Journal of Creativity 35 (2025) 100111

Contents lists available at ScienceDirect

Journal of Creativity

journal homepage: www.elsevier.com/locate/yjoc

Converging creativity through semantic processing

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ARTICLE INFO

Keywords:
Creativity
Measurement
Semantic processing
Cognition
Neuroscience
Methodologies
Language

ABSTRACT

Creativity, the ability to engage in abstract thought, novel idea production and concept construction, along with artefacts transcending everyday experience, has long been recognized as a defining feature of human cognition. Creativity has typically been defined as the capacity to generate original, effective, and expressive output. The phenomenon has been examined via diverse theories and methodologies, from psychometric assessments to neurocognitive approaches. We review how semantic processing - the integration and convergence of meaning - has been explored as a mechanism underpinning creative cognition. Research has shown that semantic flexibility and associative richness aid in creative ideation. Recent studies in cognitive neuroscience show that semantic networks and brain regions implicated in memory and language support creative thinking. The paper highlights how converging semantic processes serve to bridge conceptualization and practical measurement. We examine the application of the N400 event-related potential (ERP) method as a neuroscientific measure of semantic integration.

1. Introduction

Over recent decades creativity has gained increasing attention among the scientific community. There are many reasons why creativity is gaining much attention, many of which can be seen with the rapidly developing techno-economic conditions unfolding on the global market. With exponential developments in the field of information technology (IT) in areas such as artificial intelligence (AI – including large language models (LLMs) and generative AI), machine learning (ML), deep learning (DL) and other big data and analytics-based solutions, not only are we striving to form a vision of what is the 'next' in terms of products, services, and other innovations, but also what exactly is it that makes us human. This last point is particularly pertinent in light of current concerns regarding the role of human beings in the unravelling era of AI (Shahghasemi, 2025).

Knowledge of humanity, and indeed emphasis on creativity as a human activity, is often emphasised as being the long-term function of human beings in an ever-intelligent society (Kasparov, 2017; Winner, 1978). The rise of LLMs has, however, challenged this unique positioning in recent times, drawing attention towards whether or not AI development has already gone too far (Sætra, 2023). We argue that despite convincing evidence regarding the capabilities of current and emerging IT, humans and their creative processes remain distinct from what is witnessed in unfolding AI technology, and this is due to the issue of consciousness and intentionality (Chalmers, 2002; Gondek, 2021). These aspects in themselves require justifications that separate cognitive from neuroscience, as all matters pertaining to the *mind* cannot be accounted for in the brain and its activity (Hohwy & Frith, 2004; Sperry, 1952). This challenge is beginning to emerge in AI system development due to inabilities to fully frame and contextualise, while lacking chains of significance defined by other factors such as history (experience), personal characteristics (see e.g., Hamilton et al., 2024), and sense of *self* (Barnes and Hutson, 2024).

Creativity in everyday situations entails finding novel solutions to problems or situations. Acts of choosing some pre-existing solution from a repertoire or alternatives or mechanically copying something that has already been created without any objective or intention is not creativity. On the other hand, there must be some set of preliminary building blocks from which a new structure of creative ideas can be created (see for instance, Duff & Sumartojo, 2017).

1.1. Defining creativity

Understanding whether creativity and the capacity for creative

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https://doi.org/10.1016/j.yjoc.2025.100111
Received 11 June 2025; Received in revised form 14 September 2025; Accepted 15 September 2025
Available online 17 September 2025

cognition are exclusively human traits requires first establishing a clear and operational definition of creativity. The question "What is creativity?" has been explored across a range of disciplines, including cognitive science, neuroscience, artificial intelligence, education, and the humanities. Each field offers distinct conceptualizations and frameworks, leading to a variety of methodologies for investigating and measuring creativity.

The subsequent discussion focuses on creativity within the context of semantic processing and convergent thinking. Classical methods for examining creativity, particularly those related to convergent thinking and the neural mechanisms underlying semantic processing, are outlined. These methodologies are presented in terms of their potential applications for understanding the cognitive processes involved in creative thinking. Following this, we briefly review recent neuroscientific insights into the nature of creativity. The paper concludes with a summary of the key points discussed and an exploration of potential directions for future research.

Creativity is a construct that has puzzled scholars throughout history. Creativity has traditionally been defined in two different ways: 1) as originality - the generation of something new and authentic; and 2) as effectiveness (fluency) - the ability to swiftly make connections and unite information and elements to, for example, solve problems and multitask (Runco & Jaeger, 2012). Yet, this approach to defining creativity remains too superficial to capture the complexity of not only the phenomena that creativity represents but also how its study has been undertaken. Brown (1989) argued that creativity had been approached from several incompatible theoretical angles. Yet, he postulated that creativity comprises at least four different elements: 1) creative process; 2) creative product; 3) creative person; and 4) creative situation (see also, MacKinnon, 1970; Mooney, 1963). Boden (2004) emphasized the relationship between ability and product in her description of creativity as the capacity to generate novel ideas or objects that are value-laden, triggering emotional responses such as surprise. In the same vein, Mayer (1999) claimed that creativity could be expressed as production that is both useful and rare.

While creativity theory has advanced continuously, not all frameworks maintain pace in light of the complexity of modern thought. In addition to Brown's (1989) four-element approach, Beghetto and Kaufman's (2007) Four-C Model of Creativity, which comprised Mini-c, Little-c, Pro-C, and Big-C, has both gained traction, yet simultaneously drawn substantial critique. The four levels the model attempts to classify are: Mini-c – personal insights and internal creative cognition; Little-c – everyday creative acts in known contexts (i.e., food improvisation); Pro-C – professional-standard creative output (writing, design, engineering); and Big-C – *eminent creativity* disrupting paradigms and re-directing cultural discourse.

Scholars (see e.g., Puente-Diaz, Maier, Brem & Cavazos-Arroyo, 2016) have however argued that the Four-C framework represents categorical rigidity and overly linear assumptions. The problem with dividing creativity into distinct levels is that it risks instilling a hierarchical view. This hierarchical, and rather fixed view of creativity, veils the fact that creative thought and expression is recursive, fluid and contextually dependent. Moreover, as Puente-Diaz and colleagues (2016) pointed out, creativity is predominantly shaped by sociocultural factors, emerging dynamically between domains and via feedback loops. Thus, while the Four-C model affords an easy-to-apply heuristic, it seems to oversimplify the nuanced realities of creativity.

Challenging the traditional Four-C framework is for instance, Corazza's (2016) *dynamic definition of creativity*, that cited creativity as requiring "potential originality and effectiveness" (p. 262). Thus, there is acknowledgement of the fact that creativity may involve both or either achievement or inconclusiveness in processes. Mullen's (2020) concept of the *Hidden-c* referred to latent creative *potential* that is influenced by environmental factors and self-belief. Similarly, to the dynamic definition (or dynamic theory of creativity), 'potential' is the key word as not all creativity, and creative propensity is actualized. These newer approaches emphasize creativity as a complex and multidimensional space where creativity fluidly morphs in significance and definition depending on context, purpose, and opportunity.

The above theoretical classifications describe creativity as phenomena and in terms of its definition, while we are interested in understanding what it actually means within the mind, and how this can be explained within the brain. Rhodes (1961) proposed that creativity comprises 4 P's: the *person* – individual traits, personality, intelligence, cognitive style, motivation and emotional factors; the *process* – mental operations and strategies, idea generation, problem-solving, divergent and convergent thinking, insight and incubation; the *product* – the outcome of the creativity (tangible and intangible), such as art, inventions, theories, ideas; and *press* – external influences, including cultural, social, organization, and physical environments.

The terms 'divergent' and 'convergent' thinking are regularly referred to in studies focusing on creativity (see e.g., Ashton-James & Chartrand, 2009; Cropley, 2006; Lubart, 2016). Divergent thinking is often associated with the idea that creativity is the generation of something new, surprising, and perhaps artistic. In many forms of divergent processes, individuals deconstruct existing information to inspect from and construct new meanings (Cilliers, 2016; Khakzand & Rakhshani, 2021). This is why it is attributed to originality (Cho et al., 2010). Originality is achieved through the ideation, identification, deconstruction, and re-arrangement of knowledge, information, objects, and other phenomena to produce something novel (Runco, 2010).

Convergent thinking can be seen as embodied in effectiveness or fluency (Cho et al., 2010), in which one's store of knowledge or expertise is drawn upon when engaging in cognitively intensive activities such as problem-solving and multitasking, that require uniting and arranging data into meaningful patterns and solutions (Cropley, 2006; Tan, 2015). Divergent thinking is popular in creativity discourse such as contemporary art, as it purports the idea that creative expressions are free, without boundaries, spontaneous in their derision, and feature an openness to experience (McCrae, 1987). Divergent thinking is often associated with talent, "artistic genius" (Thagard, 2014), exceptionality, and giftedness. It is seen as a deviation from the norm to produce something unprecedented (Runco, 2010). Whereas convergent thinking can be understood through the convergence or collection and assemblage of parts (information or other elements) to create one united whole (Cropley, 2006).

These days from the perspective of technology development, there are many efforts to program AI in ways that operationalise this idea of convergence - or convergent computation (Gruner & Csikszentmihalyi, 2019). Yet, from a human perspective, we may observe key characteristics of convergent thinking within fluent logic, accuracy, and speed of assembling various information. In contrast to understandings of divergent thinking, what must be emphasised regarding convergent thinking is that it leads to a single 'best' option (answer or solution).

1.2. Creativity as a subset of intelligence?

Creativity is associated with intelligence. Intelligence tests such as the Lorge-Thorndike Intelligence test (LTI) (Wodtke, 1964; Yamamoto, 1964) maintain correlations with tests of creativity like the Torrance Tests of Creative Thinking (TTCT). There are long traditions of psychometric theories that treat creativity as a part of intelligence (see e.g., Horn & Cattell, 1966; Renzulli, 1978). Plucker and colleagues (2015) described the close associations made between creativity and intelligence. Getzels & Jackson (1962) discussed how initial developers of intelligent tests conceptualised creativity to either be a subset of intelligence or fully separate from it (Plucker et al., 2015). This can be seen in terms of the relational treatment exhibited regarding the two constructs in traditions of psychometric research. In particular, Guilford's Structure of the Intellect (Guilford, 1967) model considers divergent thinking as a cognitive operation and constituent of intelligence. Subsequently, divergent thinking assessments have been adapted from the SOI model.

The Cattell-Horn and Carroll (CHC) model combines theories of fluid and crystallized intelligence developed by Horn and Cattell (1966; 1967) with the Three-Stratum Theory (Carroll, 1993; Plucker et al., 2015). The Three-Stratum Theory represents a three-layer (strata) model of narrow, broad, and general cognitive ability. The theory was developed based on a factor-analytic study in which 460 datasets containing school grades, psychological tests, and competence ratings were analysed to observe correlations between individual difference variables (Carroll, 1993;1997). Here, Spearman's (1904) General Intelligence (g Factor) is added to the fluid component - Gf. Gf refers to the capacity to engage in numerous mental operations to tackle new forms of problems. Crystallized intelligence (Gc) on the other hand, describes the extent of an individual's stored knowledge, regarding a particular culture and context and therefore, the individual's capacity to solve problems via that accumulated knowledge (Horn & Blankson, 2005).

It was previously hypothesized that creativity was mostly connected to Gf, yet empirical research has not produced any strong evidence supporting this theory (Batey et al., 2009; Plucker et al., 2015). The Dual Process Theory (DPT) of Intelligence posits creativity as a subset of intelligence (Kaufman, 2013). DPT has evolved over centuries. From Plato and Aristotle who described the tensions between the rational and irrational, and Spinoza in the 17th century who discussed passions and reason, DPT officially arose as an explicit concept in 1974 by Wason and Evans, who articulate the term to describe processes involved in heuristic versus analytic processes (Evans, 2012).

Kahneman (2011) and Kaufman (2013) have both made significant contributions to the scholarship of DPT by classifying the cognitive processing system into two systems (Kahneman, 2011) or types (Kaufman, 2013). This follows from Wason and Evans (1974) who categorized the two types of thinking into heuristic (fast, intuitive and automatic) and analytic (slow, deliberate and effortful). For instance, Kaufman (2013) reported a two-factor model of intelligence that posited Type 1 as controlled cognition (goal-oriented thoughts and behavior), and Type 2 as spontaneous cognition often associated with creativity (thoughts and actions connected with the unconscious, including implicit learning and daydreaming). Kahneman's (2011) dual classification involved System 1 (fast, automatic, emotional) and System 2 (slow, controlled, logical).

Against this background, Plucker et al. (2015) argued that intelligence should be understood as a subset of creativity, rather than the other way around. This is claimed through the argument that creativity can be seen as a facilitator for mental function activation, attention, and application of mentally bound information. Thus, even the systems or types of thinking that DPT endeavors to explain, can be seen as sub-types of cognition that are enabled through creativity and the propensity to engage in creative thinking.

In other words, creativity is not simply about processing and producing information. It is a broader concept that incorporates aspects such as cognitive-affective (emotional) processing and control (emotional intelligence) that enables one to effectively utilise mental resources (Williams, 1969). While intelligence and creativity are still treated distinctively from one another, theories such as Renzulli's (1978) three-ring (high intellectual ability, creativity, and task commitment) foster the idea that human cognitive giftedness is based on the unity of divergent and convergent thinking, stored knowledge, motivation, and commitment.

Distinctive qualities of any individual - both convergent, seeing links between information and phenomena that many cannot, as well as divergent, devising alternative combinations and disruptive understandings of phenomena - can also be perceived as creative (Nusbaum & Silvia, 2010). Interestingly, it has been noted that people who are considered to be creative are often particular in terms of the speeds of their information processing (Martindale, 1999). In his research, Martindale found that earlier on in creative processes, individuals incorporate large amounts of information. Once issues within the process become clarified and the scope more crystalised, people tend to hone in on smaller amounts of information and focus their attention which, in turn, increases processing speed - smaller chunks of information are processed more fluently and efficiently (Chater & Vitányi, 2003). A common example of this can be seen in brainstorming exercises during workshops, where massive amounts of information are produced in response to specific problems, challenges, and tasks. Yet, as the workshop progresses, the co-design process becomes more refined, and greater detail can be attributed to fewer ideas, from which eventually the actual design solution will be extracted. The basic premise behind this initial surge of information production lies in the ability of people to understand that by indulging in ideas initially, and exhausting alternative solutions (global planning), later on in the process they will not find themselves in situations in which they need to return to the starting point (local planning) to search for another alternative (Sternberg, 1981).

On this note, the question remains in regard to the true distinction between convergent and divergent thinking, as potentially divergence is convergent as it reformulates information that is already available. One type focuses on bringing information together (convergent) while the other imposes fragmentation through dissecting information and providing many alternatives (Razumnikova, 2013). Indeed, neuroscientific research has also revealed that convergent and divergent thinking utilize divergent brain regions and/or functional parts of the brain Zhang, Sjoerds and Hommel (2020). In many real-life tasks, such as design, both forms of thinking can be considered necessary parts of the creative process depending on the stage of progress, motivations, and goals (Goldschmidt, 2016).

Current state-of-the-art knowledge attributes cognitive connectionism and memory functions such as long-term storage (long-term memory) combined with retrieval capacity (Glr) (see e.g., Cho et al., 2010; Gerver et al., 2023; Lloyd-Cox et al., 2023; Martindale, 1995; Sweller, 2009) to the ability to fluently undertake creative tasks. This means that based on long-term memory and retrieval, individuals can efficiently retrieve and apply knowledge to a variety of problems and contexts. Glr comprises the two elements of learning efficiency and fluency. This, in turn, has been described as the role of memory and learning contributing to Glr, as well as idea production, or productivity (Carroll, 1993).These insights prompt an exploration of the relationship between language and creativity, particularly through the lenses of semantics, semantic distance, and analogical reasoning (Green et al., 2012; Kennett, Anaki & Faust, 2014). Language, both in its expression and interpretation, is a product of complex cognitive processes. At the conceptual level, language functions as a highly interconnected network in which some concepts are more proximally related than others, yet all are embedded within an integrated semantic structure. This interconnectedness offers a valuable framework for investigating cognitive and neural mechanisms underlying higher-order, abstract, and associative thought processes.

2. Semantic processing and creativity

Linguistic and creative language use have historically functioned as primary modes of socio-cultural expression, and are recognized as creative outputs in their own right. Examples of such linguistic creativity include jokes, poetry, fictional narratives (as well as non-fiction, which necessitates the integration and synthesis of extensive information), irony, and various forms of humour (Faust, 2012; Kennett et al., 2014; Mirous & Beeman, 2012). These forms of expression engage complex cognitive processes, including the activation of memory, the formation of novel associations, the integration of disparate informational elements, and cognitive restructuring. Such processes enable the creation of multiple semantic pathways between informational units, supporting diverse interpretations, readings, and applications. Within this framework, creativity is understood as the generation and manipulation of meaning (semantic value), often through the connection of ideas that are typically unrelated or distantly associated (Cushen & Wiley, 2011).

Thus, social-psychological and associative linguistic aspects of creativity are fertile ground for its study (Amabile, 1983). This is coupled with the significance of context, and the socio-cultural framing (Kemp et al., 1996) of the action/production in question. This acts as a differentiator regarding whether an action or expression may be deemed as genuinely creative. For instance, a recurring problem in fields of the arts is that of occurrences in which cleaners mistake site-specific installations as accidental, or *unintentional* uncleanliness – by-products of other events. One of the published instances of this happening was in the case of Sala Murat's work in the Flip Project Space (Naples) that was mistaken for rubbish (BBC, n.d.). Similar events such as this have happened to Damien Hirst's installation of beer bottles, ashtrays, and coffee cups at the Eyestorm Gallery (London) in 2001. These were instances in which, despite the physical institutional contextual framing, or defining the boundaries of art, actors (cleaners) did not possess the social-psychological frames through which to perceive and interpret the artworks.

The same occurs the other way around, whereby mere accidents may be mistaken for creative production and/or wordplay (accidental and unintentional puns). In the general sense, accidents have led to significant innovations such as Fleming's discovery of penicillin in the general sense (Austin et al., 2012; Merton & Barber, 2011). In the linguistic context, the speech production of misheard or misunderstood concepts, i.e., 'Sandy Arabia' (Saudi Arabia) or 'Adult-ry' (the things that adults do) (Winter-Froemel & Thaler, 2018) may be mistaken for creative wordplay. Wordplay itself, defined as the utilization of structural linguistic features that are exploited to generate "significant confrontation of two (or more) linguistic structures with more or less similar forms and more or less different meanings" (Delabastita, 1996, p. 128) is either deliberately engaged in, or actively recognised in strategic communication.

Thus, language use and semantic derivation can be seen to involve association creation and problem-solving skills (Newell, Shaw, & Simon, 1962) inherent within creative production. Linguist Noam Chomsky (1965) argued that inherent to all languages is a 'creative aspect'. This means that the very nature of language is its affordance in enabling the expression of an indefinite number of thoughts. Language further enables individuals to act and react appropriately within an endless number of new situations. Based on Chomsky's understanding, language can be seen as both a process and a space for free creation and production. While the principles and laws of languages may seem fixed, or institutionalized, how languages are applied can be seen as infinitely diverse. This creative linguistic engagement includes that of interpreting language (Chomsky, 2003). While this seems to link with common understandings of particularly divergent thinking in creativity, Chomsky's theoretical rationale relates to the computational theory of the mind and language. This is evidenced by his reference to rules, and then description of the infinite interpretations and creations. Thus, as with computer programmes, Chomsky's argument was that the languages comprise particular rules that are innate to every individual from birth. These biological (biolinguistic) rules aid in language development while enabling linguistic production and interpretation. In other words, a sentence is a sentence - the combination of words, that comprise a particular structure (even if varied) that endows it with meaning (a function). This is referred to as Universal Grammar (UG) and is said to emerge through psychological development, independently of sensory experience (Barsky, 2018).

With this said, it is worthwhile looking at the notion of generative grammar, or in other words, "…a mechanical procedure by means of which preferred descriptions are chosen from among several alternatives" (Halle, 1962, p. 55). 'Simplicity' is the term used to describe the grounds of this choice. Simplicity is often likened to brevity (Rousi & Silvennoinen, 2018). This is often noticed in everyday situations when we encounter long and complicated sentences. There is a 'break-off point' in which the meaning and the function of the sentence is lost through too many elements and random structures being introduced into the linguistic expression.

Generative grammar, or syntax, may also be understood as a recursive merge operation within language and its creative use (Fujita, 2014). This is where new sentences are merged into former and other sentences to establish infinite amounts of new sentences based on varying compositions and information contents. The discipline of cognitive linguistics presents distinctions regarding the inner language (UG or Language of Thought (LOT), see Fodor, 1975) and external language (spoken and written language). While syntax exists in the representative structure of language (external), the semantic dimension, or meaning processing element, exists in the inner language. In relation to Chomsky's UG tradition, Fodor (1975) who promoted LOT, explained that linguistic semantics is enabled through LOT. This means that humans cannot innately learn linguistic signification without an inbuilt linguistic system already existing within the mind (brain). This is the baseline, platform or stream of consciousness (conscious, subconscious, and unconscious) upon which external linguistic structures are connected and made sense of (Davies, 2013).

Interesting questions are formed through these theoretical understandings that challenge the relationship between inner and external language in creative processes. These questions merge into the convergent-divergent discussions regarding whether creative practice (e.g., fine art and music etc.) and production is the expression of internal language through external linguistic means. It has been argued, however, that the syntax of spoken language for instance, is not sufficient in itself for formal symbol processing (Pinker, 1994). Nonetheless, this essential human ability to speak and indeed understand language without formal training demonstrates this inner language as a facilitating mechanism of a predetermined developmental path of every individual (Chomsky, 1965; Lenneberg, 1967; Fitch et al., 2005; Pinker, 1994). This disposition for language creation resonates with creativity - creative production and innovation in itself. Through this, many scientists have utilised language as an observable cognitive, neuroscientific and expressive domain in which to study creativity.

2.1. *Creativity in language*

While Chomsky (Hauser et al., 2002) argued that all language has a creative element, the relationship between language and creativity may still be considered complex (Bergs, 2019). For instance, Sampson (2016) suggested that in addition to the numerous types of discussed creativities, another two types should be introduced: E-creative - a form of creativity that enlarges or extends understandings of alternatives and products; and F-creative - activities that generate expressions or examples. These two 'creatives' do not exist in a dichotomy, but instead a continuum. This continuum ranges from: 1) regular productivity - i.e., everyday language use and linguistic information processing; 2) 'snow clones' - clichés, common sayings and multiple words for the same phenomena (i.e., the more abundant particular phenomena are in certain cultures the more words there are to describe them); 3) mismatch/ coercion - the combination of seemingly incompatible constructs (see e.g., Goldberg, 1995; Francis & Michaelis, 2003; Jackendoff, 1997); and 4) aberration - the construction, production and application of language that bi-passes rules and constraints.

From a linguistic creativity perspective, we may observe that creative expression is not fixed in certain categories, but rather, demonstrates the dynamic interplay between cognitive, cultural, and contextual factors. Instead of mapping linguistic creativity on a linear continuum, such as what is presented in the 4-C model (Kaufman & Beghetto, 2009) from Mini-c to Big-C, newer models emphasize the ways in which people engage in recursive cycles of meaning-making. Thus, individuals are influenced by personal insight, cultural norms and social interaction. There is a convergence of divergent and convergent thinking that renders them not as end points, but rather as ongoing processes, shaping how language evolves, adapts and innovates. In instances of either forming metaphors in conversations, or actively

re-forming discourse via academic writing, we can understand linguistic creativity as a fluid and progressive phenomenon, resisting fixed classification (see Fig. 1).

Linguistic productivity, its expression, and interpretation, provide fertile ground for creativity research as they exemplify spontaneous and active perception, interpretation, and production processes. Through studies that for example, examine semantic distance, scientists are able to readily observe the cognitive-behavioural (perception, responses, and production) aspects of linguistic interaction from the mundane to the unprecedented. *Conceptual expansion* (Ward, 1994) underpins transformative creativity. This is where monumental or revolutionary designs, engineering and artistic feats gain their ground, through reconfiguring existing concepts. This form of creativity connects concrete innovation with abstract expression, including everything from architecture to poetry, joke creation, and fictional narrative construction. Instead of being limited to categories such as "Big-C," this type of creativity could be more comprehensively understood as paradigm shifting. That is, conceptual expansion reshapes cultural discourse, re-imagining possibilities.

For instance, residents of Oulu, Finland have profound memories of the way in which architect, design consultant and the world's first City Chief Design Officer, Anne Stenros, had created curvaceous floral hats out of nothing more than office paper. Internationally, many will remember former-Beatle, artist and poet, John Lennon in his later years with his 'out of this world' wordplay that included album titles such as *Spaniard in the Works, In His Own Write*, and *Skywriting by Word of Mouth*. Or the words of his legendary *Happiness is a Warm Gun*, chanting "Mother superi-jump-the-gun…." This coincides with Sampson's E-creativity, not only disrupting the norm to connect seemingly unrelated constructs but also enlarging these concepts to illuminate relations that may actually *be there*, yet are for the most part hidden (Kröger, 2015).

These actions align with what Ward (1994) described as conceptual expansion—a process that involves stretching and redefining the usual boundaries of familiar concepts. In essence, it challenges the established understanding of concepts, whether that understanding is formally codified or informally maintained through socio-cultural norms (Lambon Ralph, 2014). Framing this within the continuum from F-creative to E-creative offers an ideal lens for examining how the brain engages in creative cultural production.

3. Measuring creativity

In addition to the efforts made in defining creativity, attempts to measure it are equally as popular. In the history of psychology, there seems to be resistance to initiating the endeavour to empirically study creativity. This is possibly due to the complexity of the topic, as it represents numerous perspectives and understandings as seen above (Rhodes, 1961). Yet, eventually, the need arose from the immense efforts placed in theory development to empirically test these theories. Early empirical research focused almost exclusively on extraordinarily gifted people in relation to what is known as H-creativity (Albert & Runco, 1999). H-creativity, otherwise known as 'historical creativity', relates to the grandiose, society changing inventions or innovations that are referred to in history (Boden, 1990). P-creativity, or 'psychological creativity' on the other hand, focuses on the creativity that is innate to any person. To fully understand the cognitive models that have contributed to H-creativity, we must first understand how P-creativity operates. P-creativity is not simply important when attempting to understand creative production, but also cognitive actions such as learning. From a constructivist perspective, learning is the reconstruction of the mind (Boden, 1990). Thus, the activity of learning is also imperative for understanding what is recognised as creativity since creativity can often be seen as the re-configuration of already existing information.

Guilford, a prominent psychologist, made significant contributions to the study of human creative potential and performance (Guilford, 1966). He proposed four key dimensions for assessing creativity: (1) fluency, referring to the quantity of generated responses; (2) flexibility, indicating the diversity of response categories; (3) originality, measuring the uniqueness or novelty of responses; and (4) elaboration,

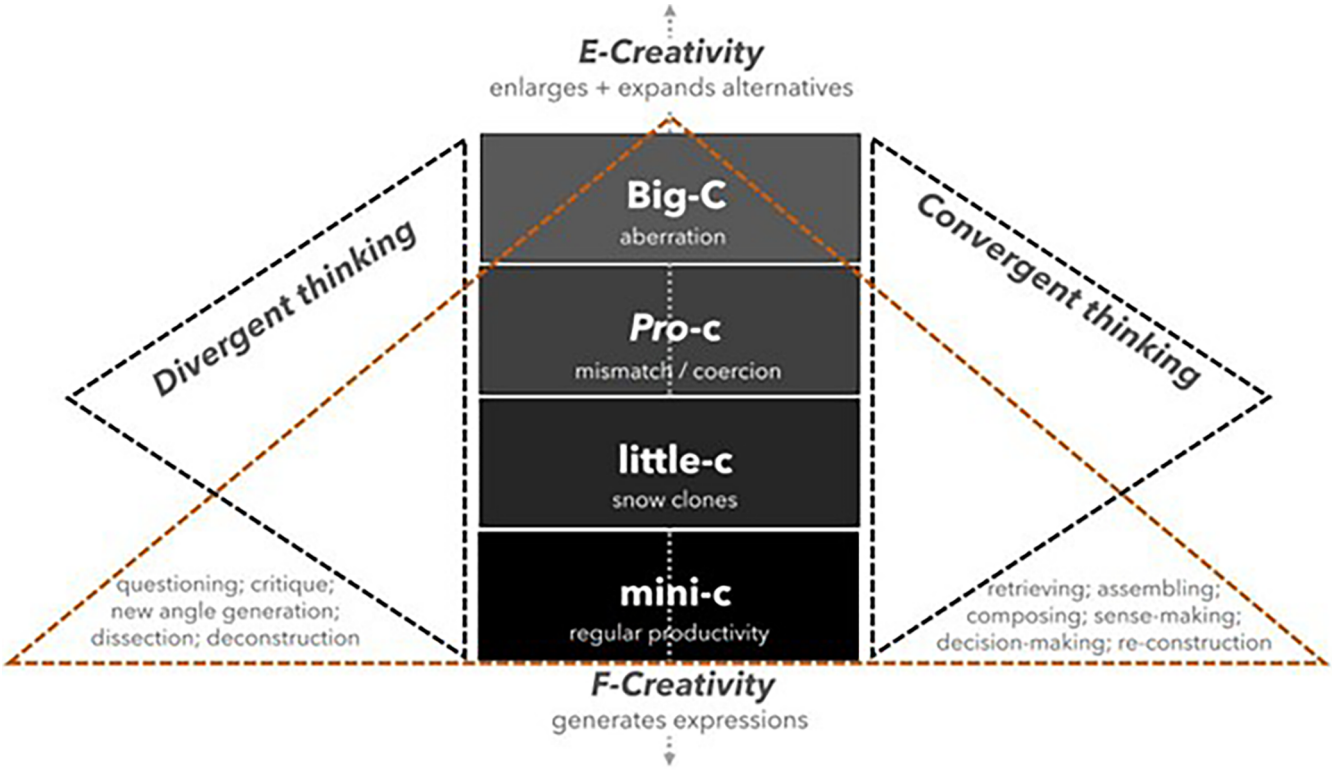

Fig. 1. Converging the creativities (adapted from Beghetto & Kaufman, 2007; Craft, 2000; Cropley, 2006; MacKinnon, 1978; Runco, 1991; Sampson, 2016).

denoting the level of detail in the responses. While Guilford has often been recognized for pioneering psychometric approaches to intelligence and creativity, his broader Structure of Intellect (SOI) model (Guilford, 1967) conceptualized intelligence as a multidimensional construct. This model encompasses three major components: operations (e.g., cognition, memory, divergent and convergent production, evaluation), contents (e.g., units, classes, relations, systems, transformations, implications), and products (e.g., visual, auditory, symbolic, semantic, behavioural), providing a comprehensive framework for understanding human intellectual functioning.

Although these two operations are considered different, psychometric evidence on the relationship between intelligence and creativity has been controversial. As noted above, the Torrance Tests of Creative Thinking (TTCT) showed a significant correlation with the Lorge-Thorndike Intelligence test (LTI) (Wodtke, 1964; Yamamoto, 1964, 1965), whereas it did not show a significant correlation with the Raven's Progressive Matrices test (RPM) (Esquivel & Lopez, 1988). The California Test of Mental Maturity (CTMM) showed correlations from –.04 to +0.70, with a mean of 0.32 with the Guilford creativity test (Guilford & Hoepfner, 1966), yet it showed negligible correlations with the Wallach-Kogan creativity tasks (Kogan & Pankove, 1972). When intelligence and creativity tests were administered to people in various IQ ranges, Schubert (1973) and Weinstein and Bobko (1980) demonstrated that intelligence had stronger association with creativity in the bottom half of the intelligence continuum than in the top half. Whereas research by Preckel et al. (2006) did not show the same result.

4. Neuroscience and creativity

The question of whether creativity can be measured through brain activity has gained increasing attention with the emergence of cognitive neuroscience. This field has provided novel insights into the neural underpinnings of creative thought. Numerous experimental studies have examined brain activity while participants engage in established or novel creativity tasks, employing a range of neuroimaging techniques such as positron emission tomography (PET), functional magnetic resonance imaging (fMRI), electroencephalography (EEG), and magnetoencephalography (MEG). Each modality offers distinct advantages in terms of spatial and temporal resolution, thus providing complementary perspectives on the neural mechanisms supporting creativity.

Creativity is considered a higher-order cognitive function that likely involves a widely distributed network of cortical and subcortical regions. As such, its investigation necessitates imaging methods capable of capturing large-scale neural dynamics with both high spatial and temporal precision. Importantly, any attempt to identify the neural correlates of creativity must begin with a clear operational definition of the specific type or dimension of creativity under investigation. As previously discussed, the contexts in which creativity is conceptualized and assessed vary widely, and at both cognitive and neural levels, there is no single process or brain region that can be isolated as the definitive basis of creative cognition.

Neuroscientific research, including studies of brain lesions, has elucidated the primary functions associated with specific brain regions (Genon et al., 2018; Jung et al., 2010; Wise et al., 1999). For instance, damage to the left temporal lobe (Lorca-Puls et al., 2021)—particularly in Broca's area—is frequently associated with impairments in language production. Higher cognitive functions are generally understood to arise from the interaction of distributed neural networks across multiple brain regions (see e.g., Pulvermüller, Tomasello, Henningsen-Schomers, & Wennekers, 2021). Consequently, complex phenomena such as creativity can be conceptualized as sequences of causally linked information-processing states within the brain.

Early insights into the neural basis of semantic processing emerged with the discovery of the N400 event-related potential (ERP), first reported by Kutas (1980) and subsequently developed in later work (Kutas & Federmeier, 2011). The N400 manifests as a negative deflection in EEG or MEG signal in response to semantically incongruent or unexpected stimuli, often within word lists or visually presented linguistic sequences. Critically, the amplitude of the N400 is modulated by the semantic relationship between stimuli: greater semantic relatedness leads to a reduced amplitude, effectively providing a neurophysiological index of semantic distance. The component is also sensitive to priming effects, with diminished responses observed when a target word is preceded by a semantically, morphologically, or orthographically related prime (Kutas & Federmeier, 2011). These characteristics position the N400 as a robust marker of semantic integration processes, which are highly relevant to the study of creativity, particularly in relation to associative thinking, concept combination, and the flexible navigation of semantic space. As discussed in the previous chapter, creativity can be associated with the N400 paradigm through its involvement in semantic processing. However, it is important to note that N400 responses alone do not provide a definitive measure of an individual's creativity.

A commonly held view suggests that creativity predominantly originates from neural activity in the right hemisphere of the brain, with highly creative individuals frequently described as "right-brain thinkers." Some neuroscientific studies lend support to this hemispheric distinction—for example, research on jazz improvisation has demonstrated increased engagement of right-hemispheric regions during creative performance (Rosen et al., 2020). This perspective is consistent with the dual-process model of creativity (Runco, 2010), which posits that creative cognition emerges from the dynamic interaction between executive control processes, typically localized in the frontal lobes, and associative processes, often associated with right-frontal cortical areas. These mechanisms correspond broadly to the cognitive modes of convergent and divergent thinking, respectively.

5. Discussion

Creativity is widely regarded as a core component of human cognition, and a phenomenon that is unique to human beings. It is typically defined as the capacity to generate ideas, solutions, or products that are both novel and valuable within a particular context. Over the years, a diverse array of theoretical frameworks and measurement methodologies have been developed to investigate creativity. Among the most promising developments in recent decades are those emerging from the field of cognitive neuroscience (e.g., Frith et al., 2021). According to this perspective, knowledge is represented in the brain as interconnected concepts within semantic networks (Orwig et al., 2021). As individuals acquire and integrate new information, these networks expand, forming increasingly complex associative structures. Concepts within these networks are linked through various types of associations, enabling a single idea to evoke multiple interpretations or meanings. As the size and complexity of a semantic network increase, so too does the potential for generating more remote or atypical associations. In this context, creativity can be understood as the ability to form uncommon or novel connections between otherwise distantly related concepts.

Operationalizing creativity involves defining the concept in a clear and measurable manner to facilitate its systematic study and assessment in both research and practical contexts. Researchers typically decompose creativity into specific, observable behaviours or constructs that can be quantified or evaluated through a range of methodologies. Creativity may be defined in terms of the outcomes of the creative process, such as the novelty and utility of ideas, products, or solutions, often requiring the establishment of criteria to assess originality and practical relevance. Alternatively, creativity can be conceptualized as the process of idea generation, encompassing divergent thinking, ideation, or problem-solving through convergent thinking, with a focus on the cognitive mechanisms that support creative performance. Operationalizing creativity is essential for its effective measurement and understanding. For example, further neuroscientific investigation is required to establish stronger correlations between the N400 and other brain responses, and creativity.

CRediT authorship contribution statement

Pauli Laine: Writing – review & editing, Writing – original draft, Conceptualization. **Rebekah Rousi:** Writing – review & editing, Conceptualization. **Tiina Parviainen:** Conceptualization. **Tuomo Kujala:** Supervision.

Declaration of competing interest

Do not recognize any financial or personal relationships that may be perceived as influencing their work.

Acknowledgements

None

References

Amabile, T. (1983). The social psychology of creativity: A componential conceptualization. *Journal of Personality and Social Psychology, 45*(2), 357–376. https://doi.org/10.1037/0022-3514.45.2.357

Albert, R. S., & Runco, M. A. (1999). A history of research on creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 16–31). Cambridge University Press.

Ashton-James, C. E., & Chartrand, T. L (2009). Social cues for creativity: The impact of behavioral mimicry on convergent and divergent thinking. *Journal of Experimental Social Psychology, 45*(4), 1036–1040. https://doi.org/10.1016/j.jesp.2009.04.030

Austin, R. D., Devin, L., & Sullivan, E. E. (2012). Accidental innovation: Supporting valuable unpredictability in the creative process. *Organization Science, 23*(5), 1505–1522. https://doi.org/10.1287/orsc.1110.0681

Barnes, E., & Hutson, J. (2024). AI and the cognitive sense of self. *Journal of Intelligent Communication, 3*(1), 35–51. https://doi.org/10.54963/jic.v3i1.320

Barsky, R. F. (2018). Universal grammar. *Encyclopedia Britannica*. https://www.britannica.com/topic/universal-grammar.

Batey, M., Chamorro-Premuzic, T., & Furnham, A. (2009). Intelligence and personality as predictors of divergent thinking: The role of general, fluid and crystallised intelligence. *Thinking Skills and Creativity, 4*(1), 60–69. https://doi.org/10.1016/j.tsc.2009.01.002

BBC (n.d.). *Cleaner throws out 'rubbish' Sala Murat artwork*. https://www.bbc.com/news/entertainment-arts-26270260.

Beghetto, R. A., & Kaufman, J. C. (2007). Toward a broader conception of creativity: A case for "mini-c" creativity. *Psychology of Aesthetics, Creativity, and the Arts, 1*(2), 73–79. https://doi.org/10.1037/1931-3896.1.2.73

Bergs, A. (2019). What, if anything, is linguistic creativity? *Gestalt Theory, 41*(2), 173–183.

Boden, M. A. (2004). *The creative mind: Myth and mechanisms*. Routledge.

Boden, M.A. (1990). *The creative mind: Myths and mechanisms*. Weidenfeld & Nicholson.

Brown, R. T. (1989). Creativity. In J. A. Glover, R. R. Ronning, & C. R. Reynolds (Eds.), *Handbook of creativity. perspectives on individual differences* (pp. 3–32). Springer.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge University Press.

Carroll, J. B. (1997). The three-stratum theory of cognitive abilities. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 122–130). Guilford Press.

Chalmers, D. J. (2002). On sense and intension. *Philosophical Perspectives, 16*, 135–182.

Chater, N., & Vitányi, P. (2003). Simplicity: A unifying principle in cognitive science? *Trends in Cognitive Sciences, 7*(1), 19–22.

Cho, S. H., Nijenhuis, J. T., van Vianen, A. E., Kim, H. B., & Lee, K. H. (2010). The relationship between diverse components of intelligence and creativity. *The Journal of Creative Behavior, 44*(2), 125–137. https://psycnet.apa.org/doi/10.1002/j.2162-6057.2010.tb01329.x.

Chomsky, N. (1965). *Aspects of the theory of syntax*. MIT Press.

Chomsky, N. (2003). For reasons of state. *Penguin*.

Cilliers, P. (2016). Complexity, deconstruction and relativism. *Critical Complexity, 22*(5), 139–152. https://doi.org/10.1177/0263276405058052

Corazza, G. E. (2016). Potential originality and effectiveness: The dynamic definition of creativity. *Creativity Research Journal, 28*(3), 258–267. https://www.tandfonline.com/doi/full/10.1080/10400419.2016.1195627.

Craft, A. (2000). *Creativity across the primary curriculum*. Routledge.

Cropley, A. (2006). Praise of convergent thinking. *Creativity Research Journal, 18*(3), 391–404. https://doi.org/10.1207/s15326934crj1803_13

Cushen, P. J., & Wiley, J. (2011). Aha! Voila! Eureka! Bilingualism and insightful problem solving. *Learning and Individual Differences, 21*(4), 458–462.

Davies, M. (2013). Concepts, connectionism, and the language of thought. In W. Ramsey, D. E. Rumelhart, & S. P. Stich (Eds.), *Philosophy and connectionist theory* (pp. 243–272). Psychology Press.

Introduction Delabastita, D. (1996). In D. Delabastita (Ed.), *Wordplay & translation. special issue of the translator: Studies in intercultural communication: 2. Wordplay & translation. special issue of the translator: Studies in intercultural communication* (pp. 127–140). St Jerome Publishing.

Duff, C., & Sumartojo, S. (2017). Assemblages of creativity: Material practices in the creative economy. *Organization, 24*(3), 418–432. https://doi.org/10.1177/1350508416687765

Esquivel, G. B., & Lopez, E. (1988). Correlations among measures of cognitive ability, creativity, and academic achievement for gifted minority children. *Perceptual and Motor Skills, 67*(2), 395–398. https://doi.org/10.2466/pms.1988.67.2.395

Evans, J. St. B. T (2012). Dual-process theories of deductive reasoning: Facts and fallacies. In K. J. Holyoak, & R. G. Morrison (Eds.), *The Oxford handbook of thinking and reasoning, Oxford library of psychology (online edn, Oxford academic)*. https://doi.org/10.1093/oxfordhb/9780199734689.013.0008

Faust, M. (2012). Thinking outside the left box: The role of the right hemisphere in novel metaphor comprehension. In M. Faust (Ed.), *The handbook of the neuropsychology of language* (pp. 319–341). Wiley Blackwell.

Fitch, W. T., Hauser, M. D., & Chomsky, N. (2005). The evolution of the language faculty: Clarifications and implications. *Cognition, 97*(2), 179–225. https://doi.org/10.1016/j.cognition.2005.02.005

Fodor, J. A. (1975). *The language of thought*. Harvard University Press.

Francis, E., & Michaelis, L. (2003). *Mismatch: Form–function incongruity and the architecture of grammar*. CLSI Publications.

Frith, E., Elbich, D. B., Christensen, A. P., Rosenberg, M. D., Chen, Q., Kane, M. J., Silvia, P. J., Seli, P., & Beaty, R. E (2021). Intelligence and creativity share a common cognitive and neural basis. *Journal of Experimental Psychology: General, 150*(4), 609–632. https://doi.org/10.1037/xge0000958

Fujita, K. (2014). Recursive merge and human language evolution. In T. Roeper, & M. Speas (Eds.), *Recursion: Complexity in cognition. studies in theoretical psycholinguistics: 43. Recursion: Complexity in cognition. studies in theoretical psycholinguistics* (pp. 234–264). Springer.

Genon, S., Reid, A., Langner, R., Amunts, K., & Eickhoff, S. B. (2018). How to characterize the function of a brain region. *Trends in Cognitive Sciences, 22*(4), 350–364. https://doi.org/10.1016/j.tics.2018.01.010

Gerver, C. R., Griffin, J. W., Dennis, N. A., & Beaty, R. E. (2023). Memory and creativity: A meta-analytic examination of the relationship between memory systems and creative cognition. *Psychonomic Bulletin & Review, 30*(6), 2116–2154. https://doi.org/10.3758/s13423-023-02303-4

Getzels, J. W., & Jackson, P. W. (1962). *Creativity and intelligence: Explorations with gifted students*. Wiley.

Goldberg, A. (1995). *Constructions: A construction grammar approach to argument structure*. Chicago University Press.

Goldschmidt, G. (2016). Linkographic evidence for concurrent divergent and convergent thinking in creative design. *Creativity Research Journal, 28*(2), 115–122. https://doi.org/10.1080/10400419.2016.1162497

Gondek, P. (2021). Creativity and intentionality: A philosophical attempt at reconstructing a creative process. *Creativity Studies, 14*(2), 419–429.

Green, A. E., Kraemer, D. J., Fugelsang, J. A., Gray, J. R., & Dunbar, K. N. (2012). Neural correlates of creativity in analogical reasoning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(2), 264–272. https://doi.org/10.1037/a0025764

Gruner, D. T., & Csikszentmihalyi, M. (2019). Engineering creativity in an age of artificial intelligence. In I. Leduda, & V. P. Gläveanu (Eds.), *The Palgrave handbook of social creativity research* (pp. 447–462). Palgrave Macmillan. https://doi.org/10.1007/978-3-319-95498-1.

Guilford, J. P. (1966). Measurement and creativity. *Theory Into Practice, 5*(4), 185–189. https://doi.org/10.1080/00405846609542023

Guilford, J.P. & Hoepfner, R. (1966). *Structure-of-intellect factors and their tests*. Reports from the Psychological Laboratory, University of Southern California, Number 36. June 1966. https://doi.org/10.21236/ad0489528.

Guilford, J. P. (1967). *The nature of human intelligence*. McGraw-Hill.

Halle, M. (1962). Phonology in generative grammar. *WORD, 18*(1–3), 54–72. https://doi.org/10.1080/00437956.1962.11659765

Hamilton, K., Nayak, A., Božić, B., & Longo, L. (2024). Is neuro-symbolic AI meeting its promises in natural language processing? A structured review. *Semantic Web, 15*(4), 1265–1306. https://doi.org/10.3233/SW-223

Hauser, M. D., Chomsky, N., & Fitch, W. T. (2002). The faculty of language: What is it, who has it, and how did it evolve? *Science, 298*(5598), 1569–1579. https://doi.org/10.1126/science.298.5598.1569

Hohwy, J., & Frith, C. (2004). Can neuroscience explain consciousness? *Journal of Consciousness Studies, 11*(7–8), 180–198.

Horn, J. L., & Blankson, N. (2005). Foundations for better understanding of cognitive abilities. In D. P. Flanagan, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 41–68). The Guilford Press.

Horn, J. L., & Cattell, R. B. (1966). Refinement and test of the theory of fluid and crystallized general intelligences. *Journal of Educational Psychology, 57*(5), 253–270. https://doi.org/10.1037/h0023816

Horn, J. L., & Cattell, R. B. (1967). Age differences in fluid and crystallized intelligence. *Acta Psychologica, 26*(2), 107–129. https://doi.org/10.1016/0001-6918(67)90011-X

Jackendoff, R. (1997). *The architecture of the language faculty*. Cambridge, MA: MIT Press.

Jung, R. E., Segall, J. M., Jeremy Bockholt, H., Flores, R. A., Smith, S. M., Chavez, R. S., & Haier, R. J (2010). Neuroanatomy of creativity. *Human Brain Mapping, 31*(3), 398–409. https://doi.org/10.1002/hbm.20874

Kahneman, D. (2011). *Thinking, fast and slow*. New York, NY: Macmillan.

Kasparov, G. (2017). *Deep thinking: Where machine intelligence ends and human creativity begins*. Hachette UK.

Kaufman, S. B. (2013). Opening up openness to experience: A four-factor model and relations to creative achievement in the arts and sciences. *The Journal of Creative Behavior, 47*(4), 233–255. https://doi.org/10.1002/jocb.33

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The four c model of creativity. *Review of General Psychology, 13*(1), 1–12.
Kennett, Y. N., Anaki, D., & Faust, M. (2014). Investigating the structure of semantic networks in low and high creative persons. *Frontiers in Human Neuroscience, 8*. https://doi.org/10.3389/fnhum.2014.00407
Kemp, W., Gillies, J., West, S., Marin, L., Preziosi, D., Ernst, Franses, & R. (1996). The narrativity of the frame. In P. Duro (Ed.), *The rhetoric of the frame: Essays on the boundaries of the artwork* (pp. 11–23). Cambridge University Press.
Khakzand, M., & Rakhshani, Z. (2021). Deconstruction as a technique for divergent thinking in pedagogy of the academic design process. *Journal of Design Thinking, 2* (2), 263–276. https://doi.org/10.22059/jdt.2022.339679.1070
Kogan, N., & Pankove, E. (1972). Creative ability over a five-year span. *Child Development, 43*(2), 427–442. https://doi.org/10.2307/1127546
Kröger, S. (2015). Neural correlates of creative thinking: Conceptual expansion processing. *[Doctoral dissertation, justus-liebig-universität giessen]*. Justus-Liebig-Universität Dissertationen/Habilitationen. https://doi.org/10.22029/jlupub-15092
Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences: Brain potentials reflect semantic incongruity. *Science, 207*(4427), 203–205. https://doi.org/10.1126/science.7350657
Kutas, M., & Federmeier, K. D. (2011). Thirty years and counting: Finding meaning in the N400 component of the event-related brain potential (ERP). *Annual Review of Psychology, 62*(1), 621–647. https://doi.org/10.1146/annurev.psych.093008.131123
Lambon Ralph M, A. (2014). Neurocognitive insights on conceptual knowledge and its breakdown. *Philosophical Transactions of the Royal Society B, 369*(1634). https://doi.org/10.1098/rstb.2012.0392
Lenneberg, E. H. (1967). *Biological foundations of language*. Wiley.
Lloyd-Cox, J., Pickering, A. D., Beaty, R. E., & Bhattacharya, J. (2023). Toward greater computational modeling in neurocognitive creativity research. *Psychology of aesthetics, creativity, and the arts*. Advance online publication. https://doi.org/10.1037/aca0000627
Lorca-Puls, D. L., Gajardo-Vidal, A., Team, PLORAS, Oberhuber, M., Prejawa, S., Hope, T. M. H., … Price, C. J. (2021). Brain regions that support accurate speech production after damage to Broca's area. *Brain Communications, 3*(4). https://doi.org/10.1093/braincomms/fcab230
Lubart, T. (2016). Creativity and convergent thinking: Reflections, connections and practical considerations. *RUDN Journal Of Psychology And Pedagogics*, (4), 7–15. https://doi.org/10.22363/2313-1683-2016-4-7-15
MacKinnon, D. W. (1970). Creativity: A multi-faceted phenomenon. In J. D. Roslansky (Ed.), *Creativity: A discussion at the Nobel conference* (pp. 17–32).
MacKinnon, D. W. (1978). *search of human effectiveness: Identifying and developing creativity*. Creative Education Foundation.
Martindale, C. (1995). Creativity and connectionism. In S. M. Smith, T. B. Ward, & R. A. Finke (Eds.), *The creative cognition approach* (pp. 249–268). The MIT Press.
Martindale, C. (1999). Biological bases of creativity. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 137–152). Cambridge University Press.
Mayer, R. E. (1999). *Fifty years of creativity research*. Cambridge University Press.
McCrae, R. R. (1987). Creativity, divergent thinking, and openness to experience. *Journal of Personality and Social Psychology, 52*(6), 1258–1265. https://doi.org/10.1037/0022-3514.52.6.1258
Merton, R. K., & Barber, E. (2011). *The travels and adventures of serendipity: A study in sociological semantics and the sociology of science*. Princeton University Press.
Mirous, H. J., & Beeman, M. (2012). Bilateral processing and affect in creative language comprehension. In M. Faust (Ed.), *Language processing in the brain: Clinical populations* (pp. 319–341). Wiley Blackwell.
Mooney, R. L. (1963). A conceptual model for integrating four approaches to the identification of creative talent. In C. W. Taylor, & & F. Barron (Eds.), *Scientific creativity: Its recognition and development* (pp. 331–340). John Wiley & Sons.
Mullen, C. A. (2020). Case study synthesis of outcomes: Highlighting hidden-c. *Revealing creativity: Exploration in transnational education cultures* (pp. 189–207). Cham: Springer International Publishing.
Newell, A., Shaw, J. C., & Simon, H. A. (1962). The processes of creative thinking. In H. E. Gruber, G. Terrell, & M. Wertheimer (Eds.), *Contemporary approaches to creative thinking: A symposium held at the* (pp. 63–119). University of Colorado.
Nusbaum, E. M., & Silvia, P. (2010). Fluid intelligence, executive processes, and strategy use in divergent thinking. *Intelligence, 39*(1), 36–45. https://doi.org/10.1016/j.intell.2010.11.002
Orwig, W., Diez, I., Vannini, P., Beaty, R., & Sepulcre, J. (2021). Creative connections: Computational semantic distance captures individual creativity and resting-state functional connectivity. *Journal of Cognitive Neuroscience, 33*(3), 499–509. https://doi.org/10.1162/jocn_a_01658
Pinker, S. (1994). *The language instinct*. William Morrow and Company.
Plucker, J. A., Esping, A., Kaufman, J. C., & Avitia, M. J (2015). Creativity and intelligence. In S. Goldstein, D. Princiotta, & J. A. Naglieri (Eds.), *Handbook of intelligence: Evolutionary theory, historical perspective, and current concepts* (pp. 283–291). Springer Science + Business Media. https://doi.org/10.1007/978-1-4939-1562-0_19.
Preckel, F., Holling, H., & Wiese, M. (2006). Relationship of intelligence and creativity in gifted and non-gifted students: An investigation of threshold theory. *Personality and Individual Differences, 40*(1), 159–170. https://doi.org/10.1016/j.paid.2005.06.022
Puente-Diaz, R., Maier, M. A., Brem, A., & Cavazos-Arroyo, J. (2016). Generalizability of the four C model of creativity: A cross-cultural examination of creative perception. *Psychology of Aesthetics, Creativity, and the Arts, 10*(1), 14.
Pulvermüller, F., Tomasello, R., Henningsen-Schomers, M. R., & Wennekers, T. (2021). Biological constraints on neural network models of cognitive function. *Nature Reviews Neuroscience, 22*, 488–502. https://doi.org/10.1038/s41583-021-00473-5
Razumnikova, O. M. (2013). Divergent versus convergent thinking. In E. G. Carayannis (Ed.), *Encyclopedia of creativity, invention, innovation and entrepreneurship* (pp. 546–552). Springer.
Renzulli, J. S. (1978). What makes giftedness? Reexamining a definition. *The Phi Delta Kappan, 60*(3), 180–184.
Rhodes, M. (1961). An analysis of creativity. *The Phi Delta Kappan, 42*(7), 305–310. https://www.jstor.org/stable/20342603.
Rosen, D. S., Oh, Y., Erickson, B., Zhang, F., Kim, Y. E., & Kounios, J. (2020). Dual-process contributions to creativity in jazz improvisations: *An spm*-EEG study. *NeuroImage, 213*. https://doi.org/10.1016/j.neuroimage.2020.116632
Rousi, R., & Silvennoinen, J. (2018). Simplicity and the art of something more: A cognitive–semiotic approach to simplicity and complexity in human–technology interaction and design experience. *Human Technology, 14*(1), 67–95. https://doi.org/10.17011/ht/urn.201805242752
Runco, M. A. (1991). The evaluative, valuative, and divergent thinking of children. *Journal of Creative Behavior, 25*, 311–319. https://doi.org/10.1002/j.2162-6057.1991.tb01143.x
Runco, M. A. (2010). Divergent thinking, creativity, and ideation. In J. C. Kaufman, & R. J. Sternberg (Eds.), *The Cambridge handbook of creativity* (pp. 413–446). Cambridge University Press.
Runco, M. A., & Jaeger, G. J. (2012). The standard definition of creativity. *Creativity Research Journal, 24*(1), 92–96. https://doi.org/10.1080/10400419.2012.650092
Sampson, G. (2016). *Two ideas of creativity. evidence, experiment and argument in linguistics and philosophy of language*. Peter Lang.
Schubert, D. S. (1973). Intelligence as necessary but not sufficient for creativity. *The Journal of Genetic Psychology: Research and Theory on Human Development, 122*(1), 45–47. https://doi.org/10.1080/00221325.1973.10533169
Shahghasemi, E. (2025). AI; A human future. *Journal of Cyberspace Studies, 9*(1), 145–173. https://doi.org/10.22059/jcss.2025.389027.1123
Spearman, C. (1904). General intelligence,' objectively determined and measured. *The American Journal of Psychology, 15*(2), 201–293. https://doi.org/10.2307/1412107
Sperry, R. W. (1952). Neurology and the mind-brain problem. *American Scientist, 40*(2), 291–312.
Sternberg, R. J. (1981). Intelligence and nonentrenchment. *Journal of Educational Psychology, 73*(1), 1–16.
Sweller, J. (2009). Cognitive bases of human creativity. *Educational Psychology Review, 21* (1), 11–19. https://doi.org/10.1037/0022-0663.73.1.1
Sætra, H. S. (2023). Generative AI: Here to stay, but for good? *Technology in Society, 75*, Article 102372. https://doi.org/10.1016/j.techsoc.2023.102372
Tan, A.-G. (2015). Convergent creativity: From Arthur Cropley (1935-) onwards. *Creativity Research Journal, 27*(3), 271–280. https://doi.org/10.1080/10400419.2015.1063892
Thagard, P. (2014). Artistic genius and creative cognition. In D. K. Simonton (Ed.), *The wiley handbook of genius* (pp. 120–138). Wiley Blackwell. https://doi.org/10.1002/9781118367377.ch7.
Ward, T. B. (1994). Structured imagination: The role of category structure in exemplar generation. *Cognitive Psychology, 27*(1), 1–40. https://doi.org/10.1006/cogp.1994.1010
Wason, P. C., & Evans, J. S. B. (1974). Dual processes in reasoning? *Cognition, 3*(2), 141–154.
Weinstein, J. B., & Bobko, P. (1980). The relationship between creativity and androgyny when moderated by an intelligence threshold. *Gifted Child Quarterly, 24*(4), 162–166.
Williams, F. E. (1969). Models for encouraging creativity in the classroom by integrating cognitive-affective behaviors. *Educational Technology, 9*(12), 7–13.
Winner, L. (1978). *Autonomous technology: Technics-out-of-control as a theme in political thought*. MIT Press.
Winter-Froemel, E., Thaler, V., & Demeulenaere, A. (2018). The dynamics of wordplay and wordplay research: Approaches, contexts and traditions. In E. Winter-Froemel, & V. Thaler (Eds.), *Cultures and traditions of wordplay and wordplay research* (1st ed., pp. 1–20). De Gruyter http://www.jstor.org/stable/j.ctvbkjv1f.3.
Wise, R. J., Greene, J., Büchel, C., & Scott, S. K. (1999). Brain regions involved in articulation. *Lancet, 353*(9158), 1057–1061. https://doi.org/10.1016/s0140-6736(98)07491-1
Wodtke, K. H. (1964). Some data on the reliability and validity of creativity tests at the elementary school level. *Educational and Psychological Measurement, 24*(2), 399–408. https://doi.org/10.1177/001316446402400229
Yamamoto, K. (1964). Threshold of intelligence in academic achievement of highly creative students. *Journal of Experimental Education, 32*(4), 401–405. https://doi.org/10.1080/00220973.1964.11010849
Yamamoto, K. (1965). Effects of restriction of range and test unreliability on correlation between measures of intelligence and creative thinking. *British Journal of Educational Psychology, 35*(3), 300–305. https://doi.org/10.1111/j.2044-8279.1965.tb01818.x
Zhang, W., Sjoerds, Z., & Hommel, B. (2020). Metacontrol of human creativity: The neurocognitive mechanisms of convergent and divergent thinking. *NeuroImage, 210*, Article 116572. https://doi.org/10.1016/j.neuroimage.2020.116572