29

Why Dark Zones Are Sacred

Turning to Behavioral and Cognitive Science for Answers

Daniel R. Montello and Holley Moyes

According to legend, the monstrous Minotaur—half-man, half-bull—made his home in the Labyrinth at Knossos on the Mediterranean island of Crete. The cave-like Labyrinth—large, dark, complex in layout, but homogeneous in appearance—was built by Daedulus for King Minos. To repay the Athenians for the slaying of his son, Minos exacted tribute of fourteen Athenian youths every nine years. This lasted until the Athenian hero, Theseus, decided to assume the role of one of the sacrificial youths, travel deep into the Labyrinth, and slay the Minotaur. But how was Theseus to find his way out of the confusing passages once the deed was done? The answer came from Ariadne, daughter of Minos. She gave Theseus a ball of string and the idea to unwind it as he traveled toward the monster. Theseus entered the Labyrinth, unwinding the string as he went along. After plunging his sword into the Minotaur, Theseus followed the string safely back out to the surface world. For her cleverness and willingness to betray her father for love, Ariadne was abandoned by Theseus on the island of Naxos during his homeward voyage.

The story of the Labyrinth at Knossos suggests the power caves have had to capture the human imagination; they are places of fear, mystery, gloominess, weirdness, and wonder. The legend of the Minotaur and his home, the Labyrinth, has been exceptionally widespread and influential in many parts of the world, showing up in art, architecture, folklore, and symbolism in many cultures for thousands of years. The Minotaur himself is a concrete personification (terrification?) of the essence of dread and strangeness induced by the cave. The psychological power of caves is reflected in many other stories and symbols besides the Minotaur, such as the attitude many people in many cultures have had about the bat as denizen of the underworld or just "bat out of hell" (Lawrence 1993).

It can hardly be accidental that dark zones of caves have so often been important sacred or mythological spaces in the ritual and ideological lives of humans. The chapters in this volume have all documented and described the roles that caves have played in the past and continue to play today among diverse human groups in terms of symbolism, cosmology, myth, and ritual. Traditions of ritual cave use have originated at different times in widely separated geographic areas and may be traced back to the earliest modern humans. The long temporal spans and deep antiquity witnessed in the archaeological record allows us to appreciate the pervasiveness of the phenomenon over time and space. The pattern argues against a solitary model of cultural diffusion and points toward the independent development of similar conceptual formulations of caves. What could explain independently occurring cave constructs?

In this chapter we address how places dynamically arise as meaningful locations by exploring the case of ritual cave use as a cross-cultural phenomenon. The phenomenological approach detailed by Alfred Schutz (1967) and adapted for environmental studies by Timothy Auburn and Rebecca Barnes (2006) provides a framework that helps explain how human–environmental interactions may produce shared constructs. The phenomenology of Schutz is based on the Husserlian observation that people fundamentally accept that a material world exists independent of themselves and that this world is the same for others. Schutz was interested in how people lived with and renewed their assumptions about the world and how this influenced the production of social order. He proposed his general thesis of the alter ego (1962) as a basis for intersubjectivity. Here Schutz posited that an encounter takes place within a "common communicative environment" but that people are aware of their subjective experiences. They are able to overcome their subjectivity and reach mutually shared constructs, or what he refers to as a "We-relationship," based on two properties of human thought that constitute his general thesis of the reciprocity of perspectives. The first, the idealization of the interchangeability of standpoints, maintains that people assume that if they change places with one another, another's "here" becomes theirs. The second, the idealization of congruency of the system of relevances, maintains that people assume, until faced with counter-evidence, that they interpret objects and features in an identical manner to others. In the We-relationship, participants are aware of each other in face-to-face encounters that are experiential and interactive, and it is through this mutual experience that they negotiate shared ideas. The relationship is not static but continues to evolve, establishing and maintaining a commonly understood world of objects, events, and motivations that constitute knowledge constructions (types, categories) and ultimately orderliness (social constructs).

Auburn and Barnes (2006, 43) point out that what is important for studies of place is that the We-relationship is not only a social relationship but a located relationship. The common communicative environment in which human interactions occur is not only a social space but an environmental one as well. We-relationships are constituted by the mutual orientation of the participants not only to each other but also to the setting in which the encounters occur.

This is a useful framework from which to understand how dark zones of caves may become socially constructed ritual spaces and idealized places. Phenomenology suggests that the shared human experience of the cave is a major factor establishing and maintaining typological designations and meanings. What it does not address is why the concept arises over and over again in various cultures throughout time and space. What is it specifically that produces this pattern?

We suggest that a shared human cognitive and emotional response to dark zones of caves is at the core of the development of similar conceptualizations, which in turn lend these spaces to mythic constructions and ritual use. In the case of long cultural traditions of ritual cave use such as those found in Paleolithic Europe (Clottes, Chapter 1, this volume), the ancient and modern Americas (Chapters 10, 11, 12, this volume), or Neolithic and Bronze Age Greece (Tomkins, Chapter 4, this volume), similar perceptual-environmental interactions would be expected to reinforce conceptual formulations and facilitate cultural transmission by providing a relatively fixed environmental referent in the form of stable geographic features. Several authors have suggested that caves also provided the referents for later ritual architecture (see this volume, Moyes and Brady, Chapter 10; Skeates, Chapter 2; Smith, Chapter 7; Stoddart and Malone, Chapter 3; and Yorke and Ilan, Chapter 6), thus reinforcing the environmental stimulus in the built environment.

Our stance requires that we reject Cartesian notions of mind–body duality in favor of modern theories of embodied knowledge such as experiential realism. This theory of the mind developed by George Lakoff and Mark Johnson (1999) is a philosophical stance that asserts that mental models of the world come from one's experience with it. Even though the mind cannot experience the world "directly," the indirect experiences of the world are shaped in consistent ways by its physical nature, by the physical nature of our individual senses, and by the physical nature of our own bodies and how they interact physically with the world. More recently, Vittorio Gallese (2005) has joined Lakoff in further developing this theory by reviewing evidence from neuroscience. Both argue that the formulation of concepts cannot be divorced from sensory-motor regions of the brain and are thus grounded in material reality and experience. This agrees with Gerald Edelman's (1992) theory of neuronal group selection (TNGS), which argues that minds become structured not on a genetically specified schedule but by the building of certain neural firing patterns reinforced by experience.

These theories suggest that events in the mental and physical development of individuals occur in physical environments, and the course of these developments depends to a great extent on the nature of the environments in which they occur. This holds true for many human characteristics—our need for water and particular nutrients, the sensitivity of our sensory systems to particular types of energy and not others, our anatomical and morphological characteristics, and so on. It also holds true for human characteristics that are behavioral and cognitive—what attracts our attention, how we remember certain kinds of information, how we reason and make decisions, what actions we tend to take in particular situations, and so on.

In this chapter, we consider the physical properties of caves as environments, including their structure and appearance. This has particular implications for human psychological responses that include perceptions, cognitions, emotions, and behaviors. To gain insight into human psychological responses to the physical environments of caves, we look to the behavioral and cognitive sciences and to environmental design fields. Spatial cognition studies conducted in a variety of disciplines attempt to describe and explain human perception and cognition in diverse environments, including built/natural environments and indoor/outdoor spaces. This literature includes work that we believe can aid in explaining why caves are often used as sacred spaces by distinct cultures separated in time and space. In particular, literature on spatial orientation points to physical factors that contribute to the ease or difficulty of maintaining orientation within environments. These factors include visibility (including the lengths of vistas or sightlines), differentiation of appearance, and structural layout complexity. Empirical and evolutionary considerations suggest a special status for three-dimensional environments in human psychology. In addition, studies on perceptual and cognitive aspects of environmental aesthetics point to culturally universal characteristics of human-environment interaction, such as "legibility" and "mystery," that can help explain emotional responses to various places.

Our chapter applies behavioral and cognitive science research to examine the responses of diverse human populations to the notion of "cave" as well as to actual psychological responses to cave environments. In this chapter, we examine literature found in such disciplines as environmental psychology, perceptual and cognitive psychology, behavioral and cognitive geography, planning, and architecture that explicitly considers the influence of the physical environment on mind and behavior. Among the interesting outcomes of analyzing caves in terms of the spatial-cognition literature is that different types of caves can be compared in terms of their structure and geological character in a way that helps explain their differential tendency to serve as sacred spaces.

ORIENTATION AND DISORIENTATION IN CAVES

A good example of a psychological response for which the physical environment of caves is relevant is spatial orientation. To be oriented is to "know" where you are, in some sense (Montello 2005). You can be oriented to various degrees in a variety of ways, with respect to spaces at different scales, and to varying degrees of conscious awareness. Knowing where you and your destinations are on the Earth's surface is *geographic orientation*. Geographic orientation involves some combination of knowledge about your location and about your heading or course—your facing and traveling directions, respectively. Knowledge of location and direction, like any spatial information, are always defined relative to some baseline locations or directions, called *reference systems*. These may be defined with reference to some combination of one's former body location or heading, the locations or headings of local features or landmarks in the environment, or the locations or headings of global features of the environment, the Earth, or the celestial sphere. The last type of reference system, based on global features that are stable and may be perceived over large areas, is known as an *abstract allocentric* or *absolute* system. Because such a system transports easily from place to place as one moves about (in cases such as the latitude-longitude system, it transports all around the Earth), it is often the most flexible and powerful reference system. Thus, to many animals, including humans, aligning one's sense of body heading or course to the orientation of an absolute system at a particular place can be key to maintaining geographic orientation.

Whether carried out formally or informally, maintaining orientation while moving about is called *updating*. Updating occurs by some mixture of two processes: landmark-based and dead reckoning. *Landmark-based* updating, also known variously as piloting or position-fixing, is updating based on recognizing external features. This recognition requires either an internal memory of the feature or an external memory, such as a cartographic map or chart. It is noteworthy that landmarks typically aid orientation in an indirect way. Sometimes they act as "beacon" destinations that can be directly oriented to, as when one knows where the cave opening is because it can be seen. But in so many situations, a recognized landmark does not directly indicate where a target destination is; instead, it functions to "key" one's perceived surroundings to an internal or external representation—a cognitive or cartographic "map"—that contains the nonperceived target destination. For example, recognizing a particular distinctive stalactite or rock cairn probably does not mean you have found your ultimate destination, but it does mean you know where you are within your representation of the portion of the cave containing that distinctive feature.

In contrast to landmark-based updating, *dead reckoning* does not involve recognition of features in the environment, so it does not require internal or external memory for any features. Dead reckoning is inferring or calculating your location after movement, based on information about your original location and about your velocity or acceleration of movement; as vector quantities, velocity and acceleration include directional information. Because dead reckoning can be thought of as essentially integrating directed motion relative to travel time, in the sense of integral calculus (even if it is not carried out by a mechanism that actually does calculus), it is often called *path integration*. Dead reckoning is based on internal (*idiothetic*) signals, such as vestibular sensing, or external (*allothetic*) signals, such as optic flow in the visual field. The key aspect of dead reckoning, however, is that it does not involve specific recognition of features or places, even if it is based on visual information like optic flow. Notice that unlike landmark-based updating, dead reckoning only tells you your new location relative to your original location. Furthermore, errors accumulate with dead reckoning, so that a small misorientation soon becomes a large misorientation. Such error must be dealt with by taking periodic fixes (landmark-based updating), and if error accumulates quickly, fixes must be taken frequently.

The processes by which people maintain orientation vary in the demands they place on limited attentional resources. That is, some processes of orientation happen outside of consciousness and do not "fill up" working memory capacity; because they are nonconscious—people are not aware they are going on and cannot tell you how they are doing them (though they certainly may tell you all about their personal theories of how they do it, mistaking that for direct access to their cognitive processing). Other processes are very much a part of conscious experience; they fill working memory and falter if a person is distracted in some way. People are aware of what they are thinking about during such processing and can tell you validly what that is. Finally, a variety of processes can be seen to be intermediate between the extremes of very implicit and very explicit, and of course, acts of orientation and disorientation typically incorporate various component processes that vary in attentional demand.

On one extreme are relatively *automatic* processes that do not require much attention and provide people with a "sense" of where they are as they turn or locomote over short distances. For example, you can probably maintain a sense that you have turned by 90° as you walk around the corner of a building without paying much conscious attention at all. People differ a great deal in their ability to automatically update in this way (Hegarty et al. 2002; Loomis et al. 1993) and in any case, such automatic updating cannot be relied on for very long distances. Exactly how long is an important research question, but it appears to be no more than several meters.

Updating while traveling over highly familiar terrain becomes automatized. For example, most people can walk or drive to work without paying much attention and not get lost. In fact, such a trip probably never becomes completely automatic; a person's attentional resources are likely to be somewhat engaged at the moment they must choose within a branching path structure, even when they have traveled the route many times. Again, there is more research to be done on the question of how attentional resources are marshaled during trips of varying familiarity.

In contrast, people often maintain a sense of orientation only with conscious effort. This is typically the case when traveling in unfamiliar environments, when lost and trying to reestablish orientation, and when giving verbal directions (the museum guard giving instructions to the bathroom for the umpteenth time provides an automatized exception). An important instance of effortful, attention-demanding orientation processes occurs when controlled, explicit *strategies* are applied. For example, children and adults can be taught the look-back strategy wherein a traveler stops, turns around, and explicitly takes a "mental snapshot" of the view going in the other direction (Cornell, Heth, and Rowat 1992). People can also intentionally retrace their steps or branch out back and forth from a familiar base point while attempting to reorient.

The converse of orientation is disorientation. Geographic disorientation—"being lost"—occurs when a person is uncertain about where he or she is or where he or she needs to go to get to some destination (Montello and Lemberg 1995). A critical aspect of this definition is that one must have a destination, a place where one wants to be or go, in order to be lost. A recreational caver who enters a cave to walk around and have a look at the cave structures is not necessarily going anyplace. People engaged in such goal-free travel cannot reasonably be said to be lost, even though they may not know where they are, because they do not care where they are or where they are going. As soon as the caver decides to end her walk and return to the entrance, however, she becomes lost when she realizes she is unsure of the way back.

This points to a further issue that is important when thinking about geographic disorientation. Being disoriented is a subjective state, not an objective state. You are lost when you *believe* you are unsure about your location or your destination. When you are lost, you may or may not actually be where you think you are or be heading in the correct direction of your destination. In fact, people rarely if ever have a complete and precise understanding of their actual location on the Earth relative to all possible features, reference systems, and so on. Likewise, people are sometimes right where they intend to be, possibly standing in front of their destination, but are unaware of it. People in such a state are lost. We may distinguish "disorientation" as a subjective state from "misorientation" as the state of being objectively mislocated, of not being where you think you are, or not knowing where you are but not caring.

Caves are clearly among the most disorienting of all environments. In the next section, we discuss characteristics of these natural labyrinths that lead to the psychological response of disorientation, as well as other responses. Caves are dark, without normal external cues like the sun, moon, or stars. The walls and features of many caves have a "sameness" or undifferentiated appearance that is infamous for its ability to confuse human navigators, dependent as they are on recognizable landmarks. The obstructed and constrained vistas of most caves restrict visibility even in the path of a flashlight beam. It is the rare cave that allows the kind of view that would support apprehension of the cave's overall structure. And this structure is usually exceedingly complex, much more than in a built environment. The web-like pathways provide numerous choice points and an irregular structure that exploits our disorientation in oblique layouts. There is no regular grid pattern here. Furthermore, the average cave has no respect for the "planar" nature of human spatial cognition—in caves we are dealing with true three-dimensional environments, not "pseudo" three-dimensional environments like high-rise buildings. Pathways that can branch off in any direction from one's body present an unusual and difficult situation for humans. Compounding these difficulties, traveling through caves requires great physical effort (try crawling on your stomach through a small passage for a hundred meters) and is often accompanied by anxiety or even claustrophobia.

When taken to the extreme, the reduction in sensory stimulation found in many caves provides some of the conditions similar to isolation experiments. Especially in the remote dark zones of many caves, there is little or no light, sound, or air movement. One may also be alone, lacking communication or social contact with others. Such conditions have been shown to produce a characteristic set of symptoms to accompany this *sensory deprivation* (Goldberger 1966; Zubek 1969). For brief periods, sensory deprivation can produce relaxation and introspection, like a meditative state. For longer periods, it can lead to more radical psychological states, including delusion, hallucination, anxiety, increased suggestibility, or a variety of cognitive deficits such as memory loss.

PHYSICAL CHARACTERISTICS OF ENVIRONMENTS RELEVANT TO PSYCHOLOGICAL RESPONSES

It is apparent that human psychological responses in various environments, including caves, can be understood better by considering physical characteristics of those environments. Physical characteristics of environments include their ambient lighting, the appearance of their surfaces (textures, colors, and surface reflectivity), the geometric structure of their chambers and path networks, their temperature and humidity, the ruggedness and ground support of their terrain, their flora and fauna, and so on. Many people (e.g., Hartig and Evans 1993) have attempted to summarize variations in the physical characteristics of environments in terms of the distinction between built and natural environments. *Built* environments are created by humans; *natural* environments are created relatively freely of human agency. There are many intermediate cases, of course, and the very concept of "natural" is complex and, to some extent, culturally constructed (Proctor 1998). There do seem to be a few general differences between natural and built environments. On average, natural environments like caves tend to contain fewer straight lines, right angles, and other regular shapes such as perfect triangles or circles; they also tend to contain fewer regularly repeating, evenly spaced, pattern elements. As a built structure, King Minos's Labyrinth had more straight and regular elements than the typical natural cave. Natural environments also tend to contain more vague and less clearly demarcated boundaries and transitions. However, this difference does not always hold; depending on the geology of their formation, for example, caves may contain very straight stalactites or smooth straight passages. The appearance of natural environments like caves does tend to vary over space "logically," with contiguous areas likely to be quite similar and transitions likely to be gradual or at least comprehensible within a larger situational context. In contrast, the appearance of built environments can vary capriciously (e.g., in color, height, materials) in ways that violate this natural logic. Alternatively, and perhaps unfortunately for the people in them, the appearance of built environments sometimes lacks variation of any kind. Natural environments also tend to contain a greater density and heterogeneity of edges, lines, textures, shadings, and fractal patterns. At some point, however, the complexity of natural environments, understood in information-theory terms, is so great that it creates a visual homogeneity, ending up being less *psychologically* complex than more minimalist built environments (Kaplan, Kaplan, and Wendt 1972).

Whatever the utility of distinguishing natural from built environments, there is clearly considerable variation among environments, all of which are natural or all of which are built. Caves, in particular, differ quite a bit from many other natural environments. Caves also differ from each other in potentially important ways, depending on the material that composes them, the history of their formation, their exposure to moisture, and their exposure to flora and fauna (including humans). Given the conceptual difficulty of the built–natural distinction and the wide variations within, as well as between, environments of each type, we think it is more fruitful to consider the influences of environmental characteristics on psychological responses independently of whether the environments are built or natural. The visual and structural characteristics of environments like caves facilitate or impede various activities of people, and they alter the experience people have in them, both cognitively and emotionally. Of course, people (especially sighted people) find it difficult to act in the dark, and they can find it difficult to walk or crawl over watery or rock-strewn cave floors. However, we find it more interesting that different environments afford different information for the people in them, information that is useful for anticipating resources and dangers and finding one's way. Different information allows different wayfinding strategies, and it makes the strategies easier or harder to apply effectively. Different information tells people what to expect ahead or keeps them uncertain. In some environments, information misleads people about what to expect. Knowing or not knowing what to expect can certainly lead to emotional responses such as calmness, anxiousness, happiness, or fear.

FOUR PHYSICAL CHARACTERISTICS

Weisman (1981) and Gärling, Böök, and Lindberg (1986) proposed a typology of environmental characteristics that is very useful for understanding how physical characteristics of environments affect psychological responses to those environments. These authors discuss the role of physical factors on spatial orientation and "legibility" within the environment, but we think the factors are very likely to be relevant to a host of psychological responses, including anxiety, uncertainty, and aesthetics. The authors also focus on understanding built environments, but their typology clearly applies to natural environments too, including caves specifically. The typology includes the factors of differentiation of appearance, visual access, and complexity of layout. Both authors also consider the role of sign systems in the psychology of environments; although typically not very relevant in cave systems, we do consider sign systems briefly in what follows.

Differentiation of appearance

Environments differ in the degree to which their parts are homogeneous or heterogeneous in appearance. They differ with respect to size, shape, color, architectural style, and so on. As we discussed above, natural environments are often more differentiated than built environments, but of course some natural environments are much less differentiated than others. Generally, people find differentiated environments easier to comprehend and wayfind in because the differentiated parts are more distinct and memorable—differentiation creates better landmarks (Appleyard 1969, Lynch 1960). At some point, however, environments may be so differentiated that they appear chaotic and would be disorienting. But it is important to remember that differentiation cannot be assessed solely as an objective physical variable. It is a subjective variable, too: what we see (what we notice) depends in part on our expectations, our interests, our training, and our state of mind. To take one relevant example, geologists who are cave specialists will see greater differentiation in caves than nonspecialists will. To the untrained eye, natural environments, in particular, can look quite undifferentiated. Gladwin (1970) tells the fascinating story of the navigators of the Pulawat Islands of Micronesia (other South and West Pacific peoples have similar traditions). They pick up a great deal of useful information from the sky and water, which are richly differentiated to those trained to perceive it. This information supports technologically unaided boat trips of up to several hundred miles or more over open ocean. The information includes air and water color, wave and swell patterns, sun and star patterns, and identified bird species and their known ranges.

Visual access

The second relevant physical characteristic of environments is their visual access, the degree to which different places and feature in an environment can be seen from various vantage locations. Conversely, it also concerns the locations *from* which people can see particular places and features, including locations where they were previously standing, locations to which they are headed, and various key landmarks or structural features. To what degree is the overall layout of an environment visible from a single vantage point? People have a greater sense of comprehension and can maintain their spatial orientation more easily when visual access is high. Greater visual access will decrease mystery and uncertainty; in a complex or unfamiliar environment, it will tend to reduce excessive stress, while in a simple or familiar environment, it will tend to reduce acceptable stress to boredom. Of course, visual access of, or from, some locations will be more informative than of, or from, other locations.

Planners and architects have systematically studied visual access, typically in interior spaces, under the guise of *isovist analysis* (Benedikt and Burnham 1985); geographers, surveyors, forest managers, and others have studied it in outside landscapes under the guise of *viewshed analysis* (Llobera 2003). Since caves are interior spaces, we use the term *isovist* for the collected spatial extent of all views, or vistas, from a single location within a cave. It is commonly assumed that the vistas are two-dimensional and 360° around a vantage point. For analyzing caves, both of these assumptions should probably be altered, as the three-dimensional structure of cave spaces is unusually important, and the dark interior illuminated by a unidirectional headlamp is less like a 360° experience than fully lit spaces would be. Large unobstructed chambers in caves have large isovists that are fairly symmetric around locations near the center of the chamber. Narrow winding cave passages have small isovists that are very asymmetric, depending on whether you face across or along the passage. Several theorists believe that isovist characteristics of environments will relate to the psychological responses the environments engender, including ease of orientation, sense of privacy, stressfulness, and aesthetic judgments. Many different physical properties of the isovist could be relevant, such as total size, symmetry, maximum length, and so on. But so far, only a little work has systematically tested these properties; for example, Sadalla and Oxley (1984) found that a rectangular room appears larger from the center than a square room of the same floor area. No one has yet applied isovist analysis to caves.

Complexity of layout

Although it is difficult to define and measure layout complexity formally, it certainly has important implications for human psychology. Exactly what constitutes a "complex layout" in a psychological sense is a question for ongoing research. A more articulated space, broken up into more different parts, is generally more complex, though the way the different parts are organized is critical. It is clear that certain patterns of path networks are more or less psychologically complex; for example, oblique turns are more disorienting than orthogonal turns (Montello 1991). However, defining psychological complexity is difficult because humans organize information into meaningful units in a way that reduces complexity in an information-theory sense to relative simplicity in a psychological sense. A case in point is the fact that the overall shape or "gestalt" of a path layout can determine whether a particular element is disorienting. In many built environments, for example, the road network consists entirely of simple rectilinear grids or symmetric radial patterns. But a grid pattern may be disorienting if its axes do not run north-south and East-West—at least for those people who incorporate cardinal directions into their wayfinding. A curved path is more complex than a straight one, but curved paths are understood better when they fit within a radial network pattern, as long as that radial pattern is in fact apprehended. Layouts may be said to vary in their closeness to a "good form"; comprehending a layout is easier when the layout has an overall pattern that can be apprehended as a single simple shape. A square is easier than a rhombus; a circle is easier than a lopsided oval. People tend to understand and remember layouts as good forms, and when the layout does not have such a form, knowledge distortion results (e.g., Tversky 1992). Kevin Lynch (1960) mentions that people interviewed by his research team were confused by the Boston Common because they tended to assume it was a square, when it is actually an irregular pentagon.

Cave layouts vary from each other, of course, but in general, they are among the most complex layouts that humans ever encounter. Few buildings, if any, have layouts anywhere near the complexity of the average cave structure. Caves are large and extremely articulated, with chambers and corridors varying greatly in size and shape. Caves may branch off into any number of corridors, sometimes with little apparent physical logic. Their corridors are never restricted to orthogonality, moving in any direction with nearly equal probability. That is, caves have a unique property that one rarely finds in other environments: a nearly true three-dimensional structure. Not only does the floor rise and fall haphazardly in caves, as might be true in any rugged natural terrain, but corridors can branch off above and below dramatically, leaving people to wonder what happened to their normal world with a horizontal terrain surface. Our sense of balance and uprightness normally depends critically on visual information about the horizon, the sky, and the ground (Gibson 1979). In some caves, people must depend on less reliable and robust proprioceptive sensations of gravity (from the utricle and saccule of the inner ear) to maintain a sense of up and down. High-rise buildings and underground construction involve three-dimensional environments, too, but the vertically arrayed spaces of such built environments are layered in a "2.5-dimensional" manner. Caves need not obey such layering; they can go from three partially overlapping layers to two layers to one layer and back again, smoothly or discontinuously (not that a person in one of the layers is likely to be aware of the vertical arrangement). It appears that people have special difficulty in comprehending three-dimensional environmental layouts, as humanity evolved on what is essentially a two-dimensional Earth surface (Montello and Pick 1993). The three-dimensional structure of caves also makes effective cave mapping quite a challenge (Moyes 2002), a challenge that is only partially solved by the standard practice of showing map readers both plan and cross-sectional views of cave chambers and corridors.

We clearly need more research on how to define and measure layout complexity so we can predict and explain how different environmental layouts, including cave layouts, lead to disorientation and other responses. We can further observe that the distinction between "unicursal and multicursal mazes or labyrinths can apply to caves (Matthews 1970). *Unicursal* labyrinths have no branching or looping structure. Their layout consists essentially of one path from the "start" location to the "goal" location; the path may or may not turn or curve, and it may have any number of side paths attached that do not ultimately lead to a goal location. In contrast, *multicursal* labyrinths have one or more branches or loops. The distinction between unicursal and multicursal has implications for the effectiveness of particular strategies for finding one's way out of a cave, and it likely has implications for the state of disorientation that people would experience in them. However, no systematic and comprehensive analysis exists to explain how cave layouts affect psychological responses. One promising analytic approach is provided by *space syntax* analysis (Hillier and Iida 2005).

Sign systems

A fourth physical factor relevant to psychological responses in built environments is the nature of sign systems. Sign systems are "semiotic artifacts" intentionally designed and placed in environments to provide information and otherwise communicate messages to people. Signs incorporate words, pictures, maps, and graphical "gestures" such as arrows. The design and placement of signs in the environment clearly influences the behavior and experience of people in that environment (Arthur and Passini 1992). Caves, like other natural environments, do not generally have sign systems; we do not consider unintentional landmarks in caves to be sign systems. However, natural environments that have been "manicured" by humans do sometimes have sign systems put in place. Many caves are not entirely untouched by human activity, and sign marks, paintings, or petroglyphs are sometimes placed on cave walls, or rock cairns or other features are built at key nodes in cave networks. In general, sign systems can facilitate orientation and reduce uncertainty, but they can also impede orientation and increase confusion, either intentionally or unintentionally, when they are poorly designed or placed. And no matter how well sign systems are designed or laid out, they cannot entirely ameliorate negative psychological effects resulting from the other three physical-environmental factors.

PHYSICAL CHARACTERISTICS AND ENVIRONMENTAL AESTHETICS

Another body of behavioral- and cognitive-science research that may shed light on the sacredness of caves involves environmental aesthetics. Why do people find some environments more aesthetically pleasing than others? Starting in the 1950s, a branch of psychological research called experimental aesthetics attempted to offer a scientific analysis of aesthetics based primarily on formal syntactical qualities of images or patterns. Specifically, Berlyne's (1960) principle of stimulus complexity proposes that aesthetic responses to stimuli depend on their so-called collative properties. *Collative properties* are those qualities that generate perceptual conflict, eliciting curiosity, interest, and a tendency to explore. They include complexity, mystery, surprisingness, and incongruity. According to Berlyne, an optimal aesthetic response is generated when a stimulus elicits an intermediate balance between the motivation to explore and the motivation to avoid novelty.

Other psychologists (Mehrabian and Russell 1974; Wohlwill 1976) extended experimental aesthetics to environmental scenes, starting the field of environmental aesthetics. A general relationship between collative properties and aesthetic preference was found, although typically the stimulus scenes that were tested were not high enough in collative properties to inspire the downturn in aesthetic preference predicted by the principle of stimulus complexity. As we mentioned above, natural scenes generally do not reach a level of subjective complexity that some built scenes can achieve. But more than questioning the range of collative properties represented by environmental scenes, researchers came to realize that formal stimulus properties like complexity will not, by themselves, provide an adequate explanation of environmental aesthetics. That is, early attempts to apply experimental aesthetics to environmental scenes were criticized for focusing too much on "syntactic" qualities and ignoring "semantic" qualities—scene content. For example, people from different cultures will generally express aesthetic preference for natural scenes over urban scenes. Similarly, people rate environmental scenes more highly if they contain water or green vegetation, aside from their collative properties.

This result has inspired researchers to consider environmental aesthetics within a biological evolutionary framework. Kaplan and Kaplan (see Kaplan 1992), for example, were inspired by Gibson's (1979) concept of environmental "affordances" to look at environments functionally. They theorized that humans evolved preferences for particular places or environments because of the functional advantage of preferring some and avoiding others. The environments in which early humans evolved functioned to facilitate or impede such adaptively important activities as stealth and hiding, hunting and gathering, wayfinding, and social organization and communication. Accurate information processing would have been important, the Kaplans theorized, but so would quick information processing. These conditions would have favored the evolution of rapid, preconscious, and relatively automatic responses, including affective responses, to various environmental characteristics. Based on this reasoning, Kaplan and Kaplan introduced their *informational model* of environmental psychology. According to this model, predictors of environmental preference result from the interaction of two human needs—"making sense" and "involvement"—with two amounts of cognitive processing—"immediate" and "inferred (or future)" (see Hartig and Evans 1993). Four concepts derive from crossing the two levels of human needs with the two levels of processing: coherence, legibility, complexity, and mystery. These are reminiscent of Berlyne's collative properties but were developed from explicit evolutionary reasoning.

Evolutionary thinking about environmental aesthetics has probably reached its greatest application in various versions of the *savannah hypothesis*. Assuming that humans evolved on the African savannah, the hypothesis conjectures that environments with savannah-like properties will be maximally aesthetic to people across cultures. Evidence for this hypothesis has come from studies of landscape preference among children and adults (Balling and Falk 1982) and studies of tree-shape preference among Japanese gardeners (Orians and Heerwagen 1992). Appleton (1975) introduced a version of the savannah hypothesis called *prospect-refuge theory*. It proposes that people evolved to prefer the control over visual access provided by savannah environments—their prospect, or opportunities for large vistas, and refuge, or cover. In other words, people will find environments appealing that afford seeing without being seen. In this way, prospect-refuge theory explicitly connects evolutionary theories of environmental aesthetics with information-based theories, such as the Kaplans's.

Arthur Stamps (2005) recently developed *permeability theory*, which like the savanna hypothesis and prospect-refuge theory has at its core the evolutionary advantage of safety as an explanatory framework for evaluating environmental preferences. In permeability theory, the environment influences safety, and these influences may be evaluated by limiting perception or motion. A limitation might be complete, such as a brick wall, or partial, such as a fog bank. It might differ for locomotion and sensation. For example, one could hear through a thin wall but not see through it, move through dense fog but not see through it, or see through a window but not move through it. Distance also figures into the safety equation. If one can perceive danger at a greater distance, the chances of escape increase. Survival could also depend on knowing how accessible regions of safety might be. In permeability theory, mystery is related to preference because mystery indicates compromised perception. Stamps's experiments were conducted in both urban and natural settings and investigated the properties that most influenced impressions of mystery—occlusion, depth of view, and light. His findings suggest that mystery may primarily be a function of light levels, which is of interest when thinking about cave environments.

UNDERSTANDING CAVE USE FROM AN ENVIRONMENTAL PERSPECTIVE

Surveys of prehistoric and historic cave use suggest that cave morphology largely determines how cave space is used. Archaeologists have long noted that cave habitation occurs almost solely in the mouth of caves or in rockshelters (for discussion see Introduction, this volume), a point that has been reiterated throughout the essays of this volume. These sites tend to be relatively open and, in some cases, cave mouths may be quite large (see Barker and Lloyd-Smith, Chapter 17, this volume), well lit, and have open access so that they were not likely to entrap their inhabitants. When we think of these characteristics in terms of the interplay between human cognition and the environment, archaeological findings begin to make sense. For instance, ideas about environmental aesthetics such as the savannah hypothesis, prospect-refuge theory, and permeability theory all suggest that humans will feel safer in open, well-lit environments or in environments in which they may view the surrounding area without being seen. Many cave mouths or rockshelters are situated in high places, affording large vistas, and may have increased feelings of security. In these cases, isovist or viewshed analysis would be expected to aid in understanding why certain sites were chosen for habitation over others (see Sabo et al., Chapter 16, this volume).

In studies of environmental aesthetics, cave dark zones would score very highly with respect to collative or informational properties, such as mystery and complexity. From an evolutionary perspective, they would have been unusual environments, lacking in revealing vistas or vegetation, and therefore not preferred for habitation. This leads us to believe that due to their morphology and low-light conditions, dark zones would not be highly preferred habitation sites insofar as they would generate too much uncertainty, and lack cohesion and legibility. It also suggests that as the quality of light dims, perceptions of mystery and danger should increase. It may account for the almost total lack of habitation in dark zones and explain why they are only inhabited under overriding or desperate conditions such as extreme cold (see Taçon et al., Chapter 9, this volume).

The very conditions that make caves inhospitable habitations render them useful for other purposes. One might expect that because cave interiors are hostile environments for humans, they may be considered "fugitive lairs" suitable for antisocial behavior (see Leicht and Tolan-Smith 1997, 125), or provide a protective barrier for those wishing to conceal themselves (see Ranger, Chapter 22, this volume; Stone 1997, 202). When inhabited dark zones are discovered in the archaeological record, one should ask what overriding conditions were present in this choice of environment.

Consider cave environments from the Gibsonian perspective of "affordances." In Gibson's (1979) view, human and nature are not separate but are in an intertwined reciprocal relationship. To Gibson, it is a mistake to separate a cultural from a natural environment, or to distinguish mental products from the world of material products. We are created by the world we live in, while at the same time we are consistently changing, modifying that world. The Earth and its environments offer affordances. Affordances are properties of environmental entities that may include geographic features, rocks, minerals, air, animals, or any other material entity that, from a human perspective, may provide a means to fulfill real or perceived needs. In this sense, affordances may be seen as dynamic and changing, insofar as our needs are dynamic and changing, or fixed and universal, insofar as our needs are fixed and universal. In this sense, affordances defy classification. While a stone may be used as a projectile, it may also be a paperweight, a bookend, or a plumb bob. Human creativity is a major factor in designating affordances and is thus dynamic and highly variable, but all affordances are ultimately defined in reference to an observer while not deriving from the experiences of the observer. That is, affordances are not subjective values such as feelings of pleasure and pain but are, rather, the ways in which an entity may be employed.

According to Gibson, the habitat of a given animal contains places. Places are not neutral and have affordances that may be positive, such as a berry patch, or negative, such as the edge of a cliff. What caves offer humans is an environment that lacks light and is morphologically complex. These qualities offer special affordances for caves, both negative and positive, relative to human needs. In many caves, interior passages do not allow upright mobility, while they also require increased physical effort, special equipment, or technical knowledge to traverse them. Wayfinding is difficult, and even with modern equipment one is easily disoriented in the dark and often relatively unfamiliar environment. Cave interiors may also be enclosed spaces in which one can become trapped. For these reasons, cave dark zones do not offer high-quality affordance for habitation, but they do offer high-quality affordance for hiding and secrecy. Caves offer a shadowy environment that is different from the surface world, an environment of mystery. In addition, due to sensory deprivation, dark zones of caves can help produce meditative states or stimulate otherworldly experiences, such as hallucinations that are characteristic of many shamanic practices (see Williams 2002 for a thorough discussion).

While these properties are not conducive to habitation, dark zones stimulate human imagination and encourage "imaginary geographies," as described by Gallese and Lakoff (2005, 9). Because of this property, we suggest that cave dark zones offer *transcendental affordance*. While Gibson never discussed the notion of symbolic places, this extension is in keeping with his ideas that affordances straddle the material world and the world of the mind. It is telling that some of the first known ritual practices and art of early humans (see Clottes, Chapter 1, this volume) occurred in deep caves in Europe during the Paleolithic period, as indicated by painted cave walls and the use of the spaces for burials. While there is little doubt that earlier forms of portable art existed, and that these cave remains are an artifact of differential preservation, it is also possible that the caves themselves offered an affordance not presented elsewhere. The human-cave interaction may have worked reciprocally to facilitate and encourage symbolic or ritual behaviors. In other words, these early expressions may have been as much about the caves themselves as what occurred within them.

CONCLUSION

This chapter examined why cave dark zones are the subject of myths and stories and are so often used as ritual spaces. Part of our approach is quasi-phenomenological; we find that phenomenology is useful in defining patterns and can help us understand the active role of environments in the development of shared ideas. But phenomenology offers no explanatory power for why humans interpret some environments in similar ways.

We suggest that the physical properties of caves have particular implications for human psychological responses, and to understand these responses, we turned to studies of spatial cognition in the behavioral and cognitive sciences, and in the environmental behavior and design fields. Our review of the literature suggests that there is a correlation between types of environments and human perceptions that are important in inferring how caves were used in the past. The literature suggest that a number of factors such as low-light or no-light conditions, and three-dimensional complex morphology, lead to a general perception of cave dark zones as dangerous, mysterious, and illegible, rendering them useless for all but temporary habitation. By framing our discussion in terms of Gibson's affordances, we have come to understand that the very qualities that prevent caves from "affording" habitation are the very qualities that make them attractive as transcendent or imagined spaces that may be incorporated into myth and used in ritual. Although we have elected to analyze broad patterns of cave usage, we expect that our approach will be useful for analyses of single sites as well as intersite analyses.

REFERENCES CITED

Appleton, Jay. 1975. *The Experience of Landscape*. London: Wiley.

Appleyard, Donald. 1969. "Why Buildings Are Known." *Environment and Behavior* 1 (2): 131–56. http://dx.doi.org/10.1177/001391656900100202.

Arthur, Paul, and Romedi Passini. 1992. *Wayfinding: People, Signs, and Architecture*. Toronto: McGraw-Hill Ryerson.

Auburn, Timothy, and Rebecca Barnes. 2006. "Producing Place: A Neo-Schutzian Perspective on the 'Psychology Of Place.'" *Journal of Environmental Psychology* 26 (1): 38–50. http://dx.doi.org/10.1016/j.jenvp.2006.03.002.

Balling, John D., and John H. Falk. 1982. "Development of Visual Preference for Natural Environments." *Environment and Behavior* 14 (1): 5–28. http://dx.doi.org/10.1177/0013916582141001.

Benedikt, Michael, and Clarke A. Burnham. 1985. "Perceiving Architectural Space: From Optic Arrays to Isovists." In *Persistence and Change: Proceedings of the First International Conference on Event Perception,* ed. W. H. Warren and R. E. Shaw, 103–14. Hillsdale, NJ: Lawrence Erlbaum Associates.

Berlyne, Donald E. 1960. *Conflict, Arousal, and Curiosity*. New York: McGraw-Hill. http://dx.doi.org/10.1037/11164-000.

Cornell, Edward H., C. Donald Heth, and Wanda L. Rowat. 1992. "Wayfinding by Children and Adults: Response to Instructions to Use Look-Back and Retrace Strategies." *Developmental Psychology* 28 (2): 328–36. http://dx.doi.org/10.1037/0012-1649.28.2.328.

Edelman, Gerald M. 1992. *Bright Air, Brilliant Fire: On the Matter of the Mind*. New York: Basic Books.

Gallese, Vittorio. 2005. "Embodied Simulation: From Neurons to Phenomenal Experience." *Phenomenology and the Cognitive Sciences* 4 (1): 23–48. http://dx.doi.org/10.1007/s11097-005-4737-z.

Gallese, Vittorio, and George Lakoff. May 2005. "The Brain's Concepts: The Role of the Sensory-Motor System in Conceptual Knowledge." *Cognitive Neuropsychology* 22 (3): 455–79. http://dx.doi.org/10.1080/02643290442000310. Medline:21038261.

Gärling, Tommy, Anders Böök, and Erik Lindberg. 1986. "Spatial Orientation and Wayfinding in the Designed Environment: A Conceptual Analysis and Some Suggestions for Postoccupancy Evaluation." *Journal of Architectural and Planning Research* 3: 55–64.

Gibson, James J. 1979. *The Ecological Approach to Visual Perception*. Boston: Houghton Mifflin.

Gladwin, Thomas. 1970. *East Is a Big Bird*. Cambridge, MA: Harvard University Press.

Goldberger, Leo. 1966. "Experimental Isolation: An Overview." *American Journal of Psychiatry* 122, 7 (Jan): 774–82. Medline:5321573.

Hartig, Terry, and Gary W. Evans. 1993. "Psychological Foundations of Nature Experience." In *Behavior and Environment: Psychological and Geographical Approaches*, ed. T. Gärling and R. G. Golledge, 427–57. Amsterdam: North-Holland. http://dx.doi.org/10.1016/S0166-4115(08)60053-9.

Hegarty, Mary, Anthony E. Richardson, Daniel R. Montello, Kristin Lovelace, and Ilavenil Subbiah. 2002. "Development of a Self-Report Measure of Environmental Spatial Ability." *Intelligence* 30 (5): 425–47. http://dx.doi.org/10.1016/S0160-2896(02)00116-2.

Hillier, Bill, and Shinichi Iida. 2005. "Network and Psychological Effects in Urban Movement." In *Spatial Information Theory*, ed. Anthony G. Cohn and David M. Mark, 475–90. Berlin: Springer. http://dx.doi.org/10.1007/11556114_30.

Kaplan, Stephen. 1992. "Environmental Preference in a Knowledge-Seeking, Knowledge-Using Organism." In *The Adapted Mind: Evolutionary Psychology and the Generation of Culture*, ed. Jerome H. Barkow, Leda Cosmides, and John Tooby, 581–98. New York: Oxford University Press.

Kaplan, Stephen, Rachel Kaplan, and John S. Wendt. 1972. "Rated Preference and Complexity for Natural and Urban Visual Material." *Perception & Psychophysics* 12 (4): 354–6. http://dx.doi.org/10.3758/BF03207221.

Lakoff, George, and Mark Johnson. 1999. *Philosophy in the Flesh: The Embodied Mind and Its Challenge to Western Thought*. New York: Basic Books.

Lawrence, Elizabeth Atwood. 1993. "The Sacred Bee, the Filthy Pig, and the Bat Out of Hell: Animal Symbolism as Cognitive Biophilia." In *The Biophilia Hypothesis*, ed. Stephen R. Kellert and Edward O. Wilson, 301–41. Washington, DC: Island Press.

Leicht, Roger, and Christopher Tolan-Smith. 1997. "Archaeology and Ethnohistory of Cave Dwelling in Scotland." In *The Human Use of Caves*, ed. Clive Bonsall and Christopher Tolan-Smith, 122–26. BAR International Series 667. Oxford: Archaeopress.

Llobera, Marcos. 2003. "Extending GIS-Based Visual Analysis: The Concept of *Visualscapes*." *International Journal of Geographical Information Science* 17 (1): 25–48. http://dx.doi.org/10.1080/713811741.

Loomis, Jack M., Roberta L. Klatzky, Reginald G. Golledge, Joseph G. Cicinelli, James W. Pellegrino, and Phyllis A. Fry. 1993. "Nonvisual Navigation by Blind and Sighted: Assessment of Path Integration Ability." *Journal of Experimental Psychology General* 122, 1 (Mar): 73–91. http://dx.doi.org/10.1037/0096-3445.122.1.73. Medline:8440978.

Lynch, Kevin. 1960. *The Image of the City*. Cambridge, MA: MIT Press.

Matthews, W. H. 1970. *Mazes and Labyrinths: Their History and Development*. Mineola, NY: Dover.

Mehrabian, Albert, and James A. Russell. 1974. *An Approach to Environmental Psychology*. Cambridge, MA: MIT Press.

Montello, Daniel R. 1991. "Spatial Orientation and the Angularity of Urban Routes: A Field Study." *Environment and Behavior* 23 (1): 47–69. http://dx.doi.org/10.1177/0013916591231003.

Montello, Daniel R. 2005. "Navigation." In *The Cambridge Handbook of Visuospatial Thinking*, ed. P. Shah and A. Miyake, 257–94. Cambridge: Cambridge University Press.

Montello, Daniel R., and David S. Lemberg. 1995. "The Minotaur's Revenge: Geographic Disorientation in Caves." Paper presented at the International Conference on Spatial Analysis in Environment-Behaviour Studies, Eindhoven, The Netherlands.

Montello, Daniel R., and Herbert L. Pick. 1993. "Integrating Knowledge of Vertically-Aligned Large-Scale Spaces." *Environment and Behavior* 25 (3): 457–84. http://dx.doi.org/10.1177/0013916593253002.

Moyes, Holley. 2002. "The Use of GIS in the Spatial Analysis of an Archaeological Cave Site." *Journal of Caves and Karst Studies* 64 (1): 9–16.

Orians, Gordon H., and Judith H. Heerwagen. 1992. "Evolved Responses to Landscapes." In *The Adapted Mind: Evolutionary*

Psychology and the Generation of Culture, ed. J. H. Barkow, L. Cosmides, and J. Tooby, 555–79. New York: Oxford University Press.

Proctor, James D. 1998. "The Social Construction of Nature: Relativist Accusations, Pragmatist and Critical Realist Responses." *Annals of the Association of American Geographers. Association of American Geographers* 88 (3): 352–76. http://dx.doi.org/10.1111/0004-5608.00105.

Sadalla, Edward K., and Diana Oxley. 1984. "The Perception of Room Size: The Rectangularity Illusion." *Environment and Behavior* 16 (3): 394–405. http://dx.doi.org/10.1177/0013916584163005.

Schutz, Alfred. 1962. *Collected Papers I: The Problem of Social Reality*. Ed. M. Natansen. The Hague: Martinus Nijhoff.

Schutz, Alfred. 1967. *The Phenomenology of the Social World*. Trans. G. Walsh and F. Lehnert. London: Heinemann Educational Books.

Stamps, Arthur E., III. 2005. "Visual Permeability, Locomotive Permeability, Safety, and Enclosure." *Environment and Behavior* 37 (5): 587–619. http://dx.doi.org/10.1177/0013916505276741.

Stone, Andrea. 1997. "Pre-Columbian Cave Utilization in the Maya Area." In *The Human Use of Caves*, ed. Clive Bonsall and Christopher Tolan-Smith, 201–6. BAR International Series 667. Oxford: Archaeopress.

Tversky, Barbara. 1992. "Distortions in Cognitive Maps." *Geoforum* 23 (2): 131–8. http://dx.doi.org/10.1016/0016-7185(92)90011-R.

Weisman, Jerry. 1981. "Evaluating Architectural Legibility: Way-Finding in the Built Environment." *Environment and Behavior* 13 (2): 189–204. http://dx.doi.org/10.1177/0013916581132004.

Williams, David Lewis. 2002. *The Mind in the Cave: Consciousness and the Origins of Art*. New York: Thames and Hudson.

Wohlwill, Joachim F. 1976. "Environmental Aesthetics: The Environment as a Source of Affect." In *Human Behavior and Environment*, vol. 1, ed. I. Altman and J. F. Wohlwill, 37–86. New York: Plenum.

Zubek, John P., ed. 1969. *Sensory Deprivation: Fifteen Years of Research*. New York: Appleton-Century-Crofts.