Neural Reuse: A New Perspective on Theory of Mind and the TPJ
Josh Bowie — Department of Cognitive Science, Carleton University

INTRODUCTION

The turn in scientific direction from behaviorism to cognitive science in the late 1970s marked a new focus on the inner workings of the brain; a new and ardent effort to describe and explain a perpetual list of cognitive functions. As research in cognitive science, neuroscience and neuropsychology advanced it became clear that certain regions located within the brain are linked to specific functions; both observable and implied.

General functions (e.g., memory, emotion, language) have been attributed course grained anatomical sites, while more specific functions (performing tasks, perceiving faces, language production) are associated with finer grained localities. As we move from general functions to those that are more specific, the ability to easily recognize functions becomes strained, if not lost altogether, as they are too far removed from our understanding of how the world works and how we work within it. At times, this dismantling of the cognitive machine, can present significant challenges. However, if overcome, the fine grained understanding of the mind can present profound new insights that not only change the rules of the game, but the game itself.

To paint this more clearly, an analogy from chemistry and molecular biology might be useful. I will use the molecular combination of glucose and water for simplicity, however there are countless combinations to choose from. The molecular formula of glucose is C₆H₁₂O₆, where C is carbon, H is hydrogen and O is oxygen. Water contains similar elements, H and O, in the form of H₂O. While both H and O are contained within both molecules they combine to form very different functions. The same can be said for sub-functions within the brain — they can be re-used to support multiple functions. While the field of chemistry is old and highly advanced i.e., the composition of molecules and their functions are well understood, the field of cognitive science is young and immature. In cognitive science, our work is very much ahead of us. Defining the vast number of sub-functions and understanding the role they play in higher-level functions, I would suggest, is paramount to understanding how the mind works.

Objective: to expand the literature in this area by shedding new light on the sub-functions associated with the temporoparietal junction (TPJ). A broad range of behaviours associated with IMH activity in the TPJ will be examined from a neural reuse perspective, with the aim of inferring lower level sub-functions.

Massive Modularity

Massive modularity follows many of the same general principles as Fodorian modularity but holds less to a pipeline model associated with a few functions, rather is more flexible in nature and covers a broad spectrum of domain specific functions.

• Networks are massively modular if they contain highly connected clusters of nodes that are sparsely connected to nodes in other clusters.

Each module operates solely with its own innate “set of procedures, formats, and representational primitives closely tailored to the demands of its targeted family of problems.”

It has been proposed that the mind contains an allocation system that respond to signal detection mechanisms that function in parallel, where specific patterns of activation trigger specific mental representations, which in turn activate modules.

The argument for massive modularity is almost always presented in an evolutionary context:

• Just has the body has evolved physical features to adapt to environmental conditions, the brain has evolved modules in response to a wide range of adaptive problems.

• The strongest empirical evidence for this view comes from Cosmides’ proposed cluster-detector module which employs results of the Wason selection task.

It has been proposed that modular networks evolve because their sparse connectivity has lower connection costs.

Problems With Modularity

The strengths of Fodorian modularity are also its vulnerabilities. Its narrowness enables it to be particularly useful as a psychological concept, however this same specificity makes it difficult to truly understand the mind.

Popular arguments against modularity tend to target encapsulation. They assert that processing within a module is influenced by external processes and not simply entrance inputs.

• Evidence from Muller-Lyser illusion is mischaracterized. Cognitive heuristic → a perception always trumps a belief when the two are in conflict.

• Input systems can communicate with each other → Ramachandran’s mirror technique for relieving phantom pain.

• Other arguments that highlight the existence of domain-general abilities such as logical reasoning, working memory are targeted more specifically at massive modularity.

• “Unused cells of the “visual system” can be co-opted for touch.

It has also been proposed that the ability to do cognitive work with novel stimuli is a problem for massive modularity, from an evolutionary perspective.

In a similar vein, some argue that a connectionist mechanism could generate the pattern of performance on the Wason selection task that Evolutionary Psychologists have taken as evidence of modularity.

Fodorian Modularity

In his 1983 book The Modularity of Mind Jerry Fodor sets out the first comprehensive explanation of mind being comprised, in part, of distinct modules that perform unique cognitive functions. Fodor sets out clear and precise elements of which a module is comprised:

• Domain specificity - the types of inputs processed in a given area are limited. The implication of this idea is that certain functions or abilities are innate, rather “hard-wired”.

• Mandatory operation - if the right type of input is provided the operations that lead to the functions will always be activated.

• Limited access - the processed information in modules is not accessible to conscious processing.

• “Waste” processing - processing that takes place within modules is fast, in the 100-300 ms range.

• Information is encapsulated - the module does not have access to information stored in other areas.

• Shallow inputs - information processed by the module is general and therefore relatively easy to process.

• Fixed neurological architecture - modules are said to be located in distinct locations within the brain.

Theory of Mind and rTPJ

There is evidence that many neural circuits are activate by different stimuli across different cognitive domains. For example, in addition to being strongly associated with language processing, Broca’s area has also been linked to movement preparation, action sequencing, action recognition and action imitation.

Neutral reuse has been proposed a fundamental organizational principle of the brain. It’s proposed that neural circuits that have evolved for one purpose are often co-opted for other uses. This so called neutral reuse is said to occur at low levels of neural circuitry. Hypotheses that this reuse occurs over evolutionary time or developmental time have been put forward.

The processes associated with the low level circuitry at which neutral reuse occurs is referred to in different ways in the literature, including ‘working zones’ or ‘operations’. In either case, the objective is to demonstrate that particular lower level structure can produce similar sub-functions that combine in unique ways with other sub-functions and result in distinct macro level functions.

According to the neural reuse hypothesis:

• There should be a correlation between the phylogenetic age of the brain and the frequency with which it is redeployed in various cognitive functions - older areas, having been available for reuse for longer, more likely to have been integrated into later-developing functions.

• There should be a correlation between phylogenetic age of a cognitive function and the degree of localization of its neural components. More recent functions should generally use a greater number of and more widely scattered brain areas than evolutionarily older functions.

LITERATURE CITED


