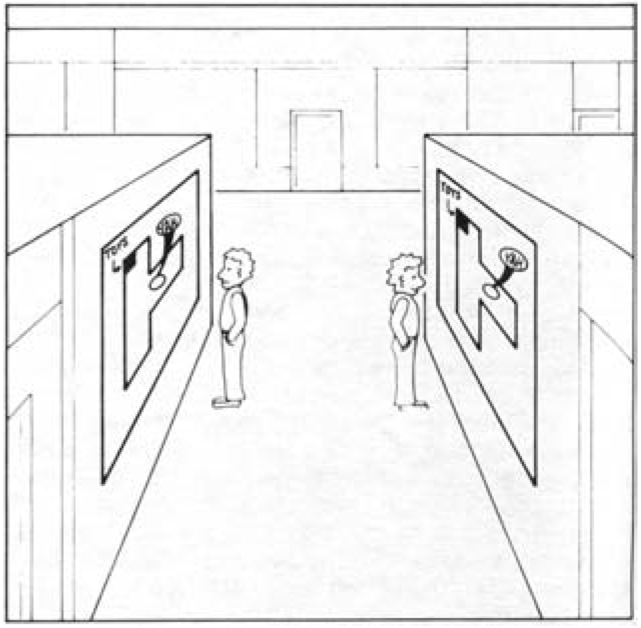

FIG. 663. MISALIGNED YOU-ARE-HERE MAPS. Illustration of how identical you-are-here maps placed on facing walls necessarily place at least one map out of alignment. When maps are misaligned (as on the left), adults commonly walk off in the wrong direction because they fail to take alignment into account.
From Marvin Levine, Iris Marchon, and Gerard Luke Hanley, "The Placement and Misplacement of You-Are-Here Maps." *Environment and Behavior* 16 (1984): 139–57, esp. 144. Permission courtesy of Sage Publications.

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Experimental Studies in Psychology. Maps are symbolic representations that communicate information of varying veracity to people, thereby assisting their reasoning and decision making. Communication, reasoning, and decision making are, in part, psychological acts involving perception, learning, thinking, and memory. During the twentieth century, especially the latter half, a variety of cartographers, geographers, psychologists, and other behavioral and cognitive scientists conducted basic and applied scientific research on perception and cognition with and about maps—an area of research that may be referred to collectively as perceptual and cognitive cartography.

This entry focuses on research that used maps and map-like stimuli to conduct basic scientific research on human mental processes and structures, including perception, thinking, learning, memory, reasoning, decision making, imagery, and language; this can be called experimental map-psychology research to distinguish it from perceptual and cognitive research on map design, human factors, and map education, which are discussed elsewhere in this volume. Experimental studies were conducted mostly by perceptual, cognitive, educational, and developmental psychologists, although geographers James M. Blaut, Roger M. Downs, Robert Lloyd, and Alan M. MacEachren made noteworthy contributions. With very few exceptions, most such research was concerned little, if at all, with improving map design, map use, or map users. Instead, these researchers were mostly interested in basic scientific questions about human spatial and symbolic thinking.

In addition to its relative lack of concern for improving maps or their use, experimental map-psychology research also frequently used exceptionally abstract and simplified "maps" as stimulus materials to show human research subjects. Most academic and professional cartographers would not consider these simple graphics to be maps (fig. 664). Often lacking information about scale, cardinal directions, projection, and map currency, these graphics were not representations of the earth's surface. Furthermore, psychological research often evinced limited conceptions of the design and content of maps and of the variety of tasks for which maps can be used. For these and other reasons, experimental map-psychology research had very little influence on map design or production.

Experimental map-psychology during the twentieth century may be organized into three broad topical areas. The first involved research on the mental knowledge structures and processes involved in map use. Memory tests and protocol analyses (a technique in which map users systematically think aloud while looking at or reasoning with maps) showed that experience with particular classes of maps or particular knowledge domains in-

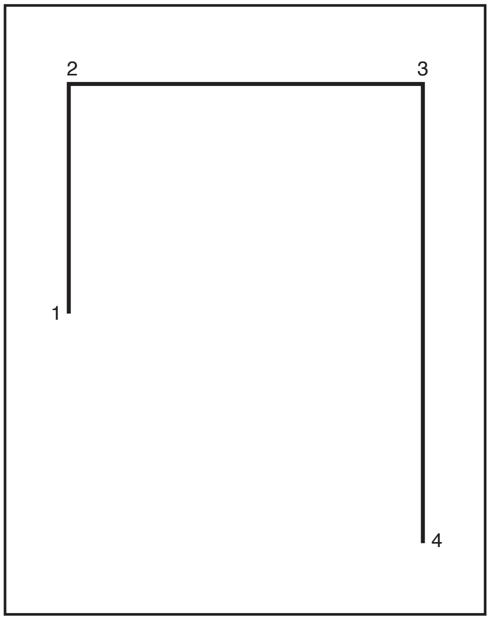

FIG. 664. HIGHLY SIMPLIFIED MAP-LIKE GRAPHIC USED AS A STIMULUS. This example is similar to graphics used in several psychological research programs (including Levine, Jankovic, and Palij 1982; and Presson, Delange, and Hazelrigg 1989).

fluences how people look at and reason with maps, what they remember from maps, and how they organize the knowledge in memory (e.g., Thorndyke and Stasz 1980). Another common method for researching questions on knowledge structures and processes was to analyze patterns of distortion in people's map-based judgments. Such research repeatedly demonstrated that maps are not encoded and stored in memory as unitary "pictures in the head." Nonpictorial cognitive structures—rules or heuristics—organize one's knowledge of map content and layout, presumably because they decrease memory load and typically facilitate map interpretation. For example, just as people mentally regionalize earth surface spaces, they mentally regionalize map spaces and organize them hierarchically (McNamara, Ratcliff, and McKoon 1984). Barbara Tversky (1981) proposed other heuristics to explain patterns of distortions in people's judgments about the relative directions of urban streets and of world cities, learned from maps; these heuristics lead people to assume directional alignment of locations with various local or global reference systems.

A second topical focus of experimental map-psychology concerned the way map orientation when used to navigate in situ influences how it is interpreted (Levine, Jankovic, and Palij 1982; Shepard and Hurwitz 1984). Maps such as road maps and "you-are-here" maps are typically used by people to orient themselves in their immediate surrounds. Research repeatedly confirmed the common observation that most people find maps like these easiest to use in situ when the forward direction of the map viewer is represented toward the top of the map. Maps oriented in any other way, such as with the backward direction of the viewer toward the top of the map, are used more slowly and less accurately when orienting. The extra time required or errors produced in using maps without this forward-top agreement—maps that are misaligned to the surrounds—was dubbed the alignment effect. In order to cope with misaligned maps, viewers must first recognize the misalignment and then mentally or physically transform the map, themselves, or their surrounds.

A third topical focus of experimental map-psychology compared maps as sources of geographic and environmental knowledge to other sources, especially direct experience sensing and moving through the landscape. As sources of information, maps have characteristics that differentiate them from direct experience. They usually provide a survey overview from a vertical or oblique perspective that allows viewers to apprehend the geometric layout of places between which they may never have traveled and may not be able to travel directly. The most influential study on this topic was by Perry W. Thorndyke and Barbara Hayes-Roth (1982). They compared research subjects who learned the layout of an office building from viewing a map for an hour or less to subjects who learned it by working in the building over the course of several months or more. Based on analysis of error patterns in spatial judgments about the building, these researchers developed models for the mental processing of spatial knowledge acquired either from maps or from direct experience, noting that "the obvious advantage of acquiring knowledge from a map is the relative ease with which the global relationships can be perceived and learned" (Thorndyke and Hayes-Roth 1982, 585).

Other researchers produced evidence that knowledge acquired from maps is more tied to a single orientation than that acquired from direct experience. That is, just as maps of the surrounds tend to be used in an orientation-specific way while viewed during navigation, as discussed above, they tend to be recalled from memory in a fixed orientation, requiring time and error-prone mental transformations to use them in any other orientation. Some researchers suggested that knowledge acquired directly might be stored and accessed from memory in a more flexible manner, so that the information could be used in any orientation just about as quickly and accurately as any other. For example, Gary W. Evans and Kathy Pezdek (1980) found that alignment effects occurred more strongly when human research subjects answered questions about the relative locations of U.S. cities—knowledge presumably acquired from maps—but were weaker when subjects answered questions about places on campus, knowledge presumably acquired from direct experience (see also Presson, DeLange, and Hazelrigg 1989). However, subsequent research by others questioned the meaning of the proposed difference between map-acquired and directly acquired knowledge and whether surrounds are even stored in memory in an orientation-flexible manner at all (Roskos-Ewoldsen et al. 1998).

Psychologists came to the study of perceptual and cognitive cartography later in the twentieth century than did cartographers. (Educational psychologists were an exception.) However, perceptual and cognitive map research by psychologists was a busy enterprise in the last two decades of the century, and it actively continued in the early twenty-first century, when ongoing research examined a wide spectrum of maps and newer forms of geographic symbol systems and technologies, including animations, multiscale displays, sonifications, virtual and augmented environments, and more. Psychologists and others continued to apply a variety of methods to study maps, including analyses of errors in spatial judgments, response times, verbal protocols, and eye movements. The advent of new brain imaging techniques in the late twentieth century, notably functional magnetic resonance imaging (fMRI), fostered innovative studies of the neuroscience of map perception and cognition in the early twenty-first century.

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SEE ALSO: Academic Paradigms in Cartography; Color and Cartography

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Psychophysics. Perceptual and cognitive cartography is an approach to cartographic research and design that emerged during the twentieth century. This approach recognizes that maps provide symbolic representations to people, offering perspectives on the world that must be interpreted by human minds; maps do not simply present the world to people directly and transparently. Thus, perceptual and cognitive cartographers realize that the content of maps—the information they potentially provide to map viewers—depends not just on the graphical marks placed on the page or computer screen but also on the perceptual and cognitive processes of the viewer.

One of the earliest systematic expressions of the perceptual and cognitive approach to cartography was the application of psychophysics in map design research. Psychophysics is a subdiscipline of experimental psychology that studies the relationship of variation in a physical stimulus dimension, such as the amount of energy emitted by a light source or the concentration of sugar in a solution, to variation in a person's subjective responses to that stimulus, such as perceived brightness or sweetness (Boring 1942). The logic of applying psychophysics to map design, particularly the design of thematic maps, was straightforward and sensible in intent. For example, proportional-area symbols represent the values of a quantitative variable (e.g., graduated circles for population size), according to variations in their graphical area. In order to decode such symbols, map viewers must perceive the area of the symbol and then relate this to the corresponding value of the variable being mapped. It is clear that the map viewer will interpret the symbol according to its perceived or apparent size, not its actual size. If the perceived area of the symbol differs much from its actual area, and if it does so in a sufficiently consistent way across time and viewers, then it makes sense to determine the relationship of perceived area to actual area and use this relationship to design the symbols.

The development of psychophysics played a fundamental role in the emergence of psychology as a separate scientific discipline in the nineteenth century. The year 1879, when Wilhelm Max Wundt opened his psychology lab in Leipzig, Germany, is conventionally identified as its start. Along with Ernst Heinrich Weber and Gustav Theodor Fechner, Wundt was a pioneer in the study of psychophysics. These researchers worked on problems including identifying the absolute and difference thresholds for various stimulus continua, such as the brightness of lights or the volume of sounds. The absolute threshold is the weakest stimulus intensity that can be