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Neurobiology of Intelligence: Emotional, Social, and Spiritual Dimensions in the Light of Neuroplasticity

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Abstract

Contemporary neuroscience has substantially expanded our understanding of human intelligence beyond traditional psychometric models. Current evidence indicates that intelligence emerges from the dynamic interaction of cognitive, emotional, social, and higher-order meaning-oriented processes, supported by distributed functional brain networks and continuously shaped by neuroplastic mechanisms. This narrative review synthesizes contemporary evidence from cognitive neuroscience, neuropsychology, and behavioral science concerning the neurobiological foundations of human intelligence. The literature was identified through a structured, non-systematic search of PubMed/MEDLINE, Scopus, and Google Scholar, prioritizing meta-analyses, large neuroimaging and lesion studies, and seminal theoretical works. The review also proposes a theoretical, not yet empirically validated, integrative framework in which experience-dependent neuroplasticity is considered a shared biological substrate that may link multiple adaptive dimensions of human functioning.

The reviewed evidence indicates that intelligence is not localized to isolated brain regions but instead emerges from the coordinated activity of distributed neural networks, including the executive, salience, and default mode networks. Neuroplasticity supports lifelong structural and functional brain adaptation in response to learning, experience, environmental influences, and social interaction, while cognitive, emotional, and social processes interact closely but remain conceptually and psychometrically distinct constructs. Plasticity is, however, not invariably beneficial, as the same mechanisms can also support maladaptive learning. In addition, meaning-oriented processes, including self-awareness, value integration, purpose in life, and existential reflection, may represent higher-order adaptive functions that contribute to resilience and psychological well-being, although their precise neurobiological mechanisms remain under investigation.

Overall, while psychometric general intelligence (g) remains the most robustly validated construct, human adaptive functioning may be usefully conceptualized as a dynamic system in which neuroplasticity provides a common substrate through which cognitive, emotional, social, and meaning-oriented processes interact throughout the lifespan. Testable predictions derived from this framework are outlined. This integrative perspective offers a contemporary framework for understanding adaptive human behavior and identifies promising directions for future interdisciplinary research in neuroscience, psychology, psychiatry, and behavioral medicine.

Categories: Neurology
Keywords: adaptive behavior, brain networks, cognitive intelligence, emotional intelligence, human intelligence, meaning-oriented processes, neurobiology, neuroplasticity, neuroscience, social intelligence

Introduction And Background

Human intelligence is among the most complex and extensively studied constructs in contemporary science. For more than a century, it has been the focus of intensive research in psychology, neuroscience, cognitive science, and, more recently, systems neuroscience. Traditionally, intelligence was conceptualized as a general cognitive ability that could be quantified through psychometric assessment and expressed as an intelligence quotient (IQ) [1,2]. Although this approach substantially advanced the scientific study of cognition, it offered only a partial explanation of the remarkable complexity of human adaptive behavior.

Advances in cognitive neuroscience and the development of modern neuroimaging techniques have fundamentally transformed this traditional perspective [3]. Current evidence indicates that human intelligence cannot be attributed to the activity of a single brain region or explained solely by cognitive performance [3]. Rather, intelligence emerges from the dynamic interaction of large-scale functional brain

networks that collectively support executive control, learning, memory, emotional regulation, social cognition, and adaptive decision-making [3,4].

Equally transformative has been the recognition of neuroplasticity, which has challenged the long-standing assumption that intelligence is a fixed and immutable characteristic. Throughout life, the human brain retains the capacity to modify its structural and functional organization in response to learning, environmental demands, social interaction, and lived experience. Through continuous synaptic remodeling and large-scale network reorganization, neuroplasticity provides the biological foundation for lifelong adaptation and cognitive development [5]. Importantly, plasticity is valence-neutral: the same mechanisms that support learning can also entrench maladaptive patterns, such as persistent fear responses or addiction [6,7].

Increasingly, evidence from neuroscience, psychology, and the behavioral sciences indicates that successful human adaptation cannot be understood solely in terms of intellectual performance. Emotional regulation, interpersonal competence, social integration, resilience, and the ability to derive meaning from life experiences all contribute to adaptive functioning and psychological well-being. Although cognitive, emotional, and social intelligence are well-established areas of research, growing interdisciplinary interest has also focused on the human capacity for meaning-making, self-transcendence, and value-oriented decision-making, constructs discussed within the broader framework of spiritual intelligence [8]. While this concept remains the subject of ongoing scientific debate, it reflects an emerging effort to understand how existential and value-based processes contribute to human adaptation and flourishing [9].

Despite substantial scientific progress, these dimensions of intelligence are still frequently examined as distinct constructs. Accordingly, there is a growing need for an integrative framework that bridges classical theories of intelligence with contemporary advances in systems neuroscience, network neuroscience, and neuroplasticity. This narrative review aims to synthesize current scientific evidence on the neurobiological foundations of human intelligence, with particular emphasis on the role of neuroplasticity and the functional integration of large-scale brain networks in shaping adaptive human behavior. This review further advances an interdisciplinary perspective in which cognitive, emotional, social, and meaning-oriented (spiritual) processes are understood as distinct but interacting constructs supported by partially overlapping and plastic brain networks that evolve continuously through reciprocal interactions among the brain, individual experience, and the social environment.

In this review, the term “intelligence” in its strict sense refers to psychometric intelligence, that is, general cognitive ability (g) and the broad abilities hierarchically organized beneath it, as measured by standardized tests [8,10]. Emotional and social intelligence are discussed as related but distinct constructs with their own theoretical models and measures, whereas emotional regulation, interpersonal competence, resilience, and well-being are treated as adaptive outcomes or correlates rather than as forms of intelligence. “Spiritual intelligence” is discussed as a debated, meaning-oriented construct whose status as an intelligence has not been validated. Accordingly, when we refer to an integrated adaptive system, we mean the interaction of these distinct constructs, not their equivalence.

The specific contribution of this review is threefold. First, it bridges psychometric and network neuroscience accounts of intelligence, such as the parieto-frontal integration theory (P-FIT) and network neuroscience theory, with the triple-network model and the neuroscience of emotion and social cognition, literatures that are usually reviewed separately [3,10,11]. Second, it explicitly distinguishes established mechanisms from theoretical proposals and treats meaning-oriented processes as a debated construct that can be operationalized through validated measures, such as meaning in life, rather than as an established intelligence. Third, it formulates testable hypotheses linking measurable psychological constructs to network-level plastic changes.

Literature search strategy

This narrative review was prepared following the recommendations of the Scale for the Assessment of Narrative Review Articles (SANRA) [12]. Relevant literature was identified through searches of PubMed/MEDLINE, Scopus, and Google Scholar covering publications from 1990 to September 2026, supplemented by hand-searching reference lists and seminal books for historical and theoretical context. The principal search terms, used alone and in combination, were “intelligence,” “general intelligence,” “g factor,” “emotional intelligence,” “social intelligence,” “social cognition,” “theory of mind,” “empathy,” “spiritual intelligence,” “meaning in life,” “neuroplasticity,” “synaptic plasticity,” “adult neurogenesis,” “brain networks,” “default mode network,” “salience network,” “central executive network,” and “parieto-frontal integration theory.” English-language sources were prioritized according to the following hierarchy: (i) meta-analyses and systematic reviews; (ii) large-sample neuroimaging, lesion-mapping, longitudinal, and interventional studies; (iii) influential theoretical papers and authoritative reviews; and (iv) books, used mainly for historical context and the original formulation of theoretical constructs. Clinical studies were included when they informed rehabilitation and translational outcomes. Consistent with the narrative design, no formal risk-of-bias assessment or quantitative synthesis was performed; therefore, the conclusions should be regarded as interpretive rather than exhaustive.

Review

Contemporary perspectives on human intelligence

Historical Evolution of the Concept of Intelligence

The concept of intelligence has long held a central place in psychology and cognitive science and, more recently, in neuroscience [1]. Early scientific theories primarily defined intelligence as the capacity to acquire knowledge, reason logically, solve problems, and adapt effectively to environmental demands [13].

The emergence of psychometrics in the early twentieth century marked a significant milestone in the scientific study of intelligence. Among the most influential theoretical contributions was Charles Spearman's concept of the general intelligence (g) factor, which proposed that performance across diverse cognitive tasks reflects a common underlying mental capacity [14]. This model provided the conceptual foundation for standardized intelligence testing and profoundly influenced educational, clinical, and psychological assessment for decades [15].

The g factor remains one of the most replicated findings in differential psychology. Positive correlations among diverse cognitive tests (the “positive manifold”) are consistently observed, and the g factors extracted from different test batteries are almost perfectly correlated [16]. Hierarchical models, culminating in the Cattell-Horn-Carroll framework, integrate g with broad abilities such as fluid and crystallized intelligence [15,17]. Psychometric g predicts educational attainment, occupational performance, and health outcomes, is substantially heritable, and has identifiable structural and functional neural correlates [18]. Accordingly, the multidimensional approaches discussed below are presented as complementary to, rather than as having superseded, psychometric models.

As research in psychology and neuroscience has advanced, it has become increasingly evident that human adaptation cannot be adequately explained by cognitive abilities alone [19]. Effective functioning depends not only on reasoning and problem-solving but also on emotional regulation, behavioral flexibility, interpersonal competence, and the capacity to respond adaptively to changing environmental and social contexts [20]. This conceptual evolution has stimulated a multidimensional perspective alongside psychometric models, in which cognitive, emotional, and social processes are regarded as complementary components of adaptive human functioning [1].

More recently, increasing attention has been directed toward the human capacity to construct meaning, maintain coherent personal values, and integrate life experiences into a broader existential framework [8]. Although these processes are often discussed under the umbrella of spiritual intelligence, they are more appropriately regarded as higher-order adaptive functions that remain subjects of active interdisciplinary investigation rather than as established neurobiological constructs [21].

Contemporary Theories of Intelligence

Advances in psychology, cognitive neuroscience, and the behavioral sciences have led to the development of theoretical models that conceptualize intelligence as a multidimensional phenomenon. Although these models differ in their underlying assumptions, they share the view that successful human adaptation cannot be explained solely by a single general cognitive ability [1].

One of the most influential frameworks is Howard Gardner's Theory of Multiple Intelligences, which proposes that human intelligence comprises several relatively independent yet complementary domains, including linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, interpersonal, and intrapersonal abilities. This framework significantly broadens the traditional concept of intelligence by emphasizing the diversity of human cognitive potential [19].

Subsequently, Peter Salovey and John Mayer introduced the concept of emotional intelligence, which Daniel Goleman later popularized [20,22]. This concept emphasizes the importance of recognizing, understanding, regulating, and effectively applying emotions in personal and social contexts [20]. Emotional competence is now widely studied in relation to psychological well-being, interpersonal relationships, leadership, and adaptive decision-making [22].

Similarly, the concept of social intelligence has gained increasing prominence alongside advances in social neuroscience. Social intelligence encompasses the ability to understand others' intentions, beliefs, emotions, and behaviors and to respond appropriately in complex social environments [23]. These functions are supported by distributed neural systems involved in empathy, perspective-taking, social learning, and interpersonal communication [24].

Rather than viewing these domains as isolated forms of intelligence, the present review adopts an integrated adaptive system as a working hypothesis, in which cognitive, emotional, and social processes continuously interact through the coordinated activity of large-scale brain networks [25]. This systems-based perspective

serves as the conceptual foundation for the present review, while recognizing that these constructs differ in definition, measurement, and degree of empirical validation. The principal theories of intelligence are summarized chronologically in Table *1*.

Year	Author(s)	Theory/model	Core proposition
1904	Binet and Simon [26]	First standardized intelligence scale	Intelligence assessed through age-graded tasks of judgment and reasoning; origin of mental age and, later, of the IQ
1904/1927	Spearman [14]	Two-factor theory; g	Positive correlations among diverse tests reflect a common general factor plus task-specific factors
1920	Thorndike [27]	Social intelligence	Ability to understand and manage people; distinguished from abstract and mechanical intelligence
1963	Cattell [17]	Gf and Gc	General ability comprises reasoning with novel problems (Gf) and acquired knowledge (Gc)
1983	Gardner [19]	Multiple intelligences	Several relatively independent intelligences (linguistic, logical-mathematical, spatial, musical, bodily-kinesthetic, interpersonal, and intrapersonal)
1985	Sternberg [28]	Triarchic theory (later adaptive intelligence [2])	Analytical, creative, and practical abilities used to adapt to, shape, and select environments
1990	Salovey and Mayer [20]	Emotional intelligence (ability model)	Abilities to perceive, use, understand, and manage emotions, measured with performance tests
1993	Carroll [15]	Three-stratum theory (basis of the CHC model)	Hierarchy of g, broad abilities, and narrow abilities derived from factor analysis of hundreds of datasets
1995	Goleman [22]	Mixed model of emotional intelligence	Combines emotional abilities with motivational, personality, and social competencies
2000	Emmons [29]; Zohar and Marshall [30]	Spiritual intelligence	Adaptive use of spiritual and meaning-related resources; its status as an intelligence is disputed [31]
2001	Petrides and Furnham [32]	Trait emotional intelligence	Emotion-related self-perceptions located within personality hierarchies, measured by self-report
2007	Jung and Haier [10]	P-FIT	Individual differences in intelligence depend on a distributed fronto-parietal network
2018	Barbey [3]	Network neuroscience theory	g reflects the flexibility and dynamic reconfiguration of large-scale brain network topology

TABLE 1: Chronological overview of the principal theories of human intelligence

CHC: Cattell-Horn-Carroll; IQ: intelligence quotient; P-FIT: parieto-frontal integration theory; g: general intelligence; Gf: fluid intelligence; Gc; crystallized intelligence

Neurobiological Foundations of Intelligence

Advances in neuroimaging and systems neuroscience have substantially reshaped our understanding of the biological foundations of intelligence [10]. Current evidence indicates that intellectual functioning does not arise from isolated cortical regions but instead emerges from the coordinated interaction of distributed neural networks that support cognition, emotion, and social behavior [3].

Central to this perspective is the organization of the brain into large-scale functional networks [33]. Among the most extensively investigated are the default mode network (DMN), associated with self-referential processing, autobiographical memory, and internal mentation [25]. The central executive network (CEN), which supports executive control, working memory, and goal-directed behavior, and the salience network (SN), which detects biologically and behaviorally relevant stimuli and dynamically coordinates communication between the DMN and CEN [11].

The efficiency of these networks depends not only on the activity of individual brain regions but also on the quality of functional connectivity among them [4]. Effective integration across frontal, parietal, temporal, and limbic structures enables higher-order cognitive functions, including reasoning, planning, decision-making, emotional regulation, and social cognition, whereas disruptions in network connectivity have been implicated in numerous neurological and psychiatric disorders [3,34]. Collectively, these findings are consistent with the contemporary view that intelligence represents an emergent property of a highly interconnected and continuously adaptive neural system rather than the output of isolated cognitive modules.

An important caveat applies to all the network-level associations discussed in this review. Large-scale networks and individual regions are functionally pleiotropic: the prefrontal cortex, insula, and anterior cingulate cortex, for example, are engaged in attention, interoception, pain, cognitive control, and emotion alike [35]. Inferring a specific psychological construct, let alone a specific form of intelligence, from regional activation constitutes reverse inference, which is justified only when activation is selective for that process [36]. Throughout this review, network findings are therefore treated as correlates rather than as direct evidence of a particular type of intelligence. The strongest inferences derive from convergent evidence across neuroimaging, lesion mapping, behavioral assessment, and meta-analysis, such as lesion-mapping studies showing that general and emotional intelligence depend on overlapping, distributed frontoparietal substrates [37].

Neuroplasticity and the development of human intelligence

Neuroplasticity is among the most transformative discoveries in contemporary neuroscience [38]. It refers to the brain's capacity to modify its structural organization and functional connectivity in response to experience [39]. This concept has fundamentally challenged the traditional view of the mature brain as a static, immutable organ, demonstrating that the human nervous system retains the capacity for structural and functional reorganization throughout life in response to learning, experience, environmental demands, and social interaction [40,41].

This lifelong adaptive capacity is mediated by multiple biological mechanisms, including synaptic remodeling, dendritic reorganization, changes in neuronal excitability, and dynamic modifications to the functional connectivity of large-scale brain networks [42,43]. These mechanisms provide the neurobiological foundation for learning, memory, behavioral adaptation, and cognitive development [5].

Beyond cognition, a growing body of evidence indicates that neuroplasticity also contributes to emotional regulation, social learning, resilience, and adaptive behavior [9]. Through experience, the brain's functional architecture is continuously shaped, enabling individuals to respond effectively to changing biological, psychological, and environmental demands [44,45]. Two claims should, however, be kept distinct. The first, which is well established, is that experience-dependent plasticity underlies learning and neural adaptation across cognitive, emotional, and social domains. The second, which represents the theoretical proposal of this review, is that plasticity provides a common substrate through which these domains interact and co-develop. Plasticity per se does not establish that these processes form a single intelligence system or that neuroplastic change necessarily improves intelligence. The same mechanisms also mediate maladaptive learning, such as conditioned fear and the persistence of anxiety-related responses, as well as drug-induced synaptic remodeling in addiction [6,7].

Biological Mechanisms of Neuroplasticity

Neuroplasticity is supported by a broad spectrum of molecular, cellular, and network-level mechanisms that enable the nervous system to adapt continuously throughout the lifespan, thereby underpinning learning, memory consolidation, cognitive flexibility, and behavioral adaptation [5,43,46]. Among the most extensively investigated mechanisms is synaptic plasticity, defined as the activity-dependent strengthening or weakening of synaptic connections [42]. Long-term potentiation (LTP) and long-term depression (LTD) are the best-characterized cellular models of synaptic mechanisms underlying long-term learning and memory formation. The strongest causal evidence comes from studies of hippocampal- and amygdala-dependent learning in animal models [47]. These mechanisms remain central concepts in modern neuroscience [48,49].

Neuroplastic adaptation also encompasses structural remodeling, including dendritic spine formation, axonal reorganization, and synaptogenesis [50,51]. Adult neurogenesis is a more contested mechanism. It is robust in the rodent dentate gyrus, but its extent in humans remains controversial: some post-mortem studies report that hippocampal neurogenesis declines to undetectable levels in adulthood, whereas others, using different tissue-processing methods, describe persistent neurogenesis into old age [52,53]. Its extent and functional significance therefore vary by species, brain region, age, and methodological interpretation, and it should not be regarded as a general mechanism of human intelligence [54]. These processes enhance the efficiency and flexibility of neural communication, enabling the brain to adapt to novel cognitive and environmental challenges [55].

Both biological and environmental factors substantially influence the expression of neuroplasticity [9]. Age, genetic background, physical exercise, nutrition, sleep quality, chronic stress, cognitive stimulation, and social interaction all modulate the brain's adaptive capacity [56]. Among the molecular mediators, brain-derived neurotrophic factor (BDNF) plays a pivotal role in neuronal survival, synaptic plasticity, learning, and memory. It is considered an important regulator of experience-dependent neural adaptation, largely on the basis of animal studies [57].

Overall, the direct evidence linking these mechanisms to specific functions is strongest for learning and memory and for fear and extinction learning, whereas their roles in complex emotional, social, and meaning-oriented capacities are currently inferred from indirect evidence. In this review, the latter links are therefore presented as proposed explanatory relationships rather than as established mechanisms.

Experience, Environment, and Lifelong Brain Adaptation

The human brain develops through continuous interactions with its physical, social, and cultural environment [38]. Experience is not merely a consequence of brain function; rather, it actively shapes neural organization and functional connectivity throughout life [45]. This process represents one of the fundamental mechanisms through which neuroplasticity is thought to contribute to the development of adaptive behavior [44].

Formal education, cognitively stimulating activities, lifelong learning, and intellectually enriched environments have been associated with structural and functional changes in neural systems involved in executive functioning, attention, memory, and problem-solving [58,59]. The strength of this evidence varies: training studies demonstrate experience-dependent gray matter changes, and education causally increases measured intelligence; however, whether these structural changes mediate the cognitive gains has not been established [58-60]. Similarly, supportive interpersonal relationships and meaningful social engagement are associated with the development of neural circuits underlying empathy, emotional regulation, and social cognition [45]. Conversely, chronic psychosocial stress, prolonged social isolation, adverse childhood experiences, and persistent activation of the hypothalamic-pituitary-adrenal (HPA) axis may impair synaptic plasticity and reduce the efficiency of functional brain networks involved in cognition and emotional regulation [9].

Lifestyle factors exert comparably significant effects on brain plasticity [61]. Regular physical exercise, restorative sleep, balanced nutrition, ongoing intellectual engagement, and sustained social participation have consistently been associated with increased expression of neurotrophic factors, enhanced functional connectivity, and the preservation of cognitive performance during healthy aging [62,63]. Most of this evidence is observational. Randomized trials support some specific effects; for example, aerobic exercise increases hippocampal volume and modestly improves memory in older adults, whereas cognitive-training programs produce gains on trained tasks, with limited transfer to g [64-66]. The direction and magnitude of these effects differ across interventions and populations, and it should not be assumed that all favorable lifestyle or social experiences enhance intelligence through a common biological pathway.

The multidimensional nature of human intelligence

Contemporary neuroscience increasingly supports the view that human intelligence cannot be adequately characterized as a single cognitive ability or as the function of isolated brain regions [3]. Instead, intelligent behavior is increasingly understood as emerging from ongoing interactions among multiple neural networks responsible for cognition, emotion, social behavior, and adaptive decision-making [67].

This systems-based perspective complements traditional psychometric models by providing a more integrated understanding of human functioning [4]. Cognitive performance, emotional regulation, interpersonal competence, and adaptive behavior are increasingly studied as interdependent, though distinct, processes supported by large-scale functional brain networks that continuously reorganize through neuroplastic mechanisms [11,25].

Cognitive Intelligence

Cognitive intelligence encompasses the mental processes that enable individuals to acquire knowledge, reason, learn, solve problems, make decisions, and adapt to novel situations. These processes include attention, memory, executive control, working memory, abstract reasoning, cognitive flexibility, and planning, all of which contribute to goal-directed behavior [13].

Neuroscientific evidence indicates that cognitive intelligence is not localized to a single cortical region but instead arises from coordinated activity across distributed neural systems [10]. Functional interactions among the prefrontal, posterior parietal, and anterior cingulate cortices, as well as other association areas, provide the neural substrate for executive functioning and complex cognitive performance [68].

One of the most influential neurobiological models, the P-FIT, proposes that intellectual performance

depends primarily on the efficiency of information transfer between frontal and parietal brain regions rather than on activity within isolated regions [10]. This model has received substantial support from structural and functional neuroimaging studies examining individual differences in intelligence [67].

Importantly, cognitive intelligence is continually shaped by experience [38]. Quasi-experimental evidence indicates that education causally increases measured intelligence by approximately one to five IQ points per additional year of schooling, whereas commercial and working memory training programs improve performance on trained tasks, with little or no transfer to g [60,65,66]. At the same time, individual differences in g show high rank-order stability across the lifespan [18]. Cognitive intelligence should therefore be regarded as relatively stable in rank order but modifiable in level, with neuroplastic mechanisms providing a plausible, though not yet directly demonstrated, mediating pathway [5].

Emotional Intelligence

Emotional intelligence refers to the capacity to perceive, understand, regulate, and appropriately express emotions in oneself and others [69]. Since its introduction by Peter Salovey and John Mayer [20] and its subsequent popularization by Daniel Goleman [22], it has become an important construct in psychology, organizational science, education, and behavioral medicine.

Three main approaches to emotional intelligence should be distinguished because they differ in their theoretical foundations and assessment methods [70]. Ability emotional intelligence, as formulated by Mayer and Salovey, conceptualizes emotional intelligence as a set of cognitive-emotional abilities measured using maximum-performance tests such as the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) [69,71]. Trait emotional intelligence refers to emotion-related self-perceptions and dispositions, assessed through self-report and situated within personality hierarchies [32]. Mixed models, such as those proposed by Goleman and Bar-On, combine emotional abilities with motivational, personality, and social competencies [22,72]. Ability measures correlate moderately with g, whereas trait and mixed measures overlap substantially with personality traits [70]. Unless otherwise specified, this review refers to the ability-based construct, which is most closely aligned with the psychometric notion of intelligence.

Neuroimaging research has associated the emotional processes relevant to emotional intelligence with cortical and subcortical regions, including the prefrontal cortex, amygdala, anterior cingulate cortex, insular cortex, and other limbic structures [73,74]. Collectively, these regions contribute to emotional awareness, behavioral inhibition, empathy, and adaptive responses to emotionally salient stimuli [75].

Effective emotional regulation relies on the dynamic balance between executive control networks and neural systems involved in emotional processing [74]. The optimal integration of these systems supports psychological resilience, adaptive decision-making, stress regulation, and healthy interpersonal relationships [75]. Conversely, impaired communication among these networks has been associated with numerous psychiatric and neurological disorders [76].

These associations should be interpreted cautiously. The prefrontal cortex, amygdala, insula, and anterior cingulate cortex are not specific to emotional intelligence; they participate in a wide range of affective and non-affective functions [35,73]. Moreover, most studies examine emotional processes, such as emotion perception or reappraisal, rather than individual differences in emotional intelligence measured as an ability. Inferring a distinct neural basis for emotional intelligence from such associations therefore risks reverse inference [36]. Lesion-mapping evidence suggests instead that ability emotional intelligence relies on a distributed network that largely overlaps with the network supporting g [37].

Emotion-regulation skills are also responsive to experience [38]. Factors such as the family environment, education, social interaction, psychotherapy, mindfulness practices, and other life experiences have been associated with functional reorganization of the neural circuits underlying emotional regulation, although it remains unclear whether these neural changes mediate improvements in measured emotional intelligence [9].

Social Intelligence

Social intelligence refers to the capacity to understand, anticipate, and respond appropriately to the thoughts, emotions, intentions, and behaviors of others [24]. This ability is essential for interpersonal communication, cooperation, empathy, leadership, and effective adaptation to increasingly complex social environments [77].

In this review, social intelligence is used as an umbrella term rather than as a single measurable ability. Psychometric attempts, dating back to Thorndike, to isolate social intelligence as a factor distinct from g have yielded mixed results, and contemporary research instead examines a family of partially dissociable social-cognitive processes [27,78]. Social cognition is the broader domain; theory of mind (inferring others' mental states) and empathy (sharing and understanding others' affective states) are distinct components of this domain, with partially separable neural substrates and developmental trajectories [78,79]. Social

intelligence, as used here, denotes the adaptive application of these processes in real-world interactions.

The neurobiological foundations of social intelligence are embedded in distributed neural systems collectively known as the social brain [24]. These systems include the medial prefrontal cortex, temporoparietal junction, superior temporal sulcus, anterior cingulate cortex, insular cortex, and amygdala [80]. Together, they process socially relevant information and facilitate perspective-taking, empathy, and interpersonal understanding [81]. However, the involvement of a distributed social brain does not by itself establish social intelligence as an independent or unified neurobiological construct, as these regions also support non-social functions such as autobiographical memory and attention [25,81].

A central component of social intelligence is theory of mind, which refers to the capacity to infer the beliefs, intentions, emotions, and mental states of others [80,82]. In conjunction with empathy and social learning, theory of mind enables individuals to navigate complex interpersonal relationships and contributes to moral reasoning, cooperation, and social adaptation [79].

Like other dimensions of adaptive functioning, social intelligence develops through continuous interactions between biological predispositions and environmental experiences [77]. Early attachment, education, cultural influences, and sustained social engagement all contribute to the neuroplastic refinement of neural systems that support social cognition [25,83]. These social-cognitive processes interact closely with cognitive and emotional processes, consistent with, though not proof of, the integrative framework presented in this review.

Toward an integrative neurobiological model of human intelligence

The remarkable advances in cognitive neuroscience over recent decades have significantly broadened our understanding of human intelligence [1]. Rather than representing a single cognitive ability or a collection of independent competencies, current evidence is consistent with the view that intelligence emerges from the coordinated interaction of distributed neural systems that continually adapt through neuroplastic mechanisms [3,67].

From this perspective, cognition, emotional regulation, social functioning, and adaptive behavior should not be regarded as isolated domains. Rather, they are mutually interacting processes that collectively support successful adaptation to changing internal and external environments, thereby providing a conceptual foundation for an integrated understanding of human intelligence.

At the same time, growing interdisciplinary attention has focused on higher-order adaptive capacities associated with the construction of personal meaning, self-transcendence, value-guided decision-making, and existential reflection. Although these capacities are often discussed under the umbrella term “spiritual intelligence,” their neurobiological foundations remain an active area of scientific investigation. They should therefore be regarded as emerging interdisciplinary constructs rather than fully established neuroscientific entities.

Neurobiological Integration of Cognitive, Emotional, Social, and Meaning-Oriented Processes

Human adaptive behavior depends on the continuous integration of cognitive, emotional, and social processes rather than on the independent functioning of distinct mental systems [4]. Large-scale functional brain networks, including the DMN, CEN, and SN, dynamically coordinate to support flexible adaptation to complex environmental demands [11,25].

We propose that neuroplasticity provides a shared biological mechanism through which these distributed systems continuously reorganize in response to experience. Consequently, learning, emotional regulation, interpersonal competence, resilience, and adaptive decision-making may be understood as interconnected, though distinct, expressions of an adaptive neural system rather than as isolated psychological functions.

Emerging evidence further indicates that self-awareness, autobiographical integration, value-based reasoning, and the capacity to construct coherent personal meaning involve coordinated activity across multiple functional brain networks [84,85]. Although these processes cannot yet be regarded as distinct neurobiological systems, they appear to constitute higher-order integrative functions that contribute to long-term psychological adaptation and human flourishing [77].

Spiritual Intelligence as an Emerging Integrative Perspective

The concept of spiritual intelligence has been proposed to describe the human capacity to seek meaning, integrate life experiences, maintain coherent personal values, and respond adaptively to existential challenges. Unlike traditional models of intelligence, this perspective emphasizes the integration of cognition, emotion, self-awareness, ethical reflection, and purpose-directed behavior [29,30].

The construct was introduced by Emmons, who proposed five components: the capacity for transcendence,

the ability to enter heightened spiritual states, the investment of everyday activities with a sense of the sacred, the use of spiritual resources to solve problems, and the capacity for virtuous behavior [29]. It was later operationalized in self-report instruments, such as the Spiritual Intelligence Self-Report Inventory [86]. Its status as an intelligence has been criticized, notably by Gardner, who argued that it fails to meet several criteria for an intelligence and preferred the narrower notion of existential intelligence [19]. The principal conceptual and measurement limitations include reliance on self-report, the absence of maximum-performance tests, substantial overlap with measures of personality, religiosity, and well-being, and limited evidence of incremental validity. Spiritual intelligence must also be distinguished from related but non-equivalent constructs: spirituality and religiosity (beliefs, experiences, and practices), meaning in life (the experienced coherence and purpose of one's life, measurable with instruments such as the Meaning in Life Questionnaire [87]), self-transcendence, psychological resilience, and value-guided decision-making. Most of the evidence cited in this review concerns meaning-making and spirituality, rather than spiritual intelligence as such [8,21].

From a neuroscientific perspective, current evidence does not support the existence of a dedicated "spiritual intelligence network" in the human brain. Instead, the adaptive capacities commonly associated with spiritual intelligence appear to emerge from the coordinated interaction of neural systems involved in executive functioning, emotional regulation, autobiographical memory, social cognition, and self-referential processing.

Accordingly, spiritual intelligence may be conceptualized not as an independent form of intelligence, but as a higher-order integrative adaptive capacity through which cognitive, emotional, social, and existential processes converge to support resilient, value-oriented, and meaningful human behavior. This interpretation is consistent with contemporary systems neuroscience and avoids attributing unsupported neurobiological specificity to a concept that continues to evolve scientifically. Within the proposed model, the meaning-oriented dimension is therefore included as a hypothesized, rather than validated, dimension and is operationalized through measurable constructs such as meaning in life and value-guided decision-making.

An Integrative Model of Human Intelligence

Based on the evidence reviewed in this article, we propose a theoretical framework, not yet empirically validated, in which human intelligence may be conceptualized as a dynamic, adaptive neurobiological system underpinned by lifelong neuroplasticity and the coordinated interaction of distributed functional brain networks. Within this model, cognitive processes support reasoning, learning, executive control, and problem-solving, whereas emotional processes regulate affective responses, resilience, and adaptive decision-making [10,68,74,75]. Social processes, in turn, foster empathy, cooperation, communication, and interpersonal adaptation, while meaning-oriented processes foster self-awareness, the integration of values, a sense of purpose in life, and existential coherence [8,24,80,85]. These dimensions should not be regarded as equivalent forms of intelligence, but rather as distinct components of an adaptive system that interact continuously and develop throughout life through experience-dependent neuroplasticity.

The proposed model builds on, rather than replaces, existing network neuroscience frameworks. The P-FIT locates individual differences in g primarily within a frontoparietal network that largely overlaps with the CEN, while network neuroscience theory attributes g to the dynamic flexibility of large-scale network topology [3,10]. The triple-network model describes how the SN coordinates switching between the DMN and CEN and how dysfunction in this switching contributes to psychopathology [11]. These frameworks primarily address general cognitive ability and psychopathology, respectively. The added value of the present framework is to (i) extend the triple-network logic to individual differences in emotional and social functioning, (ii) propose experience-dependent plasticity in between-network coupling as a potential common substrate through which these constructs co-develop, and (iii) include meaning-oriented processes as an explicitly hypothesized component, linked mainly to DMN-related self-referential processing [25,83].

The framework generates testable and potentially falsifiable predictions: (1) after controlling for g, ability-based emotional intelligence and social-cognitive performance should show incremental associations with SN-CEN coupling rather than with frontoparietal efficiency alone; (2) interventions targeting one domain, such as emotion-regulation training, should produce measurable changes in between-network connectivity that statistically mediate improvements in the trained outcome, with limited transfer to g; (3) maladaptive plasticity, for example, under chronic stress, should reduce network flexibility and predict declines across more than one domain; and (4) validated measures of meaning in life should show incremental associations with DMN-related connectivity beyond those explained by personality and well-being. Longitudinal, multimodal designs combining psychometric assessment, neuroimaging, and lesion data will be required to test these predictions.

Translational implications and limitations

Clinical, Educational, and Translational Implications

The recognition of neuroplasticity as a lifelong biological process has substantially shaped contemporary clinical neuroscience, rehabilitation medicine, educational neuroscience, and preventive healthcare [38,40]. Current evidence indicates that targeted interventions can promote the adaptive reorganization of neural circuits and improve functional outcomes throughout the lifespan [88,89].

In clinical practice, neuroplasticity provides the scientific basis for cognitive rehabilitation following stroke, traumatic brain injury, neurodegenerative disorders, and other neurological conditions [40,89]. Structured rehabilitation programs, multidisciplinary therapeutic approaches, and intensive, task-specific training support functional recovery by promoting the adaptive reorganization of distributed neural networks [88,90]. These interventions improve specific functional outcomes, such as motor recovery, language function, and activities of daily living, but have not been shown to increase g.

Educational neuroscience has likewise incorporated principles of neuroplasticity to optimize learning [91]. Active engagement, repeated practice, timely feedback, intrinsic motivation, and emotionally supportive educational environments enhance experience-dependent neural adaptation and improve long-term learning outcomes [59,92]. From a public health perspective, interventions that promote physical activity, healthy nutrition, adequate sleep, lifelong education, social participation, and cognitive engagement are associated with cognitive resilience and the preservation of functional brain network integrity during aging [61,63].

Taken together, the translational evidence supports improvements in specific, measurable outcomes, such as motor and language recovery after stroke, academic achievement, and the maintenance of memory in aging, rather than increases in general, emotional, social, or spiritual intelligence as such. Claims of the latter kind should await direct experimental evidence.

Limitations

This review has several limitations. As a narrative rather than a systematic review, the selection of studies may be subject to selection bias, and the synthesis is interpretive. Much of the mechanistic evidence on plasticity derives from animal models, and much of the human evidence is correlational and cross-sectional. Finally, the constructs considered differ markedly in psychometric maturity, from the robust g factor to the debated construct of spiritual intelligence, which limits direct comparison between them.

Conclusions

The present review advances an integrative understanding of human intelligence that extends beyond traditional psychometric models while remaining firmly grounded in contemporary neuroscience. Current evidence suggests that intelligence, while robustly captured by psychometric g, arises from the coordinated activity of distributed brain networks whose organization is continually shaped by neuroplastic mechanisms throughout the lifespan. Within this framework, cognitive, emotional, social, and meaning-oriented adaptive processes are best understood as distinct but interacting constructs, supported by overlapping and plastic brain networks, rather than as equivalent or isolated intelligences. Future interdisciplinary research integrating neuroscience, psychology, psychiatry, behavioral science, and philosophy will further elucidate how these processes contribute to human resilience, psychological well-being, and lifelong flourishing. Ultimately, psychometric intelligence remains a robust and relatively stable construct, yet its expression and interaction with emotional, social, and meaning-oriented processes are shaped by experience-dependent, and not invariably beneficial, neuroplasticity. The integrative framework proposed here is theoretical; its value will depend on whether its testable predictions are confirmed by longitudinal, multimodal research.

Additional Information

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All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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