

Neurodevelopmental Aspects of Spatial
Navigation: A Virtual Reality fMRI Study
Pine et. al. (2002)

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Core Questions of Navigation

- Where am I?
- Where is the place I want to get to?
- How can I get there? (What landmarks can I recognize and use along the way?)

In a previous study (Maguire 1998), key brain regions that are activated by a navigation task were identified using positron emission tomography (PET).

Using the commercial video game “Duke Nukem 3D”, their paradigm included 4 different conditions:

- Direct way-finding
- Indirect way-finding - where detours were necessary to navigate around barriers
- Arrow-following (non-navigation)
- Identification of features in a static scene

Results

<u>Brain Region</u>	<u>Variance of Activation</u>	<u>General Implications</u>
Right Hippocampus	Significant activation in way-finding conditions compared to arrow-following condition.	Representation of allocentric cognitive map.
Left Hippocampus	Activity did not co-vary significantly with measure of accuracy of navigation.	Necessary for episodic memory, not specific to navigation.
Right Inferior Parietal Cortex	Along with right hippocampus, activation co-varied significantly with quantitative measure of accuracy of navigation.	Complementary egocentric computations to enable movement towards the goal, given the current heading and relative location of obstacles.
Left Middle and Superior Frontal Gyri	Significant activation in indirect way-finding condition compared to direct way-finding condition.	Necessary for planning and decision making.
Right Caudate Nucleus	Activation co-varied significantly with speed of navigation.	Representation of speed of motion.

Key Issues Raised in 2002 Study

- The emergence of allocentric memory, as an important developmental change.
- The localization of a neural circuits implicated in spatial navigation.

Egocentric Memory vs. Allocentric Memory

- Egocentric = first-person perspective
- In previous studies, it has been shown that pre-adolescent children tend to perform as well as adults when directly navigating in a novel environment. This makes sense because we normally view the world from a first-person perspective.
- Allocentric = third-person perspective; birds-eye view
- Interestingly, the ability to navigate efficiently by using abstract mental representations of the environment matures relatively late in adolescence.

Methods

Using the commercial video game “Duke Nukem 3D”, subjects were given two previous training sessions on separate days, in order to familiarize themselves with the layout of the virtual city.

BOLD signal was measured in 8 adolescents and 8 adults during 3 different conditions:

- Memory-guided navigation (2-minute epoch)
- Arrow-guided navigation (2-minute epoch)
- Fixation (1-minute epoch)

While in the scanner, navigation ability was evaluated as the number of goal locations successfully reached in 4 minutes of memory-guided navigation.

20 minutes after scanning, subjects were given a timed retrieval test, where they were asked to label as many of the goal locations as possible in 60 seconds.

Results

- For memory-guided navigation, adolescents found on average 9.3 ± 2.7 locations, while adults found 8.7 ± 3.0 locations.
- For the allocentric memory test, adults labeled about twice as many locations (9.9 ± 3.8) as adolescents (5.0 ± 2.3).
- Also, memory-guided navigation ability positively correlated with activity in various brain regions, including a right medial temporal region.