

# Cognitive Maps and Spatial Sound

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# Why?

- ◆ Artificial spatial sound and music doesn't quite engender the kind of spatial perception I experienced as a choirboy in the cathedral (*the butterfly in the matchbox*)

# Again, why?

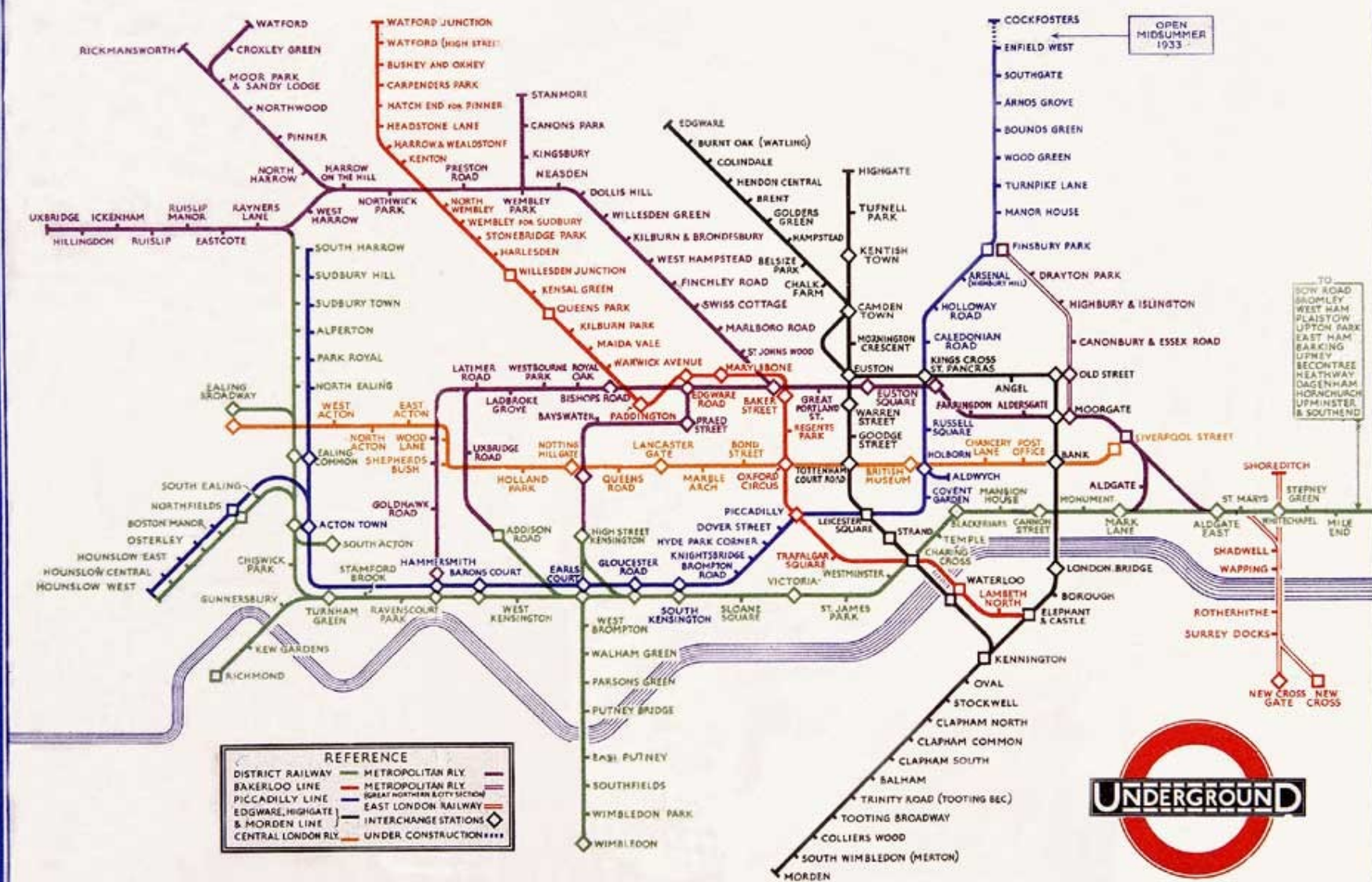
- ◆ Bottom-up model of perception leavened with a little top-down: Sensation + 'cognitive factors' (the mysterious workings in the '**black box**') = perception.

# Open the box...

- ◆ Is it possible to describe how 'prior knowledge', memory, prediction, cognition, conception integrate in **real time** with the ongoing influx of sense data ?

# Cognitive map

- ◆ A simplified 'cartoon' that highlights salient features
- ◆ Like the London Underground map?



OPEN MIDSUMMER 1933

TO  
 HOW ROAD  
 BROMLEY  
 WEST HAM  
 PLAISTOW  
 UPTON PARK  
 EAST HAM  
 BARKING  
 UFRY  
 BECKTREE  
 HEATHWAY  
 DAGENHAM  
 HORNRCHURCH  
 UPHMSTER  
 & SOUTHEAD

**REFERENCE**

DISTRICT RAILWAY	METROPOLITAN RLY
BAKERLOO LINE	METROPOLITAN RLY (GREAT NORTHERN & CITY SECTION)
PICCADILLY LINE	EAST LONDON RAILWAY
EDGWARE, HIGHGATE & MORDEN LINE	INTERCHANGE STATIONS
CENTRAL LONDON RLY	UNDER CONSTRUCTION



# Tolman

- ◆ Cognitive Maps in rats and men (1948)
- ◆ Metaphorical -way of describing how prior knowledge (in this case spatial knowledge) can facilitate successful spatial action

# O'Keefe and Nadel; Maguire *et al*

- ◆ Specific neural substrates associated with encoded spatial knowledge
- ◆ Famous study of London taxi drivers demonstrated localised structural changes in the brain correlating with continued learning and practise of particular spatial layouts/problems



# Why posit maps at all?

- ◆ Ecological approach (Gibson, J): why 'represent' what's already out there?
- ◆ Cognitive constructivism: "information bandwidth" insufficient for the richness of perceptual content

# What problems ameliorated by 'maps'?

- ◆ Signal-to-noise ratios (information overload)
- ◆ Momentary sensation impoverishment
- ◆ Real time interaction ('quick-and-dirty' processing of salient features)
- ◆ Anticipation ...perception is the process of *choosing* a preferred future

# A caution on reification

- ◆ No assumption of “Euclidean equivalence” (no tiny maps of London appear under the microscope...)

*“the map is not the territory”* (Alfred Korzybski)

Not all conceptualisations of ‘cognitive maps’ are equivalent - or even compatible

# Cognitive maps in the wild and in captivity...

- ◆ Spatial perception in the lab may differ qualitatively from that in the real world
- ◆ Dancers, race drivers, crane drivers, taxi drivers, ball players pilots, actors, dogs and kings....
- ◆ Specialise in quite different spatial behaviours, probably have finely tuned *neural* spatial representations *specific* to their lives...

# Elaborating cognitive maps:

- ◆ Spatial (*things in positions in places*)
- ◆ Spatiotemporal (*events' trajectories*)
- ◆ Causal (*prediction and counterfactuals*)
- ◆ Territorial (me, mine, theirs, yours)
- ◆ Affordance (opportunities and constraints)

# Spatial maps

- ◆ “**Where**” (Ungeleider and Mishkin)  
Direction/dimension/distance -  
Representing *position* in *place*  
Representing ‘place’ itself (but what  
is actually represented?)

# Spatial maps 2

- ◆ **“What”** Mapping of *“things”*  
Size, shape, orientation, mass,  
construction.... “affordances” (?)

# Spatial maps- frames of reference

- ◆ Egocentric (various) - “me-” or “mine-” centric
- ◆ Allocentric (various) - overview - the way things are from no particular viewpoint



# Spatiotemporal maps

- ◆ Route maps (sequence of signposts *and actions*)
- ◆ Events: trajectories, vectors, speeds amplitudes, rotations *changes* of spatial relationships

# Causal mapping

- ◆ **What, Where** and **How** (Milner and Goodale) spatiotemporal mapping
- ◆ Extend into the future (predict, anticipate, adjust, interact); not “now” but “next”
- ◆ Counterfactuals (Gopnik and Wellman) - should/not, might/not - event trajectories - expectation/surprise

# Intuitive physics

- ◆ Rough-and-ready reckoning of how items *can* interact (Piaget, Baillargeon, Spelke, Gibson[E], Van de Valle)

# Intuitions of animate behaviour

- ◆ Physical capabilities
- ◆ Estimates of intentionality (territoriality, theories of other minds?)

# “Opportunity map” For fun, profit and survival

- ◆ Mapping territoriality:
- ◆ Near, far, adjacent, connected, ‘way’ open, blocked, vantage, shelter, tool
- ◆ Prey, predator, competitor, ally -intercept, avoid, hide, negotiate, threaten, placate, persuade

# Composing and Engineering with Cognitive Maps

- ◆ Physical plausibility (physic engine)
- ◆ Causal plausibility (there's always a causal narrative to be had)
- ◆ Territory and intentionality: interaction, negotiation, communication:

*Call-and-response, musical themes 'chasing', musical objects scattering, coalescing, flocking, swarming, fleeing, angry*

# Examples

- ◆ The mousetrap game (marbles rolling along a track and dropping to a lower level) doesn't simply scale up (in ambisonics or any other surround sound system) – treble the system diameter and the perceived movement speed and the angular changes don't match – **Implausible!**

# Examples

- ◆ The courting rituals of the medicine ball, the tennis ball and the eventual arrival of the baby ping pong balls

*The sources can be **animated** to display intentionality and interaction, causing unfolding events and **plausible** conclusion*



# Examples

- ◆ Multichannel mono makes no sense

*Precedence effects mean the sound just appears at the nearest speaker. Images shouldn't move when you move.*

*Complex **place** sounds like rain, background noise, sea, etc – should always be **spacious**, not source-like*

# Examples

- ◆ Circular panners don't model straight line trajectories

*How often do sources orbit the listener in real environments? – the humble panoramic potentiometer was a positioning-across-the-speaker-array device, not a “dynamic trajectory device”*

Something else is needed for plausible movement...

# Examples

- ◆ Reverb should have ‘shape’ – it’s the sound of ***place***;

*The cognitive processing of reflected sound is subtle, complex and not comprehensively understood.*

*Simplifying the spatial character of the reflected sound field undermines perceptual “foreground-background” separation*

# Conclusions

- ◆ Spatial sound constitutes 'artificial environment'
- ◆ Environments have 'rules' - *complex*, not *random*
- ◆ Cognitive maps *represent* causal relationships and rules
- ◆ Perception is happy to entertain fiction – as long as *plausibility* is maintained

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