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The Theory of Multiple Intelligences After 40 Years: A Scientific Idea Whose Time Has Come or Gone?

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Abstract

The nature of human intelligence as a unitary concept has been debated for over a century. Numerous alternative, multi-intelligence theories have been offered but only the theory of multiple intelligences has had sustained interest by educators around the world despite criticism from psychologists who question its empirical basis. This investigation reviews four lines of research testing MI theory's essential validity. Extensive evidence supports that multiple intelligences theory has evolved from a mere "inspirational" framework to a paradigm changing scientific theory work-in-progress that bridges between general intelligence and non-academic abilities. Implications for theoretical development and educational reform are discussed.

Introduction

An idea can be a powerful force. It can forge a nation or launch a technological effort to send astronauts to the moon. Ideas are the foundations of science and all the scholarly disciplines. Ideas are the roadmaps in life that guide many of our decisions, choices and behaviors. For over a century, most psychologists have accepted that human intelligence can be adequately conceptualized by a single idea (general intelligence, *g*) and communicated as a simple score (intelligence quotient, IQ). The notion of IQ is one of psychology's most successful and enduring ideas that has permeated public consciousness.

Classrooms, schools and entire educational systems around the world have been organized around this simple, powerful idea (Ravitch 2000). But, over time, ideas change. In fact, it took decades for the field of psychology to come to terms with the concept of general intelligence and mental testing. IQ testing represented scientific progress by using objective tasks to measure mental ability rather than purely qualitative means such as phrenology, interviews or testimonials (Gould, 1981). This was an important advancement as the field of psychology was evolving from the realms of philosophy and religion to become a discipline based on empirical evidence. How "empirical evidence" is defined, however, needs to keep pace with changes in technology and epistemological advancements.

Even the most influential of ideas have their limitations and disadvantages as they become "normal science" as described by Thomas Kuhn (1970) originator of the paradigm shift concept. According to Kuhn, it is a myth to believe that scientific progress is a simple process of accumulating more and more evidence like pieces fitting into missing blanks in a puzzle until the full picture is realized. Instead, periodically there are fundamental changes in the picture itself (paradigm shifts) that are better able to account for more of the data outside the normal science frame: ". . . anomalies are ignored or explained away if at all possible. It is only the accumulation of particularly troublesome anomalies that poses a serious problem for the existing disciplinary matrix. A particularly troublesome anomaly is one that undermines the practice of normal science" (Bird, 2018).

Numerous multi-intelligence theories have been offered as an alternative to the traditional unitary intelligence. Many theorists have long argued that *g* is unable to adequately account for many valued human mental abilities despite the fact there is no agreed upon scientific definition for general intelligence* (Neisser, 1996; Sternberg & Detterman, 1986). These theories include many noteworthy, but of limited acceptance, ideas such as fluid and crystallized (Cattell, 1971), triarchic (Sternberg, 2012), emotional intelligence (Goleman, 1995; Salovey & Mayer, 1990), structure of intellect (Guilford, 1967); faculties of mind (Thurstone, 1938), and cognitive styles (Kolb & Kolb, 2005). None of these alternatives have had the global and continuing influence of the theory of multiple intelligences as described by Howard Gardner (*Frames of Mind*, 1983) thus posing a significant challenge unlike any other to the essential adequacy of the unitary idea of intelligence.

Despite active resistance from educational institutions, governmental policies and traditional psychologists (Herrnstein, & Murray, 1994; Visser, Ashton, & Vernon, 2006; Waterhouse, 2006; Willingham, 2004), three forces have served to sustain interest in MI theory as a viable alternative to *g*: enthusiastic response from millions of classroom teachers (Chen, Moran, & Gardner, 2009); socio-cultural advances in our understanding of cognition (Immordino-Yang, 2015); and increasingly sophisticated neuroscientific understanding of cognition (Posner, & Barbey, 2020). At the same time that multiple intelligences theory (MI) was inspiring educators worldwide to alter lesson plans, re-envision curriculum, and redesign entire school systems, the theory itself suffered from distortion, over-simplification and a lack of theoretical development**. What started as an inspirational *framework* for a vast number of educators did not evolve to become a more mature scientific theory. This unstable foundation inhibits MI's acceptance and full integration into established educational systems.

Kuhn describes an immature science, in what he sometimes calls its 'pre-paradigm' period, as lacking consensus. Competing schools of thought possess differing procedures, theories, even metaphysical presuppositions. Consequently there is little opportunity for collective progress. Even localized progress by a particular school is made difficult, since much intellectual energy is put into arguing over the fundamentals with other schools instead of developing a research tradition (Bird, 2018).

Despite conflicts among psychologists debating the various multi-intelligence models, has there been an accumulation of evidence that moves MI from its pre-paradigmatic stage to a more fully realized scientific theory? This is the question explored by four lines of investigation described in this article. However, it is first necessary to correct a misapprehension of MI theory that puts it in direct opposition to and denies the existence of general intelligence (*g*). This is an essential shift not only because it accords with a wealth of accumulated evidence but also because according to Kuhn ". . . a worthy replacement (theory of intelligence) must also retain much of the problem-solving power of its predecessor" (Bird, 2018) (clarification added). In other words, don't throw the baby out with the bathwater. Conversely, it is not wise to keep all the dirty bathwater by arguing that babies with grimy grey faces look just fine, e.g., normal according to 20th century science.

MI theory emerged from research in the late 1970s with the goal of shedding light on the question: "What is known about the nature and the development of human potential?" (Gardner, 2020). To extend the metaphor, how can all babies' faces develop so their unique potentials are fully revealed? Gardner concluded that a significant factor undermining people achieving their full potential was the impact of IQ tests on education and the narrow scope of valued abilities (Gardner, 1983).

Multiple Intelligences Theory: A Primer

. . . intelligence is *a biopsychological potential to process information that can be activated in a cultural setting to solve problems or create products that of value in a culture* (Gardner, 1999, p. 33 - 34).

Gardner uses this unique definition of intelligence as the basis for MI theory and candidate intelligences are evaluated according to eight specific criteria (Table 1). Seven intelligences were identified in 1983 and based on further research an eighth intelligence was added in 1999, naturalist, and several other candidate intelligences were rejected. The original seven intelligences are linguistic, logical-mathematical, musical, kinesthetic, visual-spatial, intrapersonal and interpersonal. See Table 2 (and Supplemental Information #1) for details.

While MI theory stands on the shoulders of previous multi-intelligence theories (Guilford, 1967; Thurstone, 1938) it departs from them in two essential ways of both theoretical and practical importance. First, this definition includes thinking skills other than logical reasoning and problem-solving associated with academic achievement (i.e., divergent thinking to create products or provide services). Each of the intelligences can be expressed in qualitatively different ways including creative cognition, insight-intuition, aesthetic judgment and practical problem-solving. Second, intellectual performance is not limited to the individual's innate mind / brain but is "distributed" and influenced by context and social-cultural values (Cole & Engestrom, 1997; Pea, 1993).

It is understandable that psychologists in the normal cognitive science tradition question the validity of an idea that challenges one of its core concepts – general intelligence, *g* or IQ – without presenting reams of data obtained from psychometric testing. However, as Kornhaber explains, "MI was not constructed through formal hypothesis testing and experimental design. Instead, it is what Einstein called a constructive theory, one that offers a reasonable model for understanding a given phenomenon (e.g., variation in human intelligence as manifested in domains across cultures) versus a principle theory, which is built on confirmed, empirical generalizations" (Kornhaber, in press, p. 668).

Table 1. Criteria for Evaluating Candidate Intelligences

1- identifiable cerebral systems
2- evolutionary history and plausibility
3- core set of operations
4- meaning encoded in a symbol system
5- a distinct developmental history & mastery
6- savants, prodigies, and exceptional people
7- evidence from experimental psychology
8- psychometric findings

Source: *Intelligence Reframed* (Gardner, 1999, p. 62) and author, 2020a.

The following discussion examines four lines of investigation from various sources of evidence to determine if MI theory has evolved from a revolutionary cognitive framework hypothesis to a more robust scientific theory that can be further developed and tested according to its own scientific definition.

Multi-disciplinary Evidence for MI Theory in *Frames of Mind*

A primary criticism of MI theory is that there is not enough empirical evidence to support its validity (Herrnstein, & Murray, 1994). Gardner has frequently responded that MI theory is in fact based on "hundreds of empirical studies" cited in *Frames of Mind* (Davis, Christodoulou, Seider, & Gardner, 2011). Is this accurate? A review of the reference lists in *Frames* for two intelligences – kinesthetic and visual-spatial – reveals the following results. For kinesthetic intelligence, there are about 70 citations of scholarly books and articles in authoritative journals. These citations cover a range of sources including neuroscience (n= 14), evolution and developmental biology (n= 6), anthropology (n= 7), cultural and social psychology (n= 20) and cognitive psychology (n= 14). For visual-spatial intelligence, there are about 75 citations of scholarly books and articles in authoritative journals. These citations cover a range of sources including neuroscience (n= 13), evolution and developmental biology (n= 2), anthropology (n= 9), cultural and social psychology (n= 20) and cognitive and experimental psychology (n= 30).

A quick review of five other intelligences in *Frames* shows that the citations tally for each would be equal to or greater than these data.*** The synthetic scientific method Gardner employed emphasizes the accurate description of our human reality from bio-psychological-cultural perspectives that may not be fully captured via typical psychometric tests. The range of data sources considered by Gardner are substantial and aligned with this essential definition.

Investigating the Validity of an MI Self-Report Assessment

Despite a long and influential history, self-report measures are often viewed with suspicion for their lack of validity (Gabriel, Critelli, & Ee, 1994). A multi-tiered program to validate an assessment for the multiple intelligences was conducted over the course of 25 years (Shearer, 2007). This is a self or parent report of a person's skills and abilities as displayed in everyday life. The questions emphasize observable skill-based behaviors with qualitative response choices uniquely written to match each question's content.

Over two decades of validity research can only be summarized here by citing exemplary studies that are available on the web or have been published. Samples of reliability and validity data to accompany the text below are available in Supplemental Information #2 & #3. To determine if a respondent can provide a valid self-assessment it is first necessary to judge the scale's reliability (Giorgi, 1988). This was accomplished first with the English version in North America and then with multiple international samples and translations.

Reliability

MIDAS is unique because it evolved out of a structured clinical interview where the respondent's point-of-view was honored phenomenologically as part of therapeutic or educational relationship. The goal of the MIDAS process is for respondents to simply "describe what you do." This approach has resulted in strong reliability estimates where respondents consistently self-report around specific core constructs both over time and among primary and secondary respondents. As reported in the *Professional Manual* (Shearer, 2007),

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Table 2. Multiple Intelligences: Key Skills, Core Cognitive Components, Behavioral Expressions

Intelligence	Key Skills	Core Cognitive Components	Sample Behavioral Expressions For 4 Cognitive Qualities*
Linguistic	Verbal skill Reading Writing Speaking Rhetoric	Speech Reading Writing Multimodal Communication of Meaning	LP: written directions CC: poetry, fantasy novels II:'ah-ha', spoken/written, zen koans AJ: literary criticism
Logical-mathematical	Reasoning Calculations Math skill Abstraction Meaning making	Mathematical Reasoning Logical Reasoning	LP:calculations, fixing, task analysis CC:finding or describing novel or unique problems II:next best move in strategic AJ:elegant algebraic equations/solutions
Musical	Vocal / Singing Instrumental ability Musical appreciation Improvisation Music and emotions	Music Perception Music and Emotions Music Production	LP:environmental sound or everyday musical performances CC:jazz improvisation II: knowing just the right music enhancing emotion, cognition, behavior AJ:musical criticism
Kinesthetic	Large motor movement Fine motor Dexterity, Tool use Eye Hand coordination Dance, Athletics	Body Awareness/Control Whole Body Movement Dexterity Symbolic Movement	LP:movement analysis for sport or labor CC:modern dance improv II:knowing just the "right" movement for effective performance AJ:dance criticism
Spatial	Mental visualization Imagination Spatial orientation	Spatial Cognition Working with Objects Visual Arts Spatial Navigation	LP: mechanics, engineering, assembly, strategy games, chess CC:fantasy art, II: visualizing the solution or next best move AJ:interior design, art criticism, fashion
Interpersonal	Empathy Theory of mind Interpersonal perspective taking Leadership	Social Perception Interpersonal Understanding Social Effectiveness Leadership	LP:solving conflict between people CC:finding novel, unique solutions II: understanding another person or solution with logical analysis AJ:arranging social interactions that are elegant, inspirational or pleasing
Intrapersonal	Metacognition Emotional intelligence Self-management Impulse control	Self-Awareness Self-Regulation Executive Functions Self-Other Management	LP:logically analyzing a personal situation or problem CC:finding novel or unique solution to a personal question or problem II: knowing just the "right" decision for one's self AJ: arranging a personal plan or experience that provides inspiration or an elegant solution
Naturalist	Understanding animals Plant care Science Classification	Pattern Cognition Understanding Living Entities Understanding Animals Understanding Plant Life Science	LP:use of data and analyses to promote the life or well-being of a living entity CC:finding a novel or unique solution for caring for a living entity II:knowing just the 'right' solution or decision for dealing with a living entity AJ:using nature to create an inspirational or beautiful environment;

Note. ***Cognitive Qualities:** (LP)=Logical-Practical, (CC)=Creative Cognition, (II)=Insight-Intuitive, (AJ)= Aesthetic Judgment. *Sources*: (Shearer, 2020a; Shearer, 2020b)

across several diverse samples (*n*= 4060), mean internal consistencies of each MIDAS scale fall in the high-moderate to high range, with alpha coefficients ranging from .78 to .89 (median = .86)

Similar alpha coefficients were reported by international researchers in Iran (.82 – .90, *m*=.86, (Saeidi, Ostvar, Shearer, & Asghari Jafarabadi, 2015); Turkey (*m*= .87, (Saban, Shearer, Kayıran, & Işık, 2012a); and an Arabic translation in Jordan (ranging from .79 - .86, whole scale = .97 (Al-Onizat, 2014). Temporal stability was found to be acceptable when tested in the U.S. in three studies (one-month coefficients ranging from .76 to 92.) and one study in Jordan (*r*= .85 - .91). Of particular note, are two tests of inter-rater reliability where the respondent's self-rating was compared with select primary and secondary informants "who know you well". The first study found a 40% rate of exact categorical agreement and 80% agreement within one category. The second, larger international study examined 742 paired comparisons and found a 46% rate of exact agreement with 92% agreement within one category (Shearer, 2012b).

Validity

To evaluate validity numerous exploratory, confirmatory, cross-cultural factor analytic and criterion group-related studies were conducted first in North American and then internationally. The initial small sample factor analysis has been followed by numerous international analyses with translations including Turkish (Saban, Shearer, Kayıran, & Işık, 2012); Romanian (Sanda, 2015a & b); and Arabic in Jordan (Al-Onizat, 2014) (see sample in Supplemental 3a). Perhaps most impressive was the cross-cultural, exploratory and confirmatory factor analytic study evidence (Shearer, 2102) (*n*=20,000+) for the MIDAS factor structure that is evident despite translation into languages as diverse as Persian and Korean (Kim, 1999), Chinese (complex as well as simplified characters (Shearer & Wu, 2008) and Spanish (Pizarro, et al, 2003). These results were not always in perfect alignment with MI theory but there was substantial enough agreement to support the idea that the scales were able to discriminate among the eight hypothetical constructs across cultures (Shearer, 2012a).

Most recently, a second large-scale study (*n*= 2000+) with a Persian translation in Iran corresponded very favorably with other data obtained in numerous studies around the world (Saeidi, Ostvar, Derakhshan, & Shearer, 2019). Lastly, predictive and criterion-related validity were also tested. Several studies found that mean scale scores were able to discriminate among subjects with documented abilities. For example, when the linguistic and logical-mathematical scale scores were combined a correlation of *r*= .59 with estimated IQ score was observed (Shearer, 1997; Shearer, 2007). Likewise, an appropriate pattern of correspondence among mean scale scores and matched college majors and adult occupational groups has been reported in several studies (see Supplemental #3c).

Taking seriously the subjective and objective validities of a person's self-report has value for both scientific and practical purposes. If MI is to evolve into a fully formed scientific theory with educational utility, the concept of intrapersonal intelligence needs to be investigated with reliable instrumentation. A large body of evidence suggests that the unique MIDAS structure and its profile verification process are well aligned with MI theory so that a reasonably accurate profile may be obtained.

Psychometric Test Evidence

Evaluating the validity of MI theory with psychometric tests is difficult for several reasons including definitional differences, conceptual confusions, differing statistical interpretations and instrument design. A full description of the psychometric literature pertaining to MI is beyond the scope of this discussion, but the data from several illustrative investigations are instructive. Two different MI test batteries were reviewed. First, the Spectrum assessment system for young children developed by Gardner and colleagues (and two variants) was reviewed (Ramos-Ford, Feldman, & Gardner, 1988). Second, a battery of 16 tests of related MI abilities for adults developed by Visser, Ashton and Vernon were reviewed (2006).

Several investigators have used both exploratory and confirmatory factor analyses to determine if these psychometric tests can distinguish the underlying factors as described by MI theory (Almeida, et al, 2010; Castejon, Perez, & Gilar, 2010; Gridley, 2002; Plucker, Callahan, & Tomchin, 1996; Pyryt, 2000). These analyses provided mixed results which is not unexpected given the mismatch between the differing assumptions of psychometric testing and MI theory. Using confirmatory factor analysis where the factors were allowed to correlate Gridley (2002) concluded, "the loadings of the factors (g) were substantial for the various models, [but] there was still room for interpretation of these factors as separate abilities. . . these performance tasks measure something more than general intelligence . . . the tasks are not so separate from general ability as proposed by the original authors, nor so unitary as argued by their critic" (p. 233).

Despite mixed results, the data from psychometric testing sheds light on two important questions regarding the relationship between MI and general intelligence. First, the data confirms Gardner's proposition that *g* is most strongly associated with a combination of the logical-mathematical and linguistic intelligences (Visser, Ashton, & Vernon, 2006). Second, each of the intelligences have logical problem-solving as one of its behavioral expressions. It is also evident that the core ability assessed by the typical psychometric tests for general intelligence is logical reasoning and problem solving.

Neuroscience Evidence for the Neural Coherence of the Eight Intelligences

Gardner (1983) was one of the first of contemporary theorists to include neural evidence as an essential element in the description of intelligence. Gardner identified several key neural regions known to be crucial for the processing of each intelligence (See Table 3) but the evidence at that time was limited by prevailing technology. Since 1983 there has been an explosion in our understanding of how complex neural systems underpin various cognitive functions (Clark, Boutros, & Mendez, 2010). A multi-phase review of the neuroscience evidence pertaining to each of the multiple intelligences was conducted. Using a rational-empirical methodology, more than 500 studies of brain function (largely fMRI experiments) were matched to the skills and abilities central to each of the eight intelligences. It is noteworthy how well aligned so many neuroscience studies were with the core skills for each intelligence (Shearer, & Karanian, 2017). This made sense given that Gardner rooted MI in the best neuroscience evidence available at the time.

Table 3. The Neural Correlates of the Multiple Intelligences Originally Identified by Gardner

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

Sources. *Frames of Mind* (1983), *Intelligence Reframed* (1999) and Shearer, & Karanian, 2017.

The MI model was examined from five different perspectives essential to validity in studies conducted by neuroscientists in labs around the world since 1983. These studies addressed five essential questions:

1) Are there neural structures directly associated with the core cognitive components for each intelligence?
2) Are these neural structures part of coherent neural networks?
3) Are there neural architectures aligned with specific skill domains within each intelligence?
4) Are there appropriate neural differences among ability groups for each intelligence?
5) What is the relationship between MI and general intelligence in regard to neural functioning?

Summary of Neuroscientific Evidence

This summary is adapted from Shearer, & Karanian, 2017 and Shearer, 2018. The first question investigated the localization of neural cognitive functions for each intelligence. Analyses of over 318 reports indicated that all eight of the proposed intelligences were associated with appropriate neural architectures (Shearer, & Karanian, 2017). These clearly identifiable frameworks were comprised of structures with known cognitive correlates that were well-aligned with the core behavioral components for each of the multiple intelligences. The neural evidence for the multiple intelligences was as robust as the most widely accepted neural models underpinning general intelligence. The neural relationship between MI and general intelligence was as predicted by MI theory where IQ was most closely associated with the logical-mathematical and linguistic intelligence (see Tables 4a - e).

The second investigation involved 417 studies examining the neural correlates for specific skill units within seven intelligences (naturalist not included due to a paucity of data) (Shearer, 2019a). Neural activation patterns demonstrated that each skill unit has its own unique neural underpinnings as well as neural features that were shared with other skill units within its designated intelligence. These patterns of commonality and uniqueness provided a richly detailed neural architecture in support of MI theory as a detailed, scientific model of human intelligences (see sample in Supplemental #4a).

The third investigation examined the neural differences among groups of people of varying ability levels for seven intelligences. This study of over 420 reports found that there were observable and meaningful differences in the neural activation patterns among groups with three levels of ability: skilled, typical, and impaired (Shearer, unpublished). These differential patterns were evidenced in four levels

Tables 4a - 4e. Top Neural Structures Localized for Each MI and General Intelligence

Table 4a. Logical-Mathematical and Linguistic: A review of top neural structures

		Logical-Mathematical		Linguistic	
		Primary	**Sub-regions**	**Primary**	**Sub-regions**
Rank	1	Frontal Cortex	Prefrontal Cortex Inferior Frontal Gyrus	Temporal Cortex	Superior Temporal Gyrus
	2	Parietal	Intraparietal Sulcus Inferior Parietal Lobule Angular Gyrus	Frontal Cortex	Broca's Area Motor Cortex
	3	Temporal Cortex	Medial Temporal Lobe	Parietal	Inferior Parietal Lobule Supramarginal Gyrus Angular Gyrus

PFC= Prefrontal Cortex

Table 4b: Interpersonal and Intrapersonal: A review of top neural structures

		Interpersonal		Intrapersonal	
		Primary	**Sub-regions**	**Primary**	**Sub-regions**
Rank	1	Frontal Cortex	Prefrontal Cortex	Frontal Cortex	Prefrontal Cortex
	2	Temporal Cortex	Medial Temporal Lobe Amygdala Superior Temporal Sulcus	Cingulate Cortex	Anterior Cingulate
	3	Cingulate Cortex	Anterior Cingulate	Temporal Cortex	Medial Temporal Lobe Anterior Temporal Lobe Amygdala
	4	Parietal Cortex		Parietal Cortex	Medial Parietal Cortex Inferior Parietal Cortex
	5			Subcortical	Basal Ganglia Brainstem

Table 4c. Spatial and Naturalist: A review of top neural structures

		Spatial		Naturalist	
		Primary	**Sub-regions**	**Primary**	**Sub-regions**
Rank	1	Frontal Cortex	Motor Cortex Prefrontal Cortex	Temporal Cortex	Superior Temporal Sulcus Amygdala
	2	Parietal Cortex	Intraparietal Sulcus Superior Parietal Lobe	Subcortical Structures	Brainstem Thalamus Basal Ganglia
	3	Temporal Cortex	Medial Temporal Lobe	Frontal Cortex	-
	4	Occipital Cortex	-	Occipital Cortex	-
	5	-	-	Parietal Cortex	-

Table 4d. Musical and Kinesthetic: A review of top neural structures

		Musical		Kinesthetic	
		Primary	**Sub-regions**	**Primary**	**Sub-regions**
Rank	1	Frontal	Motor Cortex	Frontal Cortex	Motor Cortex Primary Motor Premotor Supplementary Motor
	2	Temporal Cortex	Superior Temporal Sulcus Primary Auditory Cortex	Parietal Cortex	Posterior Parietal Cortex
	3	Subcortical Structures	Basal Ganglia	Subcortical	Basal Ganglia Thalamus
	4	-	-	Cerebellum	-

Table 4e. Neural Highlights for General Intelligence

General Intelligence Neural Highlights					
Primary	**%**	**Sub-regions**	**%**	**Frontal Structures**	**Ct.**
Frontal	33	Inferior Parietal Lobule	10	Prefrontal Cortex	12
Parietal	33	Prefrontal Cortex	9	Inferior Frontal Gyrus	6
Temporal	15	Anterior Cingulate	6	Posterior Inferior Frontal Gyrus	4
Cingulate	12	Inferior Frontal Gyrus	5	Broca's Area	4
		Supramarginal Gyrus (Angular Gyrus)	4		
Total	100	Total	132	Total	47

of brain analysis: primary regions, sub-regions, particular structures, and multi-region activations. These data indicated that there were distinctive neural differences for each MI among ability groups (see sample in Supplemental Information #4b).

The fourth investigation addressed the question, are there intrinsic, resting-state functionally connected (rsFC) neural networks related to each of the multiple intelligences? This study of 48 rsFC studies found seven to fifteen neural networks that were clearly aligned with each of the multiple intelligences and with general intelligence (Shearer, 2020a). Twelve whole brain, model-free rsFC investigations revealed 13 neural networks that were closely associated with seven of the eight intelligences. These data were supported by 35 region-of-interest, model-dependent studies that also identified 20 sub-networks associated with multiple intelligences and specific skills. These data indicated that the neural regions with cognitive correlates associated with the eight intelligences form coherent units with well aligned sub-units (Supplemental Information #4c).

The fifth investigation compared the neural architectures cited for general intelligence with a proposed new category of Cognitive Qualities associated with the multiple intelligences. This investigation of 94 neuroscientific studies found neural support for the coherence of Cognitive Qualities as distinct from the convergent problem-solving of IQ (Shearer, 2020b). A similar neural pattern was evidenced among the three Cognitive Qualities (Creative Cognition, Insight-Intuition, Aesthetic Judgment) that are valued abilities integral to the definition and practical expression of each of the eight intelligences (see sample in Supplemental Information #4d).

Discussion

The evidence provided by Gardner in 1983 and elaborated in 1999 for MI can best be termed as a *framework* that has been useful to inspire educators, but not accepted by cognitive or neuroscientists. To investigate validity, numerous sources from a variety of perspectives have been gathered, compiled, and tested across cultures and over time.

Extensive psychometric evidence from around the world for an MI self-assessment indicated that informants can be reliable reporters and these reports are correlated with external measures. However, for practical applications precautions need to be taken during profile interpretation to account for possible distortions by a respondent. Extensive data analyses (over 10,000 cases were factor analyzed) demonstrated that the factor structure of an MI self-questionnaire corresponded with MI theory for many different samples including adults and children from North America, Chile, India, Iran, Jordan, Romania, Singapore, Taiwan and Turkey. This was impressive for cross-cultural validity considering that the questionnaire was successfully translated into several different languages for local use in research and education.

Psychometric evidence from MI-inspired tests provides insight into how general intelligence is related to the multiple intelligences as well as a variety of mixed factorial analytic models of MI theory. Lastly, detailed analyses of over 500 neuroscientific studies of cognitive-behavioral skills aligned with MI were reviewed to reveal coherent neural architectures for each of the eight intelligences.

Taken together, these data offer a comprehensive overview of MI theory that moves it forward from a basic framework to a more richly detailed and nuanced description of the intelligences. This work demonstrates that there were both neural and cognitive bridges that integrate MI with *g* theory in ways that do not diminish the importance of either models. Of course, the logical processing capacities at the core of *g* theory are important and they are captured largely by the logical-mathematical and linguistic intelligences (Shearer, & Karanian, 2017). Combining these two intelligences increases the explanatory power of *g*, but this alone cannot fully describe the unique and diverse powers of human intelligence. Clouding data analysis was the interesting finding that each of the eight intelligences are a composite of diverse abilities including both general intelligence-type skills (logical reasoning and problem-solving) and divergent thinking, so the relationship of MI to *g* is complicated.

Detailed descriptions of the neural correlates for eight intelligences and their sub-components provides a basis for experimentally testing their neural coherence and inter-relatedness under real-world conditions. Such research will be required to determine if MI will continue to mature into a scientific theory that can be something more than an inspirational framework for educators.

Conclusions and Future Directions

Kuhn (1970) refers to challenges to conventional scientific ideas as being "revolutionary" and MI has often been described as such. This accorded with the multitude of curricular changes that it was inspiring around the world. As with most revolutions, there was strident backlash by critics from the normal science perspective and educational traditionalists (Kornhaber, in press). The ultimate goal for a scientific investigation is to see beyond the shining allure of a new theory that provokes unquestioned enthusiasm or conversely excessive critical condemnation. In other words, is MI a real diamond or is it cubic zirconia? This investigation examined MI theory from numerous perspectives, and the evidence pointed to MI theory as a diamond-in-the-rough. If a good scientific theory has predictive power, then MI holds up well after 40 years, but it remains a work-in-progress.

This diamond has numerous facets that shine most brightly in the eyes of teachers but there are cloudy surfaces that require new cuts and polishing if its true value as a scientific theory is to be clarified. Rather than being revolutionary (implying radical upheaval) it is best to describe MI theory as being "extra-ordinary" which is Kuhn's (1970) other name for an alternative theory that sparks a paradigm shift. MI encompasses aspects of ordinary general intelligence while embracing abilities that are something "extra"— outside the limits of logical, convergent problem-solving.

For an extraordinary idea to move from the fringes to make a paradigmatic change to normal science an extended exploration of how the new theory accounts for anomalies is necessary (Kuhn, 1970). A research tradition has yet to be established for MI theory, but our data provides a foundation for continued development in five directions. First, clarify the relationship among the intelligences and general cognitive dimensions such as attention, concentration, abstract thinking and memory. Second, develop MI theory as a foundation for educational cognitive neuroscience based on comprehensive neural models for each intelligence. Explicate how MI theory bridges between everyday skills and divergent abilities and those primarily associated with general intelligence. Investigate how MI theory can serve and support educators as they personalize curriculum in order to maximize student engagement and achievement. Lastly, clarify how MI theory aligns with or deviates from cultural expressions around the world.

Accomplishing these five objectives will build a theoretical foundation for MI theory to support and inspire greater integration of teaching with neuroscience evidence. Such confidence building measures will ensure that important educational traditions will not be neglected for the sake of personalizing instruction via an MI-inspired curriculum. Future development requires that such practices can be scaled up with fidelity so MI theory may maximize the development of all students regardless of culture or profile configuration.

*At least two efforts were made to survey leading psychologists (Intelligence and Its Measurement: A symposium, 1921) and again in 1986 by Sternberg and Detterman regarding the definitive definition of intelligence. The results of both efforts led Ulric Neisser (1996) to conclude "…their answers reflected little agreement and had little practical influence…" regarding this "magical essence" that is the subject of so many varied psychometric tests. Neisser also concluded "… many of the relevant characteristics [of intelligence] are simply impossible to measure." (p. 217).

** The idea that multiple intelligences and learning styles are synonymous is a conceptual error has been promulgated by teachers and theorists alike. Gardner (1995, 2006) has attempted to clarify the distinction in numerous writings but normal science theorists continue to insist the MI fits into their framework by blurring the line between personality characteristics and abilities. People may certainly have preferences regarding each intelligence but the defining feature of MI theory is its emphasis on skills and abilities (Gardner, 2013; Shaler, 2006). More than 70 different learning styles theories have been identified so it is impossible to know what exactly is meant by this term (Coffield, Moseley, Hall, & Ecclestone, 2004)

*** The exceptions to this are the interpersonal and intrapersonal intelligences which have fewer citations. This is most likely because of the novelty at the time of describing these capabilities as "cognitive abilities" rather than merely personality characteristics. Since 1983, a wealth of experimental research has established that these skill sets are indeed cognitive abilities that are important in daily life and to humanity.

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