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REVIEW ARTICLE

Exploring the Landscape of Cognitive Load in Creative Thinking: a Systematic Literature Review

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Abstract
Creative thinking, recognized as a fundamental life skill, is a complex process influenced by cognitive load. While literature has addressed the integration of cognitive load theory into creative thinking research, a comprehensive synthesis is lacking. To address this gap, we conducted a systematic review and deductive thematic analysis, drawing from 33 eligible articles sourced from Web of Science (WoS), the Educational Resources Information Center (ERIC), and Scopus electronic databases. Thematic analysis identified diverse roles of cognitive load within creativity studies, including mediator, moderator, independent variable, dependent variable, and as a component of the theoretical framework. Management strategies for cognitive load in creativity research involve the use of external resources, environmental interventions, and self-regulation. Methodological considerations regarding internal and external validity are also discussed. This review offers implications for researchers and practitioners, informing future research directions and contributing to the effective management of cognitive load in creative thinking practices.

Keywords Cognitive load theory · Creativity · Creative thinking · Systematic review

Introduction

The innate ability to think creatively has favored humans in achieving novel and useful creations across art, science, and technology, as well as in addressing everyday challenges. Creative thinking is considered a complex cognitive activity

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involving a divergent process in which a variety of ideas are generated, followed by a convergent process in which ideas are evaluated (Amabile, 1988; Harvey & Kou, 2013; Sweller, 1988). This dual process heavily relies on information processing that requires cognitive resources such as working memory capacity (WMC), and the retrieval of information from long-term memory (LTM) to produce ideas that are both novel and useful.

A cognitive factor related to creative thinking is cognitive load. Cognitive load theory (CLT) (Sweller, 1988) acknowledges the limited capacity of working memory when processing new and complex information, as well as the use of cognitive schemas—chunked elements of information—stored in LTM to assist information processing in working memory. Traditionally, CLT distinguishes three types of cognitive load: intrinsic load, associated with task complexity; extraneous load, related to the way information is presented; and germane load which regards about the integration of new information with previously acquired knowledge. Scholars have extensively studied the effects of the three types of load on complex activities such as learning tasks (Sweller et al., 2019). However, less clear is the impact that these types of loads may have on complex tasks such as those demanding creative thinking (Redifer et al., 2019; Jenni L Redifer et al., 2021).

Creative thinking involves balancing two seemingly contradictory aspects, novelty, and usefulness (Leung et al., 2018; Miron-Spektor & Erez, 2017). On one hand, creativity encourages thinking in unconventional ways through a divergent process, which can lead to highly novel but not immediately practical ideas. On the other hand, it also involves a convergent process to make these novel ideas useful and feasible in real-world scenarios. Moreover, the management of information during both convergent and divergent processes heavily depends on the limited capacity of working memory, as well as the transfer of organized information from LTM (e.g., ideas, knowledge, concepts, and task representations). Consequently, when cognitive load exceeds the capacity of working memory, it is expected that intrinsic, extraneous, and germane load exerts an influence, to some extent, on creative thinking indicators such as fluency, flexibility, originality, feasibility, and appropriateness.

Sweller (2009) initially established the relationship between CLT and human creativity. In his review, Sweller employs a cognitive architectural framework to explain the creative process through evolutionary theory, in which randomness enables the emergence of novelty. By combining the fundamental concepts of human cognitive architecture and evolutionary principles, Sweller advocated for empirical research on cognitive load in the creativity context. Since then, the explanatory role of cognitive load in creative thinking has been examined across different perspectives. While some studies have only introduced cognitive load as a concept in their theoretical frameworks to explain the intricate dynamics between cognitive processes and creativity (Christensen, 2004, 2005; Elsbach & Hargadon, 2006; Garbuio & Lin, 2021), other studies have manipulated cognitive load through various interventions to determine its direct (Aldalalah, 2021; Sun et al., 2014) or mediating effect (Y.-C. Chen et al., 2022a, 2022b; Hao et al., 2015; Pacauskas & Rajala, 2017) on creative performance. Despite scholars' interest in investigating this relationship, there remains no synthesis of the existing literature. Thus, the primary objective of our study is to conduct a systematic literature review to investigate the following research question:

What is the relationship between cognitive load and creative thinking?

To address this question, the current study conducts a thematic analysis exploring: (i) What are the different roles played by cognitive load in theoretical frameworks of studies addressing creativity? (ii) What strategies have been proposed for managing cognitive load during creative tasks? and (iii) What methodological considerations should be considered when studying the relationship between cognitive load and creativity?

Theoretical Framework

Creative Thinking

Creative thinking is a cognitive process that generates thoughts, answers, or products that are both original and useful (Guilford, 1950; Mednick, 1962; Sternberg, 1985). It is a process associated with complex problem-solving because creative problems possess characteristics such as novelty, ill-definition, complexity, and openness (Mumford & McIntosh, 2017; Mumford et al., 1991), which challenge individuals to think innovatively and generate unique solutions. Consequently, creative thinking pushes the boundaries of conventional thinking and encourages individuals to explore new avenues and possibilities. In addition, it comprises a dual thought process involving both divergent and convergent thinking (Benedek et al., 2012; Dietrich & Kanso, 2010). Divergent thinking breaks away from conventional thought patterns to generate multiple ideas (Guilford, 1956), while convergent thinking uses an inductive process to select and integrate ideas into high-quality creative outcomes (Liu, 2016).

Individual characteristics, including expertise, intelligence, and the ability for divergent thinking, influence success in complex cognitive tasks related to creative thinking (Vincent et al., 2002). The diverse factors influencing creative output lead to a fundamental question: What serves as the basis for individuals to produce innovative solutions to problems? (Mumford et al., 2009). The continuous search for an answer to this question is essential to designing new strategies to develop, assess, and manage creative individuals (Scott et al., 2004; Vessey & Mumford, 2012). Consequently, scholars have advocated for identifying the creative thinking processes relevant to the generation of creative problem solutions, such as problem definition, information gathering, concept/case selection, conceptual combination, idea generation, idea evaluation, implementation planning, and adaptive execution (Dewey, 1910; Mumford et al., 1991). Furthermore, scholars have studied the ability of creative thinking processes to predict performance during creative problem-solving activities. The effective execution of creative thinking processes not only predicts creative performance in jobs where creative thinking is of utmost importance (Mumford et al., 1997) but also contributes to predicting performance beyond what can be anticipated by basic abilities such as intelligence and divergent thinking (Vincent et al., 2002).

Determining the originality of responses during a creative problem-solving activity is a complex cognitive process. First, it requires the ability to recall stored information from LTM to generate a broad range of ideas. The more ideas that are generated the greater the pool of options to assess for originality. Furthermore, it entails tracking ideas as they emerge, along with the assessment of their novelty compared to previous concepts or notions (Redifer et al., 2019). Since this dual cognitive demand plays a key role in creative thinking and problem-solving contexts, it requires a delicate equilibrium between divergent and convergent thinking processes. Divergent thinking, facilitated by disinhibition, leans on associative thinking, flexibility, and an openness to new experiences. Its objective is to produce numerous ideas by exploring various directions, forging connections, and transcending conventional boundaries (Benedek et al., 2012; Dietrich & Kanso, 2010). On the other hand, convergent thinking relies on critical thinking, inhibition, and pattern recognition aiming to refine and synthesize ideas into workable solutions (Baas et al., 2008). Collectively, these cognitive tasks involve multiple steps or components that require mental effort. They heavily rely on working memory, which is a cognitive function responsible for temporarily holding and manipulating information in our minds (Beaty et al., 2014; Lee & Therriault, 2013; Redifer et al., 2019).

Cognitive Load Theory

Grounded in the framework of human cognitive architecture, CLT assumes that cognitive structures, such as working memory and LTM, are organized to facilitate the processing of information elements (Sweller, 2009). An element constitutes a unit of information that an individual needs to learn or understand or a cognitive schema that has already been acquired and processed (Sweller et al., 2019). CLT emphasizes the notion that working memory has a limited capacity, meaning that if the elements requiring simultaneous processing in working memory surpass its limitations, cognitive overload is likely to occur. When working memory becomes overloaded, individuals may need to draw upon their repository of knowledge stored within LTM to effectively deal with novel and complex information (Sweller, 2003). Furthermore, as expertise within a specific domain develops, knowledge is not only constructed but also automated within cognitive schemas. These schemas serve as cognitive frameworks that organize and store information within LTM, thereby simplifying the management of information and its seamless integration into working memory.

CLT considers three distinct categories of load: extraneous, intrinsic, and germane. Extraneous cognitive load arises from non-task-related factors, such as irrelevant information introduced by task representation or instructional material design. The development of this theoretical framework predominantly centered on reducing extraneous load (Tarmizi & Sweller, 1988). Thus, experimental studies were dedicated to scrutinizing the effects associated with extraneous load reduction. Consequently, CLT proposed a variety of instructional techniques, including substituting conventional learning tasks with goal-free tasks (Sweller & Levine, 1982), presenting comprehensive worked examples incorporating complete problem solutions (Sweller & Cooper, 1985), presenting partial problem solutions for completion (Van

Merrienboer & Krammer, 1987), integrating complementary information sources to mitigate split attention (Tarmizi & Sweller, 1988), avoiding the inclusion of redundant information sources (Chandler & Sweller, 1991), and deploying multimodal information sources for task presentation, encompassing both auditory and visual modalities (Mousavi et al., 1995).

These instructional procedures worked under the assumption that diminishing cognitive load, particularly represented by extraneous load, would enhance learning outcomes. However, empirical investigations concerning the worked example, split-attention, or redundancy effect studies unveiled a surprising nuance: reducing extraneous load positively influenced learning outcomes only when confronted with high task complexity (Sweller & Chandler, 1994). This fundamental revelation prompted the integration of intrinsic cognitive load into the theoretical framework.

Intrinsic cognitive load describes the load imposed by various elements of information interacting simultaneously in working memory. In other words, intrinsic load arises from the innate complexity of a task and the knowledge required for its comprehension. Empirical studies have explored the ramifications of increasing or decreasing element interactivity within learning tasks. In scenarios where the inherent complexity of the information is low, increasing element interactivity through instructional variability heightens the likelihood of knowledge construction. This approach enables individuals to recognize resembling features across different problem situations (Paas & Van Merriënboer, 1994). Conversely, Pollock et al. (2002) postulated that in cases where the inherent complexity of the information is high, diminishing element interactivity by initially presenting task features in isolation, followed by introducing fully integrated information, can enhance the learning process.

Based on findings derived from the reduction of extraneous load and variations in intrinsic load, the theoretical framework introduces a distinct concept to account for the intentional cognitive effort required for learning (Sweller et al., 2011a). This concept is known as "germane cognitive load," representing the effort individuals invest in organizing and integrating new, relevant information with their existing knowledge. Germane load contributes to establishing meaningful connections between working memory and LTM. However, unlike extraneous and intrinsic load, empirical studies examining variations of germane cognitive load are noticeably absent. Instead, instructional techniques have been proposed under the assumption that an increase in germane load yields positive effects on learning outcomes. Some of these techniques involve encouraging self-explanations (Chi et al., 1989; Große & Renkl, 2007; Renkl & Atkinson, 2016) and identifying and rectifying errors (Große & Renkl, 2007).

Initially, CLT assumed that the cumulative sum of intrinsic, extraneous, and germane load constituted an overall cognitive load, with instructional development efforts aimed at keeping this total load within the constraints of working memory. However, a recent debate among researchers has emerged regarding whether germane load is a component of intrinsic cognitive load (Kalyuga, 2011; Sweller et al., 2011b). Within this contemporary perspective, the germane load's function is no longer to impose an additional load but rather to direct working memory resources toward processing the essential, interrelated elements of information necessary to manage intrinsic load effectively. This suggests a conceptual relationship between germane and intrinsic load. Consequently, under this latest approach of CLT, the total cognitive load is primarily determined by intrinsic and extraneous load, emphasizing the need for instructional design to reduce extraneous cognitive load. This reassignment of cognitive resources, now referred to as germane resources, enables more focused support for managing intrinsic cognitive load (Sweller et al., 2019).

Cognitive Load and Creative Thinking

CLT distinguishes between two dimensions in its construct conceptualization: causal factors and assessment factors. Factors that affect cognitive load include the task environment and subject characteristics. Factors that can be used to assess cognitive load include mental load, mental effort, and performance. Examining the potential links between creative thinking and these causal and assessment factors of CLT serves as a foundational approach upon which it is possible to elucidate the complexities surrounding the relationship between cognitive load and creative thinking.

Causal Factors: Task and Subject Characteristics

Certain aspects of the task environment, such as novelty, time pressure, and punitive consequences for errors, are suggested to increase the cognitive load (Paas & Van Merriënboer, 1994), especially in time- and performance-pressured situations. In parallel, complex tasks requiring skill variety, significance, identity, autonomy, and feedback are suggested to promote creative thinking (Oldham & Cummings, 1996). However, research concerning the link between creativity and factors like time pressure and rewards has yielded mixed results (Amabile et al., 1986; Baer & Oldham, 2006; Eisenberger & Rhoades, 2001; Ohly & Fritz, 2010). Other scholars highlight the nuanced, context-dependent nature of the relationship by suggesting that tying rewards to performance pressure may enhance intrinsic motivation and creativity (Eisenberger & Aselage, 2009).

These task characteristics suggest that cognitive load, especially in complex and meaningful tasks, can potentially stimulate creativity. Similarly, the physical environment can also influence cognitive load and creativity. Elements like noise and temperature are often seen as potential distractions that can increase extraneous cognitive load and, in turn, hinder creative thinking (Mille et al., 2022; Paas & van Merriënboer, 2020). However, elements in the environment, such as visual or auditory stimuli, hold the potential to serve as sources of inspiration, thereby fostering and enhancing creativity (Goldschmidt & Smolkov, 2006).

In terms of subject characteristics, expertise, motivation, and affect are typically studied as factors that influence cognitive load and creativity. First, expertise in CLT typically reduces intrinsic cognitive load by employing organized cognitive schemas (Kalyuga, 2009). However, in the context of creative thinking, expertise leverages existing knowledge for novel connections but may also inhibit remote associations and creative flexibility (Chiu et al., 2013; Crilly, 2015).

Second, motivation, which serves as the driving force behind task processing and creative solution generation, plays a crucial role. In cognitive load studies, motivation, task relevance, and perceived value encourage learners to invest cognitive effort (De Backer et al., 2022; Paas et al., 2005). In creative thinking, intrinsic and avoidance motivations promote effortful thinking (Grant & Berry, 2011; Roskes et al., 2012).

Finally, affect, including positive and negative emotions, is linked to motivation and may influence cognitive resources. Mixed findings underscore the complex relationship between affect and both learning and creativity (Baas et al., 2008; Fraser et al., 2012). Recent scholarly interest has focused on exploring the intricate relationship between negative affect, cognitive effort, and creativity (Jung & Lee, 2015; Nijstad et al., 2010). This line of inquiry suggests that negative mood states can enhance creative fluency and the originality of ideas by stimulating individuals to engage in more effortful, systematic, and analytical thinking to address perceived problematic situations.

Assessment Factors: Mental load, Mental Effort, and Performance

The CLT framework distinguishes between three measurable factors for assessing cognitive load: mental load, mental effort, and performance. Understanding these assessment factors becomes particularly crucial in the context of creative thinking. Mental load is an assessment factor that centers on the characteristics of a task, specifically, the load imposed by the level of element interactivity and the complexity of a task (Gopher, 2013). Creative tasks often impose a high mental load due to their inherently ill-structured or insight-based nature. They are characterized by ambiguity, multiple potential solutions, and a lack of clear rules or procedures for solving them (Simon, 1973). Therefore, when individuals engage in creative problem-solving, they must address complex, open-ended scenarios that require them to explore various possibilities, thinking both divergently and convergently, to generate novel and useful ideas.

Furthermore, in the context of creative thinking, mental effort becomes pertinent as it refers to the amount of cognitive resources individuals require to deal with task representation. This subjective experience may vary depending on individual differences, task complexity, or expertise level (Sweller et al., 2011a). Essentially, the higher the mental load, the greater the perception of mental effort. Therefore, as individuals tackle creative tasks, they not only face a high mental load due to the inherent complexity but also exert considerable mental effort in generating novel solutions. The cognitive processes involved in creative thinking, such as problem definition, conceptual combination, idea generation, and idea evaluation, demand significant cognitive resources and effort. Creativity researchers introduced the concept of "creative effort" to describe the in-depth thinking processes individuals engage in while solving creative problems (Blohm et al., 2016; Nijstad et al., 2010). According to Baas et al. (2013), engaging in a persistent thinking style typically demands a greater degree of creative effort, as it allows individuals to fully explore the potential of an idea and refine it over time.

Performance, another assessment factor reflecting cognitive load, can be determined in creative thinking through a variety of indicators assessing creative outcomes. These indicators include dimensions such as novelty, flexibility, fluency, and quality, among others (Ranjan et al., 2018). Novelty refers to the ability to produce original and unique ideas, while flexibility is the capacity to shift between different perspectives or viewpoints when exploring solutions. Fluency measures the capability to brainstorm a large quantity of ideas. These indicators are commonly associated with divergent thinking processes. In parallel, convergent thinking, focused on evaluating and selecting the best solution, is primarily associated with indicators such as feasibility, quality, or appropriateness. Cognitive load may exert a notable influence on creative thinking performance—either by limiting the capacity to explore novel ideas and exercise flexibility, while also impeding the quality of decision-making in convergent thinking, or by reducing cognitive load to free up mental resources, promoting creative exploration and thoughtful evaluation.

Methods

Search Strategy

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses—PRISMA (Braun & Clarke, 2006), we conducted a comprehensive review of the literature to explore how scholars have examined cognitive load in the field of creativity. To align with the study's objectives and research questions, we developed a protocol that specifies the search terms, information sources, and eligibility criteria.

After conducting an initial review of the conceptualizations of cognitive load and creativity, we compiled a list of terms describing each construct. Then, we retrieved data from the Educational Resources Information Center (ERIC), Web of Science (WoS), and Scopus electronic databases. The detailed electronic search strategy for each database is provided in Table 1. We conducted the search on January 5, 2023, with specific restrictions, including document type and language, as quality criteria for the initial search. We limited results to full-text, peer-reviewed English articles published between 1988 and the beginning of January 2023.

Eligibility Criteria

We screened articles identified through the database search for inclusion based on specific eligibility criteria, which included the following: (a) full-length peer-reviewed articles that described and explored the relationship between cognitive load and creativity, offering insights, evidence, or discussions on their interaction; (b) research articles written in English; (c) articles presenting original data, either through empirical (i.e., qualitative, quantitative, or mixed methods) or non-empirical (i.e., theoretical) study designs; and (d) we did not pace restrictions on the population under investigation. Additionally, we excluded studies if they (a) primarily

Table 1 Electronic search strategy

Database	Search string	Limits
Web of Science	TS = (((“cognitive load”) OR (“mental effort”) OR (“cognitive persistence”)) AND ((creativ*) OR (“design thinking”) OR (“convergent thinking”) OR (“divergent thinking”) OR (idea*) OR (brainstorm*) OR (innovati*) OR (original*) OR (novel*)))	Document type: Article Language: English Timespan: 1988–01-01 to 2023–01-05 (Publication Date)
Scopus	TITLE-ABS-KEY ((“cognitive load” OR “mental effort” OR “cognitive persistence”) AND (creativ* OR “design thinking” OR “convergent thinking” OR “divergent thinking” OR idea* OR brainstorm* OR innovati* OR original* OR novel*)) AND PUB YEAR > 1987 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English"))	Document types: Article Languages: English Publication date: After 1987
ERIC	(“cognitive load” OR “mental effort” OR “cognitive persistence”) AND (creativ* OR “divergent thinking” OR “convergent thinking” OR idea* OR brainstorm* OR novel* OR original* OR innovati*)	Peer-reviewed Languages: English Document types: Journal Article Date published: January 1988-January 2023

addressed topics unrelated to the interplay between cognitive load and creativity or exclusively focused on either cognitive load or creativity; (b) were published before 1988; (c) were published in languages other than English; and (d) were reviews, meta-analyses, commentaries, conference papers, or book chapters. We limited the publication date because CLT was initially introduced in 1988 by John Sweller. Since then, the theory has become influential in education and has expanded into other research areas, including creativity. We excluded commentaries, conference papers, and book chapters as they might not undergo the same rigorous peer review as full-length research articles. Additionally, we excluded meta-analyses and reviews as they typically do not present primary research findings but rather summarize or comment on existing research.

Selection Process

The selection process involved reviewing and coding 33 articles, as illustrated in Fig. 1. The figure summarizes the steps and indicates the number of studies included and excluded at each stage using the PRISMA flow diagram. Initially, we conducted a comprehensive search across multiple electronic databases using specific search strings and limits, resulting in a pool of 2479 articles. Then, we added references from articles identified through the database search to EndNote and removed 1010 duplicate articles. After that, we exported information from the remaining 1469 articles, including the title, abstract, authors, and year of publication, to an Excel spreadsheet. Subsequently, we screened the titles and abstracts, categorizing them as “Included” if they met the established eligibility criteria, “Undecided” if there were doubts regarding criteria fulfillment, or “Excluded” if they failed to meet the criteria. As a result, we excluded 1365 articles from the study because their abstracts did not directly describe the exploration of both cognitive load and creativity in their research.

After the initial selection, we downloaded the full text of 104 articles. Despite extensive efforts to locate them through alternative sources, it was not possible to access two articles, i.e., Kompa and Mueller (2022), Yu and Choi (2022). Subsequently, we conducted a careful reevaluation of the eligibility criteria. Out of the 102 retrieved articles, we excluded 26 because they primarily addressed topics unrelated to the interplay between cognitive load and creativity. Additionally, we discarded another 27 articles as they exclusively focused on cognitive load, and 10 articles solely concentrated on creativity. Furthermore, we excluded six records because they corresponded to book chapters (Briggs et al., 2015; Edyburn, 2015; Wyeld, 2016), meta-analyses (Nijstad et al., 2010; Pacauskas & Rajala, 2017), and review articles (Sweller, 2009).

We conducted the screening procedure independently, achieving a successful inter-rater agreement of 95% for the title and abstract screening, and 93.8% for the full-text screening. Additionally, we resolved discrepancies through discussion. Although we considered involving a third reviewer in cases where consensus could not be reached, it proved unnecessary as we effectively reached agreement.

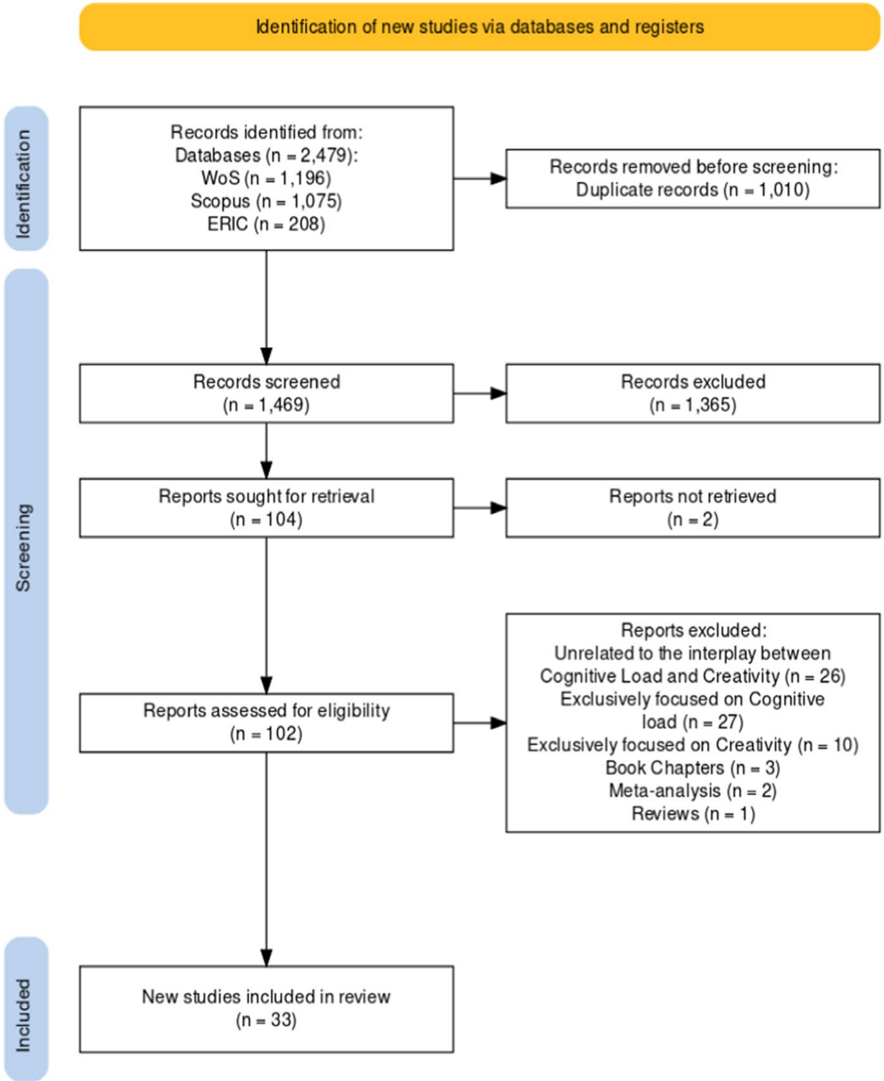

Fig. 1 PRISMA flow diagram of the study selection process. Note. We generated the flow diagram using the Shiny app tool in accordance with the PRISMA 2020 standards (Haddaway et al., 2022)

Thematic Analysis

Our systematic review utilizes deductive thematic analysis with the assistance of NVivo software. To ensure the rigor and consistency of the coding procedure, we meticulously followed a step-by-step guide for thematic analysis established by Braun and Clarke (2006). Throughout this process, we engaged in collaborative discussions to resolve disagreements and reconcile any inconsistencies until we reached a consensus. The analysis unfolded across six distinct phases, each contributing to a comprehensive understanding of the data. In the first phase, we immersed ourselves in the content by carefully reading the selected articles during the screening process, data extraction, and qualitative appraisal. In the second phase, we developed a coding framework. During this step, we extracted data to create codes around three main themes: (a) content discussing the relationship between cognitive load and creativity, (b) information suggesting mechanisms for cognitive load management, and (c) content discussing methodological issues. Subsequently, we named the initial codes generated with descriptive labels that capture the essence of each theme. For instance, we categorized content discussing the relationship between cognitive load and creativity under the code titled "Speaking Out Ideas Lead to Higher Cognitive Load and Reduces Fluency" We created the code "Social Environment Support" for content suggesting mechanisms for cognitive load management, and "Self-Reported Creativity Measurement" to categorize content discussing methodological issues.

In the subsequent three phases, we conducted iterative content coding to identify data patterns. This process involved reviewing all extracted codes within each theme and determining whether they coherently formed patterns that could be combined into sub-themes. as a result, sub-themes within (a) theme emerged, including cognitive load as an independent variable, as a dependent variable, as a moderator, as a mediator, and as a factor in the theoretical framework. in theme (b), sub-themes such as using external resources, intervention of the environment, and self-regulation emerged, while theme (c) produced sub-themes that focused on internal and external validity. In the final phase of the analysis, we reported the qualitative results in-depth within the "Results" section of our review.

Results

Study Characteristics

Appendix presents the main characteristics of the included studies. The results indicate that scholars have explored cognitive load in the field of creativity from 2004 to 2022. Figure 2 depicts the increasing attention given to investigating the relationship between cognitive load and creativity over the past decade. Researchers from various disciplines have actively contributed to this field, highlighting its interdisciplinary nature. In terms of specific research contexts, we identified five distinct domains: psychology (32.4%), education (26.5%), design (20.6%), management (17.6%), and marketing (2.9%). Among these domains, design is the only one conceptualized as a creative activity, involving problem-solving, exploration of problem spaces, and generation and evaluation of solutions (Goldschmidt, 2014; Simon, 1988). The goal of design is to produce outcomes that meet human needs. In our review, studies from the design domain mainly focused on devising functional and meaningful solutions for product design problems.

The reviewed studies employed diverse research designs, with the majority using empirical research designs ($n = 31$), followed by studies with a theoretical design ($n = 2$). Scholars recruited participants with various occupational backgrounds for

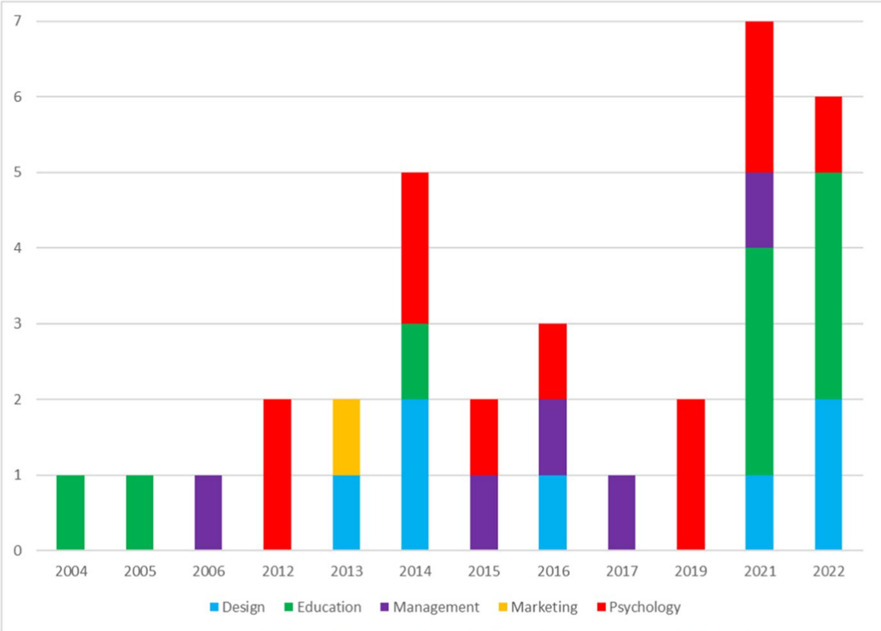

Fig. 2 Publication year and domain distribution of the reviewed studies

data collection in experimental and cross-sectional design studies. These participants included industry employees ($n=3$), police officers ($n=1$), school students ($n=5$), and university students ($n=19$). However, four studies did not specify the academic or practical background characteristics of participants. Among the studies involving university students, most of them targeted participants from specific academic programs, including architecture ($n=1$), psychology ($n=3$), engineering ($n=5$), management ($n=1$), and education ($n=1$). In contrast, two studies reported recruiting university students from a wide range of disciplines, and six studies did not specify the majors of the students. Additionally, participants performed various types of tasks during the experimental procedures. The most frequently used tasks included product design tasks ($n=7$), alternative uses tasks ($n=7$), and the presentation of specific scenarios for creative problem-solving ($n=4$). Furthermore, a subset of studies focused on addressing creative insight problems ($n=4$).

In terms of the types of cognitive load addressed, researchers most frequently investigated intrinsic load ($n=11$). They measured it either directly through self-reported mental effort ratings or manipulated it by varying sensory inputs or enhancing writing skills. Scholars also commonly focused on extraneous load ($n=10$) and often manipulated it through secondary tasks that involved memorizing numbers or presenting learning materials through audiovisual methods. Some studies simultaneously addressed intrinsic and extraneous load ($n=5$) by using self-reported scales based on these two dimensions of cognitive load. Other studies primarily used secondary task techniques aimed at measuring overall cognitive load, which includes both intrinsic and extraneous cognitive load. Additionally, some studies used physiological measures like EEG or ICG to investigate both intrinsic and extraneous aspects. Studies that addressed intrinsic, extraneous, and germane load simultaneously used self-reported questionnaires that included items assessing each type of load ($n=4$). Only one study addressed germane load by directly or indirectly manipulating prompts.

Regarding creativity measurement, the majority of studies used outcome scores to assess various dimensions within the creativity construct ($n=18$). Most of these studies solely focused on assessing dimensions associated with divergent thinking, such as fluency, flexibility, and originality ($n=10$). A subset of studies ($n=8$) also considered convergent thinking dimensions, such as appropriateness, quality, and functionality, alongside divergent thinking dimensions. Therefore, these studies considered for both divergent and convergent thinking within their assessments of creativity scores. Other researchers employed more standardized evaluations of participants' creative thinking, such as the Torrance Creativity Test ($n=1$) to assess divergent thinking or the Remote Association Test ($n=3$) for convergent thinking. Furthermore, studies used validated scales ($n=6$) to measure participants' subjective experiences and beliefs related to creativity. These scales assessed different aspects of creativity, including work creativity, experience, implicit theories of creativity, creative self-efficacy, creative achievement, and product semantics.

Quality Appraisal

The included studies consisted of empirical studies ($n=31$) and non-empirical studies ($n=2$). Empirical studies featured diverse research designs, including quantitative randomized designs (Baas et al., 2013; Blohm et al., 2016; Bose et al., 2013; Y.-C. Chen et al., 2022a, 2022b; Christensen, 2004; Chuderski et al., 2021; Cseh et al., 2016; De Dreu et al., 2012; Hao et al., 2015; Jung & Lee, 2015; Kleinkorres et al., 2021; Mille et al., 2022; Mohamed-Ahmed et al., 2013; Redifer et al., 2019; Jenni L Redifer et al., 2021; Rodet, 2022; Roskes et al., 2012; Weatherford et al., 2021), non-randomized designs (Aldalalah, 2021; Bitu et al., 2022; H. Chen et al., 2022a, 2022b; Christensen, 2004, 2005; Hao et al., 2014; Kassim et al., 2014; Mao et al., 2022; Nguyen & Zeng, 2014, 2017; Shemyakina & Nagornova, 2019; Sun et al., 2014, 2016), quantitative descriptive designs (Jung & Lee, 2015; VerPlanck, 2021), and mixed methods (Kassim et al., 2014; Sun et al., 2014, 2016). To assess the quality of these empirical studies, we employed the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018), a versatile tool tailored to various empirical research designs (i.e., qualitative research, randomized controlled trials, non-randomized studies, quantitative descriptive studies, and mixed methods studies).

For the included non-empirical studies (Elsbach & Hargadon, 2006; Garbuio & Lin, 2021), we adapted a quality appraisal method from the structural components assessment developed for theoretical studies by Halbesleben et al. (2004). These structural components encompass four comprehensive indicators: the need for the theory, explication of the theory, limitations of the theory, and guidance for future research. We reviewed the quality of both empirical and non-empirical studies using the corresponding appraisal tool and deliberated upon discrepancies until reaching a consensus. Noteworthy, the assessment conducted relied solely on the information provided within the original articles.

We found that the empirical and non-empirical studies included in our review generally exhibited sound quality. Non-empirical studies demonstrated a high standard by articulating clear rationales for their theoretical frameworks. These studies adeptly identified gaps in existing literature, acknowledged potential limitations inherent in their theoretical approaches, and provided insightful directions for future research. Similarly, empirical studies also showed strong quality. For instance, mixed-methods studies establish coherent connections between qualitative and quantitative data sources throughout the process of data collection, analysis, and interpretation. Studies employing quantitative descriptive methods demonstrate strength by ensuring alignment between respondents and the target population, as well as offering transparent justifications for any potential limitations in data analysis. Furthermore, studies employing randomized and non-randomized research designs demonstrated noteworthy strengths in providing complete outcome data, ensuring they implemented interventions as intended, and including definitions and measurements for variables.

The Role of Cognitive Load in Creativity

Exploring the relationship between cognitive load and creativity is essential to understanding the intricate mechanisms that contribute to human cognition and problem-solving abilities. Scholars in creativity literature have approached cognitive load from various perspectives, assuming different roles and positions. Collectively, these studies reveal the multifaceted relationship between cognitive load and creativity. They offer insights into how cognitive load can either act as a barrier or be strategically managed to enhance creative outcomes. These findings deepen our understanding of the cognitive processes that underlie creativity and carry implications for education, innovation, and problem-solving. Recognizing and addressing cognitive burdens that hinder creative thinking can enable individuals, educators, and organizations to create environments that foster innovation and the generation of novel ideas.

Cognitive Load as an Independent Variable

The included studies consistently identify cognitive load as an independent variable. Scholars intentionally manipulate cognitive load to assess its direct impact on divergent thinking (Aldalalah, 2021; Bose et al., 2013; Cseh et al., 2016; Kassim et al., 2014; Kleinkorres et al., 2021; Mao et al., 2022; Mille et al., 2022; Rodet, 2022; Silvia et al., 2014). Some studies consistently show a negative relationship between increased levels of cognitive load, induced through memorizing digit numbers, and divergent thinking (Bose et al., 2013; Rodet, 2022). Their findings suggest that heightened cognitive load hampers the quantity of ideas generated. Furthermore, other studies provide evidence supporting the positive influence of reducing cognitive load on shaping divergent thinking, particularly within the education context

(Aldalalah, 2021; Kassim et al., 2014). Aldalalah (2021) and Kassim et al. (2014) both found that using multi-sensory tools aimed at reducing cognitive load resulted in the generation of more flexible and original ideas compared to those who did not use such tools.

Although some of the studies that treat cognitive load as an independent variable agree on whether increasing or decreasing cognitive load levels is beneficial or detrimental for idea generation, it's important to note that the effects of cognitive load on divergent thinking were not consistent across the included studies. For instance, alterations in cognitive load through diverse medium interventions such as sketching tasks or environmental stimuli did not directly correlate with improvements in creative fluency (Cseh et al., 2016; Mao et al., 2022; Mille et al., 2022).

Beyond divergent thinking, other studies explored how cognitive load influences convergent thinking (De Dreu et al., 2012; Hao et al., 2014; Roskes et al., 2012). These studies produced diverse and even contradictory findings regarding the effect of cognitive load. Hao et al. (2014) noted a positive impact on the originality of ideas regardless of the cognitive demand level of the task, whereas Sun et al. (2014) examined how varying levels of cognitive load, influenced by factors like expertise and design approach, affect the quality of design outcomes. Moreover, increased cognitive load might hinder the capacity to generate creative insights (De Dreu et al., 2012; Roskes et al., 2012; Weatherford et al., 2021). Among these studies, Weatherford et al. (2021) hold special interest because they are the only included study in our review that directly manipulates both extraneous and germane load. The findings of this study indicate that increasing germane load through chunk decomposition, breaking down the physical properties of an object into parts, contributes to overcoming functional fixedness, and thus promotes creative problem-solving performance. However, extraneous cognitive load manipulation did not yield a significant result.

Cognitive Load as a Dependent Variable

Scholars investigate cognitive load as a dependent variable primarily to explore how various interventions impact cognitive load. H. Chen et al., (2022a, 2022b), Chuderski et al. (2021), and Mohamed-Ahmed et al. (2013) aimed to examine how the impact of different modes or methods of problem-solving and design work influenced participants' cognitive load. The different interventions in each study produced varying findings regarding their effects on cognitive load. For instance, compelling evidence supporting the effectiveness of animation-guided meditation in reducing overall cognitive load (H. Chen et al., 2022a, 2022b) contrasts with other studies reporting that their corresponding interventions (Chuderski et al., 2021; Mohamed-Ahmed et al., 2013) did not significantly affect participants' cognitive load levels.

In addition to exploring the impact of various interventions on cognitive load management, Sun et al. (2016) considered cognitive load as a dependent variable to investigate how cognitive strategies employed during creative tasks correlate with cognitive load. This investigation involved assessing cognitive load after participants had engaged in the creative activity. The authors proposed that specific cognitive strategies used in problem structuring influence cognitive load. Interestingly, the study revealed that cognitive strategies, such as explicit decomposition (systematically breaking down the problem) and the breadth-first approach (a top-down solution development process), enhanced problem structuring, and improved the quality of design outcomes. Notably, these strategies did not necessarily reduce cognitive load.

Cognitive Load as a Component of the Theoretical Framework

Studies incorporating cognitive load into their theoretical frameworks collectively employ it as a perspective to support their hypotheses (Christensen, 2004; Elsbach & Hargadon, 2006; Garbuio & Lin, 2021). None of these studies measure cognitive load. Thus, the connection between them lies in their focus on either educational or organizational contexts, rather than being grounded in empirical findings. In the educational context, the literature suggests that orthographic-motor integration (typing and handwriting) is important in creative written text production for reducing cognitive load and enhancing the ability to generate creative and original text (Christensen, 2004, 2005). In the organizational context, the literature proposes distinct approaches to reduce cognitive load and enhance creativity, such as incorporating periods of mindless work into daily routines (Elsbach & Hargadon, 2006) and applying AI interventions during problem-finding processes for idea generation (Garbuio & Lin, 2021).

Cognitive Load as a Mediator Variable

Studies investigating cognitive load as a mediator variable reveal its complex relationship with creativity across various contexts and explore how numerous factors influence creative thinking through their impact on cognitive load. These investigations emphasize that cognitive load does not exist in isolation; instead, it interacts with numerous factors, including individual differences (Hao et al., 2015), types of conflict (Jung & Lee, 2015), feedback mechanisms (Jenni L. Redifer et al., 2021), training methods (VerPlanck, 2021), and technological tools (Y.-C. Chen et al., 2022a, 2022b). These elements can either increase or reduce cognitive load during creative tasks, and they are interconnected in their effects. Effective management of cognitive load, with the aim of minimizing extraneous load and optimizing germane load, is a noteworthy aspect discussed in the literature (Y.-C. Chen et al., 2022a, 2022b; VerPlanck, 2021).

These studies provide various perspectives on the relationship between cognitive load and creativity. In general, there is consensus that high cognitive load tends to hinder creativity, possibly due to limitations in mental resources and mental overload. For instance, strategies to express ideas, whether through writing or speaking, are significantly affecting creative idea generation (Hao et al., 2015). Writing is often associated with lower cognitive load, leading to more creative ideas compared to speaking. Moreover, excessive information presented during training can impede creative thinking among trainees (VerPlanck, 2021), while the receipt of negative feedback has been shown to raise cognitive load, subsequently hindering creative thinking (Jenni L. Redifer et al., 2021). These findings suggest context-specific factors that can impede creativity, emphasizing the need for customized approaches to enhance creative performance.

However, it's worth noting that modulating cognitive load through techniques like Virtual Reality (VR), self-efficacy building, and constructive feedback can optimize this relationship and potentially enhance certain aspects of creativity (Hao et al., 2015; Jenni L. Redifer et al., 2021; VerPlanck, 2021). For example, employing user-friendly evaluation mechanisms has been shown to reduce cognitive load, consequently fostering creative thinking, especially in decision-making processes (Blohm et al., 2016). Similarly, the reduction of extraneous cognitive load through modified training methods has been found to enhance creative thinking among professionals (VerPlanck, 2021). Interestingly, VR applications within educational contexts, despite increasing cognitive load, have had a positive impact on creativity (Y.-C. Chen et al., 2022a, 2022b). Furthermore, conflicts, typically viewed as obstacles to creativity in workplace settings, can paradoxically enhance creative thinking when they take the form of relationship and process conflict (Jung & Lee, 2015). This occurs when individuals engage constructively with the conflict, rather than avoiding or suppressing it, thus leveraging cognitive load to stimulate creative solutions.

Cognitive Load as a Moderator Variable

Among the included studies, one scholar explores how cognitive load affects the strength or direction of the relationship between the independent and the dependent variable. Specifically, Bitu et al. (2022) suggest that cognitive load, induced by the different sensory feedback conditions (e.g., using a stylus on a tablet), could impact originality in drawings. Although the study's findings indicate that sensory afferences and their impact on cognitive load can influence creative performance, these results challenge the notion that higher cognitive load always hinders creativity, as demonstrated by the unexpected positive effect of using a stylus on a tablet in older children and adolescents.

Management Strategies of Cognitive Load in Creativity

Effective management of cognitive load can contribute to optimizing the use of existing WMC, and effectively retrieve information stored in LTM. These effects positively align with the requirements of creative thinking to produce novel and useful outcomes. The effective management of cognitive load in the creative thinking process may facilitate individuals to retrieve ideas from LTM while simultaneously evaluating them in working memory (Redifer et al., 2019; Jenni L Redifer et al., 2021). The literature suggests various cognitive load management strategies that can be adapted to perform creative tasks. We broadly sorted these strategies into three main categories: the use of external resources, the intervention of the environment, and self-regulation strategies. In the following sections, each category is discussed in more detail.

Using External Resources

External aids provide support to the execution of cognitive processes by assisting individuals to focus their attention on the relevant information of a task instead of the non-task-related aspects. Thus, these kinds of tools mainly contribute to reducing extraneous cognitive load. The literature suggests the use of physical mediums such as writing down ideas (Hao et al., 2015), sketching during the creative process (Cseh et al., 2016), physically manipulating insight problem elements (Chuderski et al., 2021), and amplifying proprioceptive information (Bitu et al., 2022). According to these scholars, the use of physical mediums may reduce the burden on working memory in holding task-relevant information and improving the mental representation of problems and solutions, thus enhancing creative performance.

Other external resources described by the literature include employing technological tools to overcome cognitive load and reduce time and effort spent while performing a creative task (Aldalalah, 2021; H. Chen et al., 2022a, 2022b; Y.-C. Chen et al., 2022a, 2022b; Garbuio & Lin, 2021; Kassim et al., 2014; VerPlanck, 2021). For instance, Garbuio and Lin (2021) highlighted the value of artificial intelligence (AI) and big data to facilitate the exploration and analysis of massive unstructured and structured information to produce meaningful insights, suggesting the use of AI as a powerful tool to build the problem framework in the creative process and accelerating the development of creative ideas. Other scholars recommended the use of technological tools that involve multisensory elements such as text, images, video, and audio. For instance, research conducted by Y.-C. Chen et al., (2022a, 2022b) recognizes VR applications as a sensory-immersive aid to be used in creative tasks. Similarly, while H. Chen et al., (2022a, 2022b) and Kassim et al. (2014) indicate the benefits of adding well-designed animations to improve creative task representation, Aldalalah (2021) recommends the use of infographics through interactive smart boards, and VerPlanck (2021) the introduction of simulator training programs.

Intervention of the Environment

This category recognizes the value of social context interventions in promoting creative effort. Scholars consider how introducing different stimuli into the environment impacts cognitive load and creativity. A study by Mille et al. (2022) suggests minimizing stimuli that may be perceived as disruptive elements of the environment when dealing with extraneous cognitive load. Instead, they propose promoting stimuli that can add new knowledge, which could potentially enhance creativity. In alignment with Mille et al. (2022), Aldalalah (2021) recommends that educators receive training in using multiple forms of instruction, such as developing interactive infographics, to create a learning environment that enhances creative skills and reduces cognitive load among students. In the organizational context, Jung and Lee (2015) advise managers to develop effective interventions to harness the benefits of diversity in the workplace, particularly by manipulating teamwork composition based on trait-related differences in creativity.

The literature also recognizes that interventions in the environment may impact attention management. Without attention, individuals cannot use the cognitive resources held in working memory to structure and understand the task. Thus, attention represents the cognitive engagement that individuals bring to performing a creative task. As suggested by De Dreu et al. (2012), focused attention stimulates the production of meaningful connections between short-term and LTM resources, facilitating an in-depth exploration of ideas. In this regard, Rodet (2022) and Elsbach and Hargadon (2006) argue that considering the balance between workers' task load, and work content is crucial in work design to ensure fruitful attention among employees. Moreover, H. Chen et al., (2022a, 2022b) recommend that managers in the creative industry incorporate mindfulness meditation training practices to cultivate openness and acceptance toward any sensory or external stimuli.

Self-regulation

Self-regulation involves monitoring and controlling cognitive resources in working memory. The existing literature suggests that self-regulation is an effective strategy for enhancing creativity because it reduces the perceived cognitive load and promotes adaptability and flexibility in thinking. For instance, individuals may mitigate cognitive load and enhance motivation by adopting incremental beliefs about creativity— viewing it as a skill that they can improve (Redifer et al., 2019). This, in turn, reduces the perceived difficulty of creative tasks and increases their mental effort and engagement in such tasks (Redifer et al., 2019; Jenni L. Redifer et al., 2021). Similarly, individuals may overcome stereotypes by exposing themselves to diverse ideas and making a concerted mental effort to approach creative tasks from multiple viewpoints—thus breaking free from preconceived notions and fostering more innovative perspectives (Shemyakina & Nagornova, 2019).

In addition to monitoring beliefs, individuals may help manage their cognitive resources by taking breaks from the primary task and engaging in unrelated secondary tasks with low cognitive load (Hao et al., 2014). This activity may unconsciously help them build meaningful associations, thus promoting creative thinking. Furthermore, self-regulation has the potential to intentionally control the cognitive mechanisms that individuals employ. The included studies discuss two specific dual cognitive mechanisms that have theoretical implications for the relationship between cognitive load and creativity. First, the dual routes of creative problem-solving involve individuals either explicitly or implicitly decomposing the task (Sun et al., 2016; Weatherford et al., 2021). In explicit decomposition, individuals deliberately break down the problem through a systematic process, while in implicit decomposition, the problem is automatically or unconsciously decomposed, without openly revealing the structured process. Second, the dual pathway of creativity describes a flexible and persistent mindset (Baas et al., 2013; De Dreu et al., 2012; Jung & Lee, 2015; Nijstad et al., 2010; Roskes et al., 2012). In flexibility, creativity is achieved through making connections of broad categories, while persistence involves the systematic exploration of alternatives.

Methodological Considerations

The studies included in our systematic review provide valuable insights into the relationship between cognitive load and creativity. However, future research must contemplate methodological considerations that could jeopardize the validity and reliability of the findings. To enhance external validity, future empirical studies must consider avoiding sampling bias, as many of the studies included used convenience samples that may not represent the general population. Indeed, several studies have reported limitations due to a small sample size (H. Chen et al., 2022a, 2022b; Jung & Lee, 2015; Shemyakina & Nagornova, 2019; Sun et al., 2016), and a narrow sample range (Blohm et al., 2016; H. Chen et al., 2022a, 2022b; Mao et al., 2022; Jenni L Redifer et al., 2021; Sun et al., 2014). Furthermore, other studies have highlighted the limitations of relying on a single-task modality to evaluate creative thinking and cognitive load (Hao et al., 2014; Hao et al., 2015; Kleinkorres et al., 2021; Nguyen & Zeng, 2014; Jenni L Redifer et al., 2021). For instance, many studies have exclusively used the Alternative Uses Task (AUT) to test individuals' creative potential in generating novel applications for a common object. However, this task alone may fail to capture how individuals with different personalities and backgrounds deal with the inherent cognitive load of creative tasks when they simultaneously integrate contradictory demands such as novelty and usefulness in problem-solving. Researchers may overlook these aspects by solely employing one type of task to assess either divergent or convergent thinking.

Internal validity must also consider whether the study's design and methodology support the conclusions drawn from the data. We found that causality, confounding variables, and measurement methods are important aspects of internal validity in experimental designs that test cognitive load and creativity. Researchers claimed that limitations to establishing causality between these variables include using statistical analysis techniques that only provide correlational evidence (i.e., structural equation modeling) (Redifer et al., 2019), using research designs that collect data only at a single point in time instead of longitudinal designs (H. Chen et al., 2022a, 2022b; Garbuio & Lin, 2021; Hao et al., 2015), and not including control conditions for other variables that could influence the relationship between the cause and effect (Kassim et al., 2014; Roskes et al., 2012). More specifically, confounding variables such as motivation (Bitu et al., 2022; Mao et al., 2022; Roskes et al., 2012), intelligence (Redifer et al., 2019), and physical embodiment (Cseh et al., 2016) could have impacted both cognitive load and creativity, but experimental designs did not adequately control for them.

In addition, future studies must use a measurement method that accurately reflects cognitive load and creativity to ensure internal validity. In this regard, the reviewed studies raised concerns about the use of subjective methods such as self-reports. This is because studies that exclusively rely on self-reported data may attribute their results to common method variance (da Costa et al., 2018), potentially leading to the misattribution of results to the measurement method rather than the actual relationship between the variables. Furthermore, self-reports may also be inappropriate for measuring creativity and cognitive load, as they can be biased by social desirability, causing individuals to present themselves as more creative than they actually are (Kleinkorres et al., 2021), or leading to a bias toward overestimating or underestimating their own cognitive load (VerPlanck, 2021). Additionally, self-reporting requires individuals to access their memory systems to retrieve information about their subjective experience. This could be problematic, potentially adding an additional cognitive load to the task and potentially leading to inaccurate responses (Nguyen & Zeng, 2017). To overcome these limitations, future studies may use multiple objective and subjective measures of cognitive load and creativity to cross-validate the results. Another appropriate approach would be to adopt frequently used techniques in cognitive psychology research such as the think-aloud method (Blohm et al., 2016; Garbuio & Lin, 2021). This method requires the verbalization of thoughts as individuals perform a task. Therefore, researchers can examine thought patterns and identify how the different types of cognitive load affect the creative process.

Discussion

Study Characteristics

The purpose of our systematic review is to offer a comprehensive synthesis of the state of knowledge of cognitive load in creativity studies. Considering the study characteristics, more than 75% of the reviewed articles were published after 2014, indicating a growing interest among scholars in this topic. In fact, studies conducted in 2021 and 2022 accounted for 37% of the total amount of publications. Additionally, another main finding highlights the diverse range of fields where cognitive load and creativity have been examined. This signifies their relevance and applicability across multiple domains. Nevertheless, the notion of including creativity as a fundamental life skill to be fostered through education (Shaheen, 2010), and the focus of cognitive load research in the development of learning methods, have made education the primary research area in which most of the studies reviewed have been conducted.

Importantly, we found that most empirical studies in the education field recruited university students as participants. This finding suggests that future work should further investigate the implications of cognitive load on creative tasks performed by participants from earlier levels of education such as childhood, primary, or secondary education. Conducting research in this direction may shed light on how younger students process complex information to produce creative outcomes, and therefore to design effective strategies that are tailored to different age groups. Another gap resulting from the research characteristics revealed that most of the creative tasks employed in the experimental designs addressed problem-solving-oriented creativity. Future work should consider other forms of creativity manifest through artistic endeavors such as performance or visual arts.

The included studies investigated various forms of cognitive load, encompassing intrinsic, extraneous, and germane load. While some studies exclusively focused on one type of cognitive load, others examined multiple types simultaneously. The variety in the investigated cognitive load types could potentially account to explain the observed variations in study results. It's noteworthy that scholars within the framework of CLT have employed a variety of tools to measure cognitive load, indicating a lack of consensus in this area (Sweller et al., 2019). Some studies rely on tools that offer an overall measure of cognitive load (Szulewski et al., 2017), while others attempt to develop tools capable of discriminating between different types of cognitive load (Leppink et al., 2013, 2014). Developing and refining measurement techniques within the framework of CLT has the potential to enhance our comprehension of cognitive load in the context of creative thinking.

Additionally, the included studies demonstrated a notable imbalance in empirical attention, with a greater focus on intrinsic and extraneous load compared to germane load. It's worth noting that germane load significantly contributes to our understanding of how individuals process information, build mental schemas, and facilitate meaningful learning (Kalyuga, 2011). By incorporating germane load considerations into research design and instructional practices, researchers may advance the understanding of how cognitive processes impact creative thinking and problem-solving. Importantly, recent conceptualizations of cognitive load, only distinguish intrinsic and extraneous cognitive load, since scholars understand germane cognitive load as working memory resources used to manage intrinsic cognitive load (Sweller et al., 2011b). Considering germane load as a component of intrinsic cognitive load could open up new avenues for research in cognitive psychology and creativity. Future studies could explore the intricate relationship between cognitive resource allocation, metacognition, and creative performance.

The Interplay Between Cognitive Load and Creativity

Among the 33 scrutinized studies, 16 considered cognitive load as an independent variable, exploring its direct influence on creativity. Four employed cognitive load as a dependent variable, describing how external factors influence cognitive load. Additionally, seven studies investigated cognitive load as a mediator, elucidating its role as a crucial factor that mediates the relationship between various stimuli and creative performance. Furthermore, one study explored cognitive load as a moderator, describing its potential to influence the impact of other variables on creativity. Lastly, five studies incorporated cognitive load as a conceptual component in their theoretical framework.

As observed, most of the included studies considered cognitive load as an independent variable. The variability in findings across these studies restricts us from making absolute conclusions. However, upon scrutiny, it becomes evident that the existing literature primarily focuses on investigating the direct impact of cognitive load on divergent rather than convergent thinking dimensions. While these studies evaluate their findings based on creativity outcomes, it's crucial to recognize that creative thinking entails a delicate equilibrium between divergent and convergent thinking processes (Baas et al., 2008; Benedek et al., 2012; Dietrich & Kanso, 2010). Consequently, some creative processes may benefit from increased cognitive load, stimulating creativity, while others may be adversely affected, hindering creativity. This observation suggests the need to conduct studies using diverse research methods such as neuroimaging (e.g., EEG), behavioral experiments, and self-report measures to assess cognitive load and its impact during different facets of creativity. Additionally, longitudinal studies that track changes in cognitive load and creativity over time could provide valuable insights into the temporal and process dynamics of this relationship.

Regarding cognitive load as an independent variable, the second most employed approach involved cognitive load as a mediator. In this scenario, the analysis of the studies suggests that the mixed effects of cognitive load on creativity can be attributed to the complex and context-dependent nature of this relationship. Several factors contribute to this duality: First, the nature of the creative task plays a crucial role, with some tasks benefiting from cognitive load stimulation for creative thinking, while others require focused attention, where high cognitive load can hinder creativity (Hao et al., 2015; Jung & Lee, 2015; VerPlanck, 2021). Individual differences, including working memory capacity (Hao et al., 2015) and creative self-efficacy (Jenni L. Redifer et al., 2021), also modulate this relationship. Feedback, such as positive or negative, can impact cognitive load and creative performance, with positive feedback enhancing motivation and creativity (Y.-C. Chen et al., 2022a, 2022b), while negative feedback may increase cognitive load through rumination (Jenni L. Redifer et al., 2021). Specific types of conflict, such as relationship or process conflict, as demonstrated in Jung and Lee (2015), could generate cognitive load but trigger cognitive persistence, leading to creative solutions. Moreover, interventions like modified training methods (VerPlanck, 2021) or technology introduction (Y.-C. Chen et al., 2022a, 2022b) may either increase or decrease cognitive load, depending on their design. Ultimately, the literature suggests that the intricate relationship between cognitive load and creativity, where cognitive load acts as a mediator variable, is contingent upon task requirements, individual characteristics, feedback, and environmental factors. This interaction forms a complex and multifaceted relationship.

Furthermore, we found that in comparison to other approaches, there is a lower frequency of considering cognitive load as a dependent or moderator variable in empirical studies. This emphasizes the need for future research to explore the relationship between cognitive load and creativity using alternative perspectives, moving beyond the conventional roles of an independent or mediator variable. When considered as a dependent variable, scholars focused on assessing the direct impact of intervention methods for creative tasks (H. Chen et al., 2022a, 2022b; Chuderski et al., 2021; Mohamed-Ahmed et al., 2013), and cognitive strategies for creative problem-solving (Sun et al., 2016) on cognitive load. Additionally, a singular study investigated the moderating effect of cognitive load, specifically in relation to altering motor sensory methods and its impact on originality—a dimension associated with convergent thinking (Bitu et al., 2022).

Lastly, as described earlier in the results section on study characteristics, the included studies examined the relationship between cognitive load and creativity in various contexts. However, theoretical studies providing a robust rationale for incorporating cognitive load as a conceptual element proposed mechanisms to mitigate its negative impact within organizational contexts (Elsbach & Hargadon, 2006; Garbuio & Lin, 2021).

Approaches to Cognitive Load Management

Analyses of the strategies employed in creative research to manage cognitive load resulted in three categories: external resources, intervention of the environment, and self-regulation. First, the literature suggests that the use of external resources plays a positive role in supporting cognitive processes during creative tasks. According to the literature, these resources serve to reduce extraneous cognitive load, enabling individuals to focus on relevant task information rather than non-task-related aspects (Bitu et al., 2022; Chuderski et al., 2021; Cseh et al., 2016; Hao et al., 2015). For instance, educators or organizational leaders could benefit from such strategies to support creative skills among learners. Moreover, technological tools, including AI, big data, and multisensory elements, are highlighted as valuable aids in overcoming cognitive load and streamlining the creative process (Aldalalah, 2021; H. Chen et al., 2022a, 2022b; Y.-C. Chen et al., 2022a, 2022b; Garbuio & Lin, 2021; Kassim et al., 2014; VerPlanck, 2021).

Second, the literature highlights the importance of environmental interventions, particularly within social contexts, in enhancing creative efforts (Mille et al., 2022). These interventions not only influence attention management but are also recognized as crucial components for utilizing cognitive resources in working memory to structure and comprehend tasks (De Dreu et al., 2012). Tailored to social and organizational contexts, studies suggest that environmental interventions could positively impact cognitive processes and attention management, ultimately fostering creativity (Aldalalah, 2021; Jung & Lee, 2015). Finally, findings of self-regulation strategies align with future research directions in cognitive load and self-regulation learning (Sweller et al., 2019). In this regard, we found that the use of self-regulation cues such as creativity beliefs, incubation intervals, and thinking styles could serve to inform individuals about their creative performance.

Reflecting on Methodological Issues

We identified sample size, sample range, and single-task modality as limitations for achieving external validity. We also reported confounding variables and measurement methods of cognitive load as methodological considerations of internal validity. Beyond these limitations, several reviewed articles call for attention to investigating cognitive load in the creative context at the group level (Bose et al., 2013; Garbuio & Lin, 2021; Kassim et al., 2014). This is an important gap in the existing literature, as analyses of all empirical studies were conducted at the individual level. Although group creativity and cognitive load in collaborative learning have been examined independently within the fields of creativity and education, researchers should investigate this integration of these two approaches as a promising new line of research. A significant factor that could serve as a connector in this integration is communication, as is recognized as a fundamental process in both perspectives. In fact, in a review describing cognitive load in collaborative learning, Kirschner et al. (2009) highlight the role of communication in distributing cognitive load across the limited working memory of group members, as well as an interaction activity that demands cognitive effort. Similarly, group creativity research regards communication as an effortful process necessary to achieve creative synthesis—integrating diverse perspectives to build a shared understanding—(Harvey, 2014; Sibo et al., 2023) and to collectively stimulate the generation of new ideas (Nijstad & Stroebe, 2006). Future research should explore whether distributing cognitive load when performing creative tasks collectively can overcome the cognitive effort that communication also requires.

Limitations and Conclusions

Considering that the purpose of our study is to provide a comprehensive synthesis of the existing literature investigating cognitive load in the creative context, it is important to discuss the limitations that may have compromised the inclusiveness of the review. First, as our review aimed to explore the state of knowledge in the field, we did not perform a sensitivity analysis following the quality appraisal. However, we conducted a narrative synthesis approach through thematic coding to synthesize the methodological considerations as part of the discussion about the state of knowledge and its implications, providing guidance for future research. Second, restrictions in the eligibility criteria such as language and type of publication could entail limitations to the representativeness of the included studies. While researchers commonly include only peer-reviewed journal articles to ensure quality in systematic literature reviews, it was evident during the screening process that other types of publications such as book chapters, conference papers, and books also address cognitive load in the creative context. Third, limiting the review to English articles may have overlooked valuable insights from non-English speaking contexts such as those in Europe or East Asia, where creativity have gained significant relevance in educational policy-making (Shaheen, 2010). Additionally, even though our study focusses on primary research articles to address the research questions, it's important to recognize the potential insights that reviews, and meta-analyses could offer in this context. Review articles have the capacity to provide a valuable overarching perspective by summarizing and synthesizing existing research findings (Baumeister & Leary, 1997; Fink, 2019; Shaheen, 2010). They can identify patterns, trends, and gaps in the literature, offering a broader context for our analysis. Additionally, meta-analyses, in particular, can quantitatively synthesize data from multiple studies, providing statistical evidence of relationships and effect sizes (Borenstein et al., 2021). Including these types of articles could have provided a more comprehensive understanding of the relationship between cognitive load and creative thinking. Lastly, a further limitation was having a broad scope of investigation in the research questions. Although we included a wide variety of articles for comprehensive purposes, the lack of restrictions in the context of the studies such as the level of education or the type of creative task led to divergent findings that were challenging when conducting deductive thematic analysis. Despite these limitations, the absence of previous reviews conducting an in-depth examination of cognitive load in creativity studies makes our study valuable for creativity and cognitive load literature.

Our overview summarizes the different roles of cognitive load in the context of creativity, management interventions, and methodological considerations. The thematic analysis of these aspects can benefit both researchers and educators. They reveal diverse gaps in the literature that future research should fill and offer practical insights into the effective interventions to manage cognitive load during creative practices. Considering the contextual gaps in the literature, our study suggests further investigation within the context of younger learners, as existing studies have focused on higher education students indicating a limited understanding of the topic in earlier levels of education. Similarly, the literature has insufficiently addressed the role of cognitive load in the domain of artistic creativity, as research efforts have primarily examined cognitive load and creativity within the context of problem-solving scenarios. Moreover, we identified a conceptual gap in the limited incorporation of the new conceptualization of germane load, particularly the overlooked of the intertwined relation between intrinsic and germane load. Findings regarding the diverse roles that cognitive load plays in creative thinking reveal a complex and context-dependent relationship between these multifaceted constructs, underscoring the need to view this relationship as dynamic, demanding further exploration and emphasis from a process-based perspective. Finally, besides describing important methodological considerations for achieving internal and external validity in future works, we highlighted a methodological gap in the level of analysis conducted by the existing literature.

Overall, our comprehensive review contributes significantly to informing researchers and practitioners about the current state of knowledge of cognitive load in creativity research. Thus, our work provides valuable insights that can be a promising source for future research directions. Nurturing investigation on this topic will shape effective teaching and learning practices to develop creative skills in today's fast-changing environment.

Appendix. Research Characteristics

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Cognitive load as an independent variable								
Aldalalah (2021)	Education	Educational science undergraduate students	Learning task	Extraneous load	Manipulation through two modes of infographics: (image and text) and (image and sound)	Torrance Tests of Creative Thinking (TTCT) Score (dimensions: fluency, flexibility, and originality)	Interactive smart board use influences cognitive load and creative performance in educational technology students	Reducing cognitive load by incorporating sound and images enhances creative thinking skills
Bose et al. (2013)	Marketing	University students (majors not specified)	Problem scenario	Extraneous load	Manipulation by memorizing a two-digit number (low cognitive load) or a ten-digit number (high cognitive load)	Sel-report Creativity Scale adapted from (Davis & Subkoviak, 1975) Creativity Outcome Score (fluency, novelty, and appropriateness.)	Cognitive load moderates prime salience effects on creative output quality	High cognitive load has a dampening effect on creativity

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Cseh et al. (2016)	Psychology	Psychology undergraduate students	Creative mental synthesis task	Extraneous load	Manipulation by using three-shape (regular load) or five-shape (increased load) sets	Creativity Outcome Score (dimensions: fluency/productivity and transformational complexity)	Creative drawing activities impact flow experience by easing cognitive load	Sketching impacts creative flow and task difficulty perception but not always cognitive load or creative performance
De Dreu et al. (2012)	Psychology	Undergraduate students	Creativity insight task	Extraneous load	Manipulation by memorizing a two-digit number (low cognitive load) or a five-digit number (high cognitive load)	Creativity Insight: Remote Associates Test (RAT)	Cognitive load influences creative insight performance, with sufficient working memory capacity needed for creativity	Working memory capacity supports creative insight performance
Hao et al. (2014)	Psychology	Undergraduate students	Alternative uses task (AUT)	Intrinsic load	Self-reported mental effort rating, 9-point scale	Creativity Outcome Score (dimensions: originality)	Cognitive load levels stimulate remote associative processes for post-incubation creative performance	Both low and high-cognitive demand tasks can benefit creative thinking

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Kassim et al. (2014)	Education	Mechanical engineering undergraduate students	Learning task	Extraneous load	Manipulation by using a multimedia learning tool (MLT) and no using an MLT	Torrance Tests of Creative Thinking Score (fluency, flexibility, originality) Creative Product Semantic Scale (resolution, and style)	Multimedia learning tools effectively manage working memory cognitive load, leading to creative cognitive processing	Reducing cognitive load increases the generation of flexible and original ideas
Kleinkorres et al. (2021)	Psychology	Psychology and sports undergraduate students	Alternative uses task (AUT)	Extraneous load	Manipulation by the presence or absence of the digit-tracking task during the AUTs	Creativity Outcome Score (dimensions: fluency and quality)	Different cognitive load levels impact creative performance, particularly in idea fluency and quality	Negative correlation between the high cognitive load and the quality of creative ideas
Mao et al. (2022)	Education	Middle school students (7th and 8th grade)	Creative question generation task	Extraneous load	Manipulation by using different online information searching (such as using keywords or exploring web pages)	Consensus Assessment Technique (CAT) (Amabile, 1982)	High need for cognitive closure students might experience lower cognitive load, positively affecting creative question generation	Cognitive load may have both positive and negative effects on creativity, depending on factors like instruction type

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Mille et al. (2022)	Design	Participants working or studying in the field of VR	Problem scenario and product design task	Intrinsic load, extraneous load, and germane load	Self-reported Cognitive Load Questionnaire (Klepsch et al., 2017)	Creativity Outcome Score (dimensions: fluency)	Cognitive load mediates non-relevant stimuli's influence on creativity	Environmental stimuli influence cognitive load and creativity, but more load doesn't decrease idea generation
Rodet (2022)	Design	Not specified	Alternative uses task (AUT)	Extraneous load	Manipulation by memorizing a single-digit number (low cognitive load) or a seven-digit number (high cognitive load)	Self-report of Creative Achievement Questionnaire (Dutcher & Rodet, 2022) Creativity Outcome Score (originality)	Cognitive load manipulation affects creative idea generation	Increasing cognitive load negatively affects both the quantity and variety of creative ideas generated
Roskes et al. (2012)	Psychology	Students (program not specified)	Creativity insight task	Extraneous load	Manipulation by memorizing a two-digit number (low cognitive load) or a five-digit number (high cognitive load)	Creativity Insight: Remote Associates Test	Creative performance may depend on working memory capacity, especially under varying cognitive load conditions	Cognitive load negatively impacts the creativity of avoidance-motivated individuals

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Shemyakina and Nagornova (2019)	Psychology	Right-handed individuals	Effortful creation task	Intrinsic load	Electroencephalography (EEG) Self-report of task difficulty scale, 10-point scale	Creativity Outcome Score (originality, fluency, and flexibility)	Overcoming self-induced stereotypes requires increased mental effort in creative thinking	Cognitive load plays a significant role in creative thinking, particularly when overcoming self-induced stereotypes
Silvia et al. (2014)	Psychology	Psychology course graduate and undergraduate students	Alternative uses task (AUT)	Intrinsic load and extraneous load	Impedance Cardiography (ICG)	Creative Achievement Questionnaire Creativity Outcome Score (fluency, quality)	Creative achievements predict greater cognitive effort in divergent thinking tasks	Higher creative achievements are associated with expending more cognitive effort during creative tasks
Sun et al. (2014)	Design	Graduate and undergraduate students	Product design task	Intrinsic load	The Rating Scale Mental Effort (RSME) (Zijlstra & van Doorn, 1985)	Creativity Outcome Score (novelty, variety, quality, and quantity)	Various factors, including cognitive load, influence designers' creative outcomes	Experienced designers show higher cognitive efficiency particularly in terms of quality of the creative output

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Weatherford et al. (2021)	Design	Undergraduate students	Insight problem task	Germane load and extraneous load	Increasing germane cognitive load (direct or indirect prompting) and reducing extraneous cognitive load (no transfer instructions and an eye-closure strategy)	Creative problem-solving performance:(overall accuracy, step-by-step accuracy, and response latency)	Cognitive load interacts with creative problem-solving routes and is influenced by different training techniques and testing conditions	Cognitive load positively affects the effectiveness of creative problem-solving strategies
Cognitive load as a dependent variable								
Chuderski et al. (2021)	Psychology	General population from a central-European city	Insight problem task	Intrinsic, extraneous, and germane load	The NASA Task Load Index questionnaire (Hart & Staveland, 1988)	Self-report experience scale for insight problem solutions	Physical manipulation of insight problem elements changes problem representation and solution exploration, potentially lowering cognitive load	Physical interaction and embodied cognition did not reduce cognitive load or boost creativity in insight problem-solving

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
H. Chen et al., (2022a, 2022b)	Psychology	Employees within the creative industries	Guided meditation	Extraneous load	Self-reported stress level and material difficulty	Self-report of Work Creativity Scale (Zhou & George, 2001) (creativity tendency of the individual)	Animation reduces cognitive load, improving meditation effects and creativity	Mindfulness, flow, and positive affect relate to creativity. Animation can reduce cognitive load in meditation guidance
Mohamed-Ahmed et al. (2013)	Design	Architecture university students	Product design task	Intrinsic load and extraneous load	Performance on the Secondary task (pressing a foot pedal) while using three common design media (i.e., hand sketches, physical models, and SketchUp CAD software)	Creativity Outcome Score (overall impression, esthetics, originality, and functionality)	Designers' cognitive load management during architectural design correlates with their design creativity	No significant link observed between cognitive load and creativity in design outcomes

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Nguyen and Zeng (2017)	Management	Engineering students	Product design task	Intrinsic load, extraneous load, and germane load	Electroencephalography (EEG) NASA Task Load Index questionnaire (TLX; Hart & Staveland, 1988)	Not applicable	Subjective rating measures reflect physiological measures of cognitive load during creative tasks	Stress levels during design tasks can affect cognitive load and self-assessment accuracy related to creativity
Sun et al. (2016)	Design	Graduate and undergraduate students	Product design task	Intrinsic load	The Rating Scale Mental Effort (RSME) (Zijlstra & van Doorn, 1985)	Creativity Outcome Score (quantity and quality)	Designers' cognitive load may affect the problem framework's effectiveness in the creative process	Certain problem-structuring strategies enhance creativity without significantly increasing cognitive load

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Cognitive load as a component of the theoretical framework								
Christensen (2004)	Education	Secondary school students/8th and 9th grade	Creative writing task	Intrinsic load	Manipulation by enhancing typing skills	Creativity Outcome Score (dimensions: creativity and originality of ideas)	Automatic orthographic-motor integration reduces cognitive load, enhancing creative and original text production	Improved typing automaticity reduces cognitive load and enhances creativity in typewritten text
Christensen (2005)	Education	Secondary school students/8th and 9th grade	Creative writing task	Intrinsic load	Manipulation by enhancing typing skills	Creativity Outcome Score (dimensions: creativity and originality of ideas)	Automatic orthographic-motor integration reduces cognitive load, enhancing creative and original text production	Cognitive load strongly affects students' ability to produce creative and organized written text
Elsbach and Hargadon (2006)	Management	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Low cognitive load may enhance professional creativity by supporting high attention capacity	Cognitive load management is critical for professionals' creativity in high-workload settings

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Garbuio and Lin (2021)	Management	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Low cognitive load may enhance professional creativity, but constraints on it can impede innovators' working memory	Cognitive load can hinder abductive hypothesis generation, but AI may help reducing cognitive load in problem finding
Nguyen and Zeng (2014)	Design	Quality system engineering graduate students	Product design task	Intrinsic load and extraneous load	Electroencephalography (EEG)	Mental effort as an indirect assessment of creativity	Mental effort is positively related to design novelty and quantity, indirectly assessing creativity	Greater cognitive effort might lead to more creative solutions, but further research is needed to control relevant factors

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Cognitive load as a mediator variable								
Hao et al. (2015)	Psychology	College students	Alternative uses task (AUT)	Intrinsic load	Self-reported mental effort rating, 9-point scale	Creativity Outcome score (dimensions: fluency and originality)	Cognitive load mediates the effect of response medium on creative idea generation	In the speaking condition, participants experienced higher cognitive load, and researchers identified it as a mediator in the relationship between response medium and creative idea generation
Jung and Lee (2015)	Management	Amazon mechanical Turk users and employees	Problem scenario	Intrinsic load	Cognitive Persistence Index: the degree of mental effort on a 7-point scale	Creativity Insight: Remote Associates Test (RAT)	The relational self's moderation of relationship conflict on creativity is mediated by cognitive effort	Process conflict, when an independent self is activated, positively affects creativity

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Redifer et al. (2019)	Psychology	Undergraduate students	Alternative uses task (AUT)	Intrinsic load	Self-reported mental effort rating. (Ayres, 2006)	Creativity Outcome Score (fluency and originality) Self-report of implicit theories of creativity scale	Cognitive load mediates implicit theories' influence on creative thinking performance	Implicit theories of creativity influence cognitive load, affecting creative thinking performance
Redifer et al. (2021)	Education	Psychology undergraduate students	Alternative uses task (AUT)	Intrinsic load	Self-reported mental effort rating. (Ayres, 2006)	Creativity Outcome Score (fluency and originality)	Higher cognitive load correlates with reduced fluency; its management is crucial for effective creative thinking	Performance feedback and creative self-efficacy impact cognitive load and creative thinking performance
VerPlanck (2021)	Education	Police officers	Problem scenario	Intrinsic load and extraneous load	Manipulation by using simulation training to reduce extraneous load Intrinsic load was measured through Cognitive Load Scale (Leppink et al., 2013)	Self-report of creativity be creative and innovative Creative performance (novelty)	Effective trainers in simulators can reduce cognitive load, enhancing creative thinking in crisis mitigation	Minimizing extraneous cognitive load in simulator training allows creative thinking to flourish

Author (year)	Context	Participants	Task	Type of cognitive load	Cognitive load instrument	Creativity instrument	Cognitive load and creativity	Findings
Y.-C. Chen et al., (2022a, 2022b)	Education	Junior high school students (8th grade)	Learning task	Intrinsic load, extraneous load, and germane load	Self-reported Cognitive Load Questionnaire (Andersen & Makransky, 2021)	Creative Motivation Subscale (value, expectancy, affection) Self-report of Creative Thinking Subscale (fluency, flexibility, originality, elaboration) Creativity Outcome Score (function,)	Cognitive load mediates the relationship between VR application and creative performance	VR enhances creative performance, with cognitive load management being crucial for optimal outcomes in education
Cognitive load as a moderator variable								
Bitu et al. (2022)	Education	Children and adolescents	Drawing creative task	Intrinsic load	Manipulation by different sensory afferences (specifically, stylus, finger, pen) during a drawing task	Custom-developed originality rating scale	Sensory differences, which can affect cognitive load during creative tasks, are linked to variations in creative performance, affecting originality	No decrease in originality with higher cognitive load (using a stylus on a tablet)

Data Availability The data that support the findings of this study are available from the corresponding author, Hernandez Sibo, upon reasonable request.

Declarations

Competing Interests The authors declare no competing interests.

References

Aldalalah, O. M. A. (2021). The effectiveness of infographic via interactive smart soard on enhancing creative thinking: a cognitive load perspective. *International Journal of Instruction, 14*(1), 345–364. https://doi.org/10.29333/iji.2021.14120a

Amabile, T. M. (1982). Social psychology of creativity: A consensual assessment technique. *Journal of Personality and Social Psychology, 43*(5), 997–1013. https://doi.org/10.1037/0022-3514.43.5.997

Amabile, T. M. (1988). A model of creativity and innovation in organizations. *Research in Organizational Behavior, 10*, 123–167.

Amabile, T. M., Hennessey, B. A., & Grossman, B. S. (1986). Social influences on creativity: the effects of contracted-for reward. *Journal of Personality and Social Psychology, 50*(1), 14–23. https://doi.org/10.1037/0022-3514.50.1.14

Andersen, M. S., & Makransky, G. (2021). The validation and further development of a multidimensional cognitive load scale for virtual environments. *Journal of Computer Assisted Learning, 37*(1), 183–196. https://doi.org/10.1111/jcal.12478

Ayres, P. (2006). Using subjective measures to detect variations of intrinsic cognitive load within problems. *Learning and Instruction, 16*(5), 389–400. https://doi.org/10.1016/j.learninstruc.2006.09.001

Baas, M., De Dreu, C. K., & Nijstad, B. A. (2008). A meta-analysis of 25 years of mood-creativity research: hedonic tone, activation, or regulatory focus? *Psychological Bulletin, 134*(6), 779–806. https://doi.org/10.1037/a0012815

Baas, M., Roskes, M., Sligte, D., Nijstad, B. A., & De Dreu, C. K. (2013). Personality and creativity: the dual pathway to creativity model and a research agenda. *Social and Personality Psychology Compass, 7*(10), 732–748. https://doi.org/10.1111/spc3.12062

Baer, M., & Oldham, G. R. (2006). The curvilinear relation between experienced creative time pressure and creativity: moderating effects of openness to experience and support for creativity. *Journal of Applied Psychology, 91*(4), 963–970. https://doi.org/10.1037/0021-9010.91.4.963

Baumeister, R. F., & Leary, M. R. (1997). Writing narrative literature reviews. *Review of General Psychology, 1*(3), 311–320. https://doi.org/10.1037/1089-2680.1.3.311

Beaty, R. E., Silvia, P. J., Nusbaum, E. C., Jauk, E., & Benedek, M. (2014). The roles of associative and executive processes in creative cognition. *Memory & Cognition, 42*(7), 1186–1197. https://doi.org/10.3758/s13421-014-0428-8

Benedek, M., Franz, F., Heene, M., & Neubauer, A. C. (2012). Differential effects of cognitive inhibition and intelligence on creativity. *Personality and Individual Differences, 53*(4), 480–485. https://doi.org/10.1016/j.paid.2012.04.014

Bitu, F., Galinon-Mélénec, B., & Molina, M. (2022). Modifying sensory afferences on tablet changes originality in drawings. *Frontiers in Psychology, 13*, Article 806093. https://doi.org/10.3389/fpsyg.2022.806093

Blohm, I., Riedl, C., Füller, J., & Leimeister, J. M. (2016). Rate or trade? Identifying winning ideas in open idea sourcing. *Information Systems Research, 27*(1), 27–48. https://doi.org/10.1287/isre.2015.0605

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2021). *Introduction to meta-analysis* (2nd ed.). John Wiley & Sons. Retrieved January 20, 2023, from https://www.wiley.com/en-sg/Introduction+to+Meta+Analysis%2C+2nd+Edition-p-9781119558392

Bose, M., Folse, A. G., & J., & Burton, S. (2013). The role of contextual factors in eliciting creativity: primes, cognitive load and expectation of performance feedback. *Journal of Consumer Marketing, 30*(5), 400–414. https://doi.org/10.1108/JCM-02-2013-0475

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa
Briggs, R. O., Kolfschoten, G. L., de Vreede, G.-J., Albrecht, C., Lukosch, S., & Dean, D. L. (2015). A six-layer model of collaboration. In *Collaboration systems* (1 ed., pp. 211–227). Routledge. https://doi.org/10.4324/9781315705569
Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction, 8*(4), 293–332. https://doi.org/10.1207/s1532690xci0804_2
Chen, H., Liu, C., Zhou, F., Chiang, C.-H., Chen, Y.-L., Wu, K., Huang, D.-H., Liu, C.-Y., & Chiou, W.-K. (2022). The effect of animation-guided mindfulness meditation on the promotion of creativity, flow and affect. *Frontiers in Psychology, 13*, Article 894337. https://doi.org/10.3389/fpsyg.2022.894337
Chen, Y.-C., Chang, Y.-S., & Chuang, M.-J. (2022b). Virtual reality application influences cognitive load-mediated creativity components and creative performance in engineering design. *Journal of Computer Assisted Learning, 38*(1), 6–18. https://doi.org/10.1111/jcal.12588
Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science, 13*(2), 145–182. Retrieved May 15, 2023, from https://www.sciencedirect.com/science/article/pii/0364021389900025
Chiu, C.-Y., Kwan, L.Y.-Y., & Liou, S. (2013). Culturally motivated challenges to innovations in integrative research: theory and solutions. *Social Issues and Policy Review, 7*(1), 149–172. https://doi.org/10.1111/j.1751-2409.2012.01046.x
Christensen, C. A. (2004). Relationship between orthographic-motor integration and computer use for the production of creative and well-structured written text. *British Journal of Educational Psychology, 74*(4), 551–564. https://doi.org/10.1348/0007099042376373
Christensen, C. A. (2005). The role of orthographic–motor integration in the production of creative and well-structured written text for students in secondary school. *Educational Psychology, 25*(5), 441–453. https://doi.org/10.1080/01443410500042076
Chuderski, A., Jastrzębski, J., & Kucwaj, H. (2021). How physical interaction with insight problems affects solution rates, hint use, and cognitive load. *British Journal of Psychology, 112*(1), 120–143. https://doi.org/10.1111/bjop.12442
Crilly, N. (2015). Fixation and creativity in concept development: the attitudes and practices of expert designers. *Design Studies, 38*, 54–91. https://doi.org/10.1016/j.destud.2015.01.002
Cseh, G. M., Phillips, L. H., & Pearson, D. G. (2016). Mental and perceptual feedback in the development of creative flow. *Consciousness and Cognition, 42*, 150–161. https://doi.org/10.1016/j.concog.2016.03.011
da Costa, C. G., Zhou, Q., & Ferreira, A. I. (2018). The impact of anger on creative process engagement: the role of social contexts. *Journal of Organizational Behavior, 39*(4), 495–506. https://doi.org/10.1002/job.2249
Davis, G. A., & Subkoviak, M. J. (1975). Multidimensional analysis of a personality-based test of creative potential. *Journal of Educational Measurement, 12*(1), 37–43. http://www.jstor.org/stable/1434373
De Backer, L., Van Keer, H., & Valcke, M. (2022). The functions of shared metacognitive regulation and their differential relation with collaborative learners' understanding of the learning content. *Learning and Instruction, 77*, Article 101527. https://doi.org/10.1016/j.learninstruc.2021.101527
De Dreu, C. K., Nijstad, B. A., Baas, M., Wolsink, I., & Roskes, M. (2012). Working memory benefits creative insight, musical improvisation, and original ideation through maintained task-focused attention. *Personality and Social Psychology Bulletin, 38*(5), 656–669. https://doi.org/10.1177/0146167211435795
Dewey, J. (1910). *How we think*. Heath & Company. https://doi.org/10.1037/10903-000
Dietrich, A., & Kanso, R. (2010). A review of EEG, ERP, and neuroimaging studies of creativity and insight. *Psychological Bulletin, 136*(5), 822–848. https://doi.org/10.1037/a0019749
Edyburn, D. L. (Ed.). (2015). *Accessible instructional design* (1st ed.). Emerald Group Publishing Limited. https://doi.org/10.1108/S2056-769320150000002014
Eisenberger, R., & Aselage, J. (2009). Incremental effects of reward on experienced performance pressure: positive outcomes for intrinsic interest and creativity. *Journal of Organizational Behavior, 30*(1), 95–117. https://doi.org/10.1002/job.543
Eisenberger, R., & Rhoades, L. (2001). Incremental effects of reward on creativity. *Journal of Personality and Social Psychology, 81*(4), 728–741. https://doi.org/10.1037/0022-3514.81.4.728

Elsbach, K. D., & Hargadon, A. B. (2006). Enhancing creativity through “mindless” work: a framework of workday design. *Organization Science, 17*(4), 470–483. https://doi.org/10.1287/orsc.1060.0193
Fink, A. (2019). *Conducting research literature reviews: From the internet to paper* (5th ed.). Sage Publications, Inc. Retrieved September 30, 2023, from https://us.sagepub.com/en-us/nam/conducting-research-literature-reviews/book259191#description
Fraser, K., Ma, I., Teteris, E., Baxter, H., Wright, B., & McLaughlin, K. (2012). Emotion, cognitive load and learning outcomes during simulation training. *Medical Education, 46*(11), 1055–1062. https://doi.org/10.1111/j.1365-2923.2012.04355.x
Garbuio, M., & Lin, N. (2021). Innovative idea generation in problem finding: abductive reasoning, cognitive impediments, and the promise of artificial intelligence. *Journal of Product Innovation Management, 38*(6), 701–725. https://doi.org/10.1111/jpim.12602
Goldschmidt, G. (2014). Linkography: unfolding the design process. *The MIT Press*. https://doi.org/10.7551/mitpress/9455.001.0001
Goldschmidt, G., & Smolkov, M. (2006). Variances in the impact of visual stimuli on design problem solving performance. *Design Studies, 27*(5), 549–569. https://doi.org/10.1016/j.destud.2006.01.002
Gopher, D. (2013). Analysis and measurement of mental load. In *International perspectives on psychological science* (1 ed., Vol. 2, pp. 265–292). Psychology Press. https://doi.org/10.4324/9780203775738
Grant, A. M., & Berry, J. W. (2011). The necessity of others is the mother of invention: intrinsic and prosocial motivations, perspective taking, and creativity. *Academy of Management Journal, 54*(1), 73–96. https://doi.org/10.5465/amj.2011.59215085
Große, C. S., & Renkl, A. (2007). Finding and fixing errors in worked examples: can this foster learning outcomes? *Learning and Instruction, 17*(6), 612–634. https://doi.org/10.1016/j.learninstruc.2007.09.008
Guilford, J. P. (1950). Creativity. *American Psychologist, 5*, 444–454. https://doi.org/10.1037/h0063487
Guilford, J. P. (1956). The structure of intellect. *Psychological Bulletin, 53*(4), 267–293. https://doi.org/10.1037/h0040755
Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: an R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. *Campbell Systematic Reviews, 18*(2), Article e1230. https://doi.org/10.1002/cl2.1230
Halbesleben, J. R. B., Wheeler, A. R., & Buckley, M. R. (2004). The influence of great theoretical works on subsequent empirical work. *Management Decision, 42*(10), 1210–1225. https://doi.org/10.1108/00251740410568926
Hao, N., Ku, Y., Liu, M., Hu, Y., Grabner, R. H., & Fink, A. (2014). Enhancing verbal creativity via brief interventions during an incubation interval. *Creativity Research Journal, 26*(1), 30–38. https://doi.org/10.1080/10400419.2014.873658
Hao, N., Yuan, H., Cheng, R., Wang, Q., & Runco, M. A. (2015). Interaction effect of response medium and working memory capacity on creative idea generation. *Frontiers in Psychology, 6*, Article 1582. https://doi.org/10.3389/fpsyg.2015.01582
Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), *Advances in psychology* (Vol. 52, pp. 139–183). https://doi.org/10.1016/S0166-4115(08)62386-9
Harvey, S. (2014). Creative synthesis: exploring the process of extraordinary group creativity. *Academy of Management Review, 39*(3), 324–343. https://doi.org/10.5465/amr.2012.0224
Harvey, S., & Kou, C.-Y. (2013). Collective engagement in creative tasks: the role of evaluation in the creative process in groups. *Administrative Science Quarterly, 58*(3), 346–386. https://doi.org/10.1177/0001839213498591
Hong, Q. N., Gonzalez-Reyes, A., & Pluye, P. (2018). Improving the usefulness of a tool for appraising the quality of qualitative, quantitative and mixed methods studies, the Mixed Methods Appraisal Tool (MMAT). *Journal of Evaluation in Clinical Practice, 24*(3), 459–467. https://doi.org/10.1111/jep.12884
Jung, E. J., & Lee, S. (2015). The combined effects of relationship conflict and the relational self on creativity. *Organizational Behavior and Human Decision Processes, 130*, 44–57. https://doi.org/10.1016/j.obhdp.2015.06.006
Kalyuga, S. (2011). Cognitive load theory: how many types of load does it really need? *Educational Psychology Review, 23*(1), 1–19. https://doi.org/10.1007/s10648-010-9150-7

Kalyuga, S. (2009). The expertise reversal effect. In *Managing cognitive load in adaptive multimedia learning* (pp. 58–80). IGI Global. https://doi.org/10.4018/978-1-60566-048-6.ch003
Kassim, H., Nicholas, H., & Ng, W. (2014). Using a multimedia learning tool to improve creative performance. *Thinking Skills and Creativity, 13*, 9–19. https://doi.org/10.1016/j.tsc.2014.02.004
Kirschner, F., Paas, F., & Kirschner, P. A. (2009). A cognitive load approach to collaborative learning: United brains for complex tasks. *Educational Psychology Review, 21*, 31–42. https://doi.org/10.1007/s10648-008-9095-2
Kleinkorres, R., Forthmann, B., & Holling, H. (2021). An experimental approach to investigate the involvement of cognitive load in divergent thinking. *Journal of Intelligence, 9*(1), Article 3. https://doi.org/10.3390/jintelligence9010003
Klepsch, M., Schmitz, F., & Seufert, T. (2017). Development and validation of two instruments measuring intrinsic, extraneous, and germane cognitive load. *Frontiers in Psychology, 8*, Article 1997. https://doi.org/10.3389/fpsyg.2017.01997
Kompa, N. A., & Mueller, J. L. (2022). Inner speech as a cognitive tool—or what is the point of talking to oneself? *Philosophical Psychology*, 1–24. https://doi.org/10.1080/09515089.2022.2112164
Lee, C. S., & Therriault, D. J. (2013). The cognitive underpinnings of creative thought: a latent variable analysis exploring the roles of intelligence and working memory in three creative thinking processes. *Intelligence, 41*(5), 306–320. https://doi.org/10.1016/j.intell.2013.04.008
Leppink, J., Paas, F., Van der Vleuten, C. P. M., Van Gog, T., & Van Merriënboer, J. J. G. (2013). Development of an instrument for measuring different types of cognitive load. *Behavior Research Methods, 45*(4), 1058–1072. https://doi.org/10.3758/s13428-013-0334-1
Leppink, J., Paas, F., van Gog, T., van der Vleuten, C. P. M., & van Merriënboer, J. J. G. (2014). Effects of pairs of problems and examples on task performance and different types of cognitive load. *Learning and Instruction, 30*, 32–42. https://doi.org/10.1016/j.learninstruc.2013.12.001
Leung, A. K. Y., Liou, S., Miron-Spektor, E., Koh, B., Chan, D., Eisenberg, R., & Schneider, I. (2018). Middle ground approach to paradox: Within- and between-culture examination of the creative benefits of paradoxical frames. *Journal of Personality and Social Psychology, 114*(3), 443–464. https://doi.org/10.1037/pspp0000160
Liu, S. (2016). Broaden the mind before ideation: the effect of conceptual attention scope on creativity. *Thinking Skills and Creativity, 22*, 190–200. https://doi.org/10.1016/j.tsc.2016.10.004
Mao, S., Wang, D., Tang, C., & Dong, P. (2022). Students' online information searching strategies and their creative question generation: the moderating effect of their need for cognitive closure. *Frontiers in Psychology, 13*, Article 877061. https://doi.org/10.3389/fpsyg.2022.877061
Mednick, S. (1962). The associative basis of the creative process. *Psychological Review, 69*(3), 220–232. https://doi.org/10.1037/h0048850
Mille, C., Christmann, O., Fleury, S., & Richir, S. (2022). Effects of continuous and discontinuous non-relevant stimulus on creativity. *Digital Creativity, 33*(2), 171–181. https://doi.org/10.1080/14626268.2022.2082486
Miron-Spektor, E., & Erez, M. (2017). Looking at creativity through a paradox lens: Deeper understanding and new insights. In W. K. Smith, M. W. Lewis, P. Jarzabkowski, & A. Langley (Eds.), *The oxford handbook of organizational paradox* (pp. 434–451). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198754428.013.22
Mohamed-Ahmed, A., Bonnardel, N., Côté, P., & Tremblay, S. (2013). Cognitive load management and architectural design outcomes. *International Journal of Design Creativity and Innovation, 1*(3), 160–176. https://doi.org/10.1080/21650349.2013.797013
Mousavi, S. Y., Low, R., & Sweller, J. (1995). Reducing cognitive load by mixing auditory and visual presentation modes. *Journal of Educational Psychology, 87*(2), 319–334. https://doi.org/10.1037/0022-0663.87.2.319
Mumford, M. D., & McIntosh, T. (2017). Creative thinking processes: the past and the future. *Journal of Creative Behavior, 51*(4), 317–322. https://doi.org/10.1002/jocb.197
Mumford, M. D., Mobley, M. I., Reiter-Palmon, R., Uhlman, C. E., & Doares, L. M. (1991). Process analytic models of creative capacities. *Creativity Research Journal, 4*(2), 91–122. https://doi.org/10.1080/10400419109534380
Mumford, M. D., Supinski, E. P., Baughman, W. A., Costanza, D. P., & Threlfall, K. V. (1997). Process-based measures of creative problem-solving skills: V. *Overall Prediction. Creativity Research Journal, 10*(1), 73–85. https://doi.org/10.1207/s15326934crj1001_8

Mumford, M. D., Hunter, S. T., & Byrne, C. L. (2009). What is the fundamental? The role of cognition in creativity and innovation. *Industrial and Organizational Psychology, 2*(3), 353–356. https://doi.org/10.1111/j.1754-9434.2009.01158.x

Nguyen, T. A., & Zeng, Y. (2014). A physiological study of relationship between designer's mental effort and mental stress during conceptual design. *Computer-Aided Design, 54*, 3–18. https://doi.org/10.1016/j.cad.2013.10.002

Nguyen, T. A., & Zeng, Y. (2017). Effects of stress and effort on self-rated reports in experimental study of design activities. *Journal of Intelligent Manufacturing, 28*, 1609–1622. https://doi.org/10.1007/s10845-016-1196-z

Nijstad, B. A., & Stroebe, W. (2006). How the group affects the mind: a cognitive model of idea generation in groups. *Personality and Social Psychology Review, 10*(3), 186–213. https://doi.org/10.1207/s15327957pspr1003_1

Nijstad, B. A., De Dreu, C. K. W., Rietzschel, E. F., & Baas, M. (2010). The dual pathway to creativity model: creative ideation as a function of flexibility and persistence. *European Review of Social Psychology, 21*(1), 34–77. https://doi.org/10.1080/10463281003765323

Ohly, S., & Fritz, C. (2010). Work characteristics, challenge appraisal, creativity, and proactive behavior: a multi-level study. *Journal of Organizational Behavior, 31*(4), 543–565. https://doi.org/10.1002/job.633

Oldham, G. R., & Cummings, A. (1996). Employee creativity: Personal and contextual factors at work. *Academy of Management Journal, 39*(3), 607–634. Retrieved September 18, 2023, from https://journals.aom.org/doi/abs/10.5465/256657

Paas, F. G. W. C., & Van Merriënboer, J. J. G. (1994). Variability of worked examples and transfer of geometrical problem-solving skills: a cognitive-load approach. *Journal of Educational Psychology, 86*(1), 122–133. https://doi.org/10.1037/0022-0663.86.1.122

Paas, F., & van Merriënboer, J. J. G. (2020). Cognitive-load theory: methods to manage working memory load in the learning of complex tasks. *Current Directions in Psychological Science, 29*(4), 394–398. https://doi.org/10.1177/0963721420922183

Paas, F., Tuovinen, J. E., van Merriënboer, J. J. G., & Aubteen Darabi, A. (2005). A motivational perspective on the relation between mental effort and performance: optimizing learner involvement in instruction. *Educational Technology Research and Development, 53*(3), 25–34. https://doi.org/10.1007/BF02504795

Pacauskas, D., & Rajala, R. (2017). Information system users' creativity: a meta-analysis of the link between IT use and creative performance. *Information Technology & People, 30*(1), 81–116. https://doi.org/10.1108/ITP-04-2015-0090

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction, 12*(1), 61–86. https://doi.org/10.1016/S0959-4752(01)00016-0

Ranjan, B. S. C., Siddharth, L., & Chakrabarti, A. (2018). A systematic approach to assessing novelty, requirement satisfaction, and creativity. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 32*(4), 390–414. https://doi.org/10.1017/S0890060418000148

Redifer, J. L., Bae, C. L., & DeBusk-Lane, M. (2019). Implicit theories, working memory, and cognitive load: Impacts on creative thinking. *SAGE Open, 9*(1), 1–16. https://doi.org/10.1177/2158244019835919

Redifer, J. L., Bae, C. L., & Zhao, Q. (2021). Self-efficacy and performance feedback: Impacts on cognitive load during creative thinking. *Learning and Instruction, 71*, Article 101395. https://doi.org/10.1016/j.learninstruc.2020.101395

Renkl, A., & Atkinson, R. K. (2016). Structuring the transition from example study to problem solving in cognitive skill acquisition: a cognitive load perspective. *Educational Psychologist, 38*(1), 15–22. https://doi.org/10.1207/S15326985EP3801_3

Rodet, C. S. (2022). Does cognitive load affect creativity? An experiment using a divergent thinking task. *Economics Letters, 220*, Article 110849. https://doi.org/10.1016/j.econlet.2022.110849

Roskes, M., De Dreu, C. K., & Nijstad, B. A. (2012). Necessity is the mother of invention: avoidance motivation stimulates creativity through cognitive effort. *Journal of Personality and Social Psychology, 103*(2), 242–256. https://doi.org/10.1037/a0028442

Scott, G., Leritz, L. E., & Mumford, M. D. (2004). The effectiveness of creativity training: a quantitative review. *Creativity Research Journal, 16*(4), 361–388. https://doi.org/10.1080/10400410409534549

Shaheen, R. (2010). Creativity and education. *Creative Education, 1*(3), 166–169. https://doi.org/10.4236/ce.2010.13026

Shemyakina, N. V., & Nagornova, Z. V. (2019). EEG "signs" of verbal creative task fulfillment with and without overcoming self-induced stereotypes. *Behavioral Sciences, 10*(1), Article 17. https://doi.org/10.3390/bs10010017
Sibo, I. P. H., Celis, D. A. G., Liou, S., Koh, B., & Leung, A. K. (2023). The role of argumentation on high-and low-creative performing groups: a structuration analysis of undergraduate students' group discussion. *Thinking Skills and Creativity, 47*, Article 101217. https://doi.org/10.1016/j.tsc.2022.101217
Silvia, P. J., Beaty, R. E., Nusbaum, E. C., Eddington, K. M., & Kwapil, T. R. (2014). Creative motivation: creative achievement predicts cardiac autonomic markers of effort during divergent thinking. *Biological Psychology, 102*, 30–37. https://doi.org/10.1016/j.biopsycho.2014.07.010
Simon, H. A. (1973). The structure of ill structured problems. *Artificial Intelligence, 4*(3), 181–201. https://doi.org/10.1016/0004-3702(73)90011-8
Simon, H. A. (1988). The science of design: creating the artificial. *Design Issues*, *4*(1/2), 67–82. https://www.jstor.org/stable/1511391
Sternberg, R. J. (1985). Implicit theories of intelligence, creativity, and wisdom. *Journal of Personality and Social Psychology, 49*(3), 607–627. https://doi.org/10.1037/0022-3514.49.3.607
Sun, G., Yao, S., & Carretero, J. A. (2014). Comparing cognitive efficiency of experienced and inexperienced designers in conceptual design processes. *Journal of Cognitive Engineering and Decision Making, 8*(4), 330–351. https://doi.org/10.1177/1555343414540172
Sun, G., Yao, S., & Carretero, J. A. (2016). An experimental approach to understanding design problem structuring strategies. *Journal of Design Research, 14*(1), 94–117. https://doi.org/10.1504/JDR.2016.074778
Sweller, J. (1988). Cognitive load during problem solving: effects on learning. *Cognitive Science, 12*(2), 257–285. https://doi.org/10.1016/0364-0213(88)90023-7
Sweller, J. (2009). Cognitive bases of human creativity. *Educational Psychology Review, 21*(1), 11–19. https://doi.org/10.1007/s10648-008-9091-6
Sweller, J., & Chandler, P. (1994). Why some material is difficult to learn. *Cognition and Instruction, 12*(3), 185–233. https://doi.org/10.1207/s1532690xci1203_1
Sweller, J., & Cooper, G. A. (1985). The use of worked examples as a substitute for problem solving in learning algebra. *Cognition and Instruction, 2*(1), 59–89. https://doi.org/10.1207/s1532690xci0201_3
Sweller, J., & Levine, M. (1982). Effects of goal specificity on means–ends analysis and learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8*(5), 463–474. https://doi.org/10.1037/0278-7393.8.5.463
Sweller, J., Ayres, P., & Kalyuga, S. (2011a). Cognitive load theory. *Springer*. https://doi.org/10.1007/978-1-4419-8126-4
Sweller, J., van Merriënboer, J. J., & Paas, F. (2019). Cognitive architecture and instructional design: 20 years later. *Educational Psychology Review, 31*, 261–292. https://doi.org/10.1007/s10648-019-09465-5
Sweller, J., Ayres, P., & Kalyuga, S. (2011b). Intrinsic and extraneous cognitive load. In *Cognitive Load Theory* (pp. 57–69). Springer New York. https://doi.org/10.1007/978-1-4419-8126-4_5
Sweller, J. (2003). Evolution of human cognitive architecture. In B. H. Ross (Ed.), *Psychology of learning and motivation* (Vol. 43, pp. 215–266). Elsevier. https://doi.org/10.1016/S0079-7421(03)01015-6
Szulewski, A., Gegenfurtner, A., Howes, D. W., Sivilotti, M. L. A., & van Merriënboer, J. J. G. (2017). Measuring physician cognitive load: validity evidence for a physiologic and a psychometric tool. *Advances in Health Sciences Education, 22*(4), 951–968. https://doi.org/10.1007/s10459-016-9725-2
Tarmizi, R. A., & Sweller, J. (1988). Guidance during mathematical problem solving. *Journal of Educational Psychology, 80*(4), 424–436. https://doi.org/10.1037/0022-0663.80.4.424
Van Merrienboer, J. J. G., & Krammer, H. P. M. (1987). Instructional strategies and tactics for the design of introductory computer programming courses in high school. *Instructional Science, 16*(3), 251–285. https://doi.org/10.1007/BF00120253
VerPlanck, J. (2021). The effects of simulator training on the development of creative thinking in law enforcement officers. *Policing: An International Journal, 44*(3), 455–468. https://doi.org/10.1108/PIJPSM-06-2020-0101
Vessey, W. B., & Mumford, M. D. (2012). Heuristics as a basis for assessing creative potential: Measures, methods, and contingencies. *Creativity Research Journal, 24*(1), 41–54. https://doi.org/10.1080/10400419.2012.652928

Vincent, A. S., Decker, B. P., & Mumford, M. D. (2002). Divergent thinking, intelligence, and expertise: a test of alternative models. *Creativity Research Journal, 14*(2), 163–178. https://doi.org/10.1207/S15326934CRJ1402_4

Weatherford, D. R., Esparza, L. V., Tedder, L. J., & Smith, O. K. (2021). Using a fork as a hairbrush: investigating dual routes to release from functional fixedness. *Journal of Creative Behavior, 55*(1), 154–167. https://doi.org/10.1002/jocb.442

Wyeld, T. (2016). Using video tutorials to learn maya 3D for creative outcomes: a case study in increasing student satisfaction by reducing cognitive load. In *Knowledge visualization and visual literacy in science education* (pp. 219–254). IGI Global. https://doi.org/10.4018/978-1-5225-0480-1.ch009

Yu, M., & Choi, J. N. (2022). How do feedback seekers think? Disparate cognitive pathways towards incremental and radical creativity. *European Journal of Work and Organizational Psychology, 31*(3), 470–483. https://doi.org/10.1080/1359432X.2021.1991914

Zhou, J., & George, J. M. (2001). When job dissatisfaction leads to creativity: encouraging the expression of voice. *Academy of Management Journal, 44*(4), 682–696. https://doi.org/10.5465/3069410

Zijlstra, F. R. H., & van Doorn, L. (1985). *The construction of a scale to measure subjective effort*. Delft University of Technology, Department of Philosophy and Social Sciences. https://books.google.com.tw/books?id=mRUQtwAACAAJ