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Updating Mental Models: What is the Role of the Right Hemisphere?

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Précis

The concept of the mental model has a long history in psychology. Mental models provide expectations and guide action. *We are investigating whether an inability to update mental models following focal brain injury might explain some of the behavioural impairments seen after stroke, e.g. spatial neglect* (Figures 1 & 2). Building and updating mental models depends on particular brain regions that detect environmental regularities (Figure 3). Such environmental regularities may be immediately repeated events (Figure 4) or longer term statistical trends (Figure 5). People with right-sided brain damage (RBD) are impaired on such measures, even if tested in a domain that is not visual (e.g. auditory; Figure 6). Such deficits could underly differences seen in more abstract model building tasks, such as exploiting the biased play of a computer opponent in the child's game Rock, Paper, Scissors (RPS; Figure 7). fMRI studies in normal individuals show that brain regions activated at the time of transitions from random to biased play in RPS are associated with activation in right hemisphere brain regions (Figure 8) that overlap those in Figure 2. Even if the model to be built and updated is not statistical, but rather perceptual, RBD impairs updating, such as seen with a version of an ambiguous figures task. (Figure 9). In summary, we view mental model building and updating as a useful abstraction for approaching how we solve the hard problems of choosing what to do and when to do it, given a complex and changing environment. Our studies with RBDs suggest this can account for a range of behavioral deficits after stroke and can be used to probe the brain structures that underlie this ability. Our preliminary investigations of these processes suggest that a particularly important human ability is the skill to select the right state space and update the state space representation as required by circumstances.

Clinical Features of Neglect

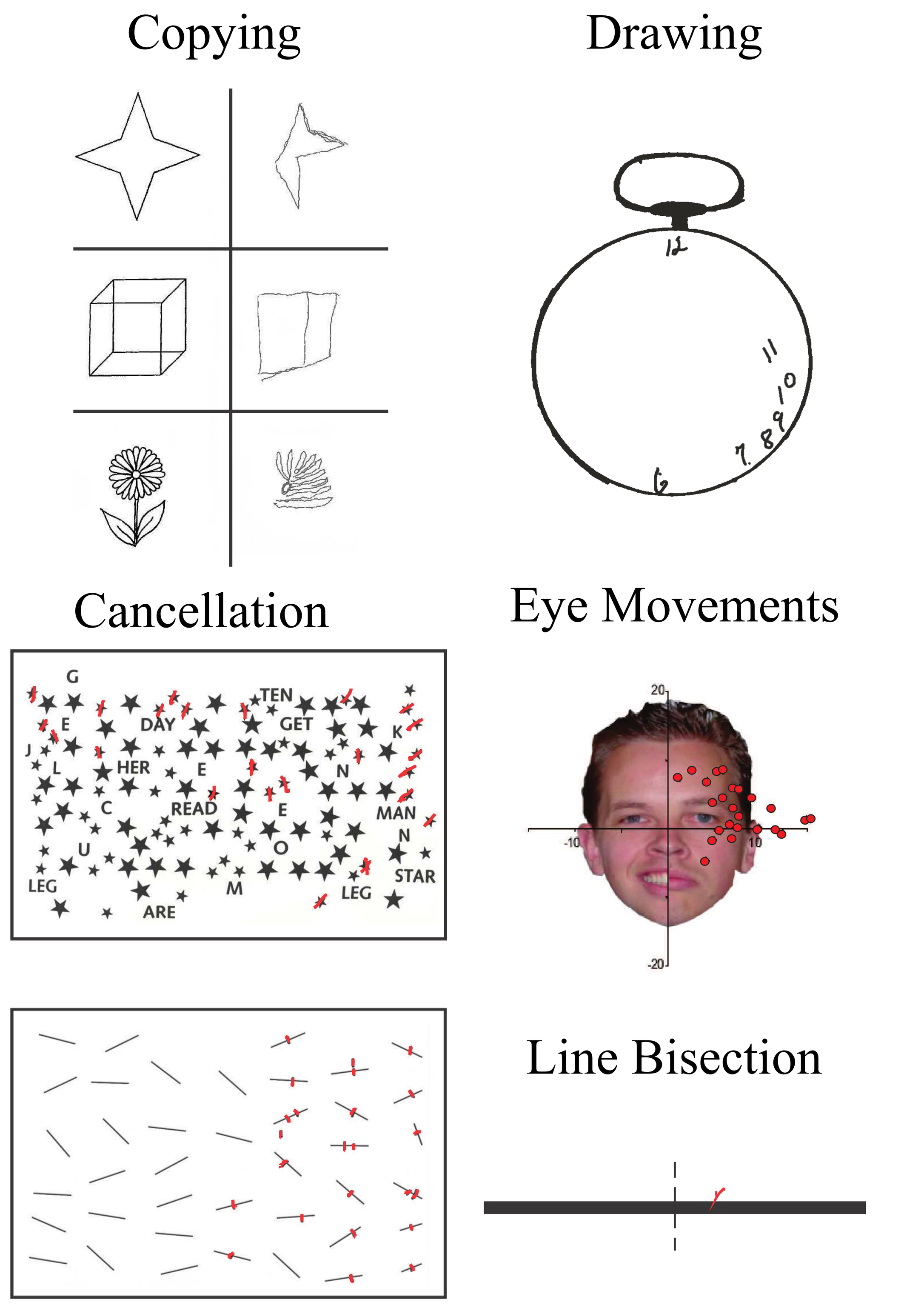

Figure 1: Clinical Signs of Neglect. Spatial neglect is a clinical disorder in which patients show a failure to respond, orient, or act on contralateral stimuli. This can show up in free drawing or copying, as well as structured search tasks or the distribution of exploratory eye movements.

Location of Lesions in Neglect

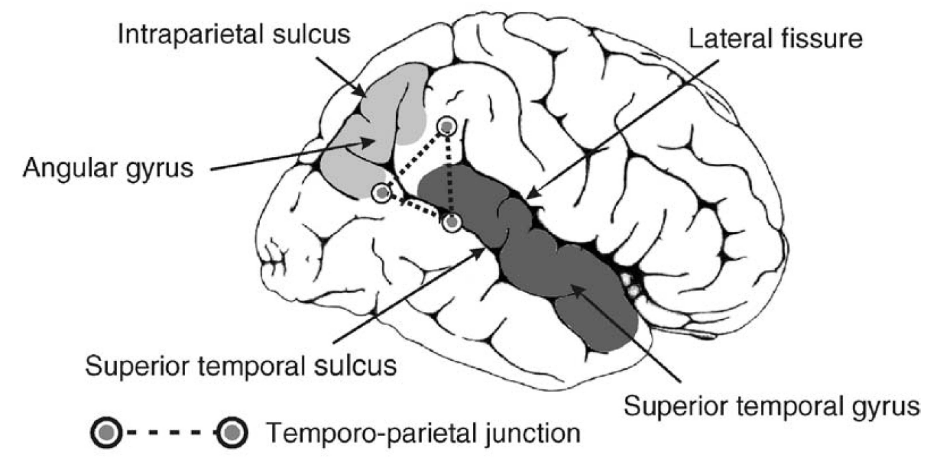

Figure 2: Brain Regions Damaged in Neglect. Neglect typically follows right hemisphere stroke. Typical damage is in the parietal or superior temporal lobe, although damage to basal ganglia, insula, thalamus, and frontal lobes are also seen.

Updating — A Schematic

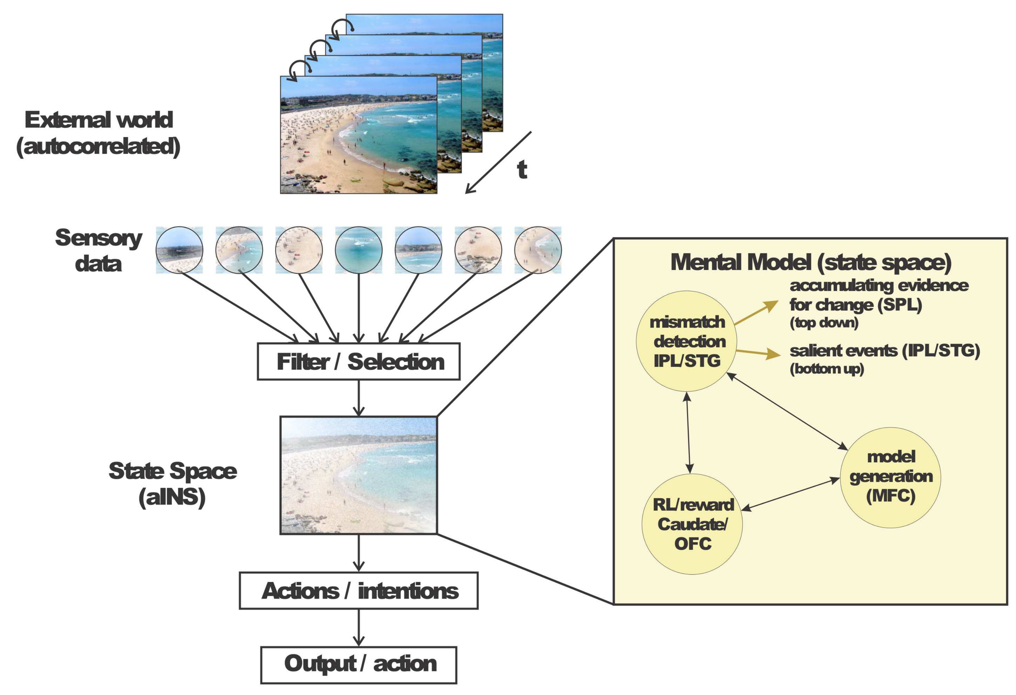

Figure 3: The beach represents the external environment that is recursive and obeys unknown laws. Our view of the world is built up from incomplete, filtered snapshots (sensory data). We use mental models to plan our actions, to direct our sensory sampling, and as the substrate for self-diagnostics. Different elements of model building/updating are postulated to rely on distinct brain regions.

Impaired Priming and Probability Learning in Neglect

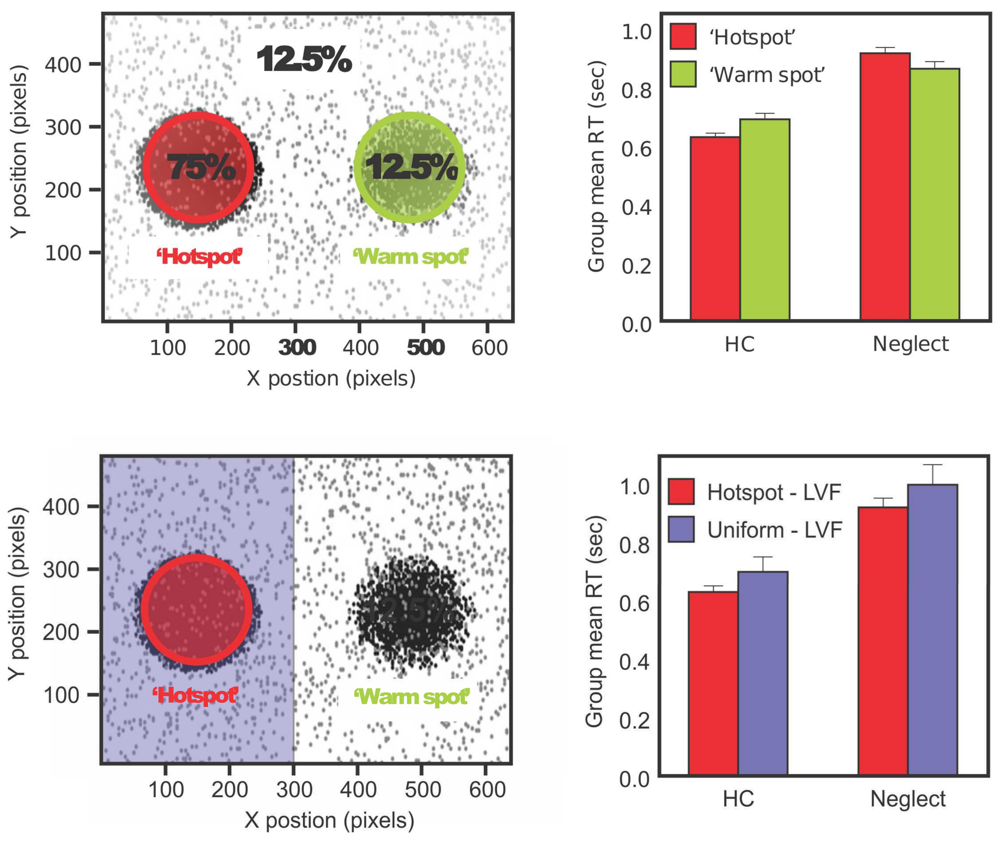

Figure 4: Learning Target Distributions. Participants classified a target dot as black or white over a large series of trials. Despite being slower than controls, the neglect participants gradually became faster to recognize targets that occurred in a high probability region of left space.

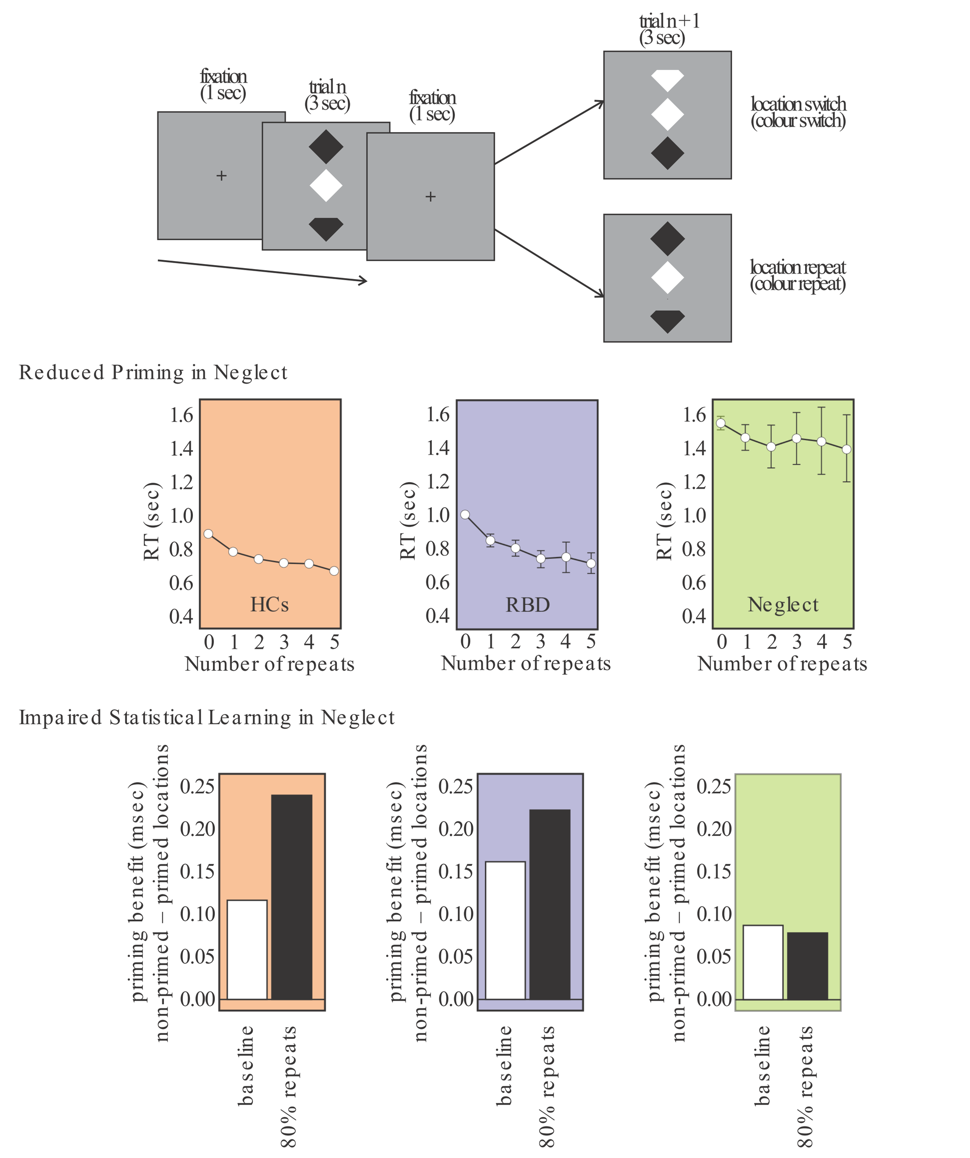

Figure 5: Impaired Transition Probability Learning. Participants reported whether the top or bottom of the odd diamond out was missing. All participants were faster when the colour or location of the target repeated across trials (*priming*). However, participants with neglect failed to modulate the benefit of repeats as a function of how likely there were to be repeated trials (compare baseline (uniform) and 80% repeat conditions.).

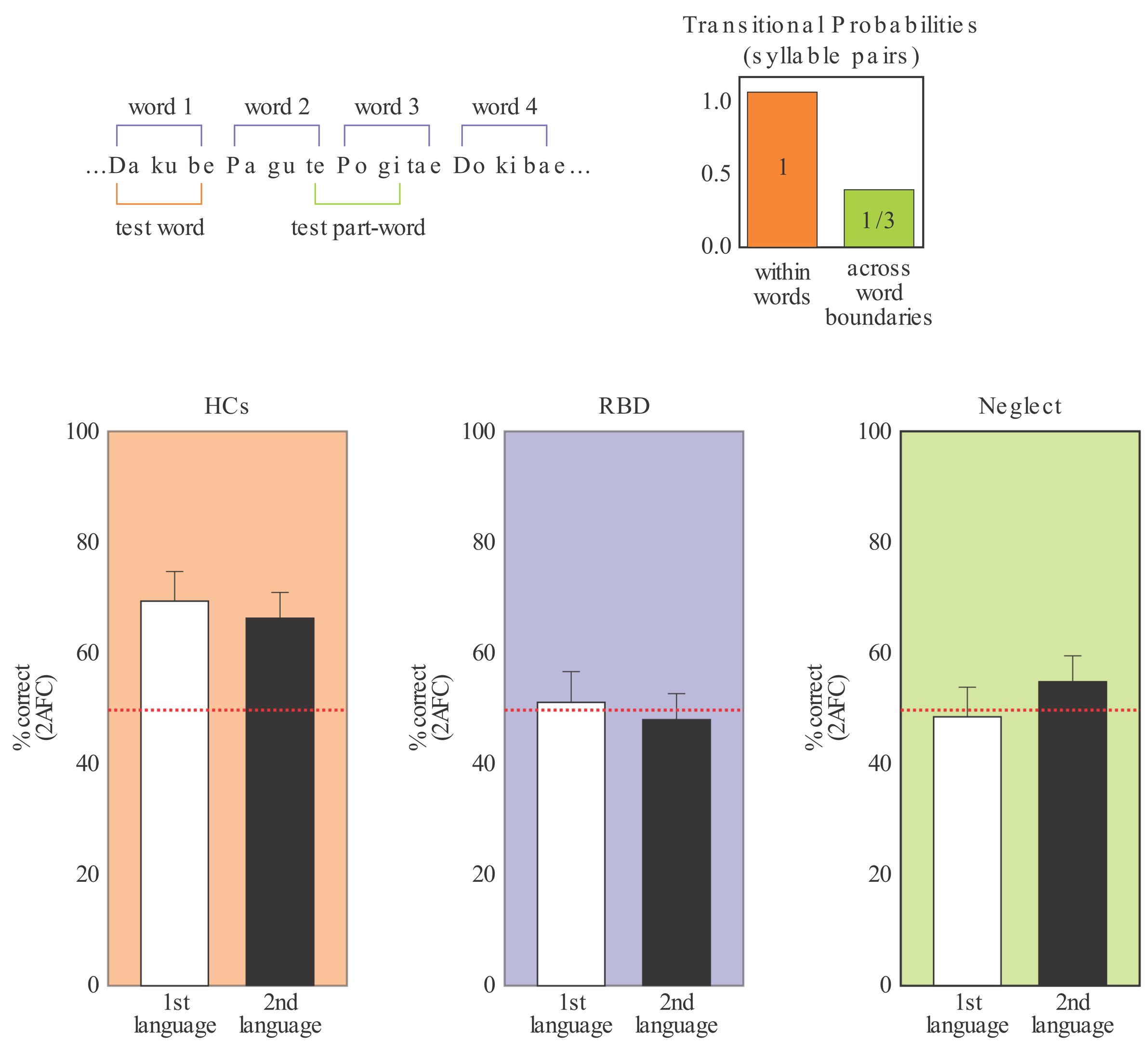

Figure 6: Impaired learning of transition probabilities in language. Brain injury impaired the ability to spontaneously and rapidly learn the statistics of a simple language where syllable transitions were encoded by virtue of transitional probability.

Rock, Paper Scissors: Patients, fMRI, and Models

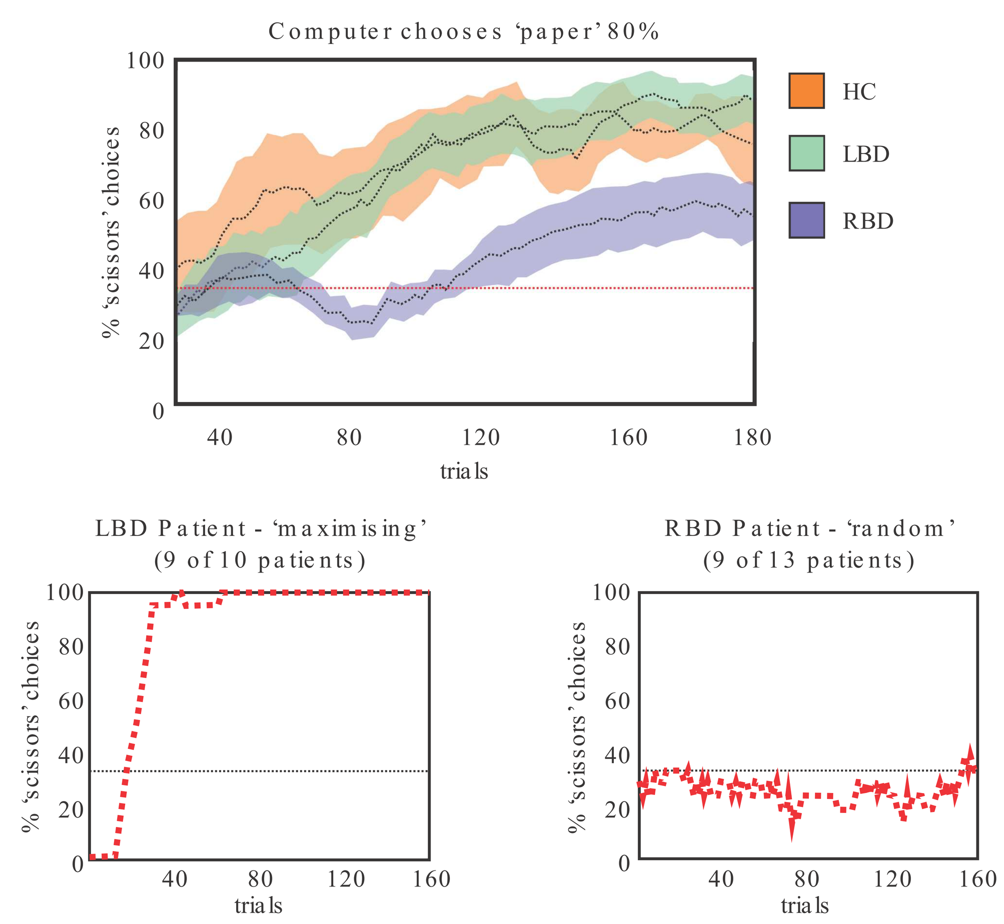

Figure 7: Brain injury affects the exploitation of a simple frequency strategy in rock, paper, scissors. Left brain damage produces a maximizing behaviour, and right brain damage often results in random appearing play.

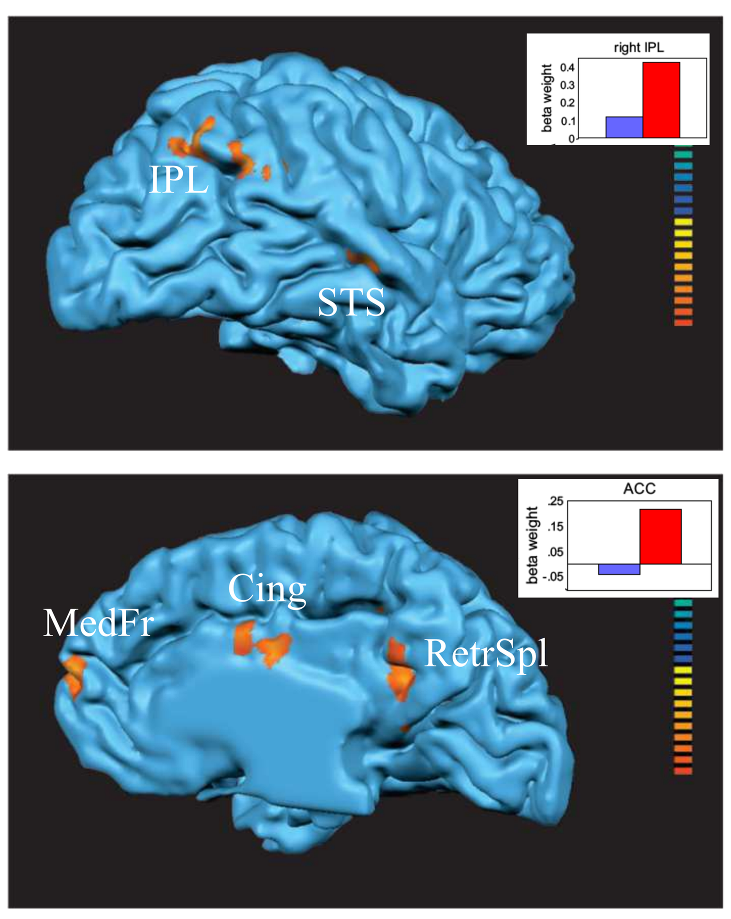

Figure 8: fMRI in normal human participants against a computer opponent with unannounced strategy shifts. The right parietal and temporal lobes show increased activations when changing from a random to frequency biased opponent. These sites overlap those where damage produces spatial neglect.

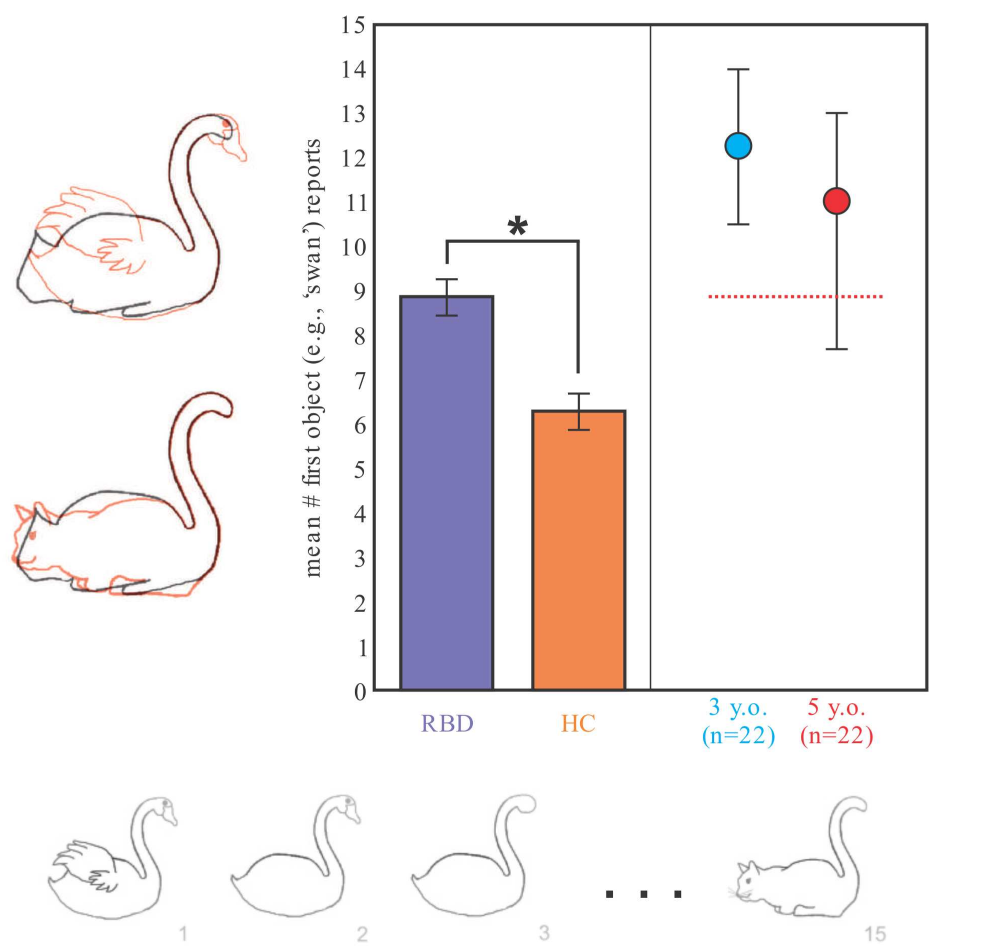

Figure 9: Ambiguous figures are not updated properly after right brain damage or in young children. When started at one end of a progression from one unambiguous figure to another, control participants report the appearance of the second figure sooner than brain damaged participants or young children.