Communication Theory

Lecture 2:
Spatial Cognition and Virtual Environments

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Cognition and Space

• Distributed cognition challenges us to investigate the relationship between space and the mind
• It is therefore important for us to understand how space features in cognition both in the laboratory and ‘in the wild’
• Fortunately, technologies have begun to provide ideal control test beds for understanding the cognitive properties of space

The Cognitive Map

McGee (1982) defined spatial orientation as “the comprehension of the arrangement of elements within a visual stimulus pattern, the aptitude for remaining unconfused by the changing orientations in which a configuration may be presented and the ability to determine spatial relations in which the body orientation of the observer is an essential part of the problem” (p.4).

Humans and animals must adopt strategies to gauge their constantly altering position within the environment if they are to successfully negotiate “that great God-given maze which is our human world” (Tolman, 1948, p. 208).

3D

• We see our world in three dimensions. Although the retina in the eye is a flat surface and therefore the images it receives are two dimensional, distance cues enable some two dimensional images to be perceived as distant in a three dimensional world.
• Monocular depth cues include relative size, superposition/occlusion and relative height. Relative size refers to smaller objects being interpreted as further away than larger objects. Occlusion is the effect when one object obstructs another, causing the overlapping object to be perceived as being nearer. The relative height of similar objects can enable distance perception, for example, objects that are seen as higher in the image are perceived as more distant.

3D

The use of two eyes (binocular vision) has advantages for depth perception. Our two eyes enable us to see two slightly different images of an object and we use this disparity to calculate the object’s orientation in space. The term stereopsis is used to explain how the brain adds depth from this disparity between the different images from the two eyes.
3D

Another type of depth cue arises from autonomous movement in space which appears to be crucial to the development of an effective internal spatial representation. Gibson (1966) stated that as the observer moves through space, there is a flow of stimulation on the retinas, which leads to a better understanding of the three dimensionality of our world. “When the observer moves,...the optic array becomes alive with motion” (Haber and Hershenson, 1973, p.332).

Theories of Space

Kant claims that “space and time are the very form of the human mind” (Ellis, 1991, p.xiii). Indeed everyday navigation and technological advances aiding exploration (flying, driving) involve complex spatial skill.

Space

- Psychological space refers to the space of our perceptual experience, “any space which is attributed to the mind...and which would not exist if minds did not exist” (O'Keefe and Nadel, 1978, p.6-7).
- Physical space refers to the three dimensional, Euclidean world in which we live.
- These two types of space overlap and interact with one another.
- We can also distinguish between virtual space and physical space, as virtual environments do not exist in the physical world.
- The focus here is psychological space and investigates whether experience of virtual space, can be used to supplement physical space.

The form of the Cognitive Map

Tolman (1948) describes a “map control room” in the brain which stimuli enter and are “worked over” and “elaborated” into “a tentative, cognitive-like map of the environment” (p.192). This “cognitive map” contains routes, paths and environmental relationships which are stored and can be used when responding to the environment. Thus accuracy of response to one’s environment is intricately linked to the quality of the cognitive map formed.

- O’Keefe and Nadel (1978) drew a distinction between the “Taxon” system (routes) and the “Locale” system (places) in the build up of spatial knowledge.
- The “Taxon” system involves using a series of S-R-S (stimulus-response-stimulus) instructions. Navigation involves moving from one landmark to the next by aligning oneself in relation to the landmarks.
- The “Locale” system is a highly flexible system, based on the development and use of internal maps.
- O’Keefe and Nadel (1978) state that exploration is essential for the creation of internal spatial cognitive maps and in constantly up-dating them.

Animal behavioural studies

- Most authors agree that humans carry spatial representations of their environment in their heads, yet there is constant debate concerning the type and content of these representations.
- Siegel and White (1975) suggest a three tiered process in the development of spatial knowledge: the use of landmarks, then the adoption of route knowledge allowing fairly simple wayfinding, and finally internal representations of space, allowing more sophisticated methods of navigation.
Landmarks, routes and maps

• Siegel and White suggest that landmarks may constitute "meaningful events" and the nervous system may be continually "taking pictures" of them.
• Routes are built up by connecting a series of landmarks. This strategy is egocentric (dependent on the body’s location and direction of pointing in space) and is efficient as long as the links between successive turns are accurate.
• A cognitive map applies to the mental images that individuals build up as they become more familiar with their surroundings. This type of representation is allocentric (not dependent on the body’s position in space or direction of regard) and thus is extremely flexible.

Properties of cognitive map

• Pick and Lockman (1981) describe three properties of spatial maps: reversibility, transitivity and enabling detours.
• Lynch (1960) suggests that the cognitive map is a product of the number and type of landmarks and the number and type of past experiences one has had in a particular location.

Cognitive Map (contd.)

• Thorndyke and Hayes-Roth (1982) state three important points about spatial cognition.
• Firstly, people build up their spatial knowledge from a variety of different sources: navigation through the environment, a wide variety of different forms of maps, verbal descriptions and photographs. The knowledge gained from each of these sources is integrated to form spatial knowledge.
• Secondly, dependent on the knowledge they have, people use different methods when making spatial judgements.
• Thirdly, the accuracy of any spatial judgement is dependent not only on the accuracy of spatial knowledge but also on the computations performed on this knowledge.

Virtual Environment (VE)

• Virtual environments (VEs) have as their core the simulation by computer of three dimensional space.
• The first defining feature of VEs is that they can be explored in real time with similar freedom to real world exploration.
• The second defining feature is that the user may interact with objects and events in the simulation.
• Virtual Environments are interesting tools for psychology research in spatial cognition, because they allow some control over testing spatial exploration.

Application of VEs

• Research using VE’s has stemmed from:
  – Military
  – Space
  – Aviation
• VEs are now used in a wide variety of settings, including:
  – Education
  – Medicine
  – Building design
  – Applications for those with disabilities
  – …

Presence in VEs

• VEs consist of three-dimensional, interactive, computer generated worlds, running in real time.
• Often, interacting with these worlds provides a feeling of “presence” as every response has a consequence, and the egocentric viewpoint gives the illusion of looking from 'within' the virtual world.
• This may be true for more or less realistic technologies (e.g. head-mounted displays vs. ‘desktop’ VEs)
Training in VEs

- Virtual environments are potential useful media for training spatial skills:
- Interactions with VEs reproduce similar visual-spatial characteristics to interactions with the real world
- Interactions with VEs can preserve the link between motor actions and their perceived effects (Regian, Shehilske and Monk, 1992). This may be primarily due to the three dimensionality of the display, which provides all of the transformations in the visual appearances of objects that would accompany real movements in space. In Gibson’s (1979) terms, the optical flow patterns that would be experienced in the course of real movements are maintained in the displayed environment.

Training in VEs (contd.)

- VEs enable assessment of the internal spatial representations within the same mode as they were acquired. A user explores a VE and then can be tested on their spatial knowledge within this same environment using pointing tasks or route tests.
- easily adaptable, allows repeated viewing, and provides tight control of cues.
- they allow learning to take place without the danger of injury
- a high level of interactivity

Training and Education

- Why use 3D environments for training
  - Take on different perspectives
  - Visualise 3D concepts
  - Interact in real time
  - Explore dangerous situations in safety
  - Independent rehearsal
  - Present realistic or abstract scenarios
  - Promote different learning styles and teaching methods
  - possess a high degree of flexibility

Training and Education

- Navigation and wayfinding
  – simulations of buildings
  – spatial orientation measures

Conclusions

- Understanding of spatial cognition has developed over the past 50 years
- Recent developments in computer graphics have allowed improved simulation of spatial environments
- These developments have in turn provided test beds for conducting research in how internal spatial representations are formed and as platforms for training spatial skills
References