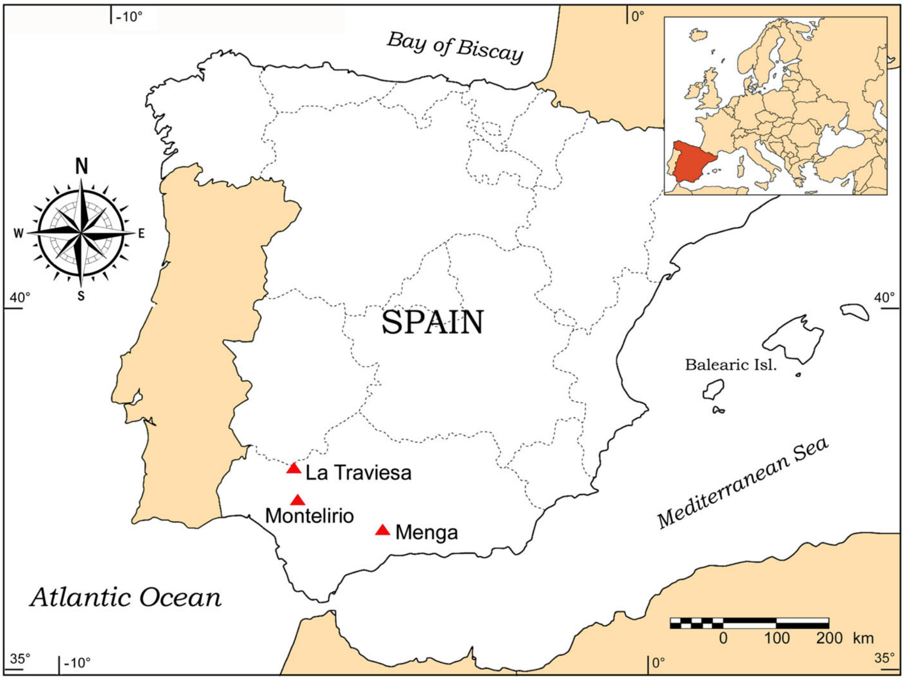

Fig. 6 Map of the Iberian Peninsula showing the location of the three megalithic monuments described in the text (provinces of Seville and Malaga, western Andalusia, Spain) (drawing by Gustavo Barrientos)

upwards, and El Torcal karstic formation (García Sanjuán *et al.* 2015; García Sanjuán and Lozano Rodríguez 2016).

Since its early exploration in the first half of the nineteenth century, Menga has become one of the most famous prehistoric constructions in Spain and an international benchmark for the study of the megalithic phenomenon. Recent and on-going research shows that, in addition to presenting unique architectural and engineering characteristics (Márquez Romero and Fernández Ruiz 2009; Lozano Rodríguez *et al.* 2014) and an exceptionally long biography (García Sanjuán and Lozano Rodríguez 2016; García Sanjuán and Mora Molina 2018), Menga emerged in the context of an intense dynamic of occupation of the territory in the surrounding region during the 4th millennium BC.

The Menga dolmen (Fig. 7) consists of a stone chamber 24.5 m in length, up to 5.7 m in width, and 3.5 m in maximum height, built with 32 huge stone blocks, of which 25 were used as uprights, five as capstones, and three as pillars. From the point of view of the investment of work and energy required for its construction, Menga stands out because of the enormous size of its stones, the largest of which (the capstone at the back of the chamber) weighs an estimated 170 metric tons. Menga's whole set of stones weighs more than 900 metric tons. The material used for the construction of the dolmen is calcarenite, a locally available sedimentary rock probably extracted from a quarry located about 800 m southwest of the dolmen. The various excavations carried out outside and inside this monument (most of them unpublished, unfortunately, but see García Sanjuán and Mora Molina 2018) have yielded significant amounts of hammers made in hard rock (*e.g.*, ophite) that are believed to be linked to the work involved in its construction. The whole of the dolmen chamber was covered with a

Fig. 7 The Menga Dolmen (Late Neolithic, built *ca.* 3800–3400 BC). **a** General view of the monument from the north-east. **b** General view of the inner space and elements, with the water well and backstone at the background

tumulus of about 50 m in diameter and up to 5 m in height, built by means of alternating layers of pressed earth and blocks of medium-sized stone. This tumulus has given the construction a great deal of stability over the centuries, which is especially remarkable considering that Antequera is located in the highest seismic-risk zone of the Iberian Peninsula.

Montelirio Tholos (Copper Age, Built *ca.* 2900–2800 BC)

In the Copper Age (*ca.* 3200–2200 BC) Iberian megalithic architecture underwent a major transformation. Although many old Neolithic megaliths continued to be used and transformed and new dolmens were built, a completely new type of construction appeared: the tholos (pl. tholoi). These megaliths generally present a narrow corridor with a flat roof leading to a circular chamber roofed in the corbelling technique or even with domes made of sun-dried mud. In this new megalithic tradition, much less emphasis was placed on extravagantly large stones. To a great extent, large monoliths were replaced by medium-sized slabs or masonry, and more prominence was given to the hemi-spherical shape of the chambers, which resulted in much "lighter" and more "ascending" inner spaces. The tholos selected here as a case study is Montelirio, which is part of the Copper Age mega-site of Valencina de la Concepción-Castilleja de Guzman (Seville), one of the most important settlements for the study of 3rd millennium Iberia (García Sanjuán *et al*. 2017, 2018a, b).

Together with El Romeral (part of the aforementioned Antequera site), and La Pastora, also part of the Valencina mega-site, Montelirio (Fig. 8) is one of the three most accomplished examples of this type of monument in Iberia. Recent investigations have shed substantial light on its cultural and social background (Fernández Flores *et al*. 2016; García Sanjuán *et al*. 2018b). Montelirio presents a long and narrow corridor of 39 m, a first chamber (designated as a Large Chamber) 4.75 m in diameter and a second compartment 2.7 m in diameter (Small Chamber), connected to the first by a narrow corridor. With 43.75 m of interior linear development, Montelirio ranks among the largest megalithic constructions of Copper Age Iberia. The main corridor, delimited by slate slabs (in some cases painted with cinnabar pigment) and covered by 42 capstones of sandstone and granite (in 28 cases), slate (10 cases), and granite (four cases) is barely half a meter in width and height, which made moving around very

Fig. 8 The Montelirio Tholos (Copper Age, built *ca.* 2900–2800 BC). **a** Aerial view of the monument. **b** Detail of slate slabs of the corridor coated with cinnabar pigment. **c** General view of the Large Chamber after the completion of its excavation. **d** Detail of the corridor showing the crawling position demanded to negotiate its roofed part. **e** General view of the corridor, looking from the Large Chamber outwards

difficult. The Large Chamber was delimited by at least 22 finely carved slate slabs of up to 0.70 m high that were coated with a thick layer of cinnabar pigment of intense red color and then decorated with symbolic motifs (zigzag lines, “oculi,” *etc.*). The roofing was achieved through a sun-dried dome of clay and marls that reached about 4 m in height (on the floor of the chamber 11 post holes were found, probably corresponding to the scaffold used to make that structure harden). The Small Chamber, which was almost completely destroyed during reuse of the monument between the first century BC and the first century AD, must have been constructed in the same way. This entire megalithic construction was “embedded” within a natural hill of about 75 m in diameter and 5.5 m in height. In the eastern sector of this hill, the Montelirio builders opened a large trench inside which they erected all the construction elements described above. This trench was later covered with the same earth previously extracted. Therefore, unlike that of Menga, the mound of Montelirio is not completely artificial, but consists of a natural hill partially adapted to receive the megalithic construction.

La Traviesa Cist 5 (Early Bronze Age, Built *ca.* 2000–1800 BC)

In the Bronze Age (*ca.* 2200–850 BC) the construction of megaliths in Iberia declined sharply. However, there is abundant evidence of the frequentation and reuse of those that had been built in the Neolithic and the Copper Age (Lorrio and Montero Ruiz 2004; García Sanjuán 2005; Aranda Jiménez 2013). In addition, in some regions, especially in the southwest, “megalithic cists” were built. These monuments include large stone slabs and small cairns as an “imitation” of the old megalithic traditions. On the whole, however, the ritual and burial architecture of this period presents a marked process of “de-monumentalisation” (García Sanjuán 2006, 160–164). Although different cultural traditions can be distinguished in this respect, in general, the most common funerary constructions were stone cists of rectangular plan and small size (1.5 × 0.5 m generally), as well as pits and “*covachas*” (small cavities carved in rocky walls) of similar size.

The case study chosen to illustrate the monumental funerary architecture of the Early Bronze Age is one such “megalithic cist,” specifically Cist 5 of La Traviesa, located in western Sierra Morena (Seville province), just 70 km north of Valencina. It is one of the few cases of cemeteries of this period for which a fairly accurate empirical description is available (García Sanjuán 1998a). La Traviesa grave number 5 (Fig. 9) consists of a rectangular chamber 3.25 m in length, 1.3 m in width, and 0.51 m in height, delimited by slate slabs and covered by medium-sized slabs of limestone and slate (the largest of them measures 1 m in maximum diameter and weighs 1327 kg). This “megalithic cist” has therefore a size that basically “triples” the standard size of the other cists in this necropolis and in southern Iberia as a whole. Cist 5 was covered by a cairn 6.45 m across (in the E-W direction) and 0.40 m maximum height, made with unworked blocks of stone of small and medium size. This cairn leans against a rocky outcrop located on its north side and provides the building with a sense of scale that is exceptional for its time, since there are very few recorded Bronze Age cists that present architectural devices of this nature. Few and poorly preserved bone remains, corresponding to a single adult male, were found inside this burial, accompanied by two ceramic vessels and a copper halberd, a distinguished object attributable to a person of high social status (García Sanjuán 1998a).

Fig. 9 The La Traviesa Cist 5 (Early Bronze Age, built *ca.* 2000–1800 BC). **a** General view of the cairn and chamber once cleared of vegetation and topsoil. **b** general View of the cairn and chamber halfway through the excavation of the latter

Comparative Assessment of the Three Selected Monuments

Figure 10 presents a comparison, to scale, between the three selected megalithic monuments. The evident differences in size and volume between the three structures imply considerable variation in the work and workload necessary to build each of them and, indirectly, in the levels of organization and complexity of the social systems involved in their production. In part, such differences reflect well the rather different purposes they were intended for, the social practices they staged, and the very societies that built them. Menga was probably built as a grandiose temple devoted to the forces of nature that presided over the Neolithic world-view. Menga's architecture and landscape settings reveal its subtle connections with the surrounding earthly forms (topography, natural monuments), the sun, and the water. In addition, it likely resulted from the concerted and coordinated effort of a very broad group of people, who collaborated voluntarily to erect it. Therefore, Menga embodies an idea of collectiveness and societal cooperation that could be connected with social practices common in the Neolithic, particularly temporary gatherings.

Montelirio, in turn, was conceived as a burial monument, although its design and organization also convey the notion of the megalith as a cult space, as suggested by the

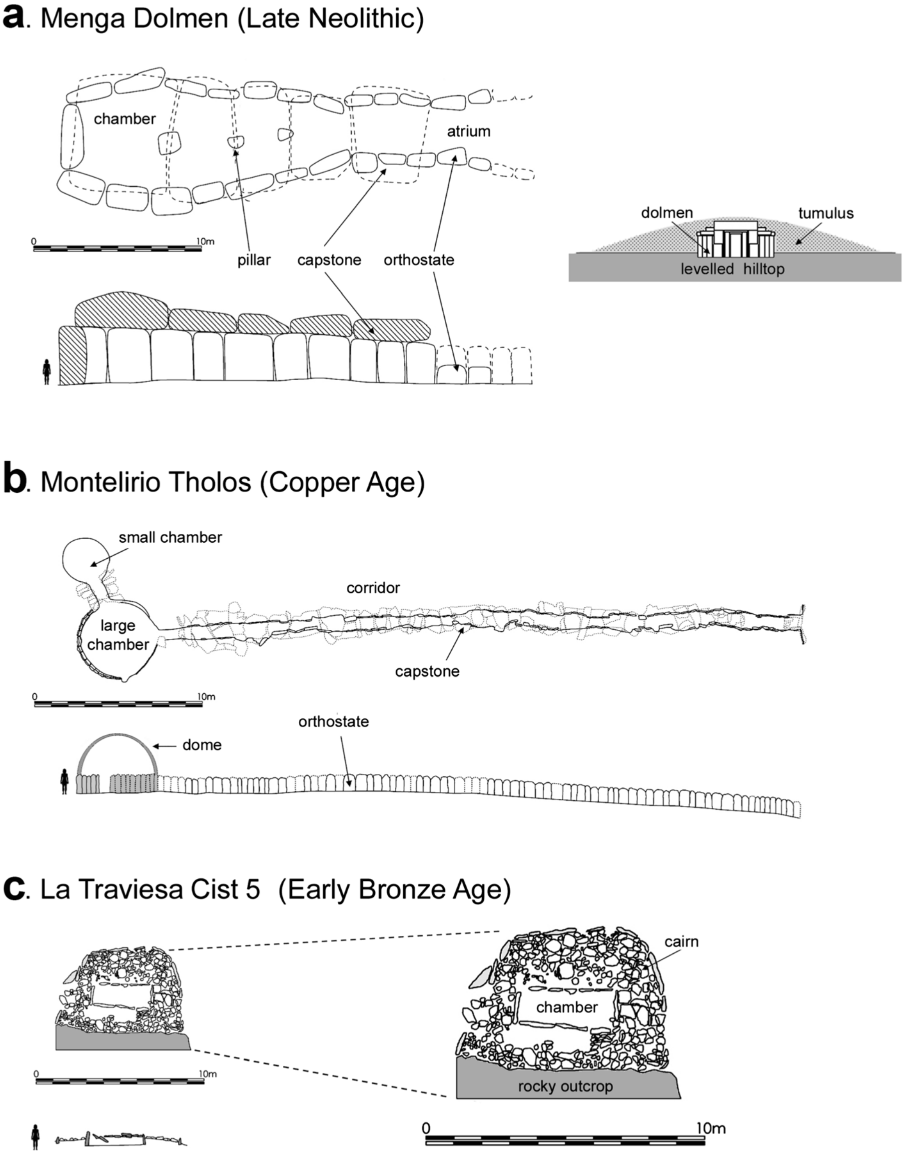

Fig. 10 Different views of the three monuments described in the text. In the three cases, figures at left (plan view and section of the buildings) are in the same scale. The right image of Menga is a schematic representation of the position of the megalithic building within the artificial tumulus (not at scale) (drawings by Ana García and Gustavo Barrientos)

clay stela placed at the center of the Large Chamber. Its primary purpose seems to have been to house the remains of a very specific contingent of people. The remains of 26 individuals were found in it. Of them, 20 had been laid inside the Large Chamber, as if they were part of a carefully choreographed scenography. Bioarchaeological evidence shows that the people buried there were a highly selected mostly female cohort, which included neither elderly people, nor children, nor men. One of those women had six toes in both her feet, a physical trait associated with "special" people in many societies across the world, and a number of them had their bones heavily contaminated by mercury, most likely as a result of the intensive use of cinnabar (Emslie *et al.* 2015, 2019). In light of this evidence, it is hard not to conclude that Montelirio was built as the resting place of a special corporate group, such as, for example, priestesses of a famous temple, sanctuary, or oracle, located at the Valencina mega-site (García Sanjuán *et al.* 2018b). The prominent symbolical role played by the stela inside the Large Chamber, around which some of the women were laid, suggests that Montelirio did also have significance as a cult place, perhaps for the deity or ancestor represented by the stela. Unlike Menga, Montelirio does not appear to have been designed by and for the entire social system in which it occurred, but for a reduced corporate group which, in light of the phenomenal amount of exotic paraphernalia it was buried with, we could well term an "elite" (García Sanjuán *et al.* 2018b). Thus, one striking difference between Menga and Montelirio is that while one monument appears to represent the entire society that built it, the other is likely to reflect the position and power of an elite.

The process of elite "appropriation" of megalithic monumentality referred to above becomes even more visible at La Traviesa Cist 5. The largest and most architecturally complex stone-made burial monument erected by the Early Bronze Age communities of southern Spain was the individual burial of a prominent person, perhaps a chiefly leader. The paucity of large funerary or ritual constructions in this period may be symptomatic of the relative limitations of the existing power—apparently more centralized but probably lacking sufficient coercive capacity—to mobilize large-scale workforce in a social context of low intra- and inter-community cooperation, *i.e.*, an inability to transform work into labor (*sensu* Fuchs and Sevignani 2013). This was critical since mechanisms to pool work and resources, such as the periodical temporary gatherings that constituted a major feature of Late Neolithic and Copper Age social life, likely disappeared in the Early Bronze Age.

Analytical Approach

In this study, we first proceeded to identify the main tasks likely performed to build each monument and then to carry out their decomposition up to the level of sub-subtasks, when feasible. The reason for this is that at that level or below, the degree of speculation (in the sense of guesses about something that is unknown) in the task breakdown exercise increases enough to make the analysis unreliable. The approach takes the general form of a hierarchical task analysis (HTA) (Annett and Duncan 1967; Annett *et al.* 1971; see also Hollnagel 2012; Kirwan and Ainsworth 1992; Shepherd 2001; Stanton 2006; Stanton *et al.* 2005), although with the necessary adaptations given the indirect nature of the information (in the sense of purely inferred, non-observational) on which the analysis is based.

In each case, the methodological steps followed were (a) breakdown of the tasks into subtasks and these, occasionally, into sub-subtasks, numbered following the system explained in Shepherd (2001); (b) identification of the goals to achieve with each task, expressed as verb-noun (*e.g.*, "supply tools," "pull megalith"); (c) formulation of the likely plans (*i.e.*, conditions under which each of a set of subgoals is undertaken to achieve their common superordinate goals; Shepherd 2001, 22) for the execution of

Table 2 Different plan types with notation convention (modified from Stanton 2006)

Type of plan	Notation	Meaning
Linear (sequential plan)	1 > 2 > 3 > 4	Do in order
Non-linear (non-sequential plan)	1/2/3/4	Do in any order
Simultaneous (concurrent plan)	1 + 2 + 3 + 4	Do at the same time
Branching (choice plan)	*X*? *Y* > 2 *N* > 3	Do when required
Cyclical (repetitious plan)	1 > 2 > 3 > 4 > 1…	Repeat the following until
Selection (exclusive plan)	1: 2: 3: 4	Choose one of the following

tasks, subtasks, and sub-subtasks using conventional notation (Stanton 2006) (Table 2); (d) representation of the products of *a* and *b* in a hierarchical diagram (Annett *et al.* 1971; Kirwan and Ainsworth 1992; Shepherd 2001; Stanton 2006); and (e) rating of tasks, subtasks, and sub-subtasks according to their degree of complexity, following the aforementioned criteria by Anderson *et al.* (2001), *i.e.*, assigning one point of complexity to individual tasks, subtasks, or sub-subtasks, two points to group tasks, subtasks or sub-subtasks, and three points to team and partitioned tasks, subtasks, or sub-subtasks; when a task of any level can be performed by either an individual or group or by a group or a team, it was awarded an average of the points corresponding to the two levels of complexity involved (*i.e.*, individual-group: 1.5 points; group-team: 2.5 points). The ratio between partitioned (P) and/or team (T) tasks and group (G) and/or individual (I) tasks (P,T/G,I ratio) was also calculated. Additionally, flowcharts of the main tasks were constructed, indicating the spatial domain at which they were likely performed (*i.e.*, on-site, off-site local, and off-site non-local). Activities without material evidence but likely indispensable for accomplishing the different proposed tasks, subtasks, and sub-subtasks were inferred from general knowledge about traditional technology, as described in specialized literature (*e.g.*, Jones 2008; Watts 2004; Wescott 1999, 2001).

Results

Menga Dolmen

Structurally, Menga is composed of two main parts: the mound and a stone structure made by large orthostats, capstones, and pillars[12] (for a detailed description in English of the structural and architectural elements of Menga, see Márquez Romero and Fernández Ruiz 2009). The process of construction of this monument likely involved the following tasks, subtasks, and sub-subtasks, graded with points (p) according to their degree of complexity (Fig. 11):

[12] A third major architectural element of this monument is the *ca*. 20-m deep water well located at the back of the chamber (García Sanjuán *et al*. 2016, 2018d, 2020). Although no direct evidence exists to prove that this well was built as part of the original dolmen during the Neolithic period, there is no evidence to conclusively prove the opposite either. However, given the lack of a precise date for the chronology of construction of this impressive hydraulic feature, we have chosen to leave it out of the analysis.

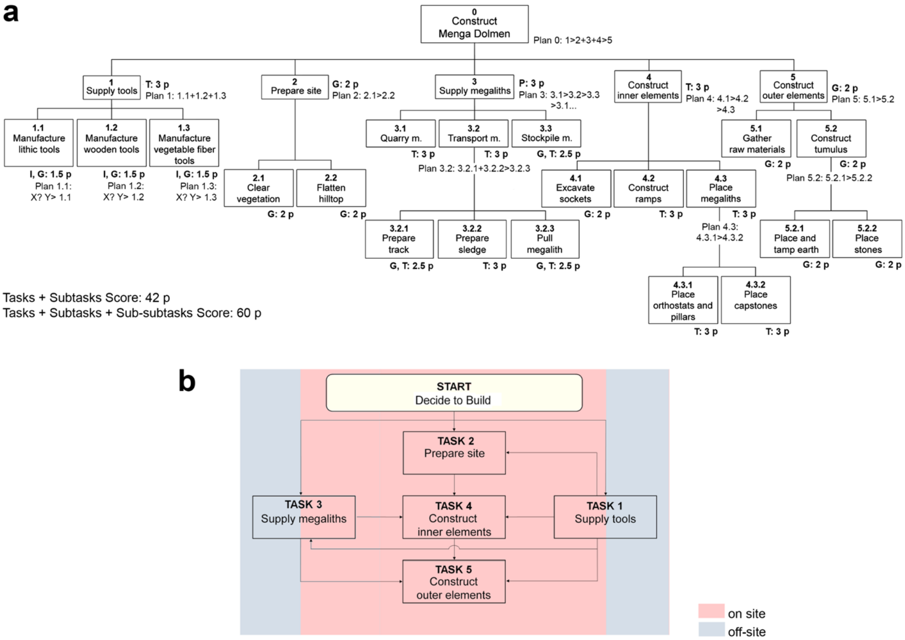

Fig. 11 Menga Dolmen. **a** Hierarchical task analysis, in red the plan of each task; **b** Flowchart of tasks with indication of the place (on-site or off-site) in which each task was likely carried out (note that some task may have been carried out at both spatial domains) (drawing by Gustavo Barrientos)

1. *Tool Supply* (team: 3 p): involves the preparation of the tools needed for all other tasks;

   1.1. *Lithic tool manufacture* (individual/group: 1.5 p): involves preparation of a large number of hammers and maces for the quarrying, dressing, and shaping of the large stones, and of sharp polished hand-axes to cut and work the abundant amount of timber that the construction process must have required; all the archaeological excavations carried out in Menga and its surroundings have yielded important amounts of such tools, made in hard rocks such as ophite, dolerite or sillimanite, or even rocks brought from further afield, such as meta-arenite. These tools are thought to have been used in the construction of the monument and then discarded or deposited in its surroundings;

   1.2. *Wooden tool manufacture* (individual/group: 1.5 p): includes the manufacture of handles for stone tools and extensive carpentry work for the construction of the road from the quarry to the dolmen, the earthen ramps for the placement of the vertical stones and capstones, and for the movement of the stones themselves. All these works must have involved large amounts of beams, poles, planks, ladders, *etc.*; no material evidence of this has ever been recovered;

   1.3. *Vegetable fiber tool manufacture* (individual/group: 1.5 p): includes the production of large amounts of baskets for transporting earth and of ropes for many of the works described, especially for the dragging of the stones from the quarry to the construction site; no material evidence of this has been ever recovered.

2. *Site Preparation* (group: 2 p): includes activities prior to the construction of the monument;

   2.1 *Vegetation clearance* (group: 2 p): involves the removal of the vegetation that covered the natural hill. It is unlikely that this work was very hard, since there is evidence that the hilltop knew substantial human activity before the construction of the megalith, including at least one burial of unknown chronology that was found underneath the mound (García Sanjuán and Lozano Rodríguez 2016, 3).
   2.2 *Hilltop flattening* (group: 2 p): consist in the leveling of the hilltop in order to create the horizontal space needed for the construction of the dolmen; this would have involved the flattening of a surface area of at least 5000 m^2 so that the huge stones could be dragged into the construction site.
3. *Megalith supply* (partitioned: 3 p): involves activities aimed at obtaining and stockpiling constructive materials;

   3.1 *Quarrying* (team: 3 p): the quarry from which the calcarenite stones used for the construction of Menga were extracted is located between the current El Rosario neighborhood and the Cerro de la Cruz hill, in the city of Antequera, about 800 m away from the dolmen as the crow flies (Carrión Méndez *et al.* 2009, 157; 2010, 61–63); this subtask involved the quarrying of a total of 30 large stones, including 24 orthostats, three pillars, and five capstones. It is important to note that Menga includes some stones of gigantic size; the capstone at the back of the chamber, measuring an estimated 7.20 m in length by 6.05 in width, has an estimated weight of 170 metric tons (Carrión Méndez *et al*. 2006, 132); combined, all the stones used in the dolmen have an estimated total weight of *ca.* 900 metric tons, which implies that their quarrying and carving must have involved a large team of well-organized workers (see Bonetto *et al*. 2014 and contributions therein);
   3.2 *Transport* (team: 3 p): implies the transfer of the megaliths from the quarry to the construction site; as already mentioned, there are different ways of transporting megaliths; of the five variants represented in Fig. 4 and in Table 1, the least likely (at least for orthostats and capstones) are variants *a* and *b*, since they are useful and practicable for the transfer of stones of smaller dimensions (*a*) or of elongated format, with a rather wide base (*b*); another variant that is unlikely because of its limited ethnographic support and relatively poor performance (experimentally demonstrated) is *e*, which is based on the use of sledges sliding on loose wooden rollers (see discussion in Harris 2018; Parry 2000); variants *c* and *d* are those with the greatest empirical support in the ethnographic record, being particularly well suited for the transport of big megaliths, so they are considered as the most likely used in this context (however, the use of variant *a* for the transport of the pillars cannot be completely ruled out); tentatively, this subtask can be decomposed into the following sub-subtasks:

      3.2.1 *Track preparation* (group/team: 2.5 p): involves the opening and maintenance of a track or road by which the megaliths could be moved more easily, creating a surface as flat as possible by the leveling of the more prominent areas and the filling of others, in order to minimize the friction of the sledges against the ground; this sub-subtask may have also included the placement, at least in some sections, of a timber slipway to facilitate the sliding of the sledges; no material evidence of this has been recovered so far;

3.2.2 *Sledge preparation* (team: 3 p): involves the construction of a wooden structure that supports the weight of the monolith and that is capable of sliding, dragged by ropes, on the ground surface or on an artificial surface like a timber slipway; for large stones, the available ethnographic information indicates that it is a specialized task that requires the intervention of several people working in teams (*e.g.*, Adams 2007; Osenton 2001; von Saher 1994); includes the lashing of the stone to the sledge; no material evidence of this has been recovered so far;

3.2.3 *Megalith pulling* (group/team: 2.5 p): depending on the method of transport, the pulling of the megaliths could be a group or a team task involving the participation from tens to several hundreds of people (for ethnographic references see, among others, Adams 2007; Dewar 1966; Graham Bower 1952; Hoskins 1986; Schröder 1917); no material evidence of this has been recovered so far;

3.3 *Stockpiling* (group/team: 2.5 p): as the construction of a megalithic monument can take a long time, perhaps years (Adams 2007), it is reasonable to think that the materials—or at least some of them—were accumulated at the site before their final emplacement in the structure; this may involve some limited handling or relocation of the stones on site; no material evidence of this has been recovered so far.

4. *Construction of inner elements* (team: 3 p): involves activities needed to place the internal elements of the structure;

4.1. *Socket excavation* (group: 2 p): includes the excavation of foundation sockets for orthostats and pillars;

4.2. *Ramp construction* (team: 3 p): involves the preparation of earth ramps and associated devices for the placement of orthostats and pillars on the one hand and capstones on the other; the efficiency of the combined use of earth ramps and other elements like timber frames and weighting stones as a method to place heavy megaliths, particularly for putting them in an upright position, has been experimentally demonstrated (Richards and Whitby 1997; see also Parry 2000, 2004); its use in Menga is hypothetical due to the absence of evidence, but plausible;

4.3. *Megalith placement* (team: 3 p): involves the sequential placement of the dolmen components, starting with the vertical elements (orthostats and pillars) and ending with the horizontal elements (capstones);

4.3.1. *Orthostat and pillar placement* (team: 3 p): involves the implementation of some column-tilting method, likely using ramps, wooden frames, and counterweights (*e.g.*, stones);

4.3.2. *Capstone placement* (team: 3 p): for the placement of the capstones, a different ramp must have been used, which in this case was aligned with the dolmen's longitudinal axis of symmetry, since these capstones were dragged from the back of the chamber towards the entrance, putting into place first the capstones of the entrance, and finally the one at the back of the chamber.

5. *Construction of outer elements* (group: 2 p): involves activities needed to place the elements of that surround and cover the megalithic structure;

   5.1 *Raw material gathering* (group: 2 p): consists in the collection and transport of small blocks of stone and earthen materials for the construction of the tumulus; these materials probably did not have to be hauled from a great distance, but given the large volume of the tumulus (estimated at 3000 m^3), they must have entailed an important investment of work and time;

   5.2 *Tumulus construction* (group: 2 p): involves the erection of the tumulus or mound that envelops the dolmen by the deposition of alternating layers of well-pressed clay and small stone blocks;

      5.2.1 *Earth placement* (group: 2 p): includes the placing and tamping of the bedding materials supporting the stones.

      5.2.2 *Stone placement* (group: 2 p): includes the more or less orderly placement of mostly tabular blocks, forming horizontal layers of rocky materials.

Montelirio Tholos

Structurally, the Montelirio tholos is composed of four main parts: the mound (which is actually a natural hill adapted to receive the megalith), the long access corridor, and the two chambers, which we will refer to as the Large Chamber (LC) and Small Chamber (SC). A detailed description of the structural and architectural elements of this monument can be found in Fernández Flores and García Sanjuán (2016). The process of construction of this monument likely involved the following tasks, substasks, and sub-subtasks, graded according to their degree of complexity (Fig. 12):

1. *Tool Supply* (team: 3 p): involves the preparation of the tools needed for all other task;

   1.1 *Lithic tool manufacture* (individual/group: 1.5 p): as for Menga;

   1.2 *Wooden tool manufacture* (individual/group: 1.5 p): as for Menga;

   1.3 *Vegetable fiber tool manufacture* (individual/group: 1.5 p): as for Menga;

2. *Site Preparation* (group: 2 p): includes activities prior to the construction of the monument;

   2.1 *Vegetation clearance* (group: 2 p): This was probably not excessively arduous or laborious, because by then, that sector of the site had known significant activity for more than 300 years and it is probable that the space had experienced substantial anthropization and vegetation clearance (for a more detailed description of activity in the SE sector of the Valencina mega-site

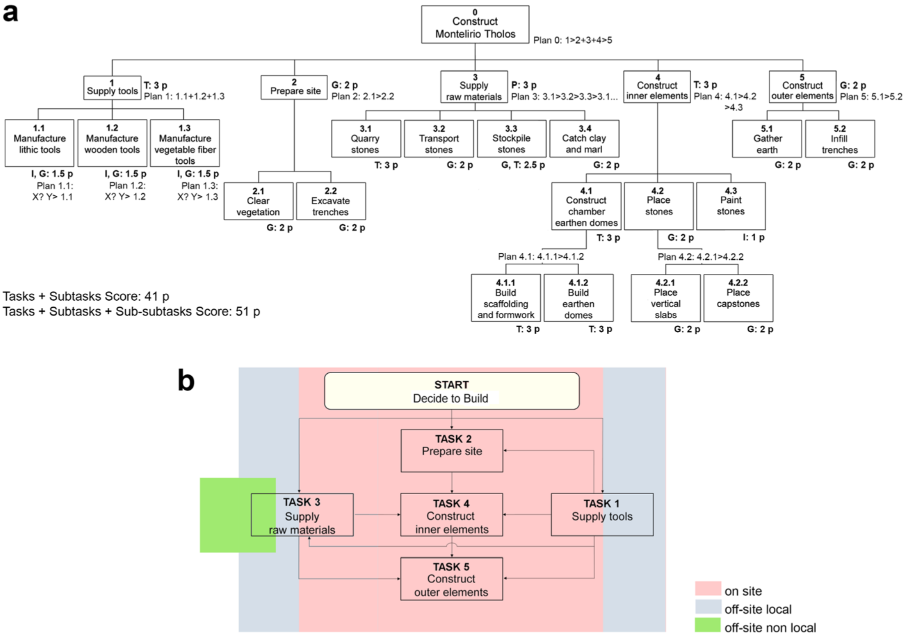

Fig. 12 Montelirio Tholos. **a** Hierarchical task analysis, in red the plan of each task. **b** Flowchart of tasks with indication of the place (on-site, off-site local and off-site non-local) in which each task was likely carried out (note that some task may have been carried out at more than two spatial domains) (drawing by Gustavo Barrientos)

before the time the Montelirio tholos was built at the end of twenty-ninth century BCE, see García Sanjuán *et al.* 2018d);

2.2 *Excavation of trench* (group: 2 p): consists in the excavation of a large trench approximately 50 m long, 10 m wide, and 5 m deep on the eastern side of the hill. This trench would receive all the other structural elements of the tholos, being later backfilled to recreate the original shape of the hill.

3. *Raw material supply* (partitioned: 3 p): as for Menga;

3.1 *Quarrying* (team: 3 p): the number of stone slabs used to line the walls of the corridor and the chambers of the monument is not known exactly as the reuse that occurred in Antiquity (first century BCE to first century AD) involved the extraction (and perhaps destruction or reuse in other buildings) of all the slabs of the SC, and almost half of those of the LC, as well as some of the main corridor; our estimate, however, is that around 200 slate slabs between 50 and 70 cm high and about 40–50 cm wide were used in the monument; the exact number of capstones in the main corridor is 42, including 28 of carbonated sandstone, 10 of gray or greenish slate, and 4 of coarse-grained granite (Borja Barrera and Borja Barrera 2016); the Montelirio builders, therefore, had to quarry around 200 fair-sized slate slabs with which the two chambers, the short corridor that joins them, and the long corridor that connects the CG with the exterior, of almost 37 m in length, were lined; four of the corridor capstones were also made in slate. In addition, quarrying work involved the extraction and preparation of 28 carbonated sandstone as well as four of coarse-grained granite for the capstones used to roof the main corridor (whose outermost section was not roofed);

3.2 *Transport* (group: 2 p): the nearest source of supply for slate and granite is at Aznalcóllar, located in the first elevations of the western Sierra Morena, about 15 km northwest from Valencina (Borja Barrera and Borja Barrera 2016, 160); the Copper Age site of Los Páramos (Hunt Ortiz 2003) is known there, suggesting activity coeval to the occupation of Valencina; the slabs of slate and granite may well have been transported downstream on the Guadalquivir river by rafts and then pulled by land from the shore of the marine gulf into which the river emptied, to the El Aljarafe plateau where Valencina is located, which means saving a slope of about 130 m within a distance of about 1 km; it is not possible to rule out, however, that the stones were moved entirely by land, since between Valencina and Aznalcóllar, there are no insurmountable gradients to transport stones of that size. In the case of the 28 carbonated sandstone slabs, although there are outcrops in the El Aljarafe plateau, very close to Valencina, the authors of the Montelirio petrological study suggested that they were quarried from Coria del Río, a town located about 20 km south of the site (Borja Barrera and Borja Barrera 2016, 160); this interpretation is based on the presence in the sandstone blocks of remains of lithophagous marine bivalves that are specifically diagnostic of Coria del Río rock formations. In fact, the same conclusion was reached in the study of the construction material of La Pastora, another great tholos of the Valencina mega-site, located just 600 m west of Montelirio (Cáceres *et al.* 2014). In summary, the main conclusion of both studies is that the only reason the builders of Montelirio (and La Pastora) had to choose that precise source for the sandstone materials, discarding closer ones, was the very presence of the marine bivalves; these bivalves must have had some kind of symbolic significance and were used as a natural "decoration" for both megaliths (Cáceres *et al.* 2019)[13];

3.3 *Stockpiling* (group/team: 2.5 p): as for Menga.

4. *Construction of inner elements* (team: 3 p): as for Menga;

4.1 *Construction of the two earthen domes for the chambers* (team: 3 p): includes the construction of wooden scaffolding and formwork and earthen domes;

4.1.1 *Building of scaffolding and formwork* (team: 3 p): to make the domes, a wooden scaffold supported on posts whose holes have been preserved in the floors, was likely used;

[13] There is further evidence of the symbolic use of marine shells in Valencina such as the presence of *Pecten maximus* (scallop) shells as grave goods, or the use of perforated shell beads in the sumptuous attires worn by the women buried in the Large Chamber of Montelirio.

4.1.2 *Building of earthen domes* (team: 3 p): the scaffolding served to place the mixture of clay and marls with which the domes were made, and to assist in their hardening, possibly through the use of wooden planks.

4.2 *Placement of stone elements* (group: 2 p): involves the stone cladding of the corridors and the chambers;

4.2.1 *Placement of vertical slabs* (group: 2 p): includes the placement of the slate slabs lining the corridor and the two chambers;

4.2.2 *Placement of capstones* (group: 2 p): involves the placement of the 42 capstones of the corridor.

4.3 *Decoration of stones* (individual: 1 p): involves the painting of the slate slabs lining the corridor and the chambers (and, perhaps of the domes themselves); all the slabs of the LC and some of the main corridor appeared covered with a thick layer of bright red pigment of very plastic texture made with cinnabar; within the LC, the slates thus coated were then painted with symbolic motifs, among which "oculi" stand out; the "oculus" motif is pervasive in the iconography of Copper Age Iberia, and has been connected to religious notions involving sunlight, esoteric knowledge, and mother earth; due to its greater technical difficulty we consider that this task was of an individual nature, since only some specific individuals would have had the skills (and perhaps the status) necessary to carry out this important work, with a strong symbolic component.

5. *Construction of outer elements* (group: 2 p): a rather simple task that involves the backfilling of the large trench cut for the installation of the constructive elements of the tholos;

5.1 *Earth gathering* (group: 2 p): involves the gathering of earth, mainly that previously excavated from the trench;

5.2 *Infilling of the trench* (group: 2 p): involves the infilling and leveling of the trench with earth.

La Traviesa Cist 5

Structurally, the megalithic cist of La Traviesa is made up of two main parts: the cist itself, and the cairn that surrounded and covered it. The cist consists of a rectangular pit of 3.25 by 1.3 m whose sides were lined with 10 well-dressed slate slabs with dimensions ranging from 1.2 to 0.4 m in maximum diameter. The chamber thus formed was then covered with 16 limestone slabs of sizes ranging between 1.30 and 0.55 m across. The cairn is 6.45 m across (in the East-West direction) and was delimited and supported by a ring of 14 limestone slabs firmly placed into the ground, the largest of which has a maximum diameter of 1.5 m, the smallest being 0.55 m across. The cairn itself was formed from several hundred stone blocks of predominantly sub-rounded shape with a maximum size of 0.60 m and a minimum of 0.10 m. The process of construction of this cist involved the following tasks and subtasks, graded according to their degree of complexity (Fig. 13):

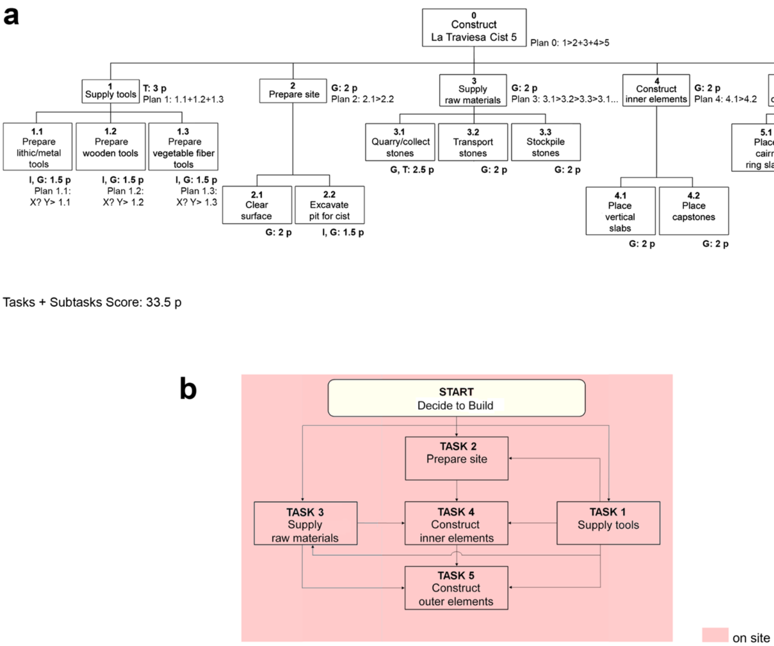

Fig. 13 La Traviesa Cist 5. **a** Hierarchical task analysis, in red the plan of each task. **b** Flowchart of tasks with indication of the place (on-site) in which each task was likely carried out (drawing by Gustavo Barrientos)

1. *Tool Supply* (team: 3 p): involves the preparation (not necessarily the manufacture) of the tools needed to accomplish all other tasks; due to the scale of the tomb and the local availability of raw materials, it is unlikely that the tools needed to carry out the different tasks and subtasks involved in its construction would have to be manufactured specifically, as it is probable that they were already in use to meet the construction and maintenance needs of the settlement where the builders lived, and which is only a few hundred meters to the East;

   1.1 *Lithic/metal tool preparation* (individual/group: 1.5 p): as for Menga;
   1.2 *Wooden tool preparation* (individual/group: 1.5 p): as for Menga;
   1.3 *Vegetable fiber tool preparation* (individual/group: 1.5 p): as for Menga;
2. *Site Preparation* (group: 2 p): includes activities prior to the construction of the tomb;

   2.1 *Surface clearance* (group: 2 p): involves the clearing of the surface of vegetation and stones and the partial flattening of the ground for the construction;
   2.2 *Excavation of the pit for cist* (individual/group: 1.5 p); involves the excavation of the pit destined to house the stones that cover the internal walls of the funerary chamber.
3. *Raw material supply* (group: 2 p): as for Menga and Montelirio;

3.1 *Quarrying and collecting of the stones* (group/team: 2.5 p): the stone materials used include 10 slabs of slate for the lining of the cist, 16 capstone slabs, 14 slabs forming the ring of the cairn, and several hundred stone blocks for the cairn itself; the lining slabs of the cist, the largest of which has a maximum diameter of 1.2 m, could be extracted from a nearby location, since there are slate outcrops at a short distance from the hill where this necropolis is located; likewise, the 16 limestone capstone slabs (the largest one being 1.3 m across), had to be extracted and dressed;
3.2 *Transport* (group: 2 p): the transportation of all these stones, over a distance of no more than 1 km (possibly only a few hundreds or even tens of meters) may have been carried out by hand, or with the help of beasts of burden (oxen, mules, or horses) and/or some vehicle like a stretcher, skid, or cart (there is no direct evidence of wheeled vehicles in Iberia until the end of the second millennium BC, but it does not seem entirely impossible that they were in use at the beginning of the Bronze Age);
3.3 *Stockpiling* (group: 2 p): as for Menga.

4. *Construction of inner elements* (group: 2 p): includes the placement of the 10 vertical delimiting slabs and 16 roofing slabs;

4.1 *Placement of vertical slabs* (group: 2 p): as for Montelirio;
4.2 *Placement of capstones* (group: 2 p): as for Montelirio.

5. *Construction of outer elements* (group: 2 p): involves the construction of the cairn;

5.1 *Placement of cairn ring slabs* (group: 2 p): consists in the placement of at least 16 limestone slabs placed vertically on the ground as support for the cairn mass;
5.2 *Placement of* cairn *blocks* (group: 2 p): involves the infilling of the space between the cist and the stone ring with several hundreds of blocks of stone.

In summary, as anticipated, the identification of sub-subtasks was highly dependent on inference about the execution of the task of which they were likely part. In this study, at least, their absence (Figs. 11, 12, and 13) does not imply that their existence cannot be conceived, but rather that their identification could not be adequately justified. For this reason, although sub-subtasks were recorded when possible, they were not considered for the computation of the complexity score. It should be borne in mind, however, that this methodological decision does not have the character of a prescription, so its implementation may be considered on a case-by-case basis.

Table 3 summarizes the information about the hierarchical complexity of the tasks involved in the construction of the three monuments. If we pay attention only to the task + subtask level, the construction of Menga and Montelirio demanded an almost equal degree of hierarchical task complexity. The maximum differentiation between both monuments occurs regarding the P,T/G,I ratio, which is significantly higher for Menga. The construction of Montelirio was more complex than that of Menga only in terms of the spatial domains involved. The monument whose construction implied the lowest degree of hierarchical task complexity according to all parameters is La Traviesa Cist 5.

Table 3 Hierarchical task complexity parameter values for the three megalithic monuments considered

Monument	Task complexity[1]	Task complexity[2]	P,T/G,I ratio	Spatial domains
Menga Dolmen	42.0	60.0	0.64	1 + 2
Montelirio Tholos	41.0	51.0	0.36	1 + 2 + 3
La Traviesa Cist 5	33.5	–	0.06	1

[1] Tasks + subtasks; [2] tasks + subtasks + sub-subtasks; 1: on-site; 2: off-site local; 3: off-site non-local

Discussion

The following discussion will be organized into two sections. The first will be dedicated to the treatment of technical aspects of the analytical method used to assess the structural complexity of work organization in past social systems. The second will be focused on the meaning of the obtained results in relation to the complexity of the social systems involved in the construction of each of the three monuments considered in this study, and the way in which this is related to the degree of complexity of the broader social systems of which the former were part.

The Structural Complexity of Work Organization in Past Social Systems: Methodological Issues

In this paper, we have focused on a structural feature of social systems as functional units, namely the hierarchical complexity of work organization. The primary assumption has been that such an approach may shed some light on the phenomenon of complexity at the level of small- or intermediate-scale social systems, particularly of those integrated into larger systems like organizations or entire societies. Small- or intermediate-scale social systems, such as groups or teams, are generally overlooked when addressing social complexity. The latter is typically understood as a property of whole social systems and not of its constituent parts, which in most cases are other systems. In this study, we choose, as a proxy measure of structural and functional social complexity at the lower organizational levels, the hierarchical structure of the tasks involved in the construction of monuments. We have assessed this trait using an adapted version of hierarchical task analysis (HTA)—a well-established method in human factors and ergonomics for representing the nested set of tasks and subtasks necessary to achieve particular aims or goals (Stanton 2006)—coupled with a scoring system devised by Anderson *et al.* (2001) to specifically deal with the hierarchical complexity of work organization.

To the best of our knowledge, this is the first time HTA has been applied to solve an archaeological problem. The analytical potential of this method is promising for the inferential study of the production of material items, particularly of those made up of multiple components and in which multiple operators intervene at different stages of the production process. In this sense, HTA constitutes a suitable method for the study of the organization of technological systems, in addition to other approaches available in the literature (some of them already used to discuss social complexity; *e.g.*, Roux and Matarasso 1999) such as *chaîne opératoire* analysis (for recent reviews on the subject, see Audouze and Karlin 2017; Roux 2016), behavioral chain analysis (Schiffer 1972, 1976), activity analysis (Roux and Matarasso 1999), and course of actions/dynamics of the shaping process analysis (Roux *et al.* 2018). Although they have different origins, theoretical and philosophical assumptions, methodological/technical repertoires, and primary fields of application, all these approaches share the same general idea: that of an operational chain as a representation of the organization of the stages of a production process. Hierarchical task analysis and task analysis in general, could also make an important methodological contribution to the developing field of archaeology of construction, which is specifically aimed at addressing issues like the construction, organization, and management of buildings (Dessales 2017). However, for the approach to reach its full potential in archaeology, some difficulties in implementation have to be recognized and addressed.

Like the reconstruction of some *chaînes opératoires* (Roux 2016), archaeological HTA involves at least two levels of inferentially constructed (as opposed to observationally derived) description: (1) the description of the main steps of a productive/constructive process, each one defined according to specific goals and tasks; (2) the description of the actions involved in the execution of each task and subtask. In the first level, the number and order of the steps can be relatively easy to infer given the nature of the process, the properties of the worked materials, and the objective(s) sought to be achieved. In the second level, work behaviors are highly variable because the way in which tasks are performed depends on cultural and idiosyncratic factors operating on inherently equifinal processes and routines. In this case, in the absence of adequate inferential tools, the descriptions that can be formulated have a high degree of uncertainty. Both actualistic studies (*e.g.*, ethnoarchaeological, experimental) and the refinement in reverse engineering techniques applied to the final products of a production/construction process could actively contribute to reduce uncertainty in the definition of tasks or subtasks of different orders, particularly of the lower ones.

In our case study, despite the abovementioned problems, the implementation of a HTA has made it possible to recognize, qualify, and hierarchically order the fundamental aspects of the respective construction processes, which is very useful for comparative purposes. This method has the virtue of allowing us to appreciate the relative complexity of the construction process and of the organization of work in the social systems involved, without the striking differences in the scale of the studied monuments significantly interfering with the comparison, as they could have done in a less analytical approach.

The Complexity of Iberian Social Systems During Late Prehistory: Some Preliminary Thoughts

Our analysis of the structural complexity of the organization of work involved in the construction of the three best documented, most structurally, and functionally complex monuments of Iberian Late Prehistory, shows marked differences between Menga and Montelirio, on the one hand, and La Traviesa, on the other. Indeed, if we establish a rank order classification (ranging from 1 to 3) of the cases on the basis of each variable represented in Table 3 and then average them, we obtain an average rank value[14] of

[14] To calculate the average rank value of a set of items, first a weight is added to each rank in such a way that the highest rank must have the highest weight, and the lower ranks must have gradually lower weights. The item with the highest average weight has the highest average rank; the items with lower average weights have gradually lower ranks.

2.75 for Menga, 2.25 for Montelirio, and 1 for La Traviesa. This difference has to do partially not only with the scale of the monuments and of their parts but also with the variety of the construction elements used in each case. Both in Menga and Montelirio, most of the tasks and subtasks necessary for their construction required organizing the workforce into groups and/or teams, while the latter form of organization was probably not needed for the building of La Traviesa Cist 5. Regarding the size of the workforce—a measure of the DNOC of the social systems involved—while no attempt was made to estimate the probable number of individuals needed to build each monument, it is clear that, in the case of Menga, it must have been of the order of several hundred, likely one and two orders of magnitude greater than in the case of Montelirio and La Traviesa, respectively. In relation to the time involved in the construction of each monument, it is difficult to provide accurate or at least meaningful estimates due to the large number of variables that need to be considered and the absence of relevant data to perform the calculations. However, the scale of Menga's architectural components and their distance from the source—which imply high costs in terms of energy and resources—suggest a construction period lasting several years. For its part, the building of Montelirio may have taken weeks or months, above all due to the logistics necessary for the supply of stones and the technological requirements necessary for the construction of its vaulted chambers. In contrast, the length of time required to build the great cist and cairn of La Traviesa can be measured in hours or, at most, days.

The whole evidence indicates that Menga probably resulted from the concerted and coordinated effort of a large number of people. Given the colossal size of the stones used to build it, it is unlikely that any single Late Neolithic community would have had, alone, the resources to undertake the huge enterprise of building Menga, thus requiring the cooperation of several communities distributed within the regional space. In contrast, the construction of Montelirio did not necessarily require mass cross-societal collaboration. The stones used at Montelirio (slabs of a few hundred kilograms at most) were nowhere near the massive size of the ones used in Menga, each weighing several tons. However, taking into account the diverse origin of the materials used, the construction of Montelirio may have involved a somewhat greater degree of logistic organization than Menga. Finally, the building of La Traviesa Cist 5 seems to have demanded only the participation of a small workforce with little or null internal division of work.

The function of each monument, as well as the social practices they staged and the structure and organization of the respective societies, may also have influenced the size and composition of the workforce involved in its construction. As already mentioned, Menga was likely built as a temple dedicated to the forces of nature that presided over the Neolithic worldview; as such, it likely embodied the ideas of collectiveness and cooperation that could be related to common social practices in that period, particularly temporary gatherings of small communities for a variety of purposes (*e.g.*, marriage, exchange of goods and information, identity construction, ritualized competition). Among early non-state "complex" societies, gatherings incorporate a dialectical tension of cooperation and competition. The element of non-violent competition associated with such events may have been key to foster a culture of creativity and originality whereby each kin group or corporate group would have felt a kind of "selective pressure" towards producing knowledge and crafts worth exhibiting in front of other communities. Montelirio, unlike Menga, was conceived as a monument with a dual function, funerary and worship, dedicated to non-public rites and the burial of a particular segment of society, probably members of an elite wielding ritual power. Consequently, Montelirio seems to have been designed and built not by and for the whole of society but by and for a corporate group. La Traviesa Cist 5, finally, was neither a temple nor a collective burial for a special segment of the society, but the burial of a seemingly prominent person. The relatively modest scale of this funerary monument suggests the involvement of a small number of people, such as those belonging to the clan, extended family, or followers of the male adult buried in it. The increasing "verticalization" of social relations, as well as the increase in intergroup conflictivity—the latter inferred from the location of the settlements in areas less topographically accessible and further away from the main water courses, military paraphernalia associated with the tombs, and the appearance of the so-called warrior stelae—suppose, in the Early Bronze Age, the progressive vanishing of the communalist ideology characteristic of the preceding periods (García Sanjuán 1998b; García Sanjuán and Hurtado Pérez 1998). Along with this also disappeared a true "culture of creativity" that had been so pervasive during the Late Neolithic and the Copper Age, leading occasionally to the production of astonishing architectural creations such as Menga or Montelirio, or artifacts as sophisticated and unique as those found in Montelirio and other tombs of the Valencina mega-site (García Sanjuán *et al*. 2018a, b, 2019). Indeed, the kind of "distinguished" objects (beaded attires, bifacially knapped flint daggers, idiosyncratic bodily ornaments), the diversity of raw materials, many of them extra-Iberian (flint, rock crystal, cinnabar, amber, ivory, ostrich eggshell, *etc.*) and the wealth of graphic arts present in Montelirio far surpasses anything to be found in La Traviesa Cist 5, where the grave goods amounted to two ceramic pots and one halberd made of arsenical copper, exotic materials being completely absent.

The ranking of complexity in the organization of the workforce necessary to build these three monuments seems to be, in this specific case, inversely related to the ranking of sociopolitical complexity attributed to the respective whole social systems (*i.e.*, order 3 for Late Neolithic, order 2 for Copper Age, and order 1 for Early Bronze Age). Indeed, a prevailing view, guided by considerations about seemingly increasing degrees of centralization of power, deepening of social inequalities, and structural violence, is that in the Early Bronze Age, there would have been higher levels of complexity than in earlier periods, particularly with respect to the smaller, more decentralized, and more egalitarian Late Neolithic societies. The question that arises is whether the lack of correspondence between, on the one hand, the observed trend in the structural complexity of the organization of work linked to the construction of specific monuments and, on the other, the inferred trend in the organization of the societies involved in each case is either unexpected or counterintuitive. Since no naturally privileged point of view exists from which, or a scale at which, the complexity of any society can be assessed, the answer is probably no. In this regard, a suggested outcome of this study is that we are more likely to understand social complexity if we see it as a trait or property of every different social system integrated into the whole society. Of course, the trend observed here could be confirmed or questioned if we analyzed, with the same methodology, other RPSTS such as ditched enclosures, hypogea, earthworks, or hydraulic constructions. Ideally, a correct characterization of the degree of complexity of a society or total social system in relation to other(s) should be established from an average value of the trends observed in the various social systems that comprise it (*i.e.*, systems defined at different scales) and in relation to one or more of the types of complexity introduced in the second section of this paper. This amounts to saying that the characterization should be statistical in nature, rather than one based on a predetermined set of descriptive features pertaining to distinct levels of differentiation and integration of systems defined on a single scale, *i.e.*, that of total social systems.

Concluding Remarks

Throughout this paper, we have tried to show that, contrary to Wilson's claim discussed in the "Introduction," both the recognition and the measurement of social complexity are indeed problematic aspects requiring further exploration. To do this, we have presented a frame of reference, namely McShea's model of systems complexity, which has allowed us to sketch a basic outline of the different ways in which social systems can vary in their degree of structural and functional complexity. This is critical to improve our ability to recognize social complexity, in both contemporary and archaeological contexts. We have also presented a methodology to measure the complexity of social systems, as functional units, that is based on hierarchical task analysis. This is particularly appropriate to analyze the complexity in the organization of work in low- and intermediate-level functional units, namely groups and teams. The application of this methodology to the analysis of a specific case, the construction of megalithic monuments in late prehistoric Iberia, has served to show its possibilities as well as its limitations. The obtained results are promising and encourage further development of this measurement instrument, which is one of the many possible approaches to the issue. The full implications and impact of these elaborations on the study of an old, but still current, anthropological and archaeological problem remain to be evaluated. However, if as a result of them a more nuanced understanding of the phenomenon of social complexity is obtained and the debate becomes more complex (and not merely more complicated), our purpose will have been fully accomplished.

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Leonardo García Sanjuán: data analysis and writing

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Data Availability Data are in the hands of the authors and accessible upon request.

Compliance with Ethical Standards

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