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The neuroscience of intelligence: Empirical support for the theory of multiple intelligences?[☆]

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ABSTRACT

The concept of intelligence has been strongly debated since introduction of IQ tests in the early 1900s. Numerous alternatives to unitary intelligence have achieved limited acceptance by both psychologists and educators. Despite criticism that it lacks empirical validity, multiple intelligences theory (Gardner, H. (1983, 1993) *Frames of mind: The theory of multiple intelligences*, New York: Basic Books), has had sustained interest on the part of educators worldwide. MI theory was one of the first formulations about intelligence to be based on neuroscience evidence. This investigation reviewed 318 neuroscience reports to conclude that there is robust evidence that each intelligence possesses neural coherence. Implications for using MI theory as a bridge between cognitive neuroscience and instruction are discussed.

1. Introduction

The concept of intelligence has a checkered history in the minds of many scientists and educational theorists. Many have abandoned the concept in part or entirely, and instead investigate cognitive abilities, problem-solving, or information processing capacities. However, many scientists have also investigated the functional neural systems that underlie intellectual achievement. The reason for this has been summed up succinctly by Jung and Haier [1, p. 171] "…there is no more important concept in education than the concept of intelligence." Those authorities assert that not all brains think the same way, thus "this simple fact could be revolutionary for education because it demands a neuroscience approach that recognizes the importance of individual differences and the necessity to evaluate each student as an individual" [2, p. 174].

The theory of multiple intelligences (MI) has motivated the present investigation. Gardner [3,4] redefined intelligence as the ability to solve problems or create products of value in a culture or community. Using this broad, common sense definition and eight criteria* that cover a range of empirical evidence (e.g., neuroscience, psychometric and evolutionary evidence, and atypical populations), Gardner identified eight distinct forms of intelligence that are possessed by all people, but in varying degrees. The eight intelligences identified are linguistic, logical-mathematical, visual-spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal and naturalist (for detailed descriptions, see Appendix A).

Traditional psychologists have criticized MI theory for a number of reasons. One criticism is that MI theory lacks support from large scale studies [4,5] or experimental research [7–9]. It has also been proposed that the eight intelligences are simply different manifestations of general intelligence [10,11]. An important practical criticism is that educators should not base instructional and curricular decisions upon a theory whose scientific status is controversial [6,12–16].

Among neuroscientists, the predominant view on intelligence is that there is either one general intelligence (g) or two types of intelligence (fluid and crystallized). However, there is a debate regarding the possible sub-divisions of intelligence and each sub-division's relationship to "g." Numerous theories that deviate from the unitary intelligence theory – including triarchic [17], emotional intelligence [18,19], structure of intellect [20], faculties of mind [21], and cognitive styles [22] – have had noteworthy, but limited, influence. Some theories have been recognized by the field of psychology, but not embraced by educators. Few have had the lasting and profound impact on education as multiple intelligences theory, still of interest worldwide more than 30 years after its introduction [3,4,23]. Despite this broad appeal to educators, MI remains more of an inspirational educational framework rather than a fully developed scientific theory [2,24,25].

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Table 1
The neural correlates of the multiple intelligences originally identified by Gardner. Source. [3] *Frames of Mind* (1983, 1993), [4] *Intelligence Reframed* (1999).

Intelligences	Neural Regions
Interpersonal	Frontal lobes as integrating station, limbic system
Intrapersonal	Frontal lobe system
Logical-Mathematical	Left parietal lobes & adjacent temporal & occipital association areas, left hemisphere for verbal naming, right hemisphere for spatial organization, frontal system for planning and goal setting
Linguistic	Broca's area in left inferior frontal cortex, Wernicke's area in the left temporal lobe, lateral sulcus loop inferior parietal lobule
Spatial	Right parietal posterior, occipital lobe
Naturalist	Left parietal lobe for discriminating living from non-living entities
Musical	Right anterior temporal and frontal lobes
Kinesthetic	Cerebral motor strip, thalamus, basal ganglia, cerebellum

The practical critiques are of particular importance as the emerging field of educational cognitive neuroscience strives to establish a foundation for evidence-based instructional approaches. This new field has struggled to build practical connections between brain activity and instruction / curriculum. In its early years, there was widespread skepticism that brain-based education could develop without an explicit use of psycho-educational theory to bridge between neuronal activity and instruction [26]. This situation has improved more recently [27–30], but the field continues to struggle to make a distinction between "pop psychology" of brain-based teaching and the science of educational cognitive neuroscience that can be systematically applied.

The present review organizes 30 years of cognitive neuroscience research on human cognition into core cognitive units that are each associated with a particular intelligence. We compared the neuroscientific evidence for each intelligence to the cortical areas outlined by Gardner [3,4] (Table 1) to address the following inter-related questions: (1) do these neural functional structures and networks display shared coherence while being conceptually unique and distinct from other functions, (2) taken together, do these data describe a solid conceptual framework for the "neural architecture" underlying each of the eight intelligences, and (3) how well do these neural architectures compare to what is known about the neural basis for general intelligence (i.e., g theory)? It should be underscored that this review of the cognitive neuroscience literature in relation to MI theory is intended to provide a foundation rather than a definitive examination of the constantly expanding literature on the neural underpinnings of human cognition.

2. Methods

2.1. Procedures

This investigation began with a detailed review of the various cognitive units and specific skills associated with each intelligence. For example, musical intelligence includes instrumental, vocal, composing and appreciation. Each of these ability sets includes technical skill as well as creative performance (e.g., singing on key and jazz improvisation); the review of musical neuroscience studies would ideally be inclusive of this range of abilities. Charts were constructed for each intelligence with rows for MI Cognitive Units and columns for matched Neural Structures and Cognitive Skills (linguistic sample in Appendix B. All data are available upon request).

Using the terms related to each Cognitive Unit or specific skill (Table 2), PubMed or Google Scholar were used to search for published peer-reviewed empirical neuroscience studies (neural organization Appendix C and journals list in Appendix D). The goal was to identify a minimum of three to five studies per major skill area. Surprisingly, a great many more studies were obtained. Studies of personality characteristics or dispositions were not included (e.g., introversion, diligence, etc.). Theoretical articles or books were used mainly for background information. Several extensive meta-analysis and topic reviews served as guides for finding pertinent studies in the target area. Over 318 articles were referenced for the eight intelligences. The minimum number of studies was 19 for logical-mathematical with a maximum of 73 for intrapersonal (Table 2).

From this large literature, excerpts from each text describing neural activations associated with carefully defined cognitive skills were entered into the charts per Cognitive Unit (see linguistic sample in Appendix B and E). As the investigation proceeded, the labels and defining characteristics for various Cognitive Units were adjusted to better align the neuroscience evidence with MI theory (Table 2, columns 6 and 7). This process can be described as a dialectic between compatible perspectives. The next step was for a trained neuroscience doctoral student to review the data charts and harmonize the various neural descriptors according to standard neural anatomical terminology. All neural regions were then put into an Excel spreadsheet and reorganized based on neural hierarchy (Appendices C and E).

Neuroscientific researchers have used a wide variety of terms and labels and specificity over the years as the technology has evolved. Some researchers identified broad regions with a single label while others used multiple terms to identify sub-regions. Still others used Brodmann numbering, Talairach Atlas or the MNI Coordinate system. This variety of nomenclatures required a careful translation and mapping onto the three-level hierarchy (primary, sub-regions and particular structures) described below.

Our analysis of these data employed both qualitative and quantitative methods to determine if a three-dimensional view of the neural structures associated with each intelligence could be created. This hybrid approach – qualitative and quantitative – reflects both the evolution of the field as well as the way that the brain processes information – from very specific to diffuse patterns of activation. Studies were included in this analysis regardless of the type of the subjects employed to better reflect a wide variety of abilities. Some studies used unselected subjects while others included those with brain damage and still others employed the use of subjects with specifically defined skills.

2.2. Analyses

First, we assessed the frequency of cited primary neural regions, which included the frontal cortex, temporal cortex, parietal cortex, occipital cortex, cingulate cortex, insular cortex, subcortical regions, and the cerebellum. We also ran a secondary analysis on the primary regions that were most associated with each of the intelligences (i.e., primary regions that represented at least 20% of the primary neural citations). Within the top cited primary regions, we identified the top sub-regions. All sub-regions that represented at least 20% of a top primary neural regions were reported. Lastly, in some instances, a third-level analysis was conducted to identify the important sub-regions within a sub-region of a top primary neural region (e.g., frontal cortex → prefrontal cortex → dorsomedial prefrontal cortex; Appendix E). These second-level and third-level analyses are highlighted in the text.

3. Results

The following descriptions are highlights from an extensive dataset (see Appendix F). Complete data and interpretations are available as Supplemental material.