TUM SCHOOL OF
ENGINEERING AND DESIGN

CREATIVITY

A HUMAN FACTORS CHALLENGE

Lorenz Kilian Prasch

Vollständiger Abdruck der von der TUM School of Engineering and Design der Technischen Universität München zur Erlangung des akademischen Grades eines Doktors der Ingenieurswissenschaften (Dr.-Ing.) genehmigten Dissertation.

Vorsitz
Prof. Dr. Markus Zimmermann

Prüfende/-r der Dissertation
1. Prof. Dr. Klaus Bengler
2. Prof. Dr. Sebastian Pfotenhauer

Die Dissertation wurde am 16.11.2021 bei der Technischen Universität München eingereicht und durch die TUM School of Engineering and Design am 10.05.2022 angenommen.

Abstract

Our world is changing rapidly, and work follows suit. Considering the traditional division of work in physical and mental labor, it is primarily physical labor that has been systematically analyzed and optimized over the last century. This made it possible to break down many manual tasks into small entities that could eventually be automated. Advances in cognitive computing and artificial intelligence suggest that mental work might be next in line. In fact, some basic cognitive tasks have already been automated. A final frontier on the road towards ubiquitous automation, however, seems to be the generation of creative ideas. This suggests that the human capability to create will become increasingly important, especially in the workforce. The overarching theme of this thesis is creativity and its role in the modern workplace. The thesis identifies and contributes to two major research areas, namely creativity measurement and creativity amplification. In the area of creativity measurement, this thesis builds upon the current literature to develop and evaluate a new and innovative tool for objective creativity measurement, the Creativity Assessment via Novelty and Usefulness (CANU). The results of several experimental studies suggest that while the CANU does not eradicate all problems connected to creativity measurement, it does prove an easy-to-use, scalable, and comparable tool. In this way, this thesis highlights the shortcomings of current creativity measurement systems, especially for fundamental research. In the area of creativity amplification, the gaining momentum in the human computer interaction community, and the identification of creativity as paradigm have prompted the user centered development of three creativity support systems. The results of experimental exploration and evaluation in this project indicate that people who are inherently creative do not need (or want) support, whereas those who traditionally struggle with creative problem solving can benefit from inspirational stimuli. Overall, this thesis highlights the need for standardization in creativity measurement. It emphasizes the opportunity that creativity support can offer in terms of ergonomic optimization of system performance, and recognizes human factors/ergonomics as particularly suited discipline to tackle creativity measurement and amplification in a human-centered way.

Contents

errare humanum est
perseverare autem diabolicum

CHAPTER 1

Creativity as Work

To err is human. To persist [in error], is diabolical. The famous Latin saying, including its somewhat less famous second part, is often attributed to the roman philosopher Seneca. Despite the fact that the origin as well as the wording are controversial, the popularity of the quote—especially considering its age—is remarkable. It describes two concepts: to err is what makes us human, to be able to recognize and act upon those errors is what makes us progress. From a modern point of view, these two key aspects still hold true. For instance, failing (fast) and iterating are both integral to creative work. This notion is supported by several recently popularized frameworks. While traditional models for product development typically focus on following a certain plan to perfection, the newer frameworks, such as agile working (see Fowler, Highsmith, et al., 2001) and design thinking (see Brown, 2008) emphasize the importance of failure and iteration. The advent of these newer approaches to the product development process can be understood as a response to societal changes in our modern world. Today's globalized environment is deeply influenced by Volatility, Uncertainty, Complexity and Ambiguity (VUCA), a fact that is universally recognized and emphasized by a multitude of scholars (e.g. Bennett & Lemoine, 2014; Mack et al., 2016; A. Sarkar, 2016). With change, there always comes opportunity. In fact, plenty of opportunity regarding the influence of VUCA has already been identified (e.g. Coleman, 2017; A. Hoff, 2013; Warwick-Ching, 2013). Especially its impact on the working environment, and the ongoing shift towards a creative knowledge economy have been discussed (Holford, 2019; Ramírez & Nembhard, 2004; Switzer, 2008). Thus, making it necessary to reconsider the traditional forms of work as we know them. A brief glimpse into the history of work following four technological revolutions (as described by Bubb, 2006) yields some insight as to how we ended up here, and how the journey might continue.

The history of work—and human history in general—is in many ways a history of progress and optimization. Following its urge for improvement, humanity was able to harness the power of fossil fuels in the first industrial revolution. With the invention of the steam engine, it was now possible to substitute repetitive manual tasks by machines. The second industrial revolution is characterized by the distribution of the energy necessary to operate such machinery (i.e. electricity networks), and followed by their widespread use. This was the first step towards a monumental shift in work and how it is being carried out—eventually becoming ubiquitous: the introduction of automation. Through the application of the principles of scientific management by F. W. Taylor (1914), manual labor was broken down into small entities. Those were subject to analysis and optimization, resulting in their eventual automation (Prasch et al., 2020). The result was a fifty-fold increase in productivity during the 20th century, and has been suggested to be at the root of all economic and social gains that were achieved during this period (Drucker, 1999).

The third industrial revolution, the invention of the computer, enabled the substitution of repetitive cognitive tasks by machines. Through vast data networks (i.e. the internet), information about said machines and their use became widely available in the fourth industrial revolution, thus advancing the exchangeability of knowledge (Kalff, 2017). If history repeats itself, cognitive work could undergo a similar development as manual labor—being increasingly automated.

Frey and Osborne (2017) estimate that 47 % of US employment is potentially automatable. Traditionally, routine work was considered the most susceptible to automation (Autor et al., 2003), rendering all non-routine jobs relatively safe. However, advances in machine learning have expanded the understanding of what computers are capable of (Frey & Osborne, 2017). Nowadays, computers are understood as possible substitute for a multitude of non-routine tasks (Brynjolfsson & McAfee, 2011). Does this mean humans will no longer be needed in the workforce? This fear of automation—and its consequences of widespread technology unemployment—has already been formulated by Keynes (1930) following the first technological revolutions, and is being discussed again these days (e.g. Susskind, 2020). Still, the prediction of humans being superfluous in the workforce of the future has not prevailed. Despite the fact that, indeed, computer-controlled equipment has been cited as possible explanation for a growth in joblessness (Brynjolfsson & McAfee, 2011), human work tends to change rather than to be completely eliminated (Acemoglu & Restrepo, 2018b; Bubb, 2006). Acemoglu and Restrepo (2018a) discuss three effects in which increased automation, Artificial Intelligence (AI), and robotics may even increase labor demand: (i) the *productivity effect* which states that due to increased productivity using automation, the economy expands which in turn increases the demand for non-automated tasks. (ii) *Capital accumulation* describing that increasing automation raises the need for, and the accumulation of capital which in turn raises the demand for labor. And (iii) *deepening of automation* which considers that not only human labor can be automated, but also tasks that were already done by machines, increasing their previous productivity and thereby increasing the demand for labor by triggering the productivity effect.

In any case, it seems clear that human work will change—just as it has done in the past. In what direction it will develop though, is something that might be hard to predict. Technology that will potentially substitute human labor does not exist yet. Any attempt to identify specific job descriptions of the future is therefore pointless. It would be like an agricultural worker from the early 20th century, trying to map out whether his descendants will work as engineers for search engine optimization, or social media marketers. The general direction in which work will shift, however, can be estimated by consideration of current trends and AI limitations. For example their lack of ability to attribute meaning to data (see section 2.2). Specifically, Frey and Osborne (2017) postulate that workers in the future will occupy work that is non-susceptible to computerization, namely creative and social intelligence tasks. Due to the fact that creativity is a long standing goal of the AI community, but remains elusive as of yet (Ward, 2020), it can be considered a final frontier for AI (see chapter 4; Colton & Wiggins, 2012).

Research on creative work is therefore inherently connected to the future of Human Factors/Ergonomics (HFE). However, creative work can not be tackled by traditional HFE methods (Bonnardel & Pichot, 2020), in part due to a lack of suitable measurement instruments (see section 2.1) and no clearly defined input-output relationship (Prasch & Bengler, 2019). Therefore the role of ergonomics might change (Dul & Neumann, 2009; Kadir et al., 2019). However, the key objective of HFE, namely an optimal synthesis of well-being and system performance (Interanational Ergonomics Association, 2021) must not waver. Research on the future of work, imagination, creativity and strategy (Pisturi, 2018), and the amount of stress they impose on humans, is vital to the advancement not only of the discipline, but humane work itself.

1.1 Definitions

To understand the characteristics of creative work and the challenges it poses for HFE, it is necessary to first delve deeper into the two concepts of work and creativity separately. In the following sections, definitions for these terms will be provided as they are used in this thesis.

1.1.1 Creativity

Creativity and its underlying processes have been of interest for researchers and philosophers for centuries. The concept fascinated great scientific minds, such as Aristotle, Helmholtz, and Poincaré, who all wrote about and published on creativity (Wallas, 1926). In ancient history, this uniquely human trait to come up with something new in order to solve a problem was considered so special, its origin had to be divine (Albert & Runco, 1999). This notion gradually shifted until creativity was perceived as a human trait—albeit only a very select few geniuses were considered to possess it. Nowadays, a consensus has been reached that creativity is neither of divine origin, nor is it reserved for only the brightest. Everyone can be creative (Runco, 2004; Treffinger et al., 2005).

Despite the ubiquity of creativity, finding a universally accepted definition for the phenomenon has proven to be difficult (Batey, 2012; Prentky, 2001). Even though several historical definitions describe aspects of creativity that are still relevant today (e.g. Becker, 1995), major advancements on definitional consensus were made only after the presidential address of Guilford (1950) to the American Psychological Association (APA), promoting creativity as an imperative research topic. In the following years, two major definitions by Stein (1953) and Barron (1955) introduced novelty and usefulness as prerequisites for creative outcome. However, the exact number of criteria necessary to fully describe and identify creativity is still disputed (Runco & Jaeger, 2012). This lack of definitional consensus hung as the "mythical albatross around the neck of scientific research on creativity" (Prentky, 2001, p. 97) for years. In fact, differing definitions are being published and discussed by prominent researchers in the field till this day (e.g. Glăveanu & Beghetto, 2021), and there is no generally agreed upon definition (P. Sarkar & Chakrabarti, 2011). While the standard definition of creativity (Runco & Jaeger, 2012) has been updated multiple times, one of the most widely used (over 1800 citations, according to Google Scholar) is the one by Plucker et al. (2004). In a systematic review of 90 articles that offered a definition on creativity, they condensed the following:

> "Creativity is the interaction among *aptitude*, *process* and *environment* by which an individual or group produces a *perceptible product* that is both *novel and useful* as defined within a *social context*." (p. 90)

This definition describes three components that interact in the creation of new and appropriate products (Zeng et al., 2011). In this regard, it is consistent with one of the most famous models in creativity research, the *4P model* by Rhodes (1961). It describes four facets that can be distinguished in creativity research: (i) the *person* that creates, (ii) the *process* used, (iii) the environmental *press* that is in place, and (iv) the resulting *product*. Batey (2012) conceptualized the relationship between the 4 P's in an equation:

$$\text{person} \times \text{process} \times \text{press} = \text{product} \tag{1.1}$$

The suggested interaction between the facets person, process, and press to form a (creative) product implies that variations of the first three variables should influence the outcome of the last. The outcome-oriented approach has seen successful application in the past (see section 2.1). The fact that a (perceptible) product must always be the result of creativity is comprehensible in a sense that creativity and innovation are inherently subjective constructs, socially bound by historical time and place (Amabile, 1982; 1983; Amabile & Pratt, 2016; J. Baer, 2016). They therefore require judgement by domain experts, or gatekeepers (Kaufman & Baer, 2012; Steiner, 2006), who need some form of perceptible entity to judge upon. Due to its practicability and success in the past, the definition by Plucker et al. (2004) will be the basis for creativity in this thesis.

1.1.2 Work

Another concept that has been studied and contemplated by philosophies, religions, and many others over centuries is work. Just as in the case of creativity, concise definitions of human work have been scarce (Bubb, 2006). Only after the famous observations of Jastrzebowski in 1857, who identified the need to scientifically research human activity, including work (Karwowski, 2006), researchers put more effort in finding a universal definition. Hilf (1976) provides a far-reaching and elegant one with:

> "work is every target and purpose oriented activity in order to create goods or thoughts"

as cited in Bubb (2006, p. 401). Despite the fact that work has traditionally been divided in physical and mental work (Bubb, 2012), a common understanding of human labor—especially since it was (and is) shifting from predominantly manual to cognitive work (Ramírez & Nembhard, 2004)—is necessary for appropriate analysis and research. Bubb (2006) characterizes work as change of information. He argues that over 85 % of manual work can be described by a cycle of basic motions (reach, grasp, move, position, release), and a similar classification can be achieved for cognitive work, or information processing. Using a Turing process (Turing, 1937), an abstract machine that describes manipulation of data using a set of simple rules and the foundation of modern computing, *reach* corresponds to recognition of symbols, *grasp* to interacting with symbols (overwriting or deleting them), and *move* to moving symbols (Bubb, 2006). Thus, the abstract description of work does essentially not differ between manual and cognitive work. As already alluded to, proper research of work requires a means of measurement or quantification. For manual work this has been fairly successful in the past, cognitive work however is still lacking widespread measurement tools (Prasch & Bengler, 2019). Considering the aforementioned abstract definition of work—and its lack of distinction between manual and cognitive work—this seems odd.

If work is the change of information, then what exactly is information and how does it change? Shannon (1948) defined information as deliberate deviation from the natural energy distribution, or entropy. If entropy is high (natural chaos, randomness is omnipresent), the probability of a certain state is low. Information on the other hand, describes the certainty of a state. In case a state is certain, information is high, and entropy is low. Thus, information must be considered the inverse of entropy. In physics, more precisely described by the second law of thermodynamics, it is regarded universal that only processes that increase entropy while simultaneously releasing energy proceed automatically. The process of using energy to move on the continuum from entropy to information, or establishment of human intended order, can therefore be understood equivalent to work (Bubb, 2006).

1.1.3 Creative Work

As discussed, both creativity and work have been of interest for a considerable amount of time, while simultaneously, achieving consensus on definitions has been challenging. Combining the two definitions provided in sections 1.1.1 and 1.1.2, creative work could be characterized as the use of energy with the purpose to produce novel and useful products. Considering the fact that research has only recently started exploring creative work as a central concept (Freedman, 2010), it is not surprising that definitions are still developing. One of the few definitions in literature is the one by Mirowsky and Ross (2007), who state that

> "Creative work is varied, challenging, nonroutine, and engaging activity directed toward the production or accomplishment of something." (p. 385)

The authors note that their definition focuses on qualities of paid work as experienced by the individual. They do not directly refer to creative industries (as for example Florida (2002)), neither do they require others to judge the created product as novel or useful (see section 1.1.1, and Simonton, 2000). Nevertheless, the definition is to a reasonable degree coherent with the one drawn from the conjunction of the definitions of creativity and work. Therefore it can be considered adequate at least to a certain degree and will be used within this thesis.

1.2 Importance

As alluded to in the beginning, our society is increasingly substituting repetitive manual and cognitive work with machines. In combination with changes to the dynamics of a VUCA world, this leads to increased importance of creativity, "mankind's ultimate capital asset" (Toynbee, 1962, p. 8). Creativity, however, is not something that can easily be achieved by machines (Berns & Colton, 2020; Colton & Wiggins, 2012; Jennings, 2010). Therefore it must be a form of work that humans will continue to do in the foreseeable future.

This is intuitive in a sense that a machine fulfilling a task will need some repairs in case it breaks. Repair work is characterized by a largely creative part (Bubb, 2006). However, efficient and effective repair work can only occur when a service operator truly understands the machinery they are working on. For example by having learned from previous breakdowns (Bubb, 2006). As such, the deviation from routine behavior can facilitate learning, particularly when its roots and consequences are reflected by the individual (Kreuzer & Weber, 2020). The ultimate goal of learning is improvement, facilitated by understanding. Machines, however, cannot understand, they are still often struggling with their newly found capability to learn. They do not attribute meaning to the constructs they cover. This is problematic, since creativity requires a certain amount of expertise (Amabile & Pratt, 2016; Issahaka & Lines, 2019), something machines are inherently incapable of (Cave et al., 2020).

Learning (from mistakes) at the workplace has been discussed in contemporary research (Ellström, 2001; Marsick et al., 2008; Streumer & Kho, 2006) and is considered highly relevant (Rybowiak et al., 1999). From the standpoint of cognitive work, mistakes are inherent to innovation and creativity (Harteis et al., 2008). Similar to nature, where random mutations appear and the successful ones survive, human error can be the basis of improvement (Bubb, 2006). Human behavior generally varies to a certain degree, even under stable environmental conditions. Depending on the degree of variation, this unexpected behavior can sometimes be considered a mere error that should be avoided, but sometimes it is creative and can be valuable (Senders & Moray, 1991). However, if "creativity and error are opposite sides of the same coin (unplanned variation in performance), then eliminating error, if that were possible, might also inhibit creative problem-solving" (Senders & Moray, 1991, p. 9). This is contrary to many efforts in HFE that focus on eliminating human error

(Bubb, 2006), and part of the potential process of change in HFE. Still, knowledge-based errors are typical for consciously deviant actions, such as problem-solving or decision-making (Kreuzer & Weber, 2020). Machine learning models however, learn for perfection, inherently limiting their creative ability (Berns & Colton, 2020). This capacity to err, is therefore not only part of a popular quote but essentially what sets humans apart from machines, and one of the main reasons, why computational creativity still remains elusive (Ward, 2020).

Additionally, one of the characteristics of creative problems is that they tend to be loosely defined. Problem elements, or structure are often not provided or at least not immediately apparent (Frederiksen & Ward, 1978; Glover, 1979). The problem-solving efforts are—due to their complexity, dynamic, and lack of definition—associated with a high degree of uncertainty (Mumford et al., 2006). This uncertainty is something notoriously difficult for computers in general, and for machine learning algorithms in particular (Kubat, 2017; Smola & Vishwanathan, 2008). Thus, additionally reducing the likelihood of creative work being automated.

1.3 Avenues for Improvement

As mentioned, the application of theory, principles, data and methods in order to optimize human well-being and overall system performance (Interanational Ergonomics Association, 2021) is at the core of HFE. However, theory and principles on creativity are scattered (section 1.1.1), reliable data on creative performance is hard to obtain (section 2.1), and current methods are at their limits when confronted with creativity (Bonnardel & Pichot, 2020). In the following, past and current efforts of researchers to deal with these issues—particularly in conjunction with the two HFE principles well-being and system performance—and the current status quo will be briefly summarized. They will be discussed in greater detail in chapter 2. In order to facilitate individual well-being, comprehensive analysis and measurement of the stress put on humans by the demands of a creative knowledge economy is imperative. In terms of system performance, the amplification of human creativity using Creativity Support Systems (CSSs) offers great potential. Therefore, we will discuss current creativity measurement and amplification methods, their application, and identify avenues for improvement.

1.3.1 Measurement

Well-being as catalyst for system performance has been shown to occur when people make creative progress in meaningful work (Amabile & Pratt, 2016). Nevertheless, there is a necessity to consider the threat of stress due to the constant need to be creative (Bubb, 2006). All the more important does it seem that the generation of creative ideas and products is fundamentally understood by the scientific community. Following Amabile (1982), a product is creative when it is judged to be novel and useful. While this definition deliberately introduced subjectivity (as opposed to Stein, 1974), how exactly novelty and usefulness are to judge—and by whom—is still a matter of debate (Cseh & Jeffries, 2019). In fact, due to the encouraging interest of a variety of disciplines in the phenomenon that is creativity, measurement has become increasingly cluttered (Prasch & Bengler, 2019). In section 2.1 the current state of the art in creativity measurement will be synthesized according to different objects of measurement, and the benefits and issues with various approaches will be discussed. Chapter 3 will subsequently introduce a new way of measuring creativity. This new approach attempts to tackle problems with current measurement systems, specifically ease-of-use, scalability, and comparability of results.

1.3.2 Amplification

System performance in terms of creative output has seen a particular interest from the Human Computer Interaction (HCI) community in recent years (Frich et al., 2019). After the first and second wave of creativity research—the initial one following the address by Guilford (1950), the latter in the 1980s after Amabile (1982) and others argued there was lack of cultural perspectives in contemporary creativity research (Sawyer, 2012)—a potential third wave has been sparked in the community only recently with the introduction of creativity as potential paradigm for HCI (Frich et al., 2018; Shneiderman, 2007; 2009). Section 2.2 introduces current approaches of creativity amplification, using analog and digital tools. In the following, chapter 4 describes a user-centered approach on the need of such systems, and evaluates three different support strategies with regard to their potential.

To summarize: the current situation is not ideal. But HFE as a discipline is—due to its inherent interdisciplinary character—ideally equipped to tackle the complex phenomenon that is creativity. Through systematic development of adequate measurement instruments and the human-centered design of creativity amplification tools, we could advance the field of creativity research as well as the discipline itself. The HFE-typical system approach is especially potent because "performance can influence well-being, and well-being can influence performance, both in the short and the long-term" (Dul et al., 2012, p.381).

CHAPTER 2

State of the Art

For many years there has been a lack of a universally valid and operational definition of creativity (see section 1.1.1). The scientific community has employed a variety of measurement methods that attempt to capture the complex construct in different ways, often producing incoherent results, and mostly failing to meet psychometric requirements (e.g. Ai, 1999; Amabile, 1982; Auzmendi et al., 1996; Batey, 2012; Domino, 1994; Furnham et al., 2008; Piffer, 2012; Said-Metwaly et al., 2017). The use of different approaches to creativity and the associated methods of data collection make it difficult to draw comparisons between the various research studies (Abraham, 2016; Plucker et al., 2004; Said-Metwaly et al., 2017). A valid and reliable measurement of creativity serves as a basic prerequisite for gaining a scientific understanding of the concept. Inter-individual differences must be quantifiable (Ramírez & Nembhard, 2004), especially since creativity is not subject to a dichotomous distribution but rather follows a continuum (Amabile, 1983; D. H. Cropley & Kaufman, 2012; Shalley et al., 2000). Additionally, in order to determine how creativity can best be supported, an understanding of how exactly it comes to fruition and which factors influence creative performance is necessary (see section 1.1).

In the following, an overview of the state of art in measuring creativity will be provided. This will be followed by current approaches and the description of creativity amplification as a newly emerging trend in the Human Computer Interaction (HCI) community.

Literature review on measurement methods was part of a thesis:

Schlorf, M. (2020). *Einfluss der wahrgenommenen sozial-organisatorischen und physikalischen Arbeitsumgebung auf die kreative Leistung von Wissensarbeitenden in Deutschland* [Master's Thesis]. Technical University of Munich

2.1 Measurement

As Batey (2012) points out, various taxonomies have emerged in the past to classify creativity measurement instruments. To account for the multidimensionality, Batey (2012) developed the heuristic framework model (see figure 2.1), which is based on Rhodes (1961) *4P model* and aims to provide a better overview of the landscape of measurement methods. Following Sternberg

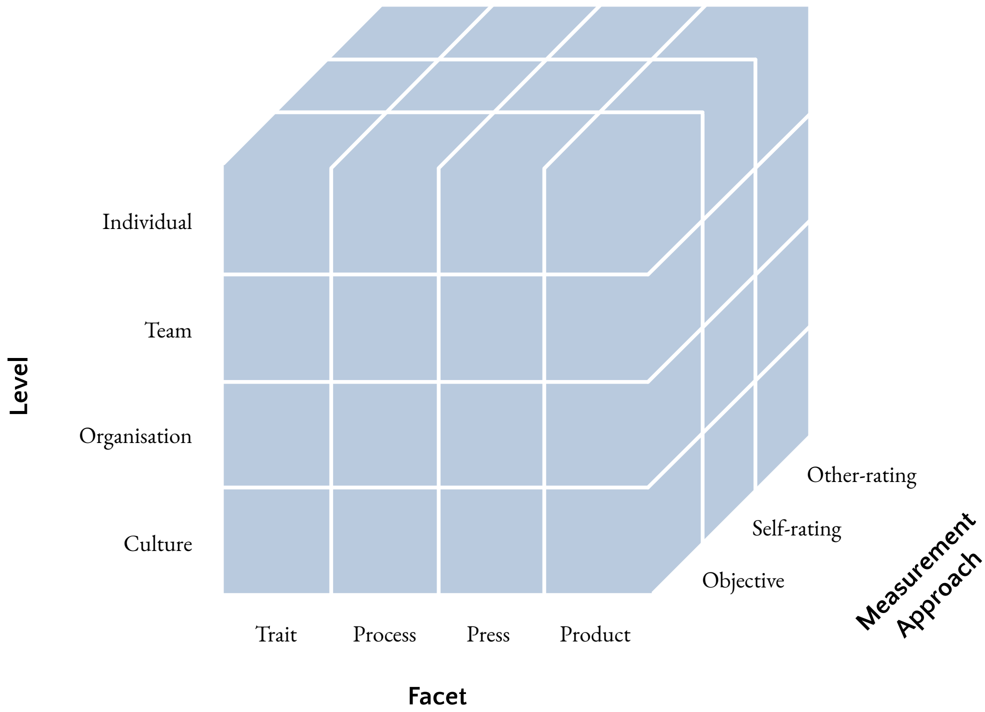

Figure 2.1 Heuristic framework for creativity measurement. Adapted from Batey (2012).

and Lubart (1999), the framework distinguishes four different social levels of observation, namely individual, team, organization and culture. Furthermore, Batey (2012) lists three measurement approaches to determine creativity. He differentiates between self-rating, other-rating, and objective measurement of creativity. According to Batey (2012), objective methods are tangible data that include, for example, patent applications on a product-related level. Some researchers have included such data in creativity studies (e.g. Oldham & Cummings, 1996; Park et al., 2007; Scott & Bruce, 1994; Tierney et al., 1999). However, it is important to note that even seemingly objective data, such as citation indices, can be traced back to a subjective origin (Gruszka & Tang, 2017). This is why Csikszentmihalyi (2014) emphasizes "that social agreement is one of the constitutive aspects of creativity, without which the phenomenon would not exist" (p. 49). Tierney et al. (1999), Scott and Bruce (1994), Dewett (2007) and Oldham and Cummings (1996) find a positive low-to-moderate relationship between objective measures and other's judgments in creativity research. In many cases, third-party assessments are carried out by experts. At the product level, those are particularly relevant to Amabile (1982). She and Csikszentmihalyi (2014) emphasize the subjective character of creativity evaluation and state that a product can only be found to be creative if suitable raters independently come to the conclusion that it is.

According to Amabile and Mueller (2008), self-assessments are used less frequently in creativity research because they can have a distorting effect for various reasons. For example, the creative judgment of experts is relative in nature since several individuals are evaluated in comparison to one another (Amabile & Mueller, 2008). Self-assessment lacks such a basis for comparison. In addition, the reliability of self-assessment is questioned because, unlike expert assessments, it is carried out by only a single person (Amabile & Mueller, 2008). However, self-assessments have the advantage that the person being assessed has information that is not accessible for outsiders (Amabile & Mueller, 2008; Janssen, 2000). Hocevar (1981) shares this opinion and points out that expert evaluations are to be criticized because evaluators cannot always distinguish creativity from other (personality) characteristics. For instance, Sternberg (2006)* emphasizes that raters tend to judge the creative products of individuals from roughly the same age cohort as more creative. Also, evaluations may depend on the expertise (Kaufman & Baer, 2012) and self-interests (Csikszentmihalyi, 1999) of the raters. Batey and Furnham (2008) and Jing Zhou et al. (2008), argue in favor of self-ratings, citing several studies demonstrating that individuals are generally capable of predicting personality and intelligence test scores. Congruently, Harris and Schaubroek (1988) state in a meta-analysis that a moderate correlation between self- and other-assessment exists in many other research areas.

This article has since been retracted due to significant overlap with previously published research. Scientific content, however, was found valid by editor and reviewers and is not in question (Sternberg, 2020).

One reason for the multitude of inconsistencies in creativity research is the multitude of measurement instruments employed. Following Rhodes (1961) famous *4P model* (see section 1.1.1), that—despite some additions (e.g. Runco, 2007; Simonton, 1995)—is still one of the most fundamental models of creativity, several assessment methods for each of the four facets (*person*, *process*, *press*, *product*) can be found in literature. For a comprehensive review, see Gruszka and Tang (2017). In the following, each of the four facets of the *4P model* is examined separately. First, basic theoretical concepts regarding the specific facet will be explained, followed by approaches and discussion of the measurement methods concerning said facet. The facets are distinguished clearly to provide an easy structure but in reality they are interdependent and subject to numerous interactions (Batey, 2012). Considering only one creativity component does not do the multi-layered construct justice (Hennessey & Amabile, 2010).

2.1.1 Person

Barron stated in 1955 that the personality of individuals who perform creative acts was understudied. From that point in time, researchers focused on exploring eminently creative personalities (Amabile & Gryskiewicz, 1989), investigating the characteristics in which creative individuals differed from the general population (Amabile & Pillemer, 2012; Feist, 1993). The fact that incremental creative achievements are also reflected in everyday (corporate) life and are of importance as well has only been given greater consideration in recent decades (Kaufman & Beghetto, 2009). Scientific interest regarding the facet can be distinguished in three main categories with researchers investigating the relationship between creativity and: (i) personality traits with special emphasis on the big five, (ii) demographic variables, and (iii) intelligence. The most important findings of all three categories will briefly be discussed in the following.

In terms of creative personality, associations have mostly been described with the five global "Big Five" personality traits (extraversion, agreeableness, openness, conscientousness, and neuroticism,

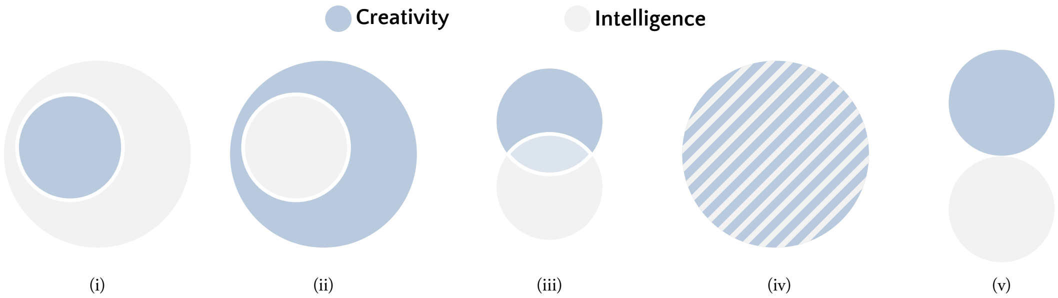

Figure 2.2
Proposed relationships between creativity and intelligence.

see Costa & McCrae, 2008; Digman, 1990; Hennessey & Amabile, 2010). Across domains, openness (to experience) is positively related to creativity (e.g. Diedrich et al., 2018; Feist, 1998; George & Zhou, 2001). Other correlations—varying between domains—are illustrated in Batey and Furnham (2006). Other traits of creative personalities, according to the meta-analysis by Feist (1998), include *self-confidence*, *self-acceptance*, *ambition*, *impulsivity*, and *dominance*.

Ma (2009) identified demographic variables such as age, gender, and birth order as influencing creativity. Dul, Ceylan, and Jaspers (2011) found a peak in creativity at approximately 40 years of age, which is consistent with other findings (Simonton, 1975; 1988). However, Eder and Sawyer (2007) concluded in their meta-analysis that age had no relationship with creativity (as cited in Binnewies et al., 2008). There is no scientific consensus on the specific relationship between age and creativity yet. Additionally, Dul, Ceylan, and Jaspers (2011) recorded higher self-rated creative performance in men. Especially in the area of higher creativity, there is evidence of more male eminent creative individuals (Abraham, 2016). However, Matud et al. (2007) emphasize that gender differences are primarily the result of environmental differences (e.g., unequal access to schooling and resources) and state that most research findings do not show gender differences. J. Baer and Kaufman (2008), who looked at gender differences in greater detail, analyzing a variety of gender-specific study results, note that, if anything, females show slightly higher levels of creativity than males.

The relationship between intelligence and creativity has been of interest for a long time, and has been studied by many researchers (e.g. Guilford, 1950; Kim, 2005; Silvia, 2008). Sternberg and Lubart (1999) categorise the heterogeneous results of that stream of research in five groups: (i) creativity as subset of intelligence, (ii) intelligence as subset of creativity, (iii) creativity and intelligence as overlapping constructs, (iv) creativity and intelligence as synonymous, (v) creativity and intelligence as unrelated constructs (see figure 2.2). An overview of the key research findings is provided by Batey and Furnham (2006). As is often the case, in reality, the categories do not seem as clear cut as postulated but rather a mix between two of them seems to apply. The majority of studies support the threshold hypothesis. It states that intelligence and creativity are positively related up to a certain IQ threshold, after which differences in intelligence are no longer relevant for creativity (Guilford (1967); cited in Jauk et al. (2013)).

Level			
1	2	3	4
mini-c	little-c	Pro-c	Big-C

Table 2.1
The four levels of creativity according to Kaufman and Beghetto (2009)

Although Runco (2014) emphasizes that avoiding categorization would be conducive to creativity, various taxonomies have emerged to distinguish degrees of creativity (e.g. Boden, 2004; Mumford & Gustafson, 1988). Best known is the *Four C Model* by Kaufman and Beghetto (2009), distinguishing four levels of creativity (see table 2.1). Initial creative performance in everyday life is of *mini-c* level, attesting to creative potential inherent in all individuals. The next higher *little-c* level is characterized by creative achievements based on expertise and skills that the individual has acquired. Years-long experience-building results in *Pro-c* level creative achievements. When they achieve legendary status, they belong to the fourth level, *Big-C* (Kaufman & Beghetto, 2009). At the level of Big-C creativity, personality traits are usually examined for their clinical salience (Hennessey & Amabile, 2010), and in particular a link to schizophrenia has been noted (e.g. Eysenck, 1993; Merten & Fischer, 1999). The *Propulsion Model* (Sternberg, 1999) as well as the *Systems Model of Creativity* (Csikszentmihalyi, 2014) focus on Big-C creativity, whereas the *Investment Theory of Creativity* (Sternberg & Lubart, 1991; 1996) primarily addresses little-c creativity (Beghetto & Kaufman, 2007).

The *Componential Theory of Creativity*, first proposed by Amabile (1983) and revised several times since then (e.g. Amabile, 1988; 1997) is a widely cited model (Amabile, 2012), particularly addressing little-c creativity. It is underpinned by the assumption that creativity can change and be nurtured (Amabile, 1983; 1997). In the current version of this theory, Amabile and Mueller (2008) distinguish three components within a person, all of which are necessary in the creative process resulting in a creative outcome: (i) domain-relevant skills, (ii) creativity-relevant processes, and (iii) intrinsic task motivation (see figure 2.3). The level of creativity depends on the proficiency of these components (Amabile & Pillemer, 2012).

Domain-relevant skills include, for example, expertise, knowledge, intelligence, and technical knowledge (Amabile & Mueller, 2008). Many researchers argue for an inverted u-shaped relationship between creativity and knowledge (Batey & Furnham, 2006). This relationship highlights that too little and too much knowledge, as well as inefficiently organized knowledge, can impair creativity (Amabile, 1988). The importance of knowledge and expertise is additionally emphasized by Toker and Gray (2008) and summed up by Andrews and Smith (1996): “It is often said that there is nothing new under the sun, only new ways of uniting existing concepts” (p. 175).

Creativity-relevant processes include, among other things that will be elaborated in section 2.1.2, certain personality traits that promote risk-taking and independence, a disciplined way of working, and idea generation skills (Amabile & Mueller, 2008).

Intrinsic task motivation results from interest in the task itself (Amabile, 1997; 2012; Amabile

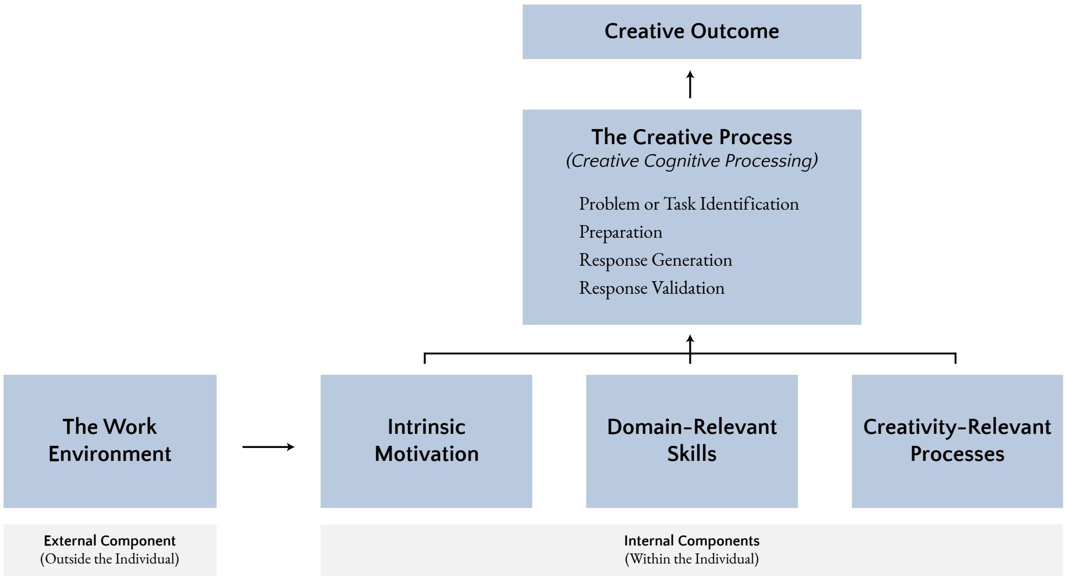

Figure 2.3
The *Componential Theory of Creativity*, which distinguishes external and internal components of a person as influencing the creative outcome. Adapted from Amabile and Mueller (2008).

& Mueller, 2008). It has been consistently articulated as an important factor influencing creativity (e.g. Amabile, 1988; 1997; 1998; Gruszka & Tang, 2017; Hennessey & Amabile, 2010; Oldham & Cummings, 1996; Sternberg, 2006). Extrinsic motivation is based on external incentives. It shifts the focus from the creative process to the outcome, which is why several authors have suggested its negative impact on creativity (e.g. Amabile, 1983; Deci et al., 1999). Amabile (1983, p. 366) states with regard to intrinsic motivation: "Task motivation can be seen in this context as the most important determinant of the difference between what a person can do and what he or she will do". However, voices are raised (also by Teresa Amabile herself) that extrinsic motivation can be conducive to creativity under certain conditions or in certain contexts (Amabile, 1983; 1988; 1997; 2012; Amabile & Mueller, 2008; Auzmendi et al., 1996; Gruszka & Tang, 2017; Kaufman & Beghetto, 2009). Amabile et al. (1996) cite that in the work context, reward and recognition for creative ideas, clearly defined overall project goals, and frequent constructive feedback can promote creativity. This can be explained by the fact that all these conditions validate employees' competence (Amabile, 2012). Money, the most common extrinsic motivator in the work context, does not necessarily prevent employees from being creative, but often does not help either and, moreover, does not alone contribute to making them enthusiastic about their work (Amabile, 1998).

In the work context, studies have addressed the relationship between creative personality traits and creative performance, finding positive correlations of varying strength (Dul & Ceylan, 2011; Dul, Ceylan, & Jaspers, 2011; Madjar et al., 2002; Oldham & Cummings, 1996; Unsworth et al., 2000) with some notable exceptions not finding any significant relationship (Zhou, 2003). To assess the creative personality, researchers tend to rely on different self-report measures. One popular tool is the *Creative Personality Scale* (CPS; Gough, 1979), which has been shown to have sufficient psychometric validity (Carson et al., 2003; 2005; Domino, 1994; McCrae & Ingraham, 1987). It is based on the assumption that creative individuals share certain personality traits. It is the best-known development of the *Adjective Check List* (ACL; Gough, 2000), which consists of 30 adjectives. On the CPS individuals indicate which of the scale's 30 adjectives associated with creativity correspond to them, resulting in a creative personality score. More recent self-report measures, such as the *Adjectives and Values Scale* (A&V; Acar & Runco, 2014) or the *Mode Shifting Index* (MSI; Pringle & Sowden, 2017), address more specific aspects related to creativity, such as values and ways of thinking. An additional explicit self-assessment of one's own creativity is required by the questionnaire *How Creative Are You* (HCAY; Raudsepp, 1981) and also by the *Revised Creativity Domain Questionnaire* (CDQ-R; Kaufman, Cole, & Baer, 2009).

2.1.2 Process

Cognitive psychologists in particular have devoted themselves to the study of the creative process over the last century (Batey, 2012). This process encompasses all cognitive processing steps that contribute to the production of creative outcomes (Amabile & Mueller, 2008). The authors divide it into four steps (*problem* or *task identification*, *preparation*, *response generation* as well as *response validation and communication*, see also figure 2.8), which were first presented by Amabile (1983) in a slightly different form. She describes that intrinsic task motivation has an influence on the first (at that time problem or task presentation) and third phase, domain-relevant skills are especially important in the second and fourth phases, and the creativity-relevant processes occur in the third phase (Amabile, 1983). The process steps are based on the four-stage process model of Wallas (1926), which has often been modified in the past (for an overview, see Palmer, 2015, p. 118), although the core ideas have always remained the same: In the preparation (phase 1), the information basis is created. During incubation (phase 2), the subject is turned away from, so that unconscious processing takes place (Lubart, 2001). Illumination (phase 3) marks the solution finding, the result of which is checked during verification (phase 4) (Lubart, 2001). In this context, the model should be understood as an iterative process (Wallas (1926); cited in Gruszka and Tang (2017)), in which phases can overlap and subprocesses can emerge (Lubart, 2001). The incubation phase is not explicitly mentioned in Amabile's process model, but she assigns a high value to incubation effects, especially during sleep (Amabile et al., 2005). Underlying are two central modes of thinking—divergent and convergent thinking—derived from the *Structure of Intellect* model of intelligence by Guilford (1967). Divergent thinking generates many creative solutions, whereas convergent thinking is characterized by identifying a single assessable solution (A. J. Cropley, 2006). They are both used in different process steps (e.g. Brophy, 1998; A. J. Cropley, 2006; A. J. Cropley & Cropley, 2008; Ma, 2009; Piffer, 2012). Yet, divergent thinking has long been considered to play a more important role in the creative process (e.g. A. J. Cropley, 2006; D. H. Cropley & Cropley, 2018).

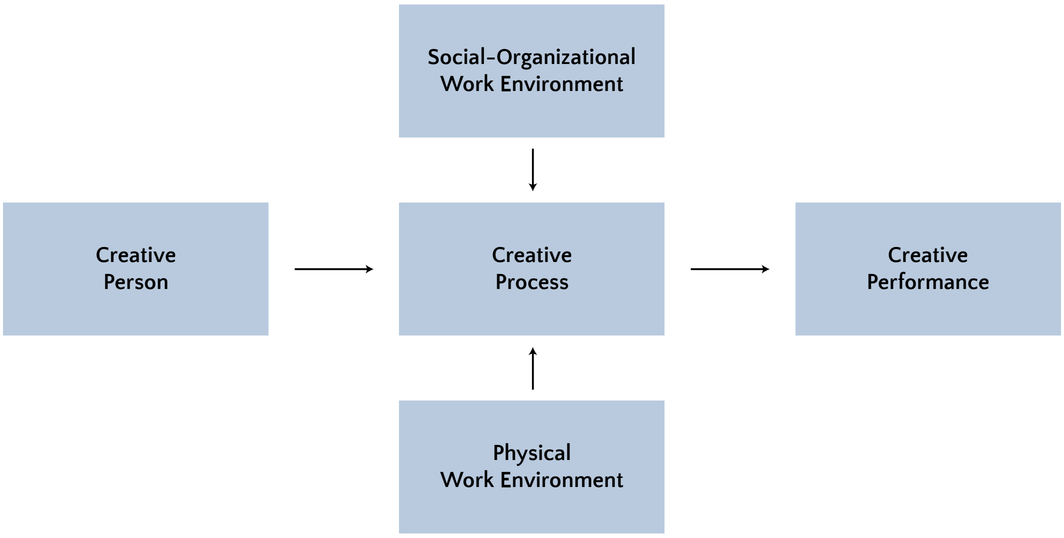

Figure 2.4
Influences of the two components of the working environment on the creative process. Adapted from Dul and Ceylan (2011).

For this reason, measurement methods regarding the creative process mainly capture this cognitive ability. Well-known examples are the *Wallach-Kogan Creativity Test* (WKCT; Wallach & Kogan, 1965), the *structure of the intellect divergent production test* by Guilford (1967), and the *Torrance Test of Creative Thinking* (TTCT; Torrance, 1966). The last is probably the best known and used most commonly (Ma, 2009; Runco & Jaeger, 2012). Even though divergent thinking tests can capture a predictor of creativity (Runco, 2008; Runco & Jaeger, 2012), it is noted that they do not do justice to a holistic view of creativity and creative processes (Zeng et al., 2011).

2.1.3 Press

The environment, in contrast to the other three creativity components, has only received increasing attention starting in the late 1970s and early 1980s (Amabile & Pillemer, 2012; Simonton, 2000), which is why there are relatively few studies examining the effects of the environment on creativity in comparison to the other three facets (Amabile & Mueller, 2008; Dul & Ceylan, 2011; Said-Metwaly et al., 2017). Nonetheless, many researchers agree that it has a meaningful impact on creative performance (e.g. Livingstone et al., 1997; Mathisen & Einarsen, 2004; Matud et al., 2007; Meinel et al., 2017; Sternberg, 2006). As Lubart (1999) put it, “Creativity does not occur in a vacuum. When we examine a creative person, creative product or creative process, we often ignore the environmental milieu. We decontextualize creativity” (p.339). The creativity that a person carries within them self could never come to fruition if certain support from the environment were missing (Sternberg, 2006).

In the context of work, this environment is heavily shaped by the employing organization. The three most influential models of organizational creativity, the *Interactionist Theory* by Woodman et al. (1993), the *Multiple Social Domains Theory* by Ford (1996), and the previously presented *Componential Theory of Creativity* (Amabile, 1988; 1997) emphasize the work environment as a factor influencing employee creativity (Amabile et al., 2004). Hereby, it is not the presence but the *perception* of the presence of the work environment components that is crucial for creative performance (Amabile et al., 1996). The actual objective work environment influences the perceived subjective work environment, which in turn determines the level of creativity. Thus, the perception of the work environment mediates the relationship between the objective work environment and creativity (Dul, 2019). The work environment can be divided into two components for better classification (Dul & Ceylan, 2011). In their conceptual model (see figure 2.4), Dul and Ceylan (2011) distinguish the social-organizational and physical work environments, both of which indirectly affect creative performance by influencing the creative process. The physical work environment refers to the immediate or surrounding physical environment of employees (e.g., background noise). In contrast, the social-organizational work environment includes all non-physical elements of the environment of a social or organizational nature (e.g., teamwork). Samani et al. (2014) and E. V. Hoff and Öberg (2015) also illustrate the relationship between the components of the work environment and creativity in comparable models. In the following, the two components of the work environment as well as their measurement are examined.

Social and Organizational Work Environment

Until a few years ago, almost only elements of the social-organizational work environment, commonly understood as the organizational climate for creativity (Vithayathawornwong et al., 2003), have been considered to describe the influence of the environment component on creativity (e.g. Andriopoulos, 2001; Egan, 2005; Greenberg, 1994; Hunter et al., 2007; Madjar & Oldham, 2006; Oldham & Cummings, 1996). Thus, the work environment in the current version of the Componential Theory of Creativity (see figure 2.3) is social-organizational in nature (Amabile, 2012; Amabile & Mueller, 2008). In a previous version of this model, Amabile (1997) specified the influence of this social-organizational work environment (see figure 2.5). She identifies three elements of the social-organizational work environment that influence individual creativity, namely (i) organizational motivation, (ii) resources, and (iii) management practices. Those elements have a particular impact on employees' task motivation, but also on the other two person-specific components (Amabile & Mueller, 2008). For a more detailed description of the person-specific components, refer back to section 2.1.1.

Organizational motivation refers to the fundamental orientation of the organization, especially the highest levels of management, toward innovation. This includes behaviors such as open and active communication of information and ideas, reward and recognition for creative work, and fair evaluation of that work. Resources include everything available to the organization to support work in the area where innovation is sought, such as sufficient time, access to expertise and (financial) work resources, and the possibility of further training. Providing positively challenging activities, forming heterogeneous and harmonious work groups and supporting them appropriately,

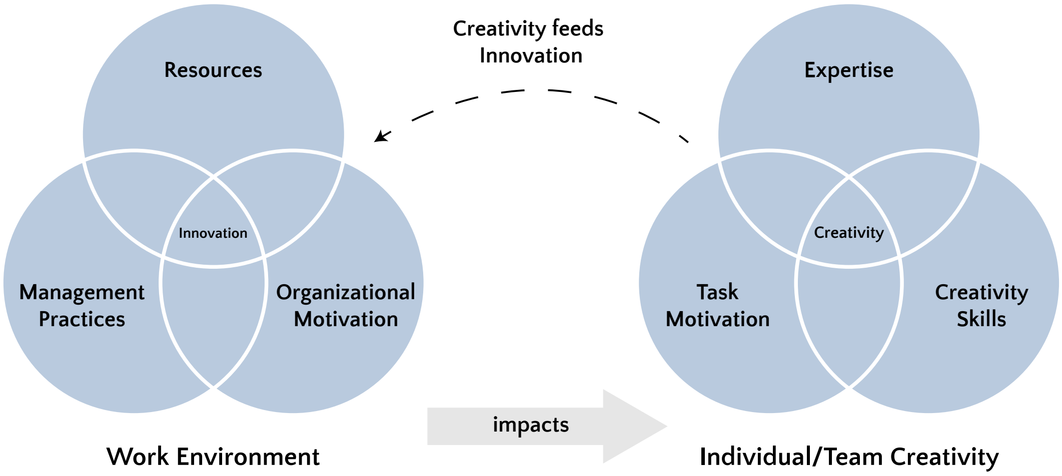

Figure 2.5
Extension of the *Componential Theory of Creativity* to include the three influences of the social-organizational work environment on individual creativity. Adapted form Amabile (1997).

formulating creative goals, and especially granting autonomy to employees are listed as behaviors of management that promote creativity (Amabile, 1997).

It is central for creativity in the workplace to engage employees at the job level with suitable work tasks (Amabile, 1997; 1998). The appropriate level of challenge must be found, as too much and too little pressure can inhibit creativity (Amabile, 1988; Amabile et al., 1996; Foss et al., 2013; Ohly et al., 2006). Especially when perceived as consequence of an urgent, intellectually challenging nature of the problem itself, pressure can enhance creativity by increasing intrinsic motivation (Amabile, 1988; Oldham & Cummings, 1996; Shalley et al., 2004). Hatcher et al. (1989) found a significant relationship between employees' self-reported work complexity and the number of creative ideas they expressed in an organization. However, the authors emphasize that the level of challenge and task complexity is person-dependent and thus subjective in nature. Similar observations were also made by de Jong and Kemp (2003) and Ohly et al. (2006). However, Shalley et al. (2009) emphasize that internal drive and an environment that supports risk taking and trying new things are more important than complex challenging work.

Physical Work Environment

Amabile (2012) and Woodman et al. (1993) emphasize the importance of the physical work environment. Sternberg and Lubart (1991) include both variants of work environment (social-organizational and physical) in their *Investment Theory of Creativity* as one of the six important sources of creativity. Similarly, Soriano de Alencar and Bruno-Faria (1997) describe components of the physical work environment that favor or inhibit creativity in their model. More recent models such as the *Five A Model* (Glăveanu, 2013) and the *Seven C Model* (Lubart & Thornhill-Miller, 2019) also take them into account. The exploration of the impact of the physical work environment on creativity has been and still is very limited (e.g. Dul, 2019; Dul, Ceylan, & Jaspers, 2011; Kris-

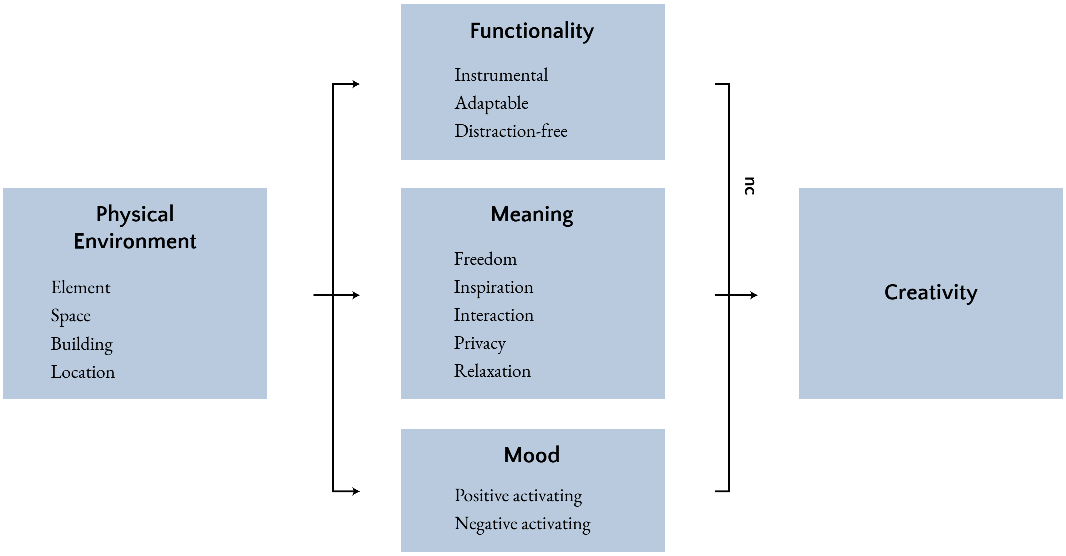

Figure 2.6
Triple Path Model, which illustrates the relationship between the objective physical environment and creativity via three perceptual pathways (mediators), where functionality is a necessary condition (nc) for creativity. Adapted from Dul (2019).

tensen, 2004; Martens, 2011; Samani et al., 2015; Vithayathawornwong et al., 2003). Dul and Ceylan (2011) report that few authors examine the direct relationship between physical work environment and creativity. In their analysis they reviewed studies from various disciplines (e.g., ergonomics, environmental psychology, architecture) that do not directly refer to creativity but on constructs related to it. This allows for an indirect conclusion about environmental elements that influence creativity. One theory that addresses such mediating influences is the *Triple Path Model* by Dul (2019) (see figure 2.6).

The model presents the three mediators: (i) functionality, (ii) meaning, and (iii) mood. These mediators are not independent from each other but rather can occur simultaneously and even interact with each other (Dul, 2019). Firstly, functionality is understood as a necessary but not sufficient condition for creativity. This factor makes creativity possible in the first place. As Dul (2019) phrases it: "Functionality is the extent to which characteristics of the physical environment that are necessary for a person's creativity are perceived to be in place" (p. 492). A person's creativity cannot be at its highest level without an instrumental, adaptive, and distraction-free physical environment (Dul, 2019). Secondly, meaning addresses the importance people place on the objective physical environment. It can be divided into the five categories of freedom, inspiration, interaction, privacy, and relaxation, all of which can be beneficial to a person's creativity (Dul, 2019). Thirdly, mood—or more specifically positive mood—is an influential mediator of the relationship between the physical environment and creativity (Dul, 2019; Fredrickson, 1998; Samani et al., 2014). Positive mood is associated with higher levels of creativity in organisations (Amabile et al., 2005). This positive effect can be, at least partly, attributed to an expansion in attentional range (Fredrickson, 1998; Shibata & Suzuki, 2004).

In recent years however, sporadic attempts have been made to explore the direct relationship between elements of the physical work environment and creativity. This followed findings that the physical work environment influences creativity-related constructs (e.g., mood, stress, organizational culture, and freedom) (E. V. Hoff & Öberg, 2015; Meinel et al., 2017; Samani et al., 2015). It has involved analyzing various individual aspects of the relationship between physical work environment and creativity (Ceylan et al., 2008; Sailer, 2011). Meinel et al. (2017) offer a summary of the state of research by identifying 17 studies from the fields of creativity management, architecture and design, human resource management, ergonomics, and psychology that address the above-mentioned relationship. The authors note that the studies differ in the creativity criterion covered (creative potential of the environment and/or creative performance) and in the type of measurement (self-assessment, expert assessment, or task outcome). Of the ten studies that captured creative potential, seven used self-assessments (Ceylan et al., 2008; E. V. Hoff & Öberg, 2015; McCoy & Evans, 2002; Soriano de Alencar & Bruno-Faria, 1997; Steiner, 2006; Stokols et al., 2002; Vithayathawornwong et al., 2003), and three used expert assessments (Haner, 2005; Y. S. Lee, 2016; Martens, 2011). A total of eight of the seventeen studies measured creative performance, five of which used self-assessments (Dul & Ceylan, 2011; 2014; Dul, Ceylan, & Jaspers, 2011; Magadley & Birdi, 2009; Toker & Gray, 2008) whereas three used task outcome (McCoy & Evans, 2002; Shibata & Suzuki, 2004; Steidle & Werth, 2013).

Work Environment Measurement

As apparent above, the variety of methods used to measure the work environment is plentiful. Due to the fact that the influence of the physical work environment has only recently attracted more attention, the landscape of measurement methods for the work environment shows a focus on the social-organizational environment. A selection of well-known measurement methods for recording the social-organizational and physical work environment is listed in chronological order in table 2.2. Only the last two of the twelve measurement methods listed also include the physical work environment. For further, in particular older, measurement methods of the social-organizational working environment, refer to Amabile and Gryskiewicz (1989). In the following, the measurement tools from table 2.2 will be briefly summarized.

Unlike the *Work Environment Scale* (WES; Insel & Moos, 1974) and *Organizational Assessment Instrument* (OAI; Van de Ven & Ferry, 1980), both of which generally assess the work environment in organizations (Amabile et al., 1996), the *Siegel Scale of Support for Innovation* (SSSI; Siegel & Kaemmerer, 1978) is a well-known instrument that uses 61 items to measure perceptions of five organizational dimensions (leadership style, ownership, diversity-oriented norms, continuous development, and consistency) with a focus on innovation. Factor analysis of responses from several thousand teachers and students at the time indicated that one major factor, support for creativity, and two others, tolerance of diversity among members and personal commitment to the organization, were important dimensions in an innovative climate (Siegel & Kaemmerer, 1978). However, this measurement instrument has only been validated in a school context with a relatively

Measurement Method	Source
Work Environment Scale	Insel and Moos (1974)
Siegel Scale of Support for Innovation	Siegel and Kaemmerer (1978)
Organizational Assessment Instrument	Van de Ven and Ferry (1980)
Creative Climate Questionnaire	Ekvall (1983)
College and University Classroom Environment Inventory	Treagust and Fraser (1986)
Achieving Styles Inventory	Lipman-Blumen (1991)
Jones Inventory of Barriers	Rickards and Jones (1991)
KEYS: Assessing the Climate for Creativity	Amabile et al. (1996)
Team Climate Inventory	Anderson and West (1996)
Situational Outlook Questionnaire	Isaksen et al. (1999)
Creativity Development Quick Scan	Dul and Ceylan (2011)
Epstein Creativity Competencies Inventory for Managers	Epstein et al. (2013)

Table 2.2
Chronological overview of work environment measurement methods. Adapted from Meinel et al. (2017).

small sample (Amabile et al., 1996; Mathisen & Einarsen, 2004). A tool that has been specifically designed for the education context is the *College and University Classroom Environment Inventory* (CUCEI; Treagust & Fraser, 1986). Using CUCEI, students or instructors rate their perceptions of the following seven social-organizational dimensions of the actual or preferred classroom environment: personalization, engagement, student cohesion, satisfaction, task orientation, innovation, and individualization. Matching the assessment between actual and preferred learning environments uncovers improvements that can be implemented. The *Achieving Styles Inventory* (ASI; Lipman-Blumen, 1991), is an example of innovation-related evaluation of organizational conditions (D. H. Cropley & Cropley, 2018). It explores the fit between employee characteristics and the characteristics of their organization. The *Situational Outlook Questionnaire* (SOQ; Isaksen et al., 1999), the slightly modified English translation of the Swedish *Creative Climate Questionnaire* (CCQ; Ekvall, 1983), as well as the *Team Climate Inventory* (TCI; Anderson & West, 1996) capture the organizational climate. The CCQ consists of 50 items measuring ten dimensions of creative climate and has been validated in various organizational settings (Gruszka & Tang, 2017). The TCI, whose 61 items were extracted from other measurement methods, primarily addresses the innovation climate in the team via four factors: vision, participatory safety, task orientation, and support for innovation. A short version consisting of 38 items, which is most frequently used (Mathisen & Einarsen, 2004), shows acceptable reliability and validity. The *Jones Inventory of Barriers* (JIB; Rickards & Jones, 1991), consists of 30 items and is designed to examine barriers to individual creativity in organizational settings. Strategy, value, perception, and self-image barriers are distinguished.

The *KEYS: Assessing the Climate for Creativity (KEYS)* by Amabile et al. (1996) has already been successfully validated in many contexts and industries (Mathisen & Einarsen, 2004). It consists of 78 items and includes eight scales for the assessment of the working environment (six scales describing incentives for creativity and two scales describing obstacles to creativity) and two scales measuring work outcomes (creativity and productivity). The scales of the work environment are based on the three elements of the social-organizational work environment (see figure 2.5), by which Amabile (1997) extended her Componential Theory of Creativity. In the KEYS, respondents indicate the extent to which the 66 items apply to their work environment and how they rate their own performance on twelve items. KEYS has been shown to have satisfactory psychometric properties, both in terms of reliability and validity (Amabile, 1997; Amabile et al., 1996; Mathisen & Einarsen, 2004). Ensor et al. (2006), who used the procedure in England, criticize KEYS for not taking into account wider cultural differences, as it has only been used in two studies outside North America (both in Germany). For a detailed description of the psychometric characteristics, refer to Mathisen and Einarsen (2004). The authors analyze five of the presented measurement procedures of the social-organizational work environment (KEYS, CCQ, SOQ, TCI, and SSSI). These five are the only instruments meeting certain criteria, including the availability of psychometric characteristics. They conclude that two measures in particular (TCI and KEYS) have emerged as useful instruments for assessing the social-organizational work environment. However, they also note that the different measurement procedures are based on different definitions of climate and that climate is measured at different organizational levels, which must be taken into account when selecting the appropriate measurement procedure.

One of the two measures including both the social-organizational and physical work environment is the *Epstein Creativity Competencies Inventory for Managers* (ECCI-m; Epstein et al., 2013). The ECCI-m is based on the assumption that the the provision of a diverse and changing physical and social-organizational work environment forms one of eight creativity-enhancing management competencies. Over one thousand managers indicated in a survey how they rate their abilities in relation to the eight competencies on 48 items, each with a five-point Likert scale. However, the ECCI-m has—to our knowledge—not been used outside its validation study (Epstein et al., 2013). In contrast to the ECCI-m, the *Creativity Development Quick Scan* (CDQS; Dul & Ceylan, 2011) has been used in various studies. It captures both the social-organizational and physical properties of the work environment and focuses on on knowledge workers (Dul, 2011). In their research, Dul and Ceylan (2011) identified nine social-organizational (challenging job, teamwork, task rotation, autonomy in job, coaching supervisor, time for thinking, creative goals, recognition of creative ideas and incentives for creative results) and twelve physical (furniture, indoor plants, calming colors, inspiring colors, privacy, window view to nature, any window view, quantity of light, daylight, indoor physical climate, sound and smell) characteristics of the work environment that can promote creativity. These 21 elements were integrated into a checklist to assess the extent to which employees perceive their presence in their working environment. Even though it has already been established how certain characteristics of elements in the work environment affect creative performance, the optimum configuration of these physical characteristics to achieve the highest level of creativity depends on the respective personal preferences (E. V. Hoff & Öberg, 2015). To be able to investigate the person-environment-fit, the CDQS not only captures the perception of the work environment but also the importance the individual places on each of the 21 environmental elements. The ratio of the importance to the perception of a specific element of the working environment is averaged over all employees for each company and results in a fit score. It illustrates the extent to which the company meets the need for support with regard to the respective environmental elements and can offer direct comparison with the fit scores of other companies.

2.1.4 Product

As early as 1961, Rhodes noted that creative products can be used to draw conclusions about creative personality traits, creative thought processes, and environments that promote creativity. This is why the study of creativity should start with a creative product (Prasch & Bengler, 2019). Moreover, measuring creative products is necessary to validate the findings of creative personality traits (Amabile, 1983), as well as the other creativity components, and to measure changes in them (Horn & Salvendy, 2006). There is a variety of different types of creative products in the work context, including services, production processes, work methods and procedures, and solutions to problems in everyday work (Dul & Ceylan, 2011). Software programs, training courses, and market research projects are concrete examples of creative products in the workplace (Amabile & Mueller, 2008). Advantageously, and in contrast to the other creativity components, the creative results can often be described (Palmer, 2015) and quantified (Horn & Salvendy, 2006). Products are considered creative when they are both novel and useful (see section 1.1.1). Horn and Salvendy (2006) list two types of measurement instruments of creative products: Rating scales and subjective ratings.

Rating scales are based on the assumption that product creativity is an objective and quantifiable variable whose expression depends on the presence of certain creative product attributes. This view, which Horn and Salvendy (2006) derived from the product-based approach of Garvin (1984), is adopted to some extent by the *Creative Product Semantic Scale* (CPSS; O'Quin & Besemer, 1989)—a modification of the *Creativity Product Inventory* of I. A. Taylor and Sandler (1972). In the CPSS, experts rate the product creativity based on the three dimensions of products by Besemer and Treffinger (1981) (novelty, resolution and elaboration & synthesis) via a semantic differential.

An example measure adopting subjective ratings is the *Consensual Assessment Technique* (CAT; Amabile, 1982). The CAT is widely used and derived from the user-based approach of Garvin (1984). Product creativity is assumed to be subjective in nature, and the evaluation takes place in a social context. The CAT follows a rather straightforward pattern. First, individuals produce products of different kinds (e.g., poems). Secondly, these products are subsequently evaluated by several experts from the respective domain. This evaluation is based on the expert's individual definition of creativity (Amabile & Mueller, 2008; J. Baer & McKool, 2009; Gruszka & Tang, 2017). It is assumed that there is no need for a universally accepted definition of creativity to evaluate creative products (Amabile, 1982) and no need for a theoretical basis of creativity (J. Baer & McKool, 2014). This method is very close to everyday creativity assessment and is therefore considered to be the gold standard of creativity measurement (J. Baer & McKool, 2014). In addition to the disadvantages of expert evaluations stated in the introduction of chapter 3, it can be argued that they are very resource-intensive (Batey, 2012; Kaufman, Baer, et al., 2008). Furthermore, in the CAT, products are only evaluated relative to works in the same sample, which does not allow for an absolute creativity judgment that can be used for comparison with other tests (J. Baer & McKool, 2009). One method, developed to at least make the recruiting of raters more easy, is the *Creative Solution Diagnosis Scale* (CSDS; D. H. Cropley et al., 2011). In this case, the products are estimated by laymen.

Subjective product ratings, however, can not only be conducted by others but also individuals themselves. For this purpose, products that have resulted from creativity in the real world are used (e.g. patents, scientific publications, musical compositions, etc.). This means that individual behavior is recorded retrospectively, and subsequently analyzed regarding its creativity. For this purpose, the *Creative Behavior Inventory* (CBI; Hocevar, 1979) and the *Biographical Inventory of Creative Behaviors* (BICB; Batey, 2007) have been developed for everyday creative actions. For extraordinary creative achievements, development of the *Creative Achievement Questionnaire* (CAQ; Carson et al., 2005) followed. An in-depth description of these procedures, can be found in Silvia et al. (2012).

2.1.5 Need for Unified Measurement

The cluttered landscape of creativity measurement tools is both encouraging as well as problematic. While the multitude of approaches from different domains shows a clear interest in the subject matter (Batey, 2012), it also leads to a multitude of results that are difficult to compare and thus inhibit a coherent understanding of and fundamental research on creativity (Barbot & Reiter-Palmon, 2019; Prasch & Bengler, 2019). Measurements for the different facets (person, process, product, press) are often not highly associated (Batey et al., 2010; Carson et al., 2005; Dollinger et al., 2004; Furnham et al., 2008), up to a point where they show a meaningful difference (Haase et al., 2018). And even measurements of the exact same constructs, influences, and independent variables show conflicting results. Especially in the facet press, containing environmental factors that can be influenced by corporations and employers, a wide variety of relationships has been researched—often yielding contradictory results.

In terms of the socio-cultural work environment, time pressure generally tends to have a negative effect on creative performance (Amabile et al., 1996; 2002; Andrews & Smith, 1996; Soriano de Alencar & Bruno-Faria, 1997). In contrast, Hennessey and Amabile (2010) discovered that on days where time pressure was high, creative performance could be as good as on days with low or moderate time pressure. Ohly et al. (2006) and M. Baer and Oldham (2006), found an

Note: + positive effect; ± positive and negative effects; n.s. no significant effects; effects in brackets indicate tendencies

Figure 2.7
Effects of the physical work environment characteristics on creativity found in empirical studies. Adapted from Meinel et al. (2017).

inverted-U relationship. Rewards have been found to undermine intrinsic motivation (and thereby creativity, Deci & Ryan, 2004; Ryan & Deci, 2000) as well as increase it (Eisenberger & Cameron, 1996; 1998; Eisenberger & Rhoades, 2001).

Regarding the physical working environment, even more studies yield contradictory results. For example, in a study by Mehta et al. (2012), in which realistic ambient sounds were used, a moderate noise level improved creative performance, presumably because abstract processing is promoted as part of the creative process. Noise that is too loud impairs information processing and therefore inhibits creativity (Hillier et al., 2006; E. V. Hoff & Öberg, 2015; Martens, 2011;

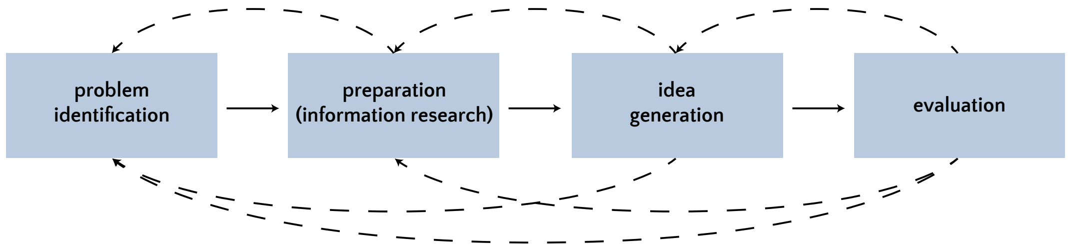

Figure 2.8
The four phases commonly associated with the creative process. This includes jumps between and loops of different phases. Adapted from Prasch et al. (2021).

Mehta et al., 2012; Stokols et al., 2002). However, Dul and Ceylan (2014) and Dul, Ceylan, and Jaspers (2011) conclude that the absence of silence can hinder creativity. According to the authors, any sound that is perceived negative can hinder creativity. They define positive sounds as silence, music and the absence of noise. Next to noise, the color design of the physical work environment can influence creativity (Dul, 2019). There are conflicting results regarding the influence of cold (e.g., blue) and warm (e.g., red) colors, with the former being associated with relaxation and the latter with stimulation (Stone, 2003). While McCoy and Evans (2002) found that cold colors were negatively linked to creativity, Ceylan et al. (2008) and Mehta and Zhu (2009) found the opposite. Dul and Ceylan (2014) and Dul, Ceylan, and Jaspers (2011) argue that both warm and cool colors are conducive to creativity. Similar to the intangible environmental elements listed so far, results vary with regard to lighting conditions at the workplace. While McCoy and Evans (2002) found no light-related influence on creative potential, others argue for adequate lighting (e.g. Soriano de Alencar & Bruno-Faria, 1997) and especially sufficient daylight (e.g. Ceylan et al., 2008; Galasiu & Veitch, 2006; E. V. Hoff & Öberg, 2015) at the workplace. In contrast, Steidle and Werth (2013) experimentally demonstrated that darkness promotes the generation of new ideas but weakens analytical thinking. Although—as with the other environmental elements—perceived control over the environmental situation seems to be positive for creativity (Samani et al., 2015), the results of Veitch and Gifford (1996) show the opposite for light control. An overview of characteristics of the physical work environment and their respective effects on creativity can be found in figure 2.7 and in Meinel et al. (2017). The authors especially cite varying measurement approaches as a possible reason for these incongruent findings.

2.2 Amplification

Despite incongruencies in the specific findings, the endeavor to support humans in the creative act has seen various approaches so far. Following the *4P model* by Rhodes (1961), primarily *process* and *press* have the potential to increase creative performance (Prasch & Bengler, 2019). The development of Creativity Support Systems (CSSs) in particular is often focused around the creative *process* (Shneiderman, 2007). This process, or succession of thoughts and actions that lead to original and appropriate productions (Lubart, 2001), can be divided in two perspectives: (i) *macro* processes describing creative stages, and (ii) *micro* processes describing mechanisms of creative thinking

(Botella et al., 2018). While there is a general consensus at the micro level that there are divergent and convergent thinking processes (Botella et al., 2019), at the macro level, the nature, as well as the number of stages involved, are still disputed. For instance, Botella et al. (2018) describe 20 different process models developed between 1926 and 2016, while noting these models represent only a fraction of the total number of models developed. However, the most common approach follows Wallas (1926) and proposes four phases associated with the creative process (Amabile, 1996; Lubart, 2001). Those phases are (i) problem identification/finding, (ii) preparation (or information research/finding), (iii) idea generation/finding, and (iv) idea evaluation (Amabile, 1983; 1988; Gero & Kannengiesser, 2004; Howard et al., 2008; Olszak & Kisielnicki, 2018; Prasch et al., 2021). This process, including iteration or jumps and loops between the different phases is depicted in figure 2.8.

In her *Componential Theory of Creativity* (for a detailed description, see section 2.1), Amabile (1996) connects the existing four phases of the creative process with the additional phase she calls *outcome*. These five phases may be followed sequentially or non-sequentially, using loops or iterations as necessary. Figure 2.9 additionally includes factors influencing the different stages as identified by Amabile (1983). At the center of this model is task motivation, which either directly or indirectly impacts all other components of the creative process. It is influenced by the social environment, as well as explicit and implicit feedback based on the outcome of the process. In turn, task motivation directly influences problem or task identification, as well as response generation. Additionally, it indirectly (via domain relevant skills and creativity relevant processes) influences preparation and response validation and communication.

When supporting creativity as part of these processes, we speak of CSSs (e.g. Massetti, 1996; Wierenga & van Bruggen, 1998). Research on CSSs has been growing in recent years but is still developing (Bonnardel & Zenasni, 2010; Shneiderman, 2007). Analog tools and methods have a rather rich history (e.g. Osborn, 1952). They can be roughly divided into procedural and phase-specific methods of support addressing macro or micro processes respectively. While procedural support systems often take the shape of frameworks covering the entire process (macro support, e.g. TRIZ (Savransky, 2000); Design Thinking (Brown, 2008)), phase-specific methods usually are used as parts of said frameworks and support specific goals within certain phases (micro support). Analog tools often come in the form of card decks (e.g. Friedman & Hendry, 2012; Hornecker, 2010; F. Mueller et al., 2014). Purely analog CSSs are, however, increasingly in the minority. A recent review by Frich et al. (2019) identified 143 papers published between 1999-2018 concerning CSS, a vast majority of which (131) described tools intended for digital use. This trend started approximately 25 years ago with Shneiderman (2002) and Fischer (2004) pointing out the potential of computers for enhancing human creativity. They were quickly followed by Lubart (2005), stating that "computers may facilitate (a) the management of creative work, (b) communication between individuals collaborating on creative projects, (c) the use of creativity enhancement techniques, and (d) the creative act through integrated human-computer cooperation during idea production" (p.365) in different modes of HCI. Depending on whether the systems offer group- or individual-

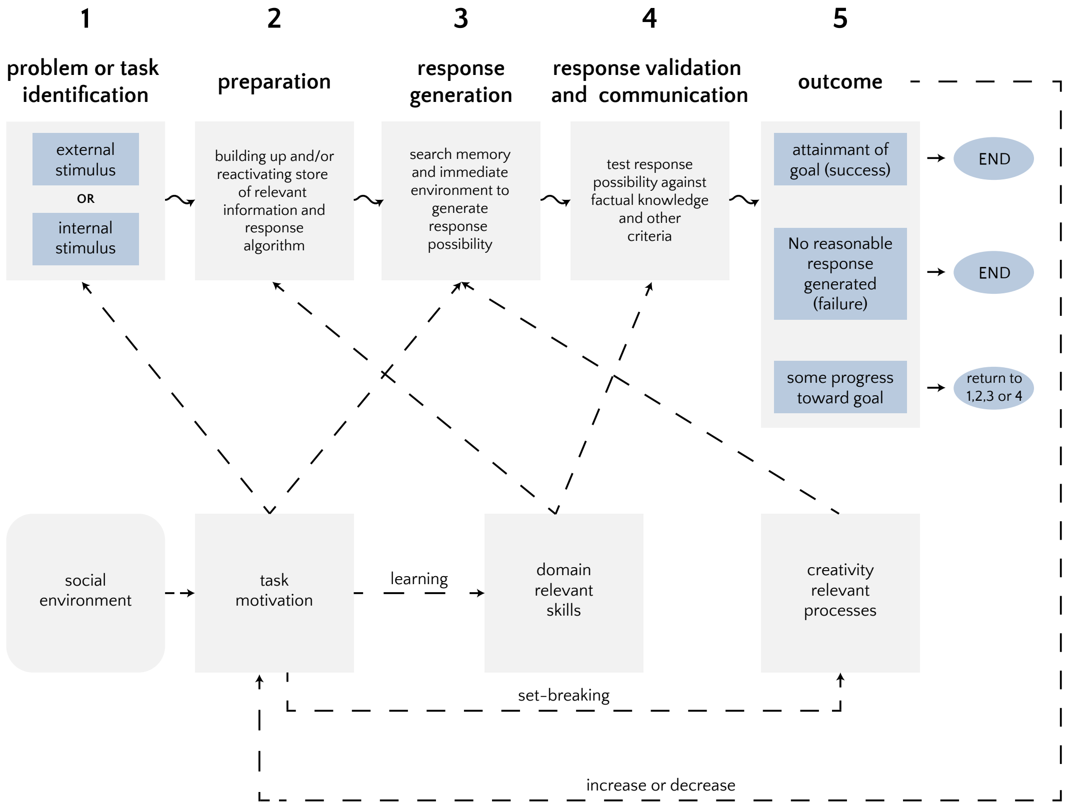

Figure 2.9
Componential Theory of Creativity displaying the stages of the creative process. The dashed lines indicate influencing factors, and the wavy lines steps in the process (variations in the sequence are possible). Adapted from Amabile (1996).

level support, there are different common practices.

Group support systems typically focus on tele-cooperation and support of the creative process by information exchange. The majority of these systems support one phase, namely ideation (Gabriel et al., 2016). This is attributed to the focus on divergent thinking as key factor in creativity research during the last decades (see Puccio & Cabra, 2012). Some of the systems for individual support address the entire creative process (e.g. Forgionne & Newman, 2007; Marakas & Elam, 1997). Most of them, however, support one or more (but not all) of the phases depicted in figure 2.8. The number of systems by which each individual phase is supported though, varies to a great extent (Prasch et al., 2021). In their review of 48 CSSs, K. Wang and Nickerson (2017) identified 7 systems supporting problem identification, 19 supporting preparation, 42 supporting idea generation, and 20 supporting evaluation. Systems that concentrate on and support only a single phase, are available for preparation and idea generation (K. Wang & Nickerson, 2017). Overall, idea generation seems to be the most widely supported phase (see Frich et al., 2019; Gabriel et al., 2016). K. Wang and Nickerson (2017) identified four aspects of support mechanisms and summarized them in their framework: (i) motivation for the creative task, (ii) a structured creative process, (iii) divergent

Aspects	Components	Features to Support the Component
Motivation	Motivational Priming	Affective Priming, Achievement Priming
Creative Process	Process Completeness	Modules to Support Each Step in a Complete Creative Process
	Process Control	Allowing Process Planning, Allowing Iteration and Selection of Steps
Divergent Thinking	Stimuli	Providing Different Levels of Stimuli, Providing Stimuli Dynamically
	Long Term Memory	External Long Term Memory, Such as Knowledge Base and Case Library; Facilitating Search
	Working Memory	Supporting Association, Visualization, Random Combination
	Creativity Techniques	Facilitating the Use of Creativity Techniques; Computational Creativity Techniques
Convergent Thinking	Comprehension	Labeling, Classification, Simulation
	Decision	Criteria Based Comparison, Decision Support

Table 2.3
The framework for designing Creativity Support Systems for individual support as proposed by K. Wang and Nickerson (2017).

thinking, and (iv) convergent thinking (see table 2.3). The most commonly supported phase, idea generation, is mostly comprised of divergent thinking. We will describe its components, as they can be supported by CSSs (stimuli, long term memory, working memory, and creativity techniques), in detail in the following sections.

2.2.1 Stimuli

The basis of using stimuli or search cues for ideation stems from the cognitive literature. Stimuli are used to retrieve concepts from long term memory. These are consequently processed in the working memory, which can result in creative ideas (Nijstad & Stroebe, 2006). Not all stimuli have a positive, creativity-enhancing effect, however (K. Wang & Nickerson, 2017). There are two main approaches to providing meaningful stimuli. The first is to limit stimuli to one certain category, providing narrow but deep insights. The second relies on deliberately touching upon many categories, providing broad but rather superficial cues. No matter which of the two approaches is followed, stimuli should be presented dynamically, starting broad and becoming increasingly targeted and closely related to the ideas that are already promising (Gabora, 2002; K. Wang & Nickerson, 2017). For example, in a study by H.-C. Wang et al. (2011), participants were shown images that were based on keywords they had used during conversation. In an additional condition, H.-C. Wang et al.

(2011) selected specifically rare concepts in order to introduce additional breadth of inspiration. Both types of stimuli had a positive effect on participants' creativity compared to a control group.

2.2.2 Long Term Memory

Searching for information can be a crucial way of obtaining the domain-relevant knowledge needed to solve a problem creatively (Amabile, 1983). It can, however, be rather time consuming and could be supported by an Artificial Intelligence (AI) (see section 4.1). Search strategies and techniques, as well as user interfaces of search engines, have been studied in relation to creativity (e.g. Stefl & Rohm, 2017). While using the internet to research information is not inherently suppressing creativity, studies suggest there might be a better way than traditional search engine User Interfaces (UIs). Designing interfaces to specifically support creative problem solving is uncommon but intriguing (Shneiderman, 2007; Stefl & Rohm, 2017).

Enabling users to effectively search and find what they are looking for is the main objective for the long term memory component. Effective search is depending on two major contributors: *where* we search, and *how* we search. In terms of digital support, this would entail which database is used (including its specific search algorithms), and how exactly the UI is designed. Google, as most widely used search engine, has been the focus of several creativity studies already (Maiden et al., 2020; Stefl & Rohm, 2017). While the current UI is often criticized as too convenient and thus enhancing conventional thinking, Stefl and Rohm (2017) found that a group using Google to build paper planes produced more creative solutions on average. They note, however, that the two most creative solutions were produced in the control group that was not using Google. The reason could be that exploratory behavior of diversive curiosity, or searching broadly for a solution and encountering new stimuli, is not the goal of an interface like Google which presents deep, narrow stimuli.

Within specific domains, there might be a variety of online resources providing domain-relevant knowledge. Inspiration, for example in the design domain, can be obtained from websites like Dribbble* or Behance*. These platforms allow individuals to share their work, and can be searched by everyone with internet access. The presentation of previous solutions can, however, have detrimental effects on idea novelty (Alipour et al., 2018). This effect is known as *design fixation* (Jansson & Smith, 1991) and describes the inappropriate reuse of certain features of precedents. As such, design fixation is one example how certain stimuli can be harmful for creativity.

www.dribbble.com
www.behance.net

2.2.3 Working Memory

The working memory component consists of "temporary information storage, combination, association and other information processing" (K. Wang & Nickerson, 2017, p.21), while visualizations and randomness play a crucial role. By providing visual stimuli during a creative task, people's creativity has been positively affected in the past (H.-C. Wang et al., 2011). Even unrelated items have been shown to increase originality of the output (Kohn et al., 2011). Those visuals have taken the form of randomly presented pictures unrelated to the topic (Clegg & Birch, 2007) or images that illustrate previous ideas of participants (H.-C. Wang et al., 2011).

Additionally to visualizations, K. Wang and Nickerson (2017) suggest supporting associations as feature of the working memory. The structure of associations is one of the differences between highly creative and less creative individuals (Mednick, 1962). It is assumed that due to flat associative hierarchies, highly creative people can more easily retrieve more remote associations. This is disputed, however. In a recent study, Benedek et al. (2013) concluded that the hierarchical flatness was not the aspect differing between less and more creative persons, but a higher associative fluency. Specifically, more creative people tend to form longer chains of associations, moving further away from the original key concept. Less creative people tend to stay fairly close to the original key concept and thus, form more closely linked associations. This concept has been reproduced in recent years, highlighting the importance of intelligence for creative cognition and divergent thinking (Frith et al., 2021).

2.2.4 Creativity Techniques

The last component of divergent thinking are creativity techniques. Couger (1995) classified two types of creativity techniques: analytical and intuitive. While analytical techniques are structured and generate logical patterns of thought, intuitive techniques allow participants to freely associate or make leaps to arrive at a solution (McFadzean, 1998). K. Wang and Nickerson (2017) suggest to include those techniques in a CSS and propose to label them accordingly. These labels should enable the users to decide which one to pick for a certain task. The correct application of a creativity technique can enhance peoples creativity-relevant processes, or, in other words their "explicit knowledge of heuristics for generating novel ideas" (Amabile, 1983, p.362). Generally, the literature on creativity techniques, especially handbooks on how to use them, is manifold (e.g., Backerra et al., 2020).

The repertoire of techniques can be used in different ways by groups or individuals. For instance, they could be used in thought experiments, role-plays or discussions—depending on the chosen technique. The Walt-Disney-Technique, for example (see Dilts, 1994), motivates people to change perspectives, encouraging them to think about a problem as a pessimist, optimist, and neutral observer. When used in a group, those different perspectives can be played by different participants. When used by individuals, regularly and actively changing ones perspective is crucial. Besides the two traditional settings (group vs. individual), chatbot technology has been studied as a means to structure the creative approach by moderation of a virtual brainstorming session (Strohmann et al., 2017). The general use of digital technologies to foster idea generation by guiding participants through several creativity techniques has been discussed by S. Manske et al. (2014) in their Multi-Perspective Thinking (MuPeT) framework. The authors recommend future use of creativity techniques presented via digital tools to foster divergent thinking.

For continued development, the evaluation of CSSs plays a crucial role in order to generate meaningful support. In their recent review, Frich et al. (2019) specifically criticize the lack of

Method	Creativity Aspects	Source
Creativity Support Index (CSI)	Collaboration, Enjoyment, Exploration, Expressiveness, Immersion, Results Worth Effort	Carroll and Latulipe (2009) and Cherry and Latulipe (2014)
Observation	Knowledge Generation Through CSS	Frich et al. (2018) and Smit et al. (2018)
Interview	Perception and Usage of Tools, Advantages and Disadvantages	Maiden et al. (2018)

Table 2.4
Evaluation methods for Creativity Support Systems.

evaluation of CSSs and call for a more meticulous approach.

2.2.5 Evaluating Creativity Support Systems

In order to properly evaluate CSSs, it is essential to determine their respective influence on the creative outcome. This entails—as discussed in section 2.1—several problems with the assessment of creativity in and of itself. Frich et al. (2019) observed a wide range of evaluation methods, ranging from traditional creativity traits to classic usability principles. Especially the scarcity of creativity metrics has been called out by Remy et al. (2020). The evaluation methods used range throughout the entire spectrum of HCI research, with some researchers employing quantitative questionnaires, whilst others use interviews or observations. Researchers generally agree that a one-size-fits-all solution will not be feasible, but that a toolbox of methods for evaluation should be the goal (Frich et al., 2019; Remy et al., 2020; Shneiderman et al., 2005; 2006).

The most well-established and standardized tool for evaluation of the creativity-supporting aspects of digital tools is the Creativity Support Index (CSI). This questionnaire, which is in its characteristics similar to the NASA-TLX (Hart & Staveland, 1988), a widely used questionnaire assessing workload, was developed by Carroll and Latulipe (2009) and refined by Cherry and Latulipe (2014). While the CSI is flexible enough to be used for the evaluation of a variety of CSSs, the authors propose its use in conjunction with other evaluation methods. Despite the consensus, Remy et al. (2020) found in their review that only 3 out of the 113 papers included used the method. The authors additionally note that in recent years, many evaluations focused on usability instead of creativity. This is especially dangerous due to the potentially conflicting criteria (e.g. efficiency, precision, error prevention, and adherence to standards (Gerhardt-Powals, 1996; Nielsen, 1994a) for usability contrasting exploration, experimentation, and deliberate transgression of standards (Dalsgaard, 2014; Maudet et al., 2017) for creativity). Due to this potential conflict, Remy et al. (2020) caution that usability tests might not be appropriate to evaluate creativity support. Instead, they recommend to properly separate the two. An overview of used methods can be found in table 2.4.

In summary: measurement as well as amplification of creativity at work are widely inconcise, and would greatly benefit from an easy-to-use, scalable measurement instrument which makes results comparable across different studies. In the following chapter we will describe an attempt to develop such an instrument using User-Centered Design (UCD).

CHAPTER 3

Measurement

Current tests for the creativity of ideas or products often rely on self-ratings or ratings by others (usually experts). This is also the approach used in the gold standard of creativity measurement (J. Baer & McKool, 2014), the *Consensual Assessment Technique* (CAT; Amabile, 1982). Unfortunately, as already stated in the original research, there is an issue with scalability, as tests like these generally require a lot of time, effort, and resources (see section 2.1). The sheer multitude of creativity measurement instruments employed is staggering. This is the case partially because of the complexity of the construct itself. Additionally, however, hardly any of the current measurement instruments are easy to use, meet psychometric requirements (e.g. Ai, 1999; Amabile, 1982; Auzmendi et al., 1996; Batey, 2012; Domino, 1994; Furnham et al., 2008; Piffer, 2012; Said-Metwaly et al., 2017), and scale practically (Prasch & Bengler, 2019). Thus, based on the novel and useful paradigm, Prasch et al. (2020) propose several specifically tailored tasks that allow for creative solutions. These tasks can be evaluated using an algorithm and their results can be compared on a continuous scale. Additionally, having tasks that can be assessed by an algorithm enables implementation of an online variant of the test. With proper User-Centered Design (UCD), ease of use for researchers as well as study participants can be ensured. This is crucial in order to facilitate the general use of the test, and thus tackle the aforementioned problems of current creativity tests.

In the following, we introduce the Creativity Assessment via Novelty and Usefulness (CANU) as a new approach of measuring creativity and subsequent iterative design and evaluation in two studies.

Design and implementation of the CANU 1.0 were part of two theses:

Brünn, M. (2019). *Development of an Application to Measure Creative Performance* [Bachelor's Thesis]. Technical University of Munich

Drexler, M. (2019). *Entwicklung eines Messwerkzeuges für Kreativität* [Master's Thesis]. Technical University of Munich

Additionally, it was partially published in Prasch et al. (2020)

3.1 New Approach: Creativity Assessment via Novelty and Usefulness

In order to compensate for the problems described in section 2.1, an entirely computer-based task was developed that relies on the definition of Amabile (1982) in order to quantify creative production of individuals (as described in Prasch et al., 2020). The creative product is the result of a combination of all other factors contributing to creativity (see equation (1.1)) and thus the most promising point of assessment (Prasch & Bengler, 2019; P. Sarkar & Chakrabarti, 2011). In order for a product to be deemed creative, it should be judged as novel and useful (Amabile, 1983; Mumford, 2003; Runco & Jaeger, 2012; Zeng et al., 2011). Novelty and usefulness are overarching terms for clusters of characteristics (new, original, novel and appropriate, useful, valuable) found in several prominent definitions of creativity (P. Sarkar & Chakrabarti, 2008). The significant distinction between the CANU and previous approaches is that the entity judging novelty and usefulness is a machine. The test employs two different sets of tasks, each of which has to be completed in 180 seconds. The time limit was introduced because infinite (or very long) time on task limits the distinguish-ability between highly creative and moderately creative individuals (Benedek et al., 2013). The two tasks result in a computer determinable (and thus scalable) interpretation of the participant's solutions, evaluating each of them individually regarding novelty and usefulness.

In order to fulfill scalability while retaining the potential to get creative, the tasks designed for the CANU must meet the diverse requirements of humans as well as computer systems. The main difficulty in developing creativity tasks is to set them up in such a way that they can be interpreted and evaluated by a machine while still having an open solution space. Of the two relevant dimensions, novelty and usefulness, novelty is the one that is easier for an algorithm to grasp. Following the paradigm used in most product creativity measurements—judging the different outcomes in relation to each other—assessing novelty can be achieved relatively simple by using the inverse frequency. This means, the more often a certain solution to a problem has already been produced, the less novel it should be considered. In contrast, usefulness is more challenging for an algorithm to assess, because it must be understood in context (see chapter 1). Since usefulness can be understood as the degree to which a proposed solution can solve a certain problem (Prasch et al., 2020), both the problem as well as the solutions capability to solve it, must be interpretable by the algorithm. In order to achieve this, a set of rules or criteria must be defined that the algorithm can treat as conditions on the basis of which usefulness values can be assigned. To properly classify them on a continuous scale, a maximum as well as minimum useful solution should be known. To tackle these diametrically opposed requirements of humans, who need a solution space that is as open as possible for it to enable creative solutions, and machines, who need specific criteria and thus a limited solution space, two tasks have been designed: *New Words* and *Blocks*.

Both tasks essentially require the fulfillment of predefined conditions given specified building blocks. This ensures machine readability by calculation of the degree of fulfillment and comparability of the similarity of different solutions by identification of the entities used. Additionally, through alteration of either the provided building blocks or conditions to be fulfilled, multiple configurations of essentially the same task can be tested. This makes for easy retests and therefore increases the number of solutions a single participant can produce. New words is a verbal task, in which words need to be formed from a given set of letters. The letters provided can be changed, so that a new configuration of the task is achieved. Blocks is a visual constructive task, in which a

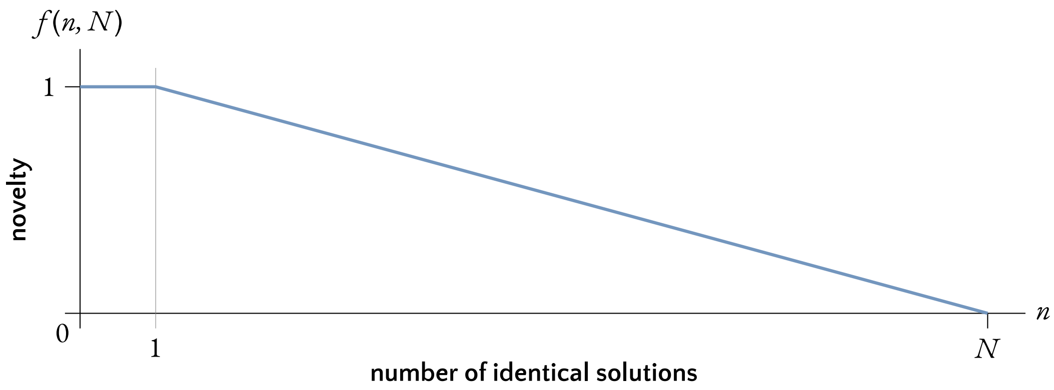

Figure 3.1
The novelty function if it were plotted, where N equals the total number of solutions, and n equals the number of solutions identical to the one in question (assuming both variables are continuous).

certain shape has to be filled using given tetrominoes. Through variation of the shape to be filled, the configuration of the task can be altered. In order to ensure a multitude of possible solutions, each tetromino can be used an indefinite number of times. A graphical representation of the two tasks can be seen in figure 3.2.

3.2 Novelty

As already stated, the novelty of a solution can be determined using the inverse of its frequency. This means a unique solution will be assigned the numeric novelty value of 1, whereas a solution that has been produced by every participant would be assigned the numeric novelty value of 0. This can be expressed in the following function of N and n:

$$f(n, N) = \begin{cases} 1 & \text{if } n = 1 \\ \frac{N-n}{N} & \text{else,} \end{cases} \tag{3.1}$$

where N equals the total number of solutions, and n equals the number of identical solutions. Figure 3.1 shows the plotted novelty function.

Hence, the novelty of a solution is independent of the task or configuration in the sense that the exact same formula can be used for all current (and potential future) tasks. The novelty of each solution (new words as well as blocks) was calculated using the formula provided in equation (3.1) for each specific task configuration (letter combination or blocks outline). The capabilities of an online test and the corresponding database enable real-time updates of each solution's novelty.

3.3 Usefulness

Usefulness, however, is highly dependent on the problem that needs to be solved and is thus context-sensitive. It is determined by the degree to which participants completed the given task successfully. Numeric usefulness values between 0 (not successful at all) and 1 (perfect solution) are calculated using the ratio between the building blocks (i.e., the letters and tetrominoes) used accurately, and the maximum amount of building blocks in a perfect solution. The more building blocks have been adequately used, the better a solution is. This entails a specific usefulness function for every task presented. The two tasks that were implemented in the CANU shall be examined in the following.

3.3.1 New Words

The task new words is in its characteristics similar to the popular board game Scrabble. Participants are presented with a set of letters in random order, from which they are instructed to build coherent words. The goal is to use as many of the letters provided as possible in order to construct new words (see figure 3.2 *left*). Thus, the usefulness of any given solution is calculated using the formula

$$f(n, N) = \frac{n_{\text{valid}}}{N_{\text{max}}}, \tag{3.2}$$

where n_{valid} is the number of letters included in valid words and N_{max} is the total number of letters provided. To determine the validity of a word, it is checked against a corpus of existing words. Any given word that is part of the corpus will be counted as valid solution*. This corpus deliberately includes colloquial phrases in order to maximize the potential for creative solutions. To increase difficulty and limit the amount of possible solutions, each individual letter can be used only once. This task is also a prime example for the above-mentioned relationship between work and entropy. While using energy, participants order the random, chaotic letters into meaningful words, thus increasing informational value.

As the CANU was initially implemented for a German audience, words are checked against an array of approx. 2 million German words, available via https://sourceforge.net/projects/germandict/

3.3.2 Blocks

The task blocks was inspired by the Chinese dissection puzzle Tangram and can be described as related to the video game Tetris or the board game Ubongo. Participants are given a particular shape that they have to fill with tetrominoes to the best of their ability. The goal is to fill the outlined form as comprehensively as possible, without overstepping the outline or leaving inner squares blank (see figure 3.2 *right*). The usefulness of a solution is calculated as

$$f(n_i, n_o, N) = \frac{n_{\text{inner}} - n_{\text{outer}}}{N_{\text{max}}}, \tag{3.3}$$

where n_{inner} is the number of filled squares within the outline, n_{outer} is the number of filled squares beyond the outline, and N_{max} is the total number of outlined squares. As already noted, to increase the number of possible solutions and enable creative problem solving—contrary to Tangram and Ubongo—each tetromino can be used multiple times. With regard to the concept of negative entropy, or informational value, the specific configuration chosen by a participant represents a new bit of previously unknown information.

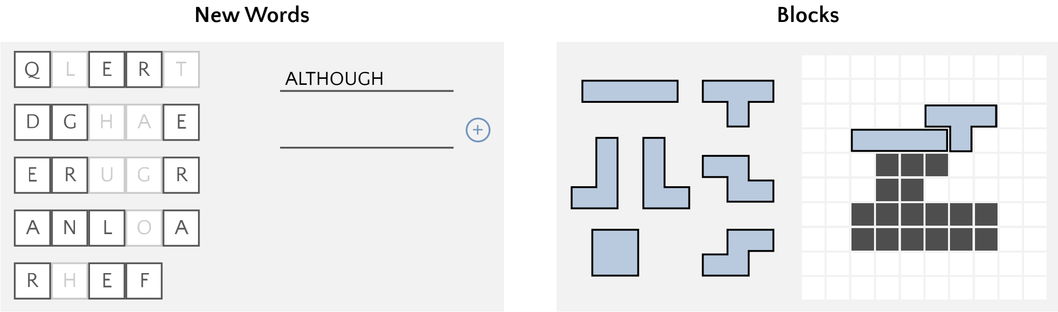

Figure 3.2 The two types of tasks presented within the CANU. New words *(left)* with a configuration of 24 letters, Blocks *(right)* with a configuration of 24 inner squares.

3.4 Evaluation 1

Evaluation of the CANU 1.0 was part of a thesis:

Büttler, J., Kursawe, H., Pütz, S., & Schlorf, M. (2019). *Validierung des CANU als objektives Messinstrument zur Erfassung von Kreativität* [Interdisciplinary Project]. Technical University of Munich

The proposed test has potential to improve creativity testing in terms of scalability and thus can contribute to make research on creativity truly comparable. To evaluate the CANU, two studies were conducted. In this first evaluation study, we investigated the convergent validity of the CANU through testing it against the Inventory of Creative Activities and Achievements (ICAA).

The ICAA is a rather new and well-developed test that has been validated comprehensively (Diedrich et al., 2018). The ICAA assesses creative achievements as well as creative activities. It is therefore opposing the CANU in respect to measuring creative potential versus creative performance. In order to quantify the true capability of the CANU, we decided to additionally investigate the discriminant validity of the CANU to the concepts of intelligence and openness towards new experiences. Intelligence has been shown in the past to have a positive influence on creativity (Cho et al., 2010), as has openness towards new experiences for novelty of solutions (George & Zhou, 2001; Ma, 2009). For statistical analysis, we formulated the following alternative hypotheses:

H_1 There is a negative correlation between novelty and usefulness values of the CANU.

H_2 There is a positive correlation between novelty values of the CANU and openness towards new experiences.

H_3 The novelty and usefulness values determined by the CANU each make an independent contribution to the prediction of creative activities that goes beyond the predictive capacity of general intelligence.

H_4 The novelty and usefulness values determined by the CANU each make an independent contribution to the prediction of creative achievements that goes beyond the predictive capacity of general intelligence.

To empirically examine these hypotheses, we conducted an online experiment running for three weeks with a total of $N = 265$ participants.

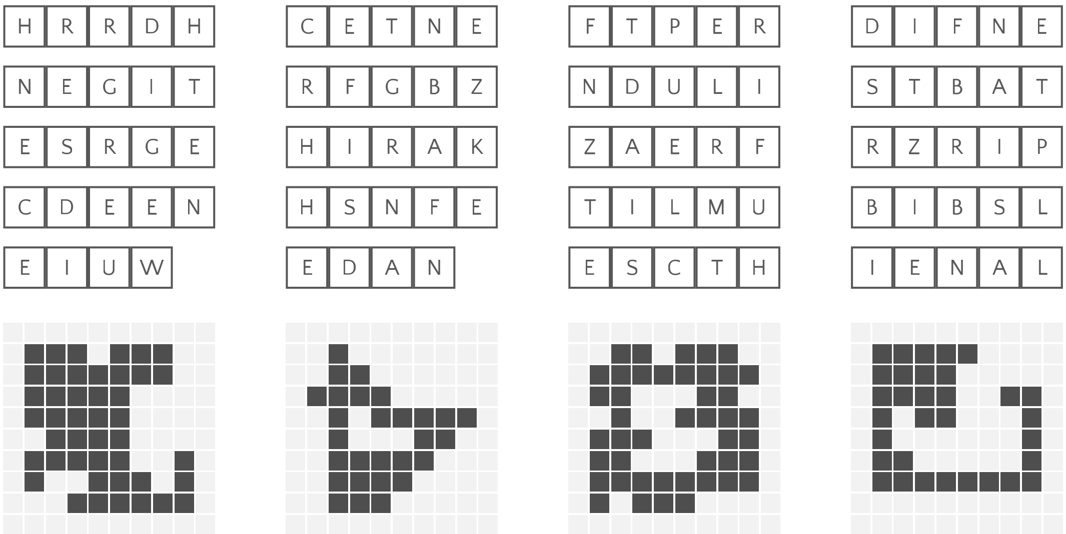

Figure 3.3 The eight configurations of the CANU used in the experiment.

3.4.1 Procedure & Materials

Participants were sent a link for participation, including the requirement to only perform the test at a computer (as compared to a smartphone or tablet). When visiting the link, participants were greeted and read a short introductory page, including the study objectives as well as a data protection notice. Following, they were carefully instructed to come up with solutions to the two tasks of the CANU that are "possible, but not everyone can think of". The participants were then forwarded to the test pages. Because of the necessity for the browser to save all relevant data in a session cookie, randomization of the test sections was not possible and always occurred in the following order: (i) CANU, (ii) ICAA, (iii) Advanced Progressive Matrix (APM), and (iv) demographics.

CANU

After an instruction video explaining the User Interface (UI) of the given task, participants started with the blocks task and produced solutions to four different configurations. Afterwards, introduction video and four configurations of the new words task followed. The configurations for the blocks tasks included 44 (twice), 32 or 28 blocks within the outline, the new words task presented 24 (twice) or 25 (twice) letters. The specific configurations used are displayed in figure 3.3.

ICAA

Following the CANU, participants were presented with the creative activities questionnaire ICAA (Diedrich et al., 2018). The questionnaire assesses creative activities in the domains literature, music, craftsmanship, cooking, sports, visual arts, performing arts as well as science with six items each, totaling 48 questions. An additional part of the questionnaire asks participants to list the top 5 creative achievements of their life, which are later scored by independent raters in the range between 0 (not creative) to 4 (extremely creative). In order to simplify the test, we asked participants for the top 3 of their creative achievements. Ratings are based on the amount of people that are able to achieve something in general and the amount of practice necessary (e.g. 0 = riding a bicycle; 4 = filing a patent).

APM

Because of the aforementioned relationship between creativity and intelligence, APM by Raven et al. (1998) were chosen as a recognized means of assessing intelligence (Sternberg, 2000). The APM consist of two sets, with set I representing a quick version of the entire test. Set I by itself already yields a robust categorization of participants in 10 % little aptitude, 80 % average aptitude and 10 % extraordinary aptitude. In order to keep the online questionnaire as short as possible and thus increase completion rate, a subset of the six most difficult matrices from set I were presented to the participants. These six matrices have the greatest capability to detect differences between participants and were presented in order of increasing difficulty.

Demographics

The final section of the online questionnaire was a demographic questionnaire that included the variables age, gender, education, occupation, language level, presence of dyslexia and openness for experience. This personality factor was measured using the two items measuring openness form the short version of the Big Five Inventory (BFI) (Goldberg, 1990; Tupes & Christal, 1992) created and tested by Rammstedt and John (2007) as BFI-10 (*"I see myself as someone who has few artistic interests"* and *"I see myself as someone who has an active imagination"*).

3.4.2 Results

Sample

Of the $N = 265$ participants who started the study, $n = 210$ (53 % female) from the age of 15 to 69 ($M = 30.2$; $SD = 10.7$) were included in statistical analysis. We excluded 43 participants from the analysis due to technical failures resulting in incomplete data. An additional 12 participants were excluded from analysis, because they stated in a comments section that they had technical problems completing the test—despite the data showing complete results. Since the new words task is highly dependent on language proficiency, we report that 92.3 % of participant's mother tongue was German, and only 1.8 % of participants had a language level below C, which corresponds to a proficient user. 9 participants (approx. 4 %) reported dyslexia. Additionally, we performed an analysis of the control variable intelligence for assumption of normal distribution. A Shapiro-Wilk

UV	Task	Mean	SD	Skew	Kurtosis	Cronbach's α
Novelty	Blocks	0.964	0.0463	-1.41	1.28	-.25
	New Words	0.998	0.0121	-8.45	80.15	.68
Usefulness	Blocks	0.903	0.380	-6.45	46.33	.93
	New Words	0.756	0.202	-1.46	2.43	.65

Table 3.1
Descriptive data of the two CANU tasks in their respective dimensions.

test revealed a violation of the assumption ($W = 0.654, p < .001$). This is contrary to distributions found in literature and the purpose of the APM, that yielded stable results in the past.

CANU

The results of the two different CANU tests are summarized in table 3.1. For reliability analysis we calculated Cronbach's alpha to assess the internal consistency of the sub-scales. Internal consistency was negative and poor for novelty of blocks and acceptable for novelty of new words. It was excellent for usefulness of blocks and acceptable for usefulness of new words. Both variables showed a significant deviation from the normal distribution (tested via Shapiro-Wilkes, novelty $W = 0.565, p < .001$ and usefulness $W = 0.521, p < .001$). Thus, the nonparametric Kendall Rank Correlation was used in the analysis of relationship. The test revealed a significant negative correlation between the two variables novelty and usefulness ($\tau_B = -.47, p < .001$). A Kendall Rank Correlation revealed no significant relationship between a participant's openness and the novelty of solutions they produced ($\tau_B = .001, p = .530$). As a limitation of these correlations, it has to be mentioned that Kendall's τ does not allow for a reliable declaration of effect size.

ICAA

The results for the ICAA were calculated according to Diedrich et al. (2018) by using the mean of the sum of all items for each participant's creative activity. Creative achievement was rated by two raters in the range of 0 (not creative) to 4 (extremely creative). The calculation of a squared Cohen's Kappa of the ordinal data revealed good inter-rater reliability with $\kappa = .81$ ($z = 20.9, p < .001$).

In order to quantify the contribution the results of the two dimensions of the CANU, novelty and usefulness, have on the prediction of creativity, we conducted two hierarchical linear regressions. To explain variance within the dependent variable, and explore whether novelty and usefulness extend the predictive power of intelligence, we conducted three steps of linear regressions. First, intelligence—determined by the solution frequency of the APM—was used as predictor. Subsequently, we added novelty and in a third step usefulness to the model. The order in which the two variables were added to the model is in line with literature which states that novelty is considered to be a more meaningful factor towards creativity than usefulness (Diedrich et al.,

Step	Predictor	R^2	ΔR^2	B	*SE* B	β	*p*
1		.01	.01				
	APM			2.96	1.90	0.11	.121
2		.01	.00				
	APM			2.79	1.93	0.10	.148
	Novelty			-12.90	22.71	-0.04	.571
3		.01	.00				
	APM			2.87	1.94	0.10	.139
	Novelty			-16.06	23.68	-0.05	.498
	Usefulness			-0.66	1.37	-0.03	.630

Table 3.2
Hierarchical multiple linear regression to predict creative activity via novelty and usefulness. The APM score is included as a control variable and measure for intelligence.

2015). Novelty as well as usefulness were aggregated for each participant using the mean in order to increase the tests reliability.

Creative Activities

The results of the first hierarchical linear regression can be found in table 3.2. The analysis revealed that none of the predictors (apm, novelty and usefulness) was able to explain a significant amount of the variance of creative activity in neither of the three models ($F_1(1, 208) = 2.43, p_1 = .121$; $F_2(1, 207) = 1.37, p_2 = .256$; $F_3(1, 206) = 0.99, p_3 = .399$). The total variance accounted for by the model is $R^2 = 1.4\,\%$ in the third step.

Creative Achievements

Results of the second hierarchical linear regression are listed in table 3.3. The three models do not differ significantly in the amount of variance explained ($F_1(1, 208) = 2.92, p_1 = .089$; $F_2(1, 207) = 2.26$, $p_2 = .107$; $F_3(1, 206) = 1.96, p_3 = .122$). When including all three variables into the model, intelligence was a significant predictor of creative achievements. The total variance accounted for in the third step is $R^2 = 2.8\,\%$.

Exploration

We conducted some additional analyses to further explore our data. As both parts of the CANU are similar to popular games, we expected performance to be correlated with the skill level in these games. We found a trend, suggesting that participants who are better at Scrabble also produce better results in the novelty dimension of the new words task ($\tau_B = -.04, p = .08$). Additionally, participants

Step	Predictor	R^2	ΔR^2	B	*SE* B	β	p
1		.01	.01				
	APM			-0.56	0.32	-0.12	.089
2		.02	.01				
	APM			-0.61	0.33	-0.13	.061
	Novelty			-4.88	3.87	-0.09	.208
3		.03	.01				
	APM			-0.65	0.33	-0.14	.049
	Novelty			-3.60	4.03	-0.06	.373
	Usefulness			0.27	0.23	0.08	.248

Table 3.3
Hierarchical multiple linear regression to predict creative achievement via novelty and usefulness. The APM score is included as a control variable and measure for intelligence.

that reported to be good in Tetris or Ubongo did produce significantly better results in the novelty dimension of the blocks task (Tetris: $\tau_B = -.11, p < .001$; Ubongo: $\tau_B = -.01, p = .001$).

When analyzing the data from the ICAA, we did not find a correlation between creative achievements and creative activity ($\tau_B = .05, p = .841$). We also did not find a correlation between intelligence and the mean of each participants usefulness ($\tau_B = .17, p = 1.00$). However, we found a significant correlation between intelligence and the mean of each participants novelty ($\tau_B = -.09, p = .048$).

3.4.3 Discussion

As of now, results are still inconclusive. Further development and testing is necessary, especially considering the distributions of novelty and usefulness in both tasks. The main issue with the new words task appears to be the fact that the solution space is too vast to properly compare solutions in terms of their novelty. To remedy this, the number of letters presented could be reduced. However, this approach needs to be implemented carefully as a reduction of the solution space could minimize creative opportunity in the task, thus rendering it obsolete. Another strategy to improve the current task is to target a word-wise comparison of solutions. Currently, solutions are only deemed equivalent if they match in their entirety.

The blocks task shows very high usefulness values, and a better comparability of solutions than the new words task in terms of novelty. Another benefit of the task that is that it is free of language-specific knowledge, which makes further development of this task promising. In order to increase the test's capability to properly differentiate between solutions, configurations should be constructed more difficult and smaller in terms of their outline (blocks to be filled). This would simultaneously reduce the number of perfectly useful solutions, and potentially increase frequency of identical solutions. As a result, truly novel solutions would become more significant. To maintain creative potential, additional options of manipulating the elements is required. We suggest adding the possibility to re-size the elements. This would open an avenue for increased manipulation and therefore expand the possibilities to alter the solution in additional ways, allowing for more creativity.

While the two dimensions novelty and usefulness do not account for a significant amount of variance (neither for creative activity, nor creative achievements), neither does intelligence. This is contrary to the common understanding that intelligence and creativity correlate positively (Guilford, 1950). A possible explanation for this might be the non-representative sample.

The significant, negative correlation between novelty and usefulness values produced by participants using the CANU is in line with findings from literature (M. E. Manske & Davis, 1968). More common solutions tend to be particularly useful. They are, however, not creative (Diedrich et al., 2015). Correspondingly, only a small amount of unusual solutions is simultaneously useful.

In contrast to the literature, we did not find a significant correlation between openness and novelty (Dollinger & Clancy, 1993; Wolfradt & Pretz, 2001). This finding suggests that either novelty (or rather the frequency of occurrence) as assessed by the CANU is a different construct than the ones measured with previous methods, or that openness was not fully captured by the two items from the short version of the BFI used in our study. The latter is supported by the fact that the reliability analysis of the two items revealed a Cronbach's $\alpha = .46$ which suggests bad internal consistency. Generally, novelty was highly skewed towards novel values (especially in the new words task), which will potentially change over time with an increase in overall solutions. This would enhance the probability that a certain solution has previously been found, therefore lowering the overall novelty values. This key concept of working with big samples should increase the informational value provided by the CANU over time.

Considering the non-significant correlation between objective (other-rated, top 3 creative achievements) and subjective (self-rated, questionnaire of creative activities) creativity, there might be an inherent difference between feeling creative (or being active in creative domains) and getting recognition for creative achievements. This distinction should be further investigated in order to determine differences and therefore comparability of results. Kurtzberg (2005) has already reported a similar effect in team creativity. For individuals however, this could be further indication of the fact stated by Diedrich et al. (2018) that creative activities seem more appropriate to assess little-c creativity, whereas creative achievements more properly describe Pro-c creativity.

Limitations & Future Research

The results suggest that creativity is comprised of more than just novelty and usefulness. Usefulness can be considered a factor which enables creative ideas to make the leap into reality, but neither usefulness nor novelty (or in this case, grade of uniqueness) explain a significant amount of variance in our models.

The tasks used within the CANU are highly artificial and do not necessarily require real-world creativity. This is however somewhat countered by the fact that new words shows a trend and blocks correlates with skill level in popular games. For these games we argue that most people would agree: A certain amount of creative problem solving is necessary.

The overall intelligence in the sample was very high and non-representative of the general population. The distribution of intelligence is by no means normal and highly skewed towards higher intelligence. A reason for this potentially lies in the recruitment strategy at the university only, and the respective educational background of our sample. More than 75 % of our sample had a Bachelor's degree, Master's degree or PhD. This is does not match the distribution of the general population, where only approx. 18 % of people are placed in this category (Statistisches Bundesamt, 2018).

The correlation between novelty and intelligence is likely present due to the high intelligence found in our sample combined with the fact that novelty values overall were very high. With an increase in solutions as well as a more representative sample, this correlation might disappear. Future tests should evaluate this relationship in order to verify that the CANU measures something other than intelligence. The lacking relationship between intelligence and usefulness (which are both traditionally associated with convergent thinking) is promising in that regard. As of now, however, it can not be stated with confidence that there is no significant overlap between the CANU and traditional intelligence tests. This is especially true when considering the fact that measurement of intelligence was conducted using only a subset of the short hand version of the APM. This might result in a lack of reliability of results. Additionally (as is always the case in online studies) we could not control the participant's environment. Overall, for a first experiment the results are promising. The continuation of the development will be further described in the next sections.

To summarize, there are several avenues one could take to improve the CANU. To increase information value, the amount of unique solutions should be reduced. Simultaneously, the possibility to interact creatively with the test should be increased. Additionally, the ability to account for multiple solutions per participant could be improved. In order to achieve this, we suggest reducing the complexity of the blocks task while enabling additional interaction possibilities. This could be complemented by collecting multiple solutions per participant, not only to increase the number of overall solutions (making each solution better distinguishable in terms of novelty), but also accounting for divergent thinking—similar to traditional creativity tasks like "finding new usages for a paper clip".

Furthermore, due to its complexity, it might seem reasonable to drop the new words task altogether. This would additionally reduce the number of different solutions while also freeing the test of its language specificity. In the future, additional tasks that comply with the same basic principles (machine readability of solution and potential for creative problem solving) can be developed and tested. This can enable research on domain specific creativity and facilitate comparison between different tasks and people.

3.5 Redesign

Following the results of the previous evaluation, the CANU was redesigned. Modifications were focused solely on the tasks and the participants' side of the measurement tool. First and foremost, the new words task was eliminated. Due to it's complexity and language-specificity, the probability that it could be altered in a way to meaningfully function in the CANUs ecosystem was deemed too low to continue development. The blocks task was changed in order to remedy the identified shortcomings in the following ways:

Design and evaluation of the CANU 2.0 were part of a thesis:

Bender, J. (2021). *Development of a measuring instrument for the analysis of creativity* [Master's Thesis]. Technical University of Munich

Including Divergent Thinking

As common with other creativity measurement types (see section 2.1) and suggested in the previous discussion, we enabled participants to submit multiple solutions to each individual problem. This approach was chosen not only to include divergent thinking patterns in the task but also to increase the frequency of each solution. When every participant can submit multiple solutions, it is reasonable to expect increased comparability between the solutions and increased frequency for low-novelty variants, making truly unique solutions more impactful.

Reducing Solution Space

We aimed to make the task more difficult to solve perfectly while simplifying configuration and task. This was achieved by instructing participants not to fill a predefined form, but rather to approximate a geometric shape (a square) with the building blocks provided. Each building block could only be used once per solution, while the dimensions of the shape to be constructed remained undefined. This procedure enables participants to create multiple solutions of different sizes.

Increasing Interaction

The redesign of the CANU involved enabling participants to resize the building blocks in order to maintain creative potential. This is especially important in order to enable truly novel solutions, especially since the solution space shall be reduced and multiple solutions per participant can be constructed.

3.5.1 Puzzle Task

All these changes resulted in a new task, which will be referred to as *puzzle task*. In this task, participants need to form squares with a set of puzzle pieces provided (see figure 3.4, left). In order to increase recombination potential, the pieces are no longer tetrominoes. The construction space is a 5×5 grid. Squares of any size will represent perfectly useful solutions. The farther participants deviate from a perfect square, the less useful a solution will be considered. There are two ways to deviate from a square: over-filling and under-filling (see figure 3.4). The amount of these over-

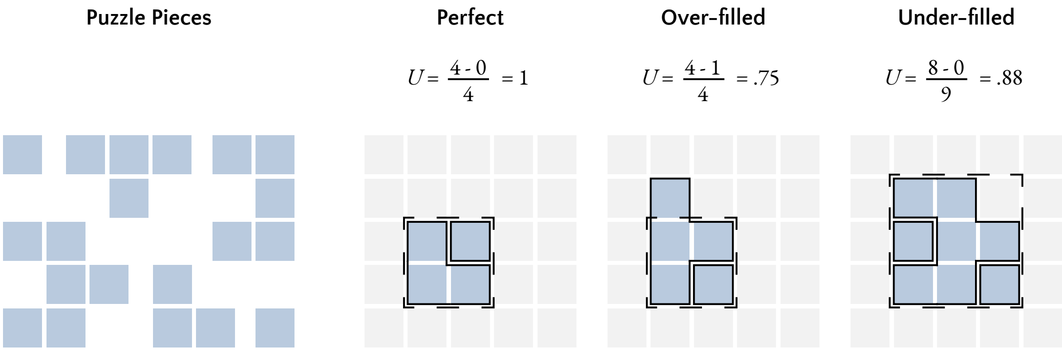

Figure 3.4
Puzzle pieces and different solutions to the puzzle task to form squares with the pieces provided. Present are one perfect, an overfilled as well as an under-filled solution with their calculated usefulness respectively. The related squares are represented by dashed borders.

or under-filled squares is set in relation to the size of the entire construct and subtracted from a perfect usefulness score using the following formula:

$$f(n_i, n_o, N) = \frac{n_{\text{inside}} - n_{\text{outside}}}{N}, \tag{3.4}$$

where n_{inside} is the total number of filled squares in the related square, n_{outside} is the total number of filled squares outside the related square, and N is the total number of fields of the related square. We understand the term related square as the square that was attempted to be filled by the participants (see figure 3.4, dashed borders). The related square is calculated depending on the usefulness values. Whichever related square within the 5×5 grid results in the highest usefulness will be treated as the related square. For example, for the under-filled solution in figure 3.4, a usefulness of $U = .88$ is calculated using $n_{\text{inside}} = 8$, $n_{\text{outside}} = 0$, and $N = 9$. The other possible related square for the under-filled solution would be one where $N = 4$, thus rendering it a heavily overfilled solution. With $n_{\text{inside}} = 4$, $n_{\text{outside}} = 4$, and $N = 4$, usefulness would be $U = 0$ however, so that the related square of $N = 9$ is chosen by the algorithm. Novelty is calculated using equation (3.1) due to its task-independence.

All possible rotations (usually four) of produced solutions are automatically submitted, since they do not represent an additional creative performance. The specific wording of the task was a matter of discussion and subject to extensive pretests. In the end, we chose the instruction: “Form squares (or close to squares) with the pieces provide in the Pieces Pallet”. It should leave sufficient room for interpretation so that unfinished solutions can be submitted while still stressing the fact that squares are the desired goal. Similar to the blocks task from the previous iteration, this task is concerned with visual constructive creativity. Each configuration chosen by a participant represents a new bit of previously unknown information, thus decreasing entropy. Eventually—with enough participants having participated in the task—the entire solutions space should be known.

Before testing the developed puzzle task on a large sample, a heuristic evaluation following Nielsen (1994a) was conducted. Particularly in the areas of “conformity between system and reality” and “consistency and standards”, individual difficulties were identified and resolved. Additionally, several problems regarding the test’s responsiveness could be fixed. Ultimately—in order to enhance

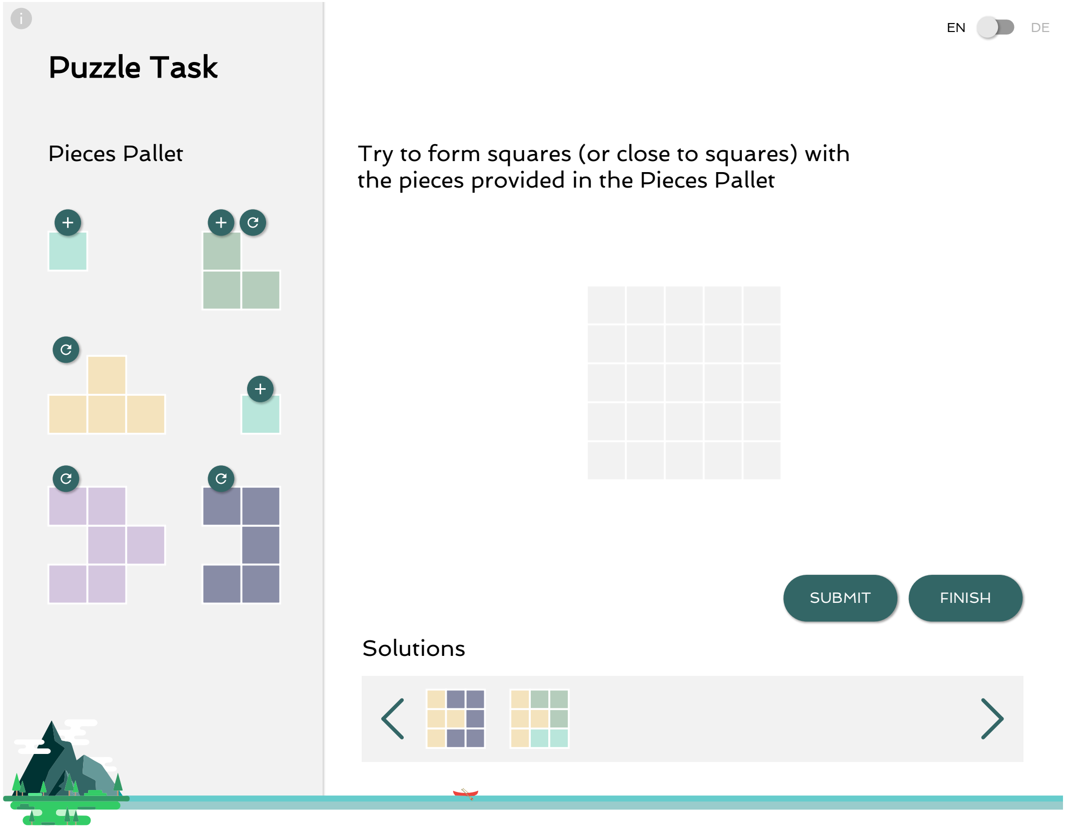

Figure 3.5
CANU 2.0 UI, including the Pieces Pallet with resizing and rotation buttons, the 5×5 construction grid, the overview of previously submitted solutions, and buttons to submit and finish.

the ease-of-use and to ensure that future participants understand the given task and the UI, we implemented a walk-through. The walk-through highlighted specific parts of the UI (see figure 3.5) and presented a quick explanation (e.g. "Pieces Pallet: Choose the puzzle pieces you need here. You can resize and rotate them only in this area").

During the puzzle task, participants have to drag and drop the pieces they choose into the construction grid and use them to form squares. Resizing and rotation is only possible in the pieces pallet, and only for pieces where it makes sense (i.e. rotation is disabled for the square pieces and enlargement is only possible for the green squares and the L-shaped piece). Each of the six pieces can be used once per solution. When a solution is submitted, the construction grid is cleared and all pieces snap back to their original position on the pieces pallet. The submitted solution then shows up in the solutions-area once, while all possible rotations of said solution are posted to the database. In case a participant tries to submit a duplicate or a rotated version of an already submitted solution, a warning pops up stating that duplicates or rotations cannot be submitted. After the participants have come up with their last solution, they click the "finish" button and after a final check whether they truly would like to end the task, are done with the experiment.

3.6 Evaluation 2

In order to evaluate the functionality of the CANU 2.0 Puzzle Task, an online study was conducted as a first step toward validation. To assess the capability of the measurement tool to meaningfully distinguish between creative and non-creative solutions, we compare it to the *Creative Personality Scale* (CPS; Gough, 1979) as a way to investigate the convergent validity of the CANU. Because the CPS covers a different facet of creativity (see figure 2.1 and section 2.1.1), as opposed to the CANU which is developed as an objective product measurement, a direct comparison of the results of these measures can be misleading. Thus, we additionally investigated whether task performance could be influenced by manipulation of the participant's creative mindset. In this way, we wanted to assess if task performance is superior under good creative conditions, exploring if the task is bound to assess creativity or a related construct. Additionally, because people are considered capable to determine whether a certain task required creativity to solve it, we recorded a subjective assessment of the CANU 2.0. The puzzle task closely resembles tools often used in intelligence tests, which is why it is important to determine whether the CANU 2.0 measures a different construct than classic intelligence tests as a way of investigating the discriminant validity (see section 3.4). For statistical analysis, we formulated the following alternative hypotheses:

H_1 There is a negative correlation between the novelty and usefulness values of the CANU 2.0.

H_2 The motivated group scores better in terms of novelty and usefulness in the CANU 2.0.

H_3 There is a positive correlation between the two dimensions of the CANU 2.0 and the CPS.

H_4 The novelty and usefulness values determined by the CANU each make an independent contribution to the prediction of the creative personality that goes beyond the predictive capacity of general intelligence.

In an online study running for four weeks, a total of $N = 78$ people divided in two groups (motivated vs. unmotivated) participated in the evaluation of the CANU 2.0.

3.6.1 Procedure & Materials

The experimental design was approved by the TUM ethics committee (reference 569/20 S)

Similar to the first evaluation, a link was distributed which led to the studies landing page. This page included a short introduction, the study objective, as well as the data protection notice. By continuing, participants gave their informed consent and started the survey. They were randomly assigned to one of the two study groups, *motivated* or *unmotivated*, and the study material was presented accordingly. After completion, a thank you page including a personal hash was displayed. This hash serves for the participant's right to request data inspection or deletion and is known only to them. Since participants performed the test online, they could choose the working environment freely as long as they were able to operate a browser-capable terminal device.

The main part of the study consisted of the CANU 2.0 puzzle task, an intelligence test, a demographic questionnaire, and the CPS, which was integrated into the questionnaire. Due to technical necessities concerning the session cookie—and therefore the possibility to link solutions to the generated hash—no randomization took place. The four elements were presented in the following order, where the items in *italics* were only present in the motivated group:

1. *Motivational Video*
2. Puzzle Task *(including Time Limit)*
3. APM
4. Questionnaire
5. CPS

Motivational Video

Motivation is an influential factor for creative performance (see section 2.1.3). We presented a motivational video before the start of the puzzle task in the motivated group. The video was chosen according to several criteria. First, a video concerning creativity was vital. To identify such a video, we searched for the key word creativity in the titles of the videos on YouTube. Second, we considered at least one million views, as well as a major positive rating (less than 1 % negative ratings) prerequisites. Thus, we selected the 2:42 minutes long video *The Creative Process* by Kolder (2019).

Puzzle Task

The puzzle task started with a walk-through, as outlined in section 3.5.1. Afterwards, participants confirmed they wanted to start the experiment. In the motivated group, a time limit of 12 minutes was set and visualized below the language toggle in the upper right corner. The time limit was chosen after a pretest and represented the average processing time of three participants. We decided to implement the time limit to strengthen our manipulation and enhance the creative output of the participants. Time pressure is positively associated with creative performance (section section 2.1.3) and as such can be understood as beneficial for creativity. The puzzle task ended after participants had clicked the finish button or the time had run out, whatever happened first.

APM

In accordance with the first evaluation and due to the close relationship between intelligence and creativity, set I of the APM by Raven et al. (1998) was presented. In order to increase the differentiation of intelligence in the sample (as opposed to the first evaluation), the entire set containing twelve geometric tasks was used.

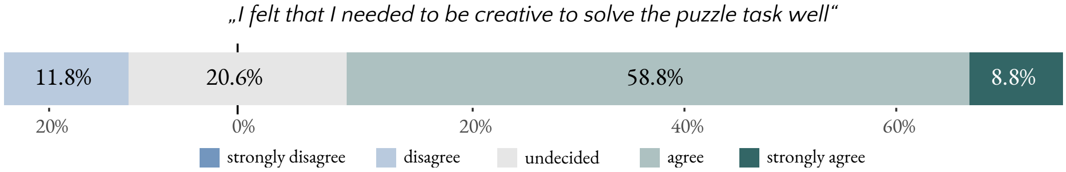

Figure 3.6
The creativity participants felt that they needed in order to complete the puzzle task of the CANU 2.0.

Questionnaire

A questionnaire containing demographic characteristics (age, gender, level of education, and field of work), as well as a subjective assessment of the task and oneself was presented next. Specifically, participants were asked to rate the items: "*I felt that I needed to be creative to solve the Puzzle Task well*" [strongly disagree—strongly agree], and "*How would you rate your creative skills*" [very poor—excellent] on a 5-point Likert scale.

CPS

The creative personality, determined by the CPS (Gough, 1979), was assessed in an additional part of the questionnaire using multiple-choice items. The CPS is widely used because of its efficiency (Batey & Furnham, 2008; Oldham & Cummings, 1996). It consists of 18 adjectives positively related to creativity and 12 adjectives negatively related to creativity. Participants indicate which adjectives best describe them. The total number of selected adjectives positively associated with creativity, minus the total number of selected adjectives that are negatively associated with it, are used as an indicator for the creative personality of an individual.

3.6.2 Results

Sample

From the total of $N = 78$ participants, the data of 10 was excluded due to incomplete results. This left $n = 68$ participants (36.8 % female) aged between 18 and 70 years ($M = 31.2$; $SD = 12.3$) for statistical analysis. The group assignment was equal, with 34 in the motivated and 34 in the unmotivated condition. For analysis, we aggregated the solutions produced by each participant and calculated the average novelty and usefulness. This procedure enabled statistical analysis despite the vastly different number of solutions provided by the participants. Whenever novelty and usefulness are reported in this study, the values always refer to the average of each individual's solutions.

Participants in the unmotivated and in the motivated group show equally high values in the APM ($M_u = 0.94$, $SD_u = 0.08$; $M_m = 0.94$, $SD_m = 0.09$), indicating the two different groups exhibited similar levels of intelligence. In line with the first evaluation, a Shapiro-Wilk test revealed a violation of normality ($W = 0.709, p < .001$), in contrast to findings in the literature. A Kendall Rank Correlation revealed no significant relationship between intelligence as measured by the APM and novelty ($\tau_B = -.067, p = .481$) or usefulness ($\tau_B = -.037, p = .700$).

Group	Novelty		Usefulness		Number of Solutions		
	Mean	SD	Mean	SD	Mean	SD	Total
Unmotivated	0.774	0.158	0.892	0.081	9.68	6.04	329
Motivated	0.835	0.119	0.863	0.078	13.40	8.79	456

Table 3.4
Descriptive data of the CANU 2.0 puzzle task. n = 68 participants submitted a total of 785 solutions.

In terms of the creative personality assessed by the CPS ($M_u = 3.18, SD_u = 2.71; M_m = 3.00, SD_m = 3.11$), both groups show results distributed around the middle of the scale from -12 (not creative at all) to 18 (extremely creative). In terms of the level of creativity needed for the puzzle task, 67.6 % of participants stated that they either agreed or strongly agreed that the puzzle task requires creativity to solve it well, while 11.8 % disagreed (see figure 3.6).

Puzzle Task

The participants produced a total of 785 solutions to the puzzle task. The descriptive statistics are summarized in table 3.4. Both dimensions showed a significant deviation from the normal distribution (tested via Shapiro-Wilkes, novelty $W = 0.926, p < .001$, usefulness $W = 0.958, p = .023$). Thus, the nonparametric Kendall Rank Correlation was used in the analysis of relationship. The test revealed a significant negative correlation between the two variables novelty and usefulness ($\tau_B = -.296, p < .001$).

Two Wilcoxon rank sum tests were computed to assess whether participants in the motivated group performed differently to the participants in the unmotivated group in terms of the novelty and usefulness of the produced solutions. The results are visualized in figure 3.7. There was no statistically significant difference between the two groups in the dimensions novelty ($Mdn_u = 0.78$, $Mdn_m = 0.82$, $p = .079$, effect size $r = 0.21$) or usefulness ($Mdn_u = 0.91$, $Mdn_m = 0.88, p = .128$, effect size $r = 0.185$). Both tests indicate a small effect.

Creative Personality

A Kendall Rank Correlation revealed no significant relationship between a participant's creative personality and the novelty ($\tau_B = .004$, $p = .962$) or usefulness ($\tau_B = -.024$, $p = .782$)) of the solutions they had produced.

Analogous to the first evaluation of the CANU, we examined the contribution of the two dimensions towards the creative personality with a hierarchical linear regression. The order of the predictors used (1. Intelligence 2. Novelty 3. Usefulness) was kept constant compared to the first evaluation. The results can be found in table 3.5. They show no significant increase for variance accounted for during the three steps ($F_1(1, 66) = 0.98, p_1 = .327$; $F_2(1, 65) = 0.47, p_2 = .495$; $F_3(1, 64) = 0.28, p_3 = .600$). The total variance accounted for in the third step is $R^2 = 2.6$ %.

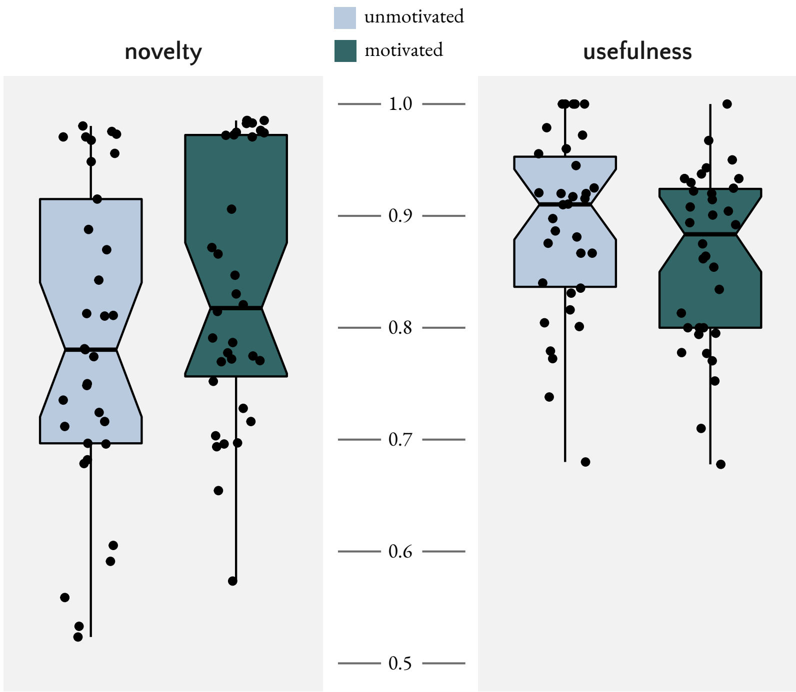

Figure 3.7
Boxplots of the two dimensions, novelty and usefulness of the puzzle task of the CANU 2.0, divided in the two experimental conditions.

Exploration

As part of this first evaluation of the CANU 2.0, we conducted additional analyses to explore our measurement tool in greater detail. Accordingly, the following results do not serve as a basis for generalizable conclusions, but to open up possible starting points for future research.

Creative Skills For investigation how self-rated creative skills ("*How would you rate your creative skills?*") correlate with the values participants achieved in the two dimensions of the task, a Kendall rank correlation revealed that neither novelty ($\tau_B = -.027, p = .779$) nor usefulness ($\tau_B = .115, p = .232$) correlate significantly. This means that participants who rated themselves as more creative did not perform significantly better (or worse) in the CANU 2.0. The analysis of the CPS values, however, revealed that participants who rated themselves as more creative in our one-item Likert scale, also produced significantly higher results in the CPS ($\tau_B = -.317, p = .002$).

Number of Solutions The total number of solutions submitted was 785. The participants in the unmotivated group produced 329 solutions and the participants in the motivated group came up with a total of 456 solutions (see table 3.4). On average, the participants in the unmotivated condition produced $M_u = 9.68$ ($SD_u = 6.04$) solutions, where those in the motivated group came up with $M_m = 13.40$ ($SD_m = 8.79$). A Wilcoxon rank sum test was calculated to investigate

Step	Predictor	R^2	ΔR^2	B	*SE* B	β	*p*
1		.01	.01				
	APM			-4.38	4.39	-0.12	.322
2		.02	.01				
	APM			-4.86	4.46	-0.14	.280
	Novelty			1.75	2.53	-0.09	.493
3		.03	.01				
	APM			-5.14	4.52	-0.14	.259
	Novelty			2.41	2.84	0.12	.399
	Usefulness			2.61	4.97	0.07	.600

Table 3.5
Hierarchical multiple linear regression to predict creative personality via novelty and usefulness. The APM score is included as a control variable and measure for intelligence.

the difference of number of solutions in the two groups, because the data significantly differed from a normal distribution (Shapiro Wilkes: $W_u = 0.914, p_u = .011$; $W_m = 0.935, p_m = .044$). It revealed a small, non-significant effect ($Mdn_u = 8, Mdn_m = 11.5, p = .052$, effect size $r = 0.24$), indicating a trend that participants in the motivated group tend to produce more solutions than the ones in the unmotivated group.

Time The participants spend an average of $M_u = 529$ s ($SD_u = 385$ s) on the task in the unmotivated group, and $M_m = 530$ s ($SD_m = 211$ s) in the motivated group. In the unmotivated group, the participants handed in their first solution after $M_u = 143$ s ($SD_u = 217$ s), while participants in the motivated group did so after $M_m = 101$ s ($SD_m = 115$ s). On average, they produced a new solution every $M_u = 55$ s ($SD_u = 41$ s) in the unmotivated and $M_m = 44$ s ($SD_m = 24$ s) in the motivated group. A series of Wilcoxon signed rank tests was performed but revealed no statistically significant differences between the groups.

Creativity Score Although the multi-dimensional approach is promising and widely used within the industry, a simple, one-dimensional creativity score would be desirable. Since it is clear that a creative solution must be both, novel as well as useful (e.g. Diedrich et al., 2015), a score would have to reflect that in case of particularly low usefulness or novelty. Following the formula first suggested by P. Sarkar and Chakrabarti (2007) and later confirmed by the authors again (P. Sarkar & Chakrabarti, 2011), we calculated a creativity score for each solution using:

$$\text{creativity} = \text{novelty} \times \text{usefulness} \tag{3.5}$$

An example of five individual solutions, and their respective creativity scores can be found in figure 3.8. It is noticeable that incomplete solutions usually show a high degree of novelty. Solution

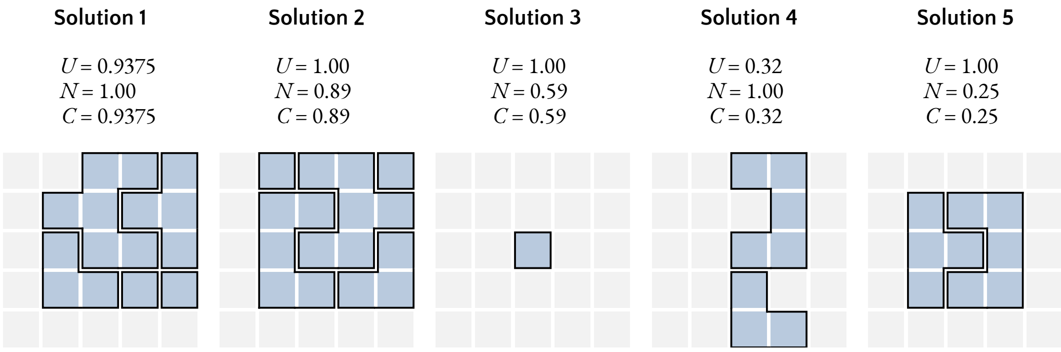

Figure 3.8
Five sample solutions with their respective usefulness, novelty and creativity values, calculated as described in equations (3.1), (3.4) and (3.5).

4 and 5 in figure 3.8 represent two extremes for usefulness and novelty respectively. While solution 4 has a very low usefulness value as it is very far from being a square, but has a high novelty value, solution 5 has a very low novelty value as $n = 46$ participants have submitted this solution, but represents a perfectly useful solution. Consequently, both solutions have a low creativity score when using the formula from equation (3.5). Solution 3 is similar to solution 5 in a sense that it too has a perfect usefulness value, but has been submitted by fewer participants, resulting in a higher (but not particularly high) novelty value. Solution 1 is an example of a cluster of 11 different solutions with the highest creativity values. All of these solutions follow a similar pattern, all being one square off a perfect 4×4 solution, and all having been discovered one time only (albeit by different participants).

3.6.3 Discussion

The redesign of the CANU yielded some promising results. Ease of execution for researchers and participants is still given, and the comparability of results is much better as opposed to the first version. The negative correlation between novelty and usefulness of results is consistent with findings in literature (M. McCarthy et al., 2018). In combination with the participant's subjective reasoning that one needs to be creative to perform well in the task, this indicates that the CANU poses a valid approach to measuring creativity.

We found a small trend suggesting that participants in the motivated condition performed better in terms of novelty and worse in terms of usefulness. However, this trend was not significant. This lack of significance, however, might not be to the detriment of the test, but rather a result of inadequate conditioning. Since neither the creativity of solutions, nor the subjective self-assessment, or the timing parameters of the submitted solutions show any differences, it seems reasonable to assume that the motivational video and the time limit alone were not sufficient to properly differentiate between the two groups.

Similar to the first study, neither novelty, nor usefulness or intelligence accounted for a significant amount of variance of the creative personality. This might be attributed to the different facet of creativity that the two tests (CANU vs. CPS) measure. Additionally, this result could have been influenced by the unconventionally intelligent sample. However, this relationship is disputed (see figure 2.2). For instance, Guilford (1967) suggested that high or at least above-average intelligence is required to be creative. Other studies show that creativity and intelligence correlate up to a certain threshold (e.g. Cho et al., 2010; Fuchs-Beauchamp et al., 1993), after which intelligence is less impactful. The threshold in these studies is usually reported to be at 120 IQ points. A more recent study found that the exact threshold, or even the existence of a threshold, varies depending on the indicator of creativity, e.g., creative potential or achievement (Jauk et al., 2013). Overall, there is no consensus yet in the literature about this relationship, as some studies found correlations only above a certain threshold (Runco & Albert, 1986) or found no threshold at all (Kim, 2005).

Considering specific solutions and their respective creativity scores, some characteristics of particularly creative solutions can be identified. Generally, solutions that show very high novelty values, but not-perfect usefulness values represent more creative solutions. When comparing perfectly useful solutions in the CANU 2.0, it is noticeable that those solutions that are comprised of several pieces, have a large area, a complex structure, and no mirror axis result in higher creativity values (e.g. figure 3.8 solution 2 vs. 3 or 5). Thus, the test replicates a fact known from literature that increased complexity often goes hand in hand with increased creativity (Eisenman, 1990).

Limitations & Future Research

This second evaluation of the CANU revealed promising trends, indicating that our redesign efforts are heading in the right direction. However, we did not find a concise relationship between the CANU and the creative personality. Similar to the first version of the CANU, the puzzle task remains highly artificial and does not necessarily require real-world creativity. This is, however, countered by the fact that the majority of participants stated that creativity was necessary to solve the given task well (figure 3.6).

As was the case in the first evaluation, the overall intelligence was very high in our sample and the distribution was by no means normal. This is potentially due to the fact that participants were mainly recruited in an academic environment.

Within the pretest according to Nielsen, the influence of the wording of the task became apparent. After consultation with the renowned creativity researcher Nathan Crilly, the task description "*Try to form squares (or close to squares) with the pieces provide in the Pieces Pallet*" was chosen. It should give the participant the mental possibility to submit unfinished solutions but also leave room for interpretation. This, however, is not guaranteed and could potentially be the subject of future research.

Despite the need for discussion of the developed task as well as the calculation of creativity, continued development of the CANU is recommended. Especially the calculation and rating of solutions could be further investigated. Although novelty calculation via frequency of occurrence has been used before (e.g. Gough, 1976; Runco & Charles, 1993), it does not necessarily have to correspond to novelty as judged for creativity. Additionally, usefulness as defined within a social context (Plucker et al., 2004) does not necessarily amount to *correctness* as prerequisite of the tests.

The puzzle task itself appears to be artificial enough so that no domain has a distinct advantage, while still retaining the potential for participants to engage in creative problem solving. While the CANU 1.0 did not provide the opportunity to deliver multiple solutions—thus, focusing convergent thinking to a great extend—the CANU 2.0 lacks this specific convergent element. Since the creative process involves both, convergent as well as divergent thinking, the task could be extended with an option for participants to indicate their most preferred/creative solutions.

Since creativity is becoming increasingly relevant, especially in the context of work, the CANU should be validated in different domains. By developing tasks that require specific domain knowledge, the dimension of usefulness could become more meaningful. The general characteristics of the measurement tool would still hold true, and it is plausible that the true potential of our approach would be revealed in specific, domain-relevant tasks.

The CANU 2.0 represents an additional step of development in tackling the problems already stated in Amabile (1982) regarding the choosing of appropriate tasks and judges. The results show the potential of enabling creative problem solving while remaining inconclusive in regards to the fact that they actually properly assess creativity. Ironically—development of the CANU demands novelty (task development) and usefulness (objectivity, comparability), or in short creativity. To obtain an adequate measurement instrument for creativity, further research, with similar tools and a continued development of the test at hand are encouraged. Especially since creative progress is often incremental (Madjar et al., 2011) and the CANU has the potential to unify scientific research on creativity in a scalable and comparable fashion.

Concluding, we were successful in redesigning the CANU in a way that is easy to use and enables proper comparability of results within and across studies. However, the CANU 2.0 still failed to satisfy all requirements. Validity of measurements remains questionable. Despite some promising results, we did not find a clear relationship between the CANU and other creativity measures. Considering the small sample size for a test that is decidedly designed to work with bigger samples, as well as the recreation of typical findings in other creativity research, results are still promising. The CANU 2.0 with its automated measurement embodies a contemporary approach for capturing creativity that embraces digitization and automation. In view of the increasing importance of creativity, a further advancement of this objective, automated measurement method seems reasonable.

CHAPTER 4

Amplification

Generation of ideas that are novel and useful, forms—despite some controversy (see Prasch & Bengler, 2019)—the definitional consensus for creativity (Batey, 2012) and basis of the Creativity Assessment via Novelty and Usefulness (CANU). Besides measuring creativity, supporting humans in being creative is another major challenge for the future of Human Factors/Ergonomics (HFE) (see chapter 1). Particularly, since creativity is considered a final frontier of human capability when compared to Artificial Intelligence (AI) (Colton & Wiggins, 2012), and the *creativity algorithm* (a deterministic approach to creativity) is unlikely to be computable (Ventura, 2015). Still, computational creativity is a long standing goal of AI research. In fact, the use of computers for the generation of outcomes that would be deemed creative if produced by a human was one of only seven goals of the Dartmouth Summer School of 1956 (J. McCarthy et al., 1955), the meeting at which AI was officially named (Besold et al., 2015). Unexpected expression of creativity is considered one of the most enduring proofs that true AI has been achieved. Yet, it still remains elusive (Ward, 2020). Therefore, scientific interest has increasingly concentrated on the two agents—human and machine—working together to produce creative output. When assuming that computer systems will not, in fact, render humans superfluous for the creative act (see chapter 1), it is important to determine where and how computers could support humans. Algorithms appear capable of such an endeavor, especially because several computational systems have already shown potential to assist humans with specific tasks in the past. For example, the interaction with automated vehicles (e.g Bengler et al., 2020) or AI-based diagnosis systems (e.g. J. H. Lee et al., 2020) can augment human capabilities in a meaningful way. Generally, however, Human Computer Interaction (HCI) poses the challenge to achieve meaningful improvement that requires constant development and evaluation (Dix et al., 2004). In a recent review paper by Remy et al. (2020), the domain of Creativity Support Systems (CSSs) has been identified as a grand challenge for HCI. The authors urge researchers—among others—to clearly define the goal of a CSS and to link it to theory to further their understanding.

The augmentation and support of creativity through HCI as well as the specific configuration of assistance systems, are the key topics of this chapter. More specifically, we investigate the answer to the question how exactly an assistance system could support humans in their means to generate truly creative solutions at work (Prasch et al., 2021) when transferring the ideas of cognitive support systems to the creative domain. Or in other terms, how can more people be supported to be more creative more often (Shneiderman, 2000; 2009; von Hippel, 2006)?

4.1 Exploration

Exploration of user needs for creativity support systems was part of a thesis:

aus dem Bruch, L. (2020). *Kreativitätsunterstützende Systeme im beruflichen Kontext* [Master's Thesis]. Technical University of Munich

Additionally, it was published in Prasch et al. (2021)

The initial step to determine user needs for a CSS, was comprised of a two-step study. First, to better understand the potential users of such systems, we conducted semi-structured interviews. Second, we conducted an online survey in order to quantify the results and represent a broader sample.

4.1.1 Interviews

Methods

www.bigbluebutton.org

We conducted $N = 7$ semi-structured interviews with people from creative professions. Following Guilford (1950)—who lists *inventing*, *designing*, *contriving*, *composing*, and *planning* amongst creative patterns—participants from certain occupations were recruited from personal contacts. All interviews were conducted in German and remotely via video conferencing tool (BigBlueButton*) due to the COVID-19 pandemic. We recorded the audio of the interviews, allowing us to prepare transcripts of the sessions. Informed consent was obtained from all participants prior to the start of the interview. During the interviews, participants were asked for their demographic data, their current modus operandi, the degree to which they followed the creative process specified in figure 2.8, and their vision of the application of CSS in the future.

To analyze the data, we conducted a a qualitative content analysis according to Mayring (2004). The audio was first transcribed, then paraphrased, and participant's statements were generalized by three individual raters. The analysis of the inter-rater reliability reveals a Krippendorff's alpha of $\alpha = .976$, which represents reliable consensus (Krippendorff, 2018).

Results

The seven participants of the study (5 female) were between the ages of 24 and 41 ($M = 30$, $SD = 4.78$). They worked in architecture, engineering, fashion design, graphic design, user experience design (2×), and theater dramaturgy. The interviews lasted 24 minutes on average, ranging from 18 to 38 minutes with a standard deviation of 6 minutes.

The data presented in the following is structured according to three themes, namely modus operandi, creative process, and vision of CSSs. Modus operandi can be understood as the way our participants currently work on creative problems, creative process as the abstract, formalized process or order they followed, and vision of CSSs as their personal view on whether or not they would like to be supported by computational systems in their creative task and—if they did—how this support might look like.

Modus Operandi The majority of the participants primarily work alone, relying on feedback from others only at certain points in the process. All interviewees work in offices with 2 to 20 co-workers, and also from home using computers or laptops. Four participants stated that they additionally rely on analogue tools like pen and paper. Convergent thinking is used more frequently by four interviewees, the other three use convergent and divergent thinking to the same extent. All but one participant indicated that convergent thinking was easier for them.

Creative Process Five participants reported that they follow a process similar to the one depicted in figure 2.8 (which was presented to them during the interviews). They emphasized the non-linearity of the process. Two interviewees were responsible for particular steps of the process within their organizations, thus limiting their exposure to the other phases. While all participants exchange ideas with colleagues, five actively request feedback when needed, whereas two stated that there are regular meetings in place for such discussions in their companies.

Vision of Creativity Support Systems Six participants would use CSSs, especially if they could be used for information research, which would save time. One participant stated that there was no need for a CSS. Said interviewee was reluctant to hand over parts of their work. The participants mentioned several ideas for potential system designs. These designs that can be roughly divided into four areas of application: data management and research (5), support for particular tasks (3), organization of workflow (2), and inspiration (2).

4.1.2 Online Survey

Methods

We conducted an online study with people working creatively in order to quantify the results from the interviews. The questionnaire was hosted at the university (using Limesurvey*), and five Amazon vouchers were raffled as an incentive to participate. The language of the questionnaire was German. At the beginning, the participants were asked to give their informed consent, followed by a demographic questionnaire. This included a question whether or not participants worked in creative domains, which was later used as an exclusion criterion. After that, the participants answered questions regarding their modus operandi, the application of the creative process, as well

www.limesurvey.org

Table 4.1
Answers of 59 participants about which of the two types of thinking they used more often in their daily work and which they considered easier.

	Convergent	Divergent	Equal
Used More Often	55.9%	6.8%	37.3%
Easier	69.5%	23.7%	6.8%

as their vision regarding CSS at the workplace. These questions were similar to the ones in the interview study, but were presented in a closed question format.

Results

In total, $N = 110$ datasets were collected in the survey. Excluded from analysis were incomplete datasets (33), datasets indicating that participants did not work in creative domains (10) or not full time (7), as well as one dataset whose participant stated they worked primarily manually. We decided to exclude these participants on the basis of their current work situation as the study was aimed at knowledge workers. This procedure resulted in $n = 59$ datasets to be analyzed. Nearly 70 % of the participants were female, 30 % male, and overall the mean age was $M = 27.89$ ($SD = 6.05$).

The domain distribution was skewed towards engineering (20 participants). The obtained results might therefore not reflect the general population. However, chi-squared tests revealed no significant relationships between domain and modus operandi (team vs. solo work: $\chi^2(60) = 59.63$, $p = .49$; divergent vs. convergent thinking: $\chi^2(30) = 25.97, p = .68$).

Modus Operandi Regarding their current working procedure, 57 participants (96.6 %) stated that teamwork, as well as working alone, were part of their daily routine (27.1 % more alone, 25.4 % more team, 44.1 % balanced). Between the two types of thinking, the majority of our participants predominantly used convergent thinking and considered it the easier one of the two due to its limited number of possible solutions (see table 4.1). Additionally, the participants preferred the logical or inferential thinking based on real-world criteria required for this type of thinking. The participants who preferred divergent thinking did so because in divergent thinking they are not required to make decisions and no evaluation takes place. Most of the participants use digital tools (33.9 % work digitally only, 50.8 % both digitally and analogue). Only 9 respondents (15.3 %) stated they work exclusively analogue.

Creative Process 55 participants, (93.2 %) responded that the four phase process depicted in figure 2.8 closely resembles the one they follow when working on their professional tasks. The other four participants stated that

- they do not have a fixed procedure (twice),
- they do not see creativity as a linear process, or

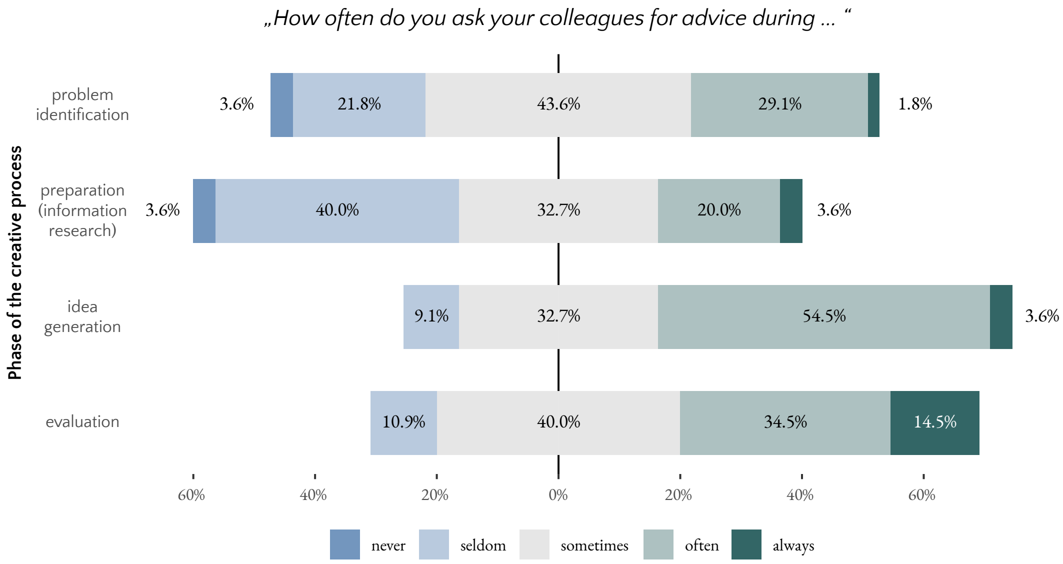

Figure 4.1
Answers of 55 participants that agreed on the process from figure 2.8 on how often they asked colleagues for help during the respective phases.

- they identify tasks rather than problems and only one solution is developed, which is then checked within the team.

We asked participants if they were uncertain of their own competence in one, or several, of the four phases. Concerns were mostly voiced regarding idea generation (35.6 %), followed by preparation (22 %), evaluation (18.6 %) and problem identification (15.3 %). When asked how often the participants requested help from their colleagues in the respective phases, a similar picture emerged. Help was sought out less frequently for problem identification and preparation when compared to idea generation or evaluation (see figure 4.1).

Vision of Creativity Support Systems If available, the majority of 41 respondents (69.5 %) would use a creativity support system at work. The remaining 18 participants indicated they would not use such a system, either because there were doubts about the capabilities of the system (10 mentions), they see social exchange as too important a factor (6 mentions), or they feel like an implementation is inconceivable (2 mentions). The preferred system for those who would use a CSS would be one that assists in preparation or information research.

4.1.3 Discussion

The two-step approach of the exploration, the interviews followed by the online questionnaire, was employed to achieve valid results. The results of these two studies are comparable. Combined with the fact that nearly all participants agreed to the proposed creative process, and the alignment in results between interviews and the online questionnaire, the validity of the overall results seems promising.

A clear relationship between the respondents' preferred way of thinking and the steps in the creative process that are most difficult for them can be observed. A large proportion of respondents use convergent thinking more often and consider it easier than divergent thinking. The point at which support or advice are sought out most often is the idea generation phase. This is also the phase were most participants feel uncertain about their own competence. This is comprehensible, since idea generation is the phase most commonly associated with divergent thinking (Runco & Jaeger, 2012). People who are more practiced at convergent thinking could be expected to have difficulties at this point. Thus, CSSs could be most helpful when specifically supporting divergent thinking.

In the interviews, participants mentioned the most potential support systems for information research, as this process can be very time consuming. This is in line with results from the online questionnaire, where a system that would assist with data management and research was preferred. These results reflect the focus in current development of CSSs. Only for the two phases preparation and idea generation there are dedicated creativity support systems available (K. Wang & Nickerson, 2017). However, while support in idea generation is common amongst current systems (Gabriel et al., 2016), for example by guiding participants through several creativity techniques (e.g. Garfield et al., 2001), supporting data management and research is still only sparsely addressed in creativity research. Overall, the results show a need for CSSs, as well as the willingness to use them in daily work. This indicates continuous development of CSSs as a promising endeavor.

4.1.4 Outlook

Based on the results of our two exploration studies, we recommend that implementation of strategic support systems for creative workers should focus on digital support systems facilitating research and providing inspiration. These systems should provide assistance during mainly the divergent phases with a combination of idea generation as well as preparation support. To add meaningful value, stimuli for idea generation should be provided dynamically (K. Wang & Nickerson, 2017), depending on the current context. To foster the collaboration within a team, an easy way to share the progress of one's work should be implemented.

4.2 Design

Design and evaluation of a creativity support system were part of a thesis:

Scotto di Carlo, M. (2021). *Development and evaluation of digital creativity assistants as supplemental tools for brainstorming* [Master's Thesis]. Technical University of Munich

Following the identified requirements, we developed several digital CSSs. The results from section 4.1 and a recent poll, indicated that a lack of inspiration is a major factor to not be creative (Hall, 2020). Hence, the focus of our design endeavors was set on supporting research and providing stimuli for idea generation. As it is one of the most prominent examples of idea generation, we chose brainstorming, as described by Osborn (1952) (cited according to Isaksen and Treffinger (2004)), as a procedure to be supported by our newly developed assistants (see figure 4.2). Based

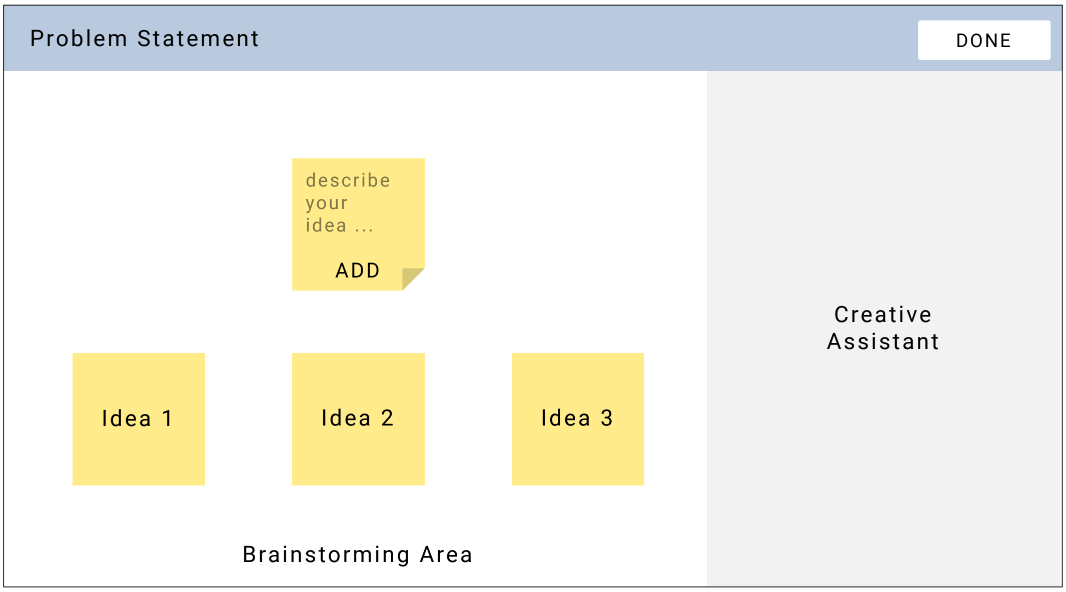

Figure 4.2
The structure of a screen in the creativity tool consisting of three elements, the problem statement, the brainstorming canvas, and the creative assistant.

on the framework of K. Wang and Nickerson (2017), three assistants were designed to support participants in the generation of ideas, namely a chatbot, inspirational pictures, and an associative search (see figure 4.3)

In a multi-phase development process, we first defined the requirements for the assistants based on the previous studies. Then, we produced static graphical prototypes of the three CSSs. These prototypes were iterated and subject to a heuristic evaluation with three usability experts, resulting in the final interfaces. Due to the COVID-19 pandemic, the tools were implemented as responsive web apps. Back-end structure and user journey were designed to enable a remote study setting.

The interface we developed consisted of three major parts (see figure 4.2). The first part, the problem statement—or topic that users need to generate ideas for—is written topmost. This top bar also includes a *done* button, in order to finish idea collection on said topic. The lower left area of the CSS represents the brainstorming canvas. The lower right area provides space for the assistants: chatbot, inspirational pictures, and associative search. During the design of the brainstorming canvas and the three assistants, we followed the famous 10 heuristics regarding user interface design by Nielsen (1994a), as well as a set of design principles specifically developed for the design of CSSs. The latter was first published as a set of 12 principles (Resnick et al., 2005; Shneiderman et al., 2006) and later augmented by Shneiderman (2007) to include the additional items 13 and 14:

1. Support exploration
2. Low threshold, high ceiling, wide walls
3. Support many paths and many styles

4. Support collaboration
5. Support open interchange
6. Make it as simple as possible – and maybe even simpler
7. Choose black boxes carefully
8. Invent things that you would like to use yourself
9. Balance user suggestions with observation and participatory processes
10. Iterate, iterate and iterate again
11. Design for designers
12. Evaluation of tools
13. Rich history keeping
14. Support exploratory search

The assistants as well as the brainstorming tool itself were designed to be appealing and fun to use, each assistant having different features to explore, thus, paying special attention to invent things that you would like to use yourself (Resnick et al. #8) during development. All assistants were designed to be used by individuals rather than groups, since participants had stated in the exploration (see section 4.1) that they often worked alone and primarily asked colleagues for help when necessary. Due to this choice, support of collaboration (Resnick et al. #4) was not adhered to. Additionally, as the assistants were merely a means to an end (research of different approaches and concept), exporting or importing ideas was not included. This is in conflict with the support of open interchange (Resnick et al. #5) as well as the feature of sharing one's work from the exploration.

4.2.1 Brainstorming Canvas

The brainstorming canvas provides the backbone of all interfaces, and it enables users to collect their ideas. Ideas can be written down on a yellow square at the top of the canvas (similar to Post-it notes), and later be added to the idea pool via the *add* button or by pressing <enter> on the keyboard (see figure 4.2). The Post-it was chosen as visualization in order to evoke a real-world association (Nielsen #2), because it is a tool typically used in offline brainstorming. To keep the design aesthetic and minimalistic (Nielsen #8), no additional styling or animations were added. Not only the aesthetics of but also the interaction with the canvas was designed to be as simple as possible (Resnick et al. #6). All previously generated ideas are displayed on individual Post-it notes with equal styling (Nielsen #4) below the topmost Post-it which serves as input mask. In case users

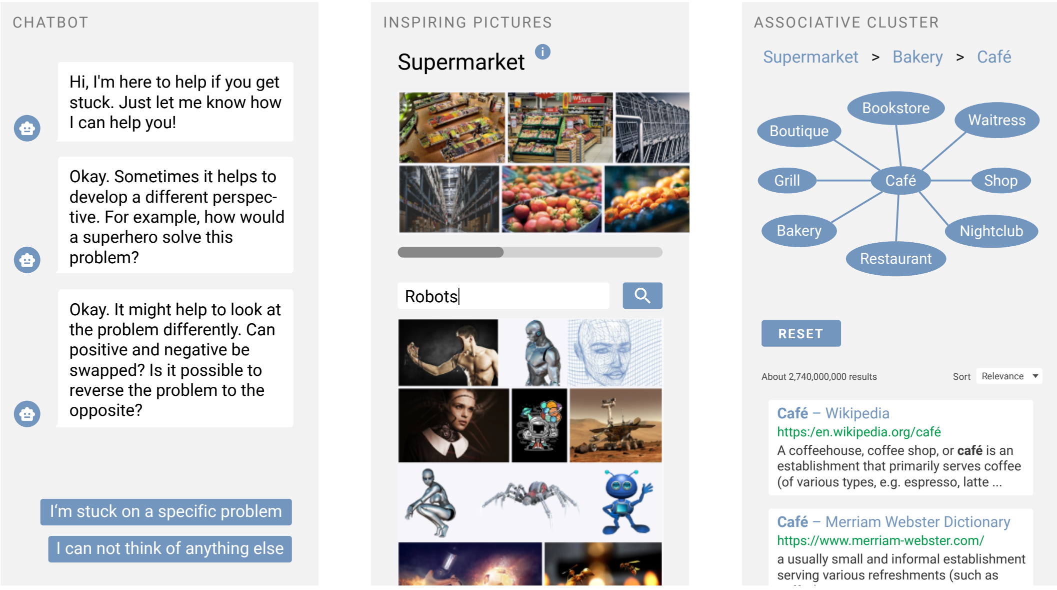

Figure 4.3
The three different creative assistants, chatbot *(left)*, inspiring pictures *(middle)*, and associative search *(right)*.

want to change an idea, they can click on the respective Post-it and directly edit the text (Nielsen #9). Once they are satisfied, a click on the *save* button, located at the bottom of the Post-it, saves all changes.

To ensure comparability and ease of study evaluation, Post-its can neither be rearranged on the canvas, nor be filled with anything other than text—contrary to similar digital tools like Miró* or Conceptboard*.

www.miro.com
www.conceptboard.com

4.2.2 Chatbot

The chatbot was designed combining best practices from various creativity techniques, frameworks, and tools (S. Manske et al., 2014; Strohmann et al., 2017). It presents several creativity techniques and tries to inspire the users to think about the topic both broadly and deeply. The exact type of thinking supported depends on the interaction with the bot and the presented creativity technique. This component of creativity techniques is also where the chatbot assistant can be placed in terms of the framework by K. Wang and Nickerson (2017). By re-framing the problem, the chatbot can encourage new perspectives on the topic.

Generally, the interaction with the chatbot starts with a message from the bot, stating "Hi, I'm here to help if you get stuck. Just let me know how I can help you!". Users then have two choices represented via buttons (see figure 4.3). In case they are stuck with a specific problem, the bot prompts the user to describe the problem in their own words. Subsequently, the bot asks "Why?" five times, always prompting a new text input from the user. This *5 Why's* technique (Serrat, 2017) forms one branch of the chatbot assistant. Selecting "I can not think of anything else" at any given

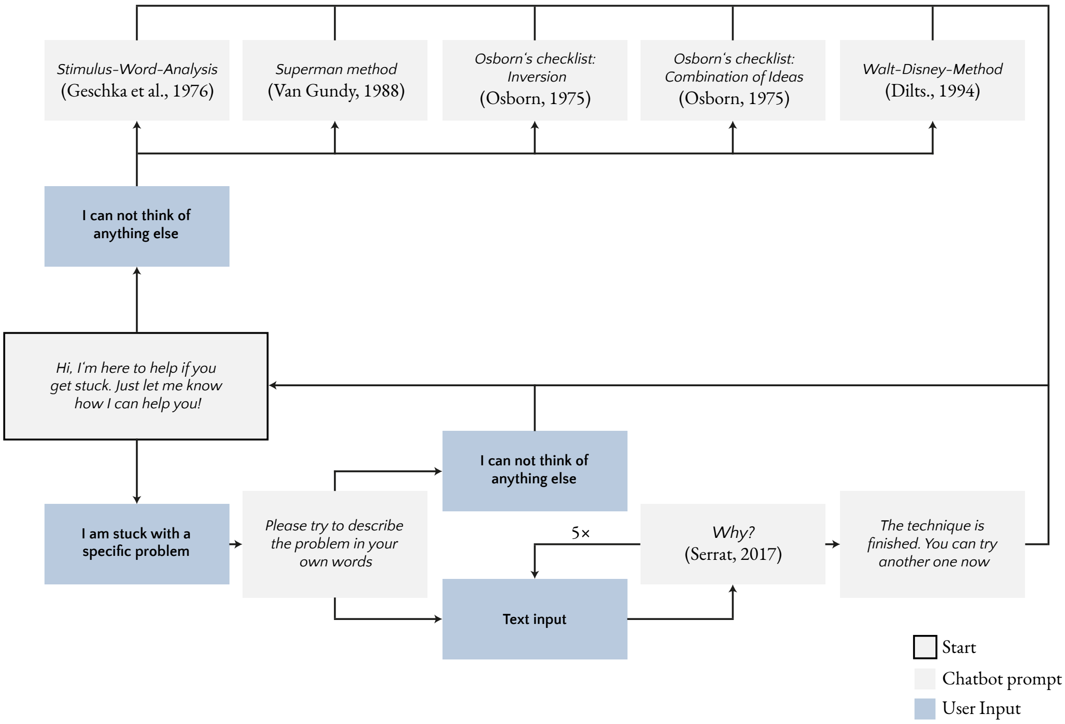

Figure 4.4
Flowchart of possible interactions with the chatbot, including the different creativity techniques presented.

point during the technique, returns the bot to the initial state. In case the users cannot think of anything else, the other branch offers support by using one of five possible techniques to provide a new perspective. Either *Stimulus-Word-Analysis* (Geschka et al., 1976), the *Superman method* (Van Gundy, 2005), *inversion* or *combination of ideas* from Osborn's checklist (Osborn, 1953), or the *Walt-Disney-Method* (Dilts, 1994) are chosen at random. For the full state diagram, see figure 4.4.

The interaction with the bot is completely controllable by the users (Nielsen #7). Since the 5 Why's technique can become tedious after a while due to the repetition, a button to revert to the initial state is always visible (Nielsen #3). The interaction is designed in a conversational flow that provides one technique at a time. This is especially convenient for users who are not familiar with creativity techniques and facilitates easy exploration. With a variety of techniques being easily accessed, the assistant provides a low threshold and high ceilings (Resnick et al. #2). The users are not made aware of the creativity technique which will show up next to foster the users' curiosity and thereby interaction with the assistant. Thus, this random component presents an adequate black box (Resnick et al. #7).

The chatbot was hard-coded using JavaScript, appending static HTML code. All pathways lead back to the initial state of the chatbot eventually, so repeated use is infinitely possible. To enable the display of the full message history, the entire conversation is temporarily saved into a local storage variable.

4.2.3 Inspirational Pictures

The inspirational pictures assistant aims to inspire new ideas based on visual input and combines two components of the framework by K. Wang and Nickerson (2017): working and long term memory. Working memory is addressed by the presentation of pictures based on the keywords from recent ideas (H.-C. Wang et al., 2011). Long term memory is supported by enabling users to search for pictures on a specific keyword (see figure 4.3). Every search request is tied to a keyword, which is why the stimuli tend to be narrow rather than broad.

There are two possible ways of interacting with the assistant: users can either enter a new idea, which will trigger new pictures to be displayed based on a keyword within the idea, or they can manually enter a keyword, thus triggering a search request. The search keyword of the automatic search is always displayed above the search results to ensure users are able to understand how it works (Nielsen #1). Additionally, a small information icon is displayed next to the keyword. Hovering over it with a cursor prompts an overlay with an explanation of how the keyword was selected, i.e., "These pictures are based on the first word of your last idea" (Nielsen #10). The manual search provides users with the freedom to search for keywords independently (Nielsen #3). The interaction with the manual search is possible whenever the users wish, and the automatic search can be used as an extended manual search, thus providing multiple pathways to results (Resnick et al. #3).

The pictures are retrieved via an Application Programming Interface (API) call to Pixabay*. Pixabay was chosen instead of the more popular Google Image Search API, because the search results tend to be less uniform, thus providing more room for inspiration. This comes with the caveat that for complex, very specific keywords, there might be few or no pictures in the database. The basis for the automatic image search is a keyword from the most recent idea. This keyword is extracted from the text by first stripping it of filler words using a keyword extractor*. From the remaining words, the first one is chosen as the search term—or keyword—for the automated picture search. In case no idea has previously been submitted (at the start of the brainstorming session), the automated search uses a keyword from the problem statement. For the manual search, the keyword is set via HTML input field, and can be chosen either via click on the *search* button, or by pressing <enter> on the keyboard (Nielsen #7).

www.pixabay.com/api

www.npmjs.com/package/keyword-extractor

4.2.4 Associative Search

A combination of semantic associations and search tools forms the basis of the third assistant, associative search. Associations are an integral part of creativity (Benedek et al., 2013; Mednick, 1962) and play an essential role the component working memory in the framework by K. Wang and Nickerson (2017). Contrary to traditional search engine interfaces (like for example Google), our assistant does not provide mere single results to a specific search keyword. Instead, the results obtained with this assistant are connected with each other through associative chains, thus supporting diversive curiosity—a type of curiosity less covered by the current Google search User

Interface (UI) (Stefl & Rohm, 2017). The assistant delivers broad stimuli encouraging users to jump from one association to the next, potentially leading them to terms unrelated to the original problem domain.

The interaction with the assistant occurs solely via mouse clicks and is entirely keyword-based. A web of associative keywords is presented as visual cluster to provide inspiration for the search (see figure 4.3). The specific keywords are chosen automatically. The central term is initially based on the problem statement. From this starting point, eight associations are visualized in clickable bubbles. When selected, the respective keyword will form the new central term and new associations will be presented accordingly (Resnick et al. #1, Shneiderman #14). The chain of selected keywords is displayed as a breadcrumb menu at the top of the assistant (Shneiderman #13, Nielsen #6). In case users want to start over, they can either select the first keyword in the breadcrumb menu, or click the *reset* button that is implemented below the visual cluster of keywords (Nielsen #7). Additionally, classical search results on the central term are displayed below the visual cluster (see figure 4.3).

api.wordassociations.net

The list of semantically associated words are obtained using a word associations API*. From an extensive list of associations for the central keyword, the assistant displays the first eight nouns. The assistant is based on nouns only, in order to achieve more uniform—and thus comparable—results. The associated words are displayed using the network display of visjs*, an open source JavaScript library. The breadcrumb navigation bar is loaded from a local storage array. The classical search results are loaded via the Google search API and can be opened in a new tab of the web browser. This element was included specifically as a reaction to the exploration and is an attempt to leverage web search platforms to foster creativity as suggested by Shneiderman (2007) and Stefl and Rohm (2017).

www.visjs.org

4.3 Evaluation

In order to determine which of the approaches supporting creative idea generation was the most promising—both in terms of subjective as well as objective criteria— we conducted a remote study using the CSSs described in section 4.2. The participants were asked to generate “as many good ideas as possible” to tackle four different problem statements while using the developed CSSs (three assistants and a baseline condition without an assistant). In order to determine the quality of support from each assistant, we employed subjective and objective measurements in our study. The number of ideas generated per participant (e.g. A. J. Cropley, 2006), as well as their respective creative quality (which was assessed using the Consensual Assessment Technique (CAT) as described by Amabile; 1982) provided objective data. A preference rating of the different conditions, as well as a calculation of the Creativity Support Index (CSI; Carroll & Latulipe, 2009; Cherry & Latulipe, 2014) were used to gather subjective feedback. As control variables, we assessed demographic data, personality (NEO-FFI; Costa & McCrae, 2008), personal creativity (CANU 2.0), and domain knowledge based on the labels by Dreyfus and Dreyfus (1980).

The following, non-directional hypotheses were formulated for statistical analysis in order to determine what type of digital assistant would support users better:

H_1 The number of ideas generated differs between baseline, chatbot, inspirational pictures and associative search.

H_2 The creative quality of ideas generated differs between baseline, chatbot, inspirational pictures and associative search.

H_3 The CSI differs between baseline, chatbot, inspirational pictures and associative search.

H_4 The preference rating differs between baseline, chatbot, inspirational pictures and associative search.

4.3.1 Procedure & Materials

We conducted a within-subject experiment with a four-level independent variable (baseline, chatbot, inspirational pictures, associative search), comparing the number of ideas generated, their respective quality, assistant preference, and perceived creativity support. The evaluation was divided into two parts: first, we conducted a remote online study, where participants were observed while generating ideas using the different assistants. Second, we sent an online survey link to experts in the fields of the problem statements asking them to rate the generated ideas using the CAT (Amabile, 1982).

The experimental design was approved by the TUM ethics committee (reference 625/20 S)

The first part of this evaluation, the idea generation, was conducted remotely using the video conferencing tool BigBlueButton and the online survey tool LimeSurvey. The video conference served as initial touch point between the participants and the researchers, and to observe participants' interaction with the assistants. After establishing the connection to the video conference and a short welcome, participants were sent the survey link and opened it in a new tab. Following informed consent, a screen recording was started by the researchers. The survey structure was entirely implemented in Limesurvey, leading the participants through all data collection. In case an external tool was used (e.g., the CANU), the survey prompted the participants to open it in a new tab and return to the survey screen after they finished.

The procedure of the study is illustrated in figure 4.5. In the first experimental block, participants were instructed to find "as many good ideas as possible" to solve a predefined problem. The problem statements were chosen to touch on areas that participants were likely to have enough knowledge on to be able to find multiple ideas, as suggested by Siemon et al. (2015). The problems participants worked on were:

- How can supermarkets become more sustainable?
- How can your hometown be transformed to be more attractive to tourists?
- How can bothersome household chores become more pleasant?

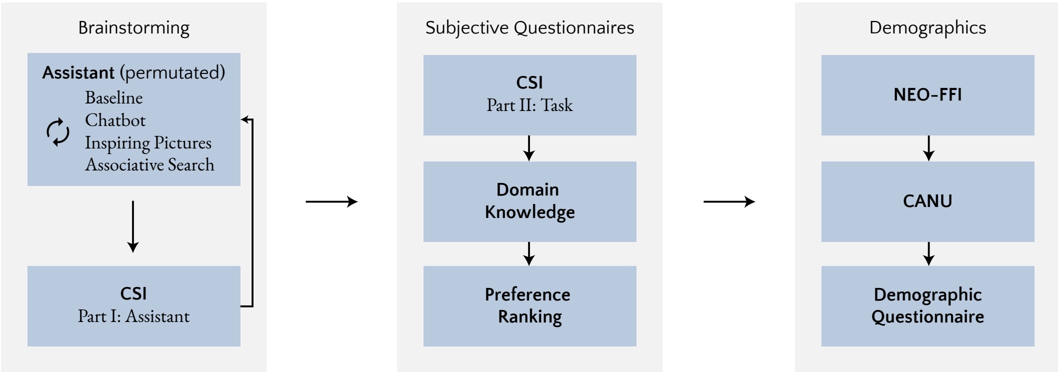

Figure 4.5
Experimental procedure of the evaluation in a between-subjects remote study design.

- How can young people be incentivized to be more involved in politics?

The participants completed four brainstorming sessions of five minutes each. The problem statements, as well as the presentation order of the assistants, were permutated using a Latin square of the order four. In case of the baseline condition (no assistant), the brainstorming canvas extended over the entire screen and took up the area usually reserved for the assistant (see figure 4.2). After each brainstorming session, the participants completed the first part of the CSI regarding the assistant they just worked with. Due to the single-user design of the assistants, all items concerning collaboration were excluded from the CSI. In the second experimental block we assessed subjective questionnaires after all assistants had been presented. It started with the second part of the CSI (which is regarding the task that has been fulfilled). This division of the CSI in two parts, the first of which is measured once for every condition while the second one is assessed only once, is in line with a suggestion by Cherry and Latulipe (2014). Following, the participants were asked to indicate their level of knowledge regarding the four topics of the problem statements on a 5-point scale (labels based on Dreyfus and Dreyfus (1980)). The participants then subjectively ranked all assistants and the baseline condition in order of preference. Additionally, participants had the opportunity to give qualitative feedback on the assistants in a text input field. The third experimental block consisted of the personal assessment. The NEO-FFI (Costa & McCrae, 2008) and the CANU, as well as demographic questions concerning age, gender and domain of study or work, were presented. Lastly, before finishing the study, participants had the opportunity to leave additional comments via text input. One session lasted between 45 and 60 minutes.

After the data collection on the assistants was finished, the generated ideas were categorized (e.g. Tseng et al., 2008) and presented to expert raters using LimeSurvey. In case identical ideas occurred, they were summarized and displayed only once. To accurately represent novelty, the number of times such ideas were generated was displayed in brackets. As suggested by Amabile (1982), the order of categories as well as order of ideas were randomized. As is usual for the CAT, the raters were asked to rate the ideas in comparison to each other on a 5-point likert scale, using their own, subjective definition of creativity. At least three experts were recruited for each problem

Assistant	Quantity			Quality		CSI		Preference
	Total	Mean	SD	Mean	SD	Mean	SD	Median
Baseline	244	8.71	2.93	2.99	0.471	46.2	17.7	3
Pictures	223	7.96	2.96	3.02	0.448	46.2	16.1	3
Chatbot	188	6.71	2.46	3.08	0.539	49.3	19.4	1.5
Associations	205	7.32	3.32	3.14	0.483	46.6	19.7	2

Table 4.2
Quantity, quality, and creativity support index of ideas generated, as well as preference ranking using the different assistants.

statement. Following Amabile (1996), experts with some formal training or experience in the target domain were selected*.

Sustainability: Climate Club Center of Digital Technology Management, Rehab Republic (NGO in Munich)
Tourism: Students of the Tourism Management study program (Hochschule München), Tourist Office Munich, tourism organizations
Household: People actively managing a (private) household
Politics: Student associations in Political Sciences (e.g., Technical University Munich), members of political parties

4.3.2 Results

In total, $N = 29$ participants took part in the experiment. One person was excluded due to a technical problem in the data recording back-end, resulting in an incomplete dataset. Therefore, $n = 28$ participants (14 female) from the age of 17 to 33 ($M = 24.61, SD = 3.06$) were included in the analysis. Descriptive data on the quantity and quality of generated ideas, the CSI, and preference ranking of the assistants can be found in table 4.2 and will be analyzed in detail in the following sections.

Quantity of Ideas

To explore the effects of the assistants on the quantity of ideas generated by the participants, we investigated the number of ideas the participants came up with per condition. The participants created a total of 860 ideas throughout all conditions. On average, they created the most ideas in the baseline condition ($M = 8.71$), followed by pictures ($M = 7.96$), associations ($M = 7.32$), and chatbot ($M = 6.71$; see table 4.2). A one-way repeated measures ANOVA revealed a significant effect of condition on the number of ideas ($F(3, 81) = 5.75$, $p = .001$, $\eta^2_G = 0.062$). Post-hoc analyses using multiple pairwise paired t-tests with Bonferroni adjustment revealed that there was a statistically significant difference between baseline and chatbot ($t(27) = 4.15, p = .002$). A comparison of the means shows that participants generated more ideas using the baseline condition. The other differences were statistically non-significant.

Quality of Ideas

To investigate the effects of the assistants on the quality of ideas generated by the participants, we analyzed the idea quality as assessed by raters in the CAT per condition. On average, the participants created the most creative ideas using the association assistant ($M = 3.14$), followed by the chatbot ($M = 3.08$), the pictures assistant ($M = 3.02$), and the baseline condition ($M = 2.99$; see table 4.2). A one-way repeated measures ANOVA revealed no significant relationship between condition and the quality of ideas ($F(2.03, 54.71) = 0.57, p = .574, \eta^2_G = 0.015$). Mauchly's test indicated that the assumption of sphericity had been violated ($p < .001$). Thus, Greenhouse-Geisser correction has been applied, resulting in adjusted degrees of freedom.

The inter-rater reliability was—as is custom for the CAT (Cseh & Jeffries, 2019)—calculated via internal consistency using Cronbach's alpha. Sustainability (3 raters, 221 ideas) showed an $\alpha = .18$, politics (5 raters, 188 ideas) an $\alpha = .29$, household (3 raters, 230 ideas) an $\alpha = .45$, and tourism (3 raters, 220 ideas) an $\alpha = .47$. Thus, internal consistency should be considered unacceptable for all questions (Tavakol & Dennick, 2011).

Creativity Support Index

To explore subjective differences of perceived creativity support, we investigated the participants' rating of the different conditions on the CSI. On average, the participants felt best supported by the chatbot assistant ($M = 49.3$), followed by associations ($M = 46.6$) and pictures ($M = 46.2$) as well as baseline ($M = 46.2$; see table 4.2). A one-way repeated measures ANOVA revealed no significant effect of condition on the perceived support ($F(3, 81) = 0.38, p = .77, \eta^2_G = 0.005$).

Preference

Subjective preference of the conditions was explored using the means of the preference ranking. This ranking of preferred assistants was lead by the chatbot ($Md = 1.5$), followed by associations ($Md = 2$), and concluded by pictures ($Md = 3$) as well as baseline ($Md = 3$; see table 4.2). A Friedman test was carried out to compare the preference rankings for the four conditions. It revealed a significant difference, $\chi^2(3) = 8.36, p = .039$. Post-hoc comparison via paired Wilcoxon signed rank tests revealed no significant differences between any two specific conditions, due to the adjusted p-value (Bonferroni). Visual comparison of the ranks (see figure 4.6) and median data (see table 4.2) suggest that participants preferred the chatbot and association assistants, as opposed to the inspirational picture assistant and baseline condition.

Exploration

Additionally to the tests regarding the hypotheses, we performed exploratory analyses on the relationships between personal creativity (CANU) and personality (NEO-FFI), quantity of ideas, perceived creativity support (CSI) and preference of the assistants. Due to the unacceptable inter-rater reliability, the exploratory analysis regarding the quality of ideas was omitted.

Correlations using Pearson's correlation coefficient revealed very few significant results. CANU usefulness correlates with agreeableness ($r(26) = .44, p = .020$) and CANU novelty correlates with

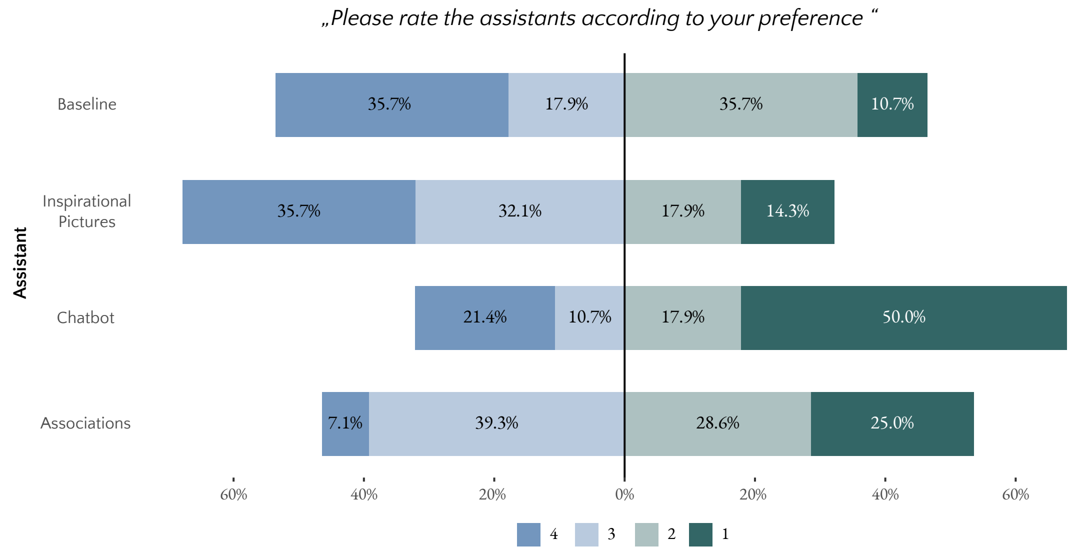

Figure 4.6
Ratings of $N = 28$ participants regarding their preferred assistants. Here, 4 equals the worst, 1 the best rating.

perceived creativity support of the baseline condition ($r(26) = .39$, $p = .043$). Other than that there were no significant relationships in the data.

To explore the time the participants spent on the interaction with each assistant, we retrospectively measured it using the screen recordings. Interaction time was defined as period of actively using the assistant, depending on mouse movements and clicks, and resulted in pictures: $M_p = 63.5$ s, $SD_p = 42.0$ s; chatbot: $M_c = 76.8$ s, $SD_c = 41.2$ s; associations: $M_a = 82.6$ s, $SD_a = 50.60$ s. Opposed to that, in the baseline condition with no assistant present, the entire time could be used to generate ideas.

4.3.3 Discussion

In this study, we investigated the influence of three different CSSs on the users' performance in terms of idea quantity and idea quality. Additionally, we assessed subjective user preferences and perceived creativity support in the four conditions. The effectiveness of the assistants differed based on the various criteria. The participants produced significantly more ideas when brainstorming without assistants when compared to the chatbot assistant. Focusing purely on idea quantity, it is reasonable to argue that a brainstorming tool without assistants could be more helpful than one including them. This is additionally supported by the qualitative feedback, in which some participants stated several of the assistants were somewhat "distracting". This is particularly relevant when a time limit for brainstorming is given, as was the case here. A potential solution—besides increasing the time limit—might be to allow participants to toggle the assistant panel. This way, visual distraction would be less dominant and assistants could be of use depending on the users' needs in a specific context, e.g., when getting stuck. This is in line with results by Gamper (2019), who identified two types of users: those who prefer feedback on ideas immediately, and those who prefer it towards the end of an ideation session. This preference can be predicted using individual motivation and domain knowledge, as users preferring immediate feedback tend to be less motivated and knowledgeable. Hence, we propose to present our assistants as support for when users are stuck.

The imposed time limit of five minutes per brainstorming session was deliberately set to avoid participants' fatigue during the study. This, however, might have impacted the number of ideas, especially considering the fact that some of the time for the assistant conditions was used to interact with the assistant. Extending the time limit may help balance between assistants which require users to interact a lot, and assistants where not much intentional interaction is needed.

There were no significant differences regarding the quality of ideas produced. Although a comparison of the means suggests that ideas generated with assistants that provide exploratory stimuli and require increased interaction (chatbot and associations) tend to be more creative, no significant difference was observed. This—again—could be attributed to the small time frame in which ideas needed to be generated, leaving little room for exploration of the assistants. Additionally, the unacceptable inter-rater reliability across all problem statements makes comparisons regarding quality less than ideal. This problem might be tackled by recruitment of more raters, although the appropriate number and proper selection of raters is a field of major discussion within the community. Daly et al. (2016) achieved acceptable inter-rater reliability (α = .70) with only two judges, whereas Valgeirsdottir et al. (2015) employed 134 judges but did not report inter-rater reliability. This variance in number of raters is one of the problems with the application of the CAT and is described in more detail in Cseh and Jeffries (2019).

All assistants seem to be perceived similarly according to the CSI that is comprised of the sub-domains *enjoyment*, *exploration*, *expressiveness*, *immersion* and *results worth the effort*. One reason for the similarity of scores between the noticeably different support mechanisms of the assistants could be that the brainstorming canvas was overall predominant. This could be due to the visual repetition or the statements of the CSI themselves, as they did not specify any assistant, but rather referred to a "system". This might be remedied by replacing the term system by the name of the CSS, as suggested in literature (Cherry & Latulipe, 2014). A comparison of the means still suggests that the chatbot might be superior in terms of perceived creativity support. This, however, would need to be reassessed in an additional study.

The preference of assistants varied significantly, but post-hoc tests were unable to identify specific differences due to the correction of p-values. An inspection of the data, however (see figure 4.6), revealed that the two assistants with which the most ideas were generated were less preferred by the participants. This is particularly interesting as subjective preference is crucial for users to willingly interact with an assistant outside of the experimental setting. Intrinsic motivation is a key factor for creativity (Amabile, 1983; 1996) and can be subject to change depending on the interactive experience with a user interface (Venkatesh, 2000). Using the preference ranking, we cannot infer whether there are conditions, or a threshold, below which participants would not use a specific assistant. Neither is it certain that the distance between the ranks is uniform. It is, however, noteworthy that the two assistants that were preferred in the ranking, chatbot and associative search, are also the two conditions in which participants produced more creative, albeit fewer ideas when compared to inspirational picture assistant and baseline condition.

Limitations & Future Research

The time limit of five minutes per assistant was deliberately short to avoid participants' fatigue during the experiment. This procedure, however, resulted in little time for interaction with the assistants, and should be considered especially in the interpretation of idea quantity (see also section 4.3.3).

The quality of ideas was assessed with the CAT. The number of experts used varies in literature. Silvia (2008) points out that "One is clearly not enough; 20 seems like overkill" (p.81). While Amabile (1982) used between 3-21 raters, Kaufman, Plucker, and Baer (2008) state that 5-10 raters should be sufficient. Due to difficulties in recruiting, each domain in this study was rated by just 3-5 raters. This reduced number of raters might be responsible for the bad internal consistency.

With the study set as a remote experiment, participants were provided with "artificial" tasks and problem statements. Even though problems were chosen to be relatable in a sense that everyone could gather ideas for them, the ecological validity of the study might be lower, as task motivation is an influencing factor (Amabile, 1996; 1997). Depending on personal interest for the different topics, this might have influenced responses. This, however, is common in contemporary research and controllability is preferred over the alternative of letting participants chose their own topics.

The exploration, design, and evaluation of a CSS, described as a "grand challenge for HCI" (Remy et al., 2020; Shneiderman, 2009), in this research did reveal interesting insights. However, this research is by no means complete. While we were able to demonstrate the general potential and openness for using CSSs in daily work, none of the developed assistants was a cut above the others—or the baseline condition for that matter. As discussed in section 4.3.3, this might be due to the limited interaction time. Particularly since one of the assistants (inspiring pictures) has been described as "distracting" by participants. At the same time, the exploration identified a need for support, specifically in idea generation. This, combined with subjective data from the evaluation suggests that development of chatbot as well as associative search should be continued. Generally, a call has been made—in reference to Nielsen (1994b)—to develop discount CSS evaluation methods. Not low of quality but with widespread access and low cost, to advance the development of new tools (Remy et al., 2020)

Especially considering these two most preferred assistants, chatbot and associative search, framing and fixation are promising areas of future research. While both assistants resulted in fewer but more creative ideas, in the context of a larger study, participants could be nudged towards a certain direction of ideas by the design of the assistants. In case of the chatbot assistant, apparently verbalizing the specific problems that needed to be tackled, helped participants in solving them—a phenomenon well known in cognitive science (Gagné & Smith, 1962). However, interaction with and design of chatbots is highly susceptible to framing in general (Araujo, 2018; Chaves & Gerosa, 2021). Especially in the context of a chatbot as CSS it would be very counter-productive to have a divergent assistant causing users to focus on particular areas, or problem solving strategies.

CHAPTER 5

Discussion

Creativity as challenge for human factors, various other scientific disciplines, and individuals is the overarching theme of this thesis. In our modern world, characterized by Volatility, Uncertainty, Complexity and Ambiguity (VUCA), the human capability for error is not only a detriment, but also an asset—if managed properly. This entails revision of and learning from those mistakes, and is emphasized by frameworks such as agile working (see Fowler, Highsmith, et al., 2001) and design thinking (see Brown, 2008). The ultimate goal is to foster creativity at work. After introductory thoughts, on creativity, work, and why creative work is bound to become increasingly relevant in the future, we established two major research areas: creativity measurement and creativity amplification. We subsequently analyzed creativity measurement in terms of its history, traditions, current approaches, and shortcomings. In terms of creativity amplification, we introduced the gaining momentum in the Human Computer Interaction (HCI) community, and identified creativity as paradigm, as well as grand challenge for HCI. To tackle the cluttered landscape of creativity measurement, we proposed a new approach, the Creativity Assessment via Novelty and Usefulness (CANU) and its development and evaluation were described in two iterations. Due to the mostly theory-driven approach in contemporary research for creativity amplification, we conducted an exploration regarding the users' need for Creativity Support Systems (CSSs), as well as an evaluation of three different approaches. The results provide insight into the two major areas of research, as well as the recommendation that they should not be regarded separately.

5.1 Results Revisited

The results regarding the CANU, a newly developed, scalable and easy to use approach at measuring creativity are inconclusive but promising. Neither the first, nor the second iteration could convincingly show their quality regarding validity. However, the usefulness and the novelty of solutions correlated negatively in both versions, a result commonly found in literature (M. E. Manske & Davis, 1968; M. McCarthy et al., 2018). Particularly useful solutions tend to be common—thus, they are not novel, and therefore not creative (Diedrich et al., 2015). We did not find any relationship between objective and subjective creativity measurements, an effect that has been considered relatively stable in the literature (Batey, 2012). However, Kurtzberg (2005) has reported results similar to ours in team creativity. Diedrich et al. (2018) argue that self-assessment might be more suitable for little-c creativity assessment, whereas other assessment might be more appropriate to describe Pro-c creativity. This would render the CANU novel in a sense that it is an other-rated type of measurement tool specifically aimed at little-c creativity. The major issue with version 1.0 of the CANU was that solutions were not similar enough. This indicates great freedom for participants and therefore the desirable characteristic of an open solution space. At the same time, this resulted in overall novelty values that were skewed towards higher novelty. This was remedied in version 2.0 by dropping the semantic-associative task (new words) and reconfiguration of the visual-constructive task (blocks) to have a smaller amount of possible perfect solutions. In this second version of the CANU (puzzle task), the comparability of solutions was much better and resulted in more naturally distributed data. While no differences could be found for the CANU data between the two experimental groups (motivated vs. unmotivated), neither was there a difference in the self-rating data. This suggests that the employed experimental manipulation was not sufficient to result in meaningful effects. However, the majority of participants stated that the CANU required creativity in order to be solved well.

Both studies failed to find novelty, usefulness, or intelligence accounting for a significant amount of variance of creative personality in the CANU versions 1.0 and 2.0. This result indicates that the CANU measures a construct other than intelligence and thus supports the discriminant validity of the CANU. The relationship between intelligence and creativity is a controversial one though. While Guilford (1967) suggested that high or at least above-average intelligence is required to be creative, more recent studies find that the two constructs only correlate up to a certain threshold (e.g. Cho et al., 2010; Fuchs-Beauchamp et al., 1993). The exact value of the threshold, or the existence of one at all, varies depending on the indicator of creativity, e.g., creative potential or achievement (Jauk et al., 2013). Overall, the theory is not undisputed, as some studies found correlations only above a certain threshold (Runco & Albert, 1986) or found no threshold at all (Kim, 2005). Individual characteristics of the solutions replicate a fact known from literature: increased complexity often goes hand in hand with increased creativity (Eisenman, 1990). Still, two main objectives of the measurement instrument, ease-of use and scalability, could be demonstrated. Considering the small sample size of the evaluation—which is particularly relevant since the test is decidedly designed to work with bigger samples—our results are still promising. The benefits of iteration CANU 2.0 were clearly visible against version 1.0.

Providing automated measurements embodies a contemporary approach for capturing creativity that embraces digitization and is well within the zeitgeist. The application of the CANU in the assistant study proved it easy-to-use. Our exploratory analysis revealed a positive correlation between agreeableness (subscale of the creative personality) and usefulness, as well as novelty and the perceived creativity support of the baseline condition without an assistant. This result is particularly interesting, as it could point toward the trend that people who are well equipped to produce novelty in a brainstorming task and do not require assistance are also the ones generating particularly novel results with the CANU. Since the analysis is of an exploratory nature, however, no causality should be implied. Despite its advantages, one of the biggest (and systemic) shortcomings of the CANU is that the creation and subsequent automatic analysis of unexpected results is not possible in the current implementation. This is due to our theory-based approach in developing the CANU, relying on novelty and usefulness only, disregarding surprise.

The exploratory, human-centered approach on how support for creative workers could best be achieved yielded promising results. However, no clear differences between inter-domain and intra-domain effects were revealed. This is might be of decreased significance though, as no relationships between domain and modus operandi were found. Thus, the process that creatives follow, seems to be consistent across domains. This domain-consistency has been suggested by some researchers before (Hong & Milgram, 2010; Scotney et al., 2019). Most participants in our studies considered divergent thinking as harder to do than convergent thinking and indicated they used divergent thinking less in their daily lives. Divergent thinking is most commonly associated with the phase of idea generation (Runco & Jaeger, 2012). As such, it is unsurprising that participants sought out advice the most during idea generation, making this phase the most intuitive and therefore common phase for CSSs support (e.g. Gabriel et al., 2016; K. Wang & Nickerson, 2017). However, the participants in our interviews suggested CSSs to support the information (re)search instead of the idea generation. This finding indicates a gap between the wants and needs of potential users, and the goals of the designers of CSSs. This gap might exist because users underestimated the capabilities of potential ideation support. It might, however, also exist because providing stimuli for ideation is fairly easy to implement. Still, results showed a need for CSSs as well as participants' willingness to use them in daily work.

In terms of the assistants that were developed and evaluated, participants' idea quantity was highest in the baseline condition when not using an assistant. This result is counter-intuitive but can be explained by the imposed time limit of five minutes. The effect is twofold. On the one hand, participants needed time to interact with the assistants—time that was not used for the creation of ideas. On the other hand, the time frame was short enough, and the proposed problems complex enough, that participants could intrinsically come up with plenty of ideas. Thus, the assistants were simply not needed, as exemplified by their description as "distracting" in the qualitative feedback by one participant. The quality of ideas produced did not vary between the assistants. The unacceptable inter-rater reliability across all problem statements requires a cautious interpretation of the results, however. While one could argue that more raters would need to have been recruited, rater selection as well as number of raters is a matter of lively debate (Cseh & Jeffries, 2019). This debate signifies—among others—the shortcomings of current creativity measurement systems, especially for fundamental research, where easy-to-use and scalable data acquisition tools are indispensable. There were no differences in perceived creativity support, as assessed by the Creativity Support Index (CSI). This lack of effect of the—considerably different—assistants could have occurred because the digital brainstorming assistant as such was predominant. Even though subjective preference varied significantly, post-hoc tests did not reveal significant results due to the correction of *p*-values. Comparison of the means showed that the two assistants that produced the most ideas were preferred the least. Since intrinsic motivation is a key factor for creativity (Amabile, 1983; 1996) and can be subject to change depending on the user interface (Venkatesh, 2000), this might be an indicator that chatbot as well as associative search assistant are worth continued development.

5.2 Objective vs. Subjective Assessment

The application of the Consensual Assessment Technique (CAT) as subjective and the CANU as objective tool in the studies revealed a particular difference between objective and subjective assessment caused by the distinction between open and closed design tasks (see Unsworth, 2001). Closed design tasks refer to tasks where the problem, as well as the presentation of the problem, is known, such as an algebra problem presented to students in class (Getzels, 1975). Open design tasks are commonly understood as tasks where participants are required to initially discover the underlying problems, such as most artistic endeavors (Dillon, 1982). Typically, real-life design tasks are of open-ended character (Gero & Milovanovic, 2020). Open design tasks can—due to their complexity—only be assessed by human raters, thus requiring subjective assessment. The CAT, as a representative of measurement for open design tasks, is particularly useful to detect and rate historical creativity, due to the knowledge and judgment by raters. The CANU—a typical representative of the closed task paradigm—can primarily infer personal creativity, despite its database which provides access to all previous solutions. This is a typical caveat of distribution-based novelty assessment and can be clarified in an example. The CANU determines a specific design to be novel when it is far from the mean of the large dataset. If it were produced again it will still be assessed as novel, since the effect of having two identical outliers in a very large dataset is minimal. However, subjective assessment (as employed in the CAT) would not deem the second occurrence particularly novel. As such, the methodology used to determine novelty can produce results that do not match human assessment of novelty. The method allows for a number of identical solutions (generated by any individual) to be classified as novel until their combined weight changes the distribution. This beautifully illustrates the differentiation between historical and personal creativity. All historical creativity must also be considered personally creative (see figure 5.1, Prasch & Bengler, 2019). This is a concession that can be made in terms of researching creativity from an Human Factors/Ergonomics (HFE) perspective. While historical creativity might be more glamorous, personal creativity is more fundamental (Boden, 1996). All influences regarding an individuals personal creativity should be true for historical creativity as well.

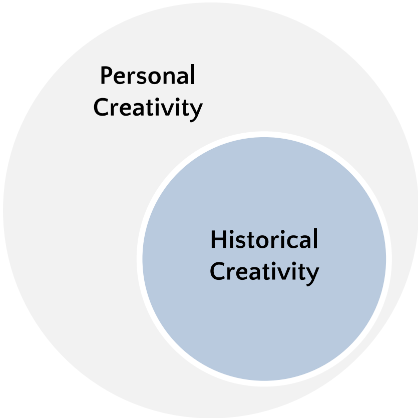

Figure 5.1
Historical creativity as a subset of personal creativity.

A more problematic concession, are the problems inherent to subjective assessment. While the comparability and the scalability of results have been discussed in chapter 3 and in a special issue on pitfalls of creativity measurement (Barbot & Reiter-Palmon, 2019), subjectivity can pose additional problems in terms of rater selection and idea rating. For example, when running a typical inspiration-fixation study (for an overview, see Crilly, 2019) that collects ideas—designs, sketches, or others—from participants, the subsequent assessment essentially represents an additional experiment, with recruitment of assessors, treatment of outliers, etc. J. S. Mueller et al. (2012) reported a bias against creativity, inhibiting participants to properly recognize creative ideas. This is particularly unfavorable for the CAT and other subjective or open creativity assessment techniques. According to Cseh and Jeffries (2019), the CAT has been very successful due to its apparent simplicity of use. However, the authors have identified task selection, number of judges, presentation of stimuli, rating procedure (most notably number of items per rater/rater fatigue), and statistical test choice—so effectively the entire CAT—as widely non-standardized (Cseh & Jeffries, 2019). This underlines the proposition that the current "gold standard" of creativity measurement is less of a standard, and more of a tool used at individual discretion. As Glăveanu (2019) and Snyder et al. (2019) showed, creativity measurement remained practically unchanged since the early 80s, despite continued discussion of the issues in assessment (Plucker et al., 2010; Vartanian et al., 2019). The field is currently evolving rapidly, but the lack of standards challenges external validity to a great extend (Barbot, Hass, & Reiter-Palmon, 2019). Unfortunately, creativity measurement was, and remains the Achilles heel of creativity research (Kaufman, 2014).

5.3 The Danger of Fixation

The two most preferred assistants were the chatbot and the associative search. Both utilize—to a certain degree—a verbalization of the current problem, with the latter including additional inspiration. The fact that verbalization can facilitate the discovery of general principles and promote success when solving well-defined problems (e.g., Tower of Hanoi) has long been known in cognitive science (e.g. Gagné & Smith, 1962). More recently, it has also been demonstrated to benefit insight-problems (Gilhooly et al., 2010). However, verbalization and the provision of associative and verbal stimuli have been shown to introduce *fixation* in open-ended design tasks (Malaga, 2000; K. Wang & Nickerson, 2019). Design fixation describes a phenomenon, where designers inappropriately reuse previously seen features or principles in suboptimal ways (Cardoso & Badke-Schaub, 2011). They can be constrained by examples or their inherent knowledge in such a way that so that fully exploring the design space becomes difficult (Berg, 2014; Jansson & Smith, 1991). Thus, the provision of stimuli and the proposition of verbalization in general must be implemented with caution in order to avoid said effects. This is particularly relevant for the associative search assistant because the degree to which a stimulus is related to the creative task is one of its most important properties (Santanen et al., 2004). The relationship of inspirational stimuli with creativity, however, is a matter of debate. While Mednick (1962) and Nijstad and Stroebe (2006) suggest that greater cognitive distance of stimuli should lead to more novel associations and thus more creative output (a notion that has some empirical support, e.g., Chiu & Shu, 2012; Hender et al., 2002), there are studies that revealed no effect (Malaga, 2000; Tseng et al., 2008). Recent results even associated remote associations with lower creativity (Althuizen & Wierenga, 2014; Chan et al., 2018). Especially considering the associative search assistant, this relationship and the cognitive distance between the task and the stimuli is easily traceable. Depending on the number of clicks that participants perform, or how far along they follow the associative path, the degree of stimulus relatedness is either high, or increasingly low. In a recent study, K. Wang and Nickerson (2019) investigated the relationship between associative stimuli and creativity using hyperlinks from Wikipedia articles. They showed that closely related stimuli promoted idea quantity and usefulness, and remotely related ones led to ideas of higher novelty in comparison to no stimuli. The authors suggest to generate stimuli that are not random but related to the creativity task in varying degrees. This is supported by Vasconcelos and Crilly (2016), who suggest the existence of an optimal distance between problem and stimuli. However, research has only offered general suggestions as to what this distance is (Vasconcelos & Crilly, 2016). In future research, the association assistant should be investigated in terms of the influence of near and far associated stimuli on creativity of ideas as well as potential fixation.

CHAPTER 6

Conclusion

Evaluation and amplification of creativity are simultaneously challenging and fascinating. The number of disciplines concerned and ongoing discussions regarding definitions and criteria have led to a plethora of alternative approaches to creativity (Barbot, Hass, & Reiter-Palmon, 2019). As Gardner (1988) put it, "creativity is precisely the kind of problem which eludes explanation within one discipline" (p. 22). Human Factors/Ergonomics (HFE) is—due to its interdisciplinary core—particularly well suited to bring order into this creative chaos. Not only is HFE particularly well suited to address the issue—but given the ongoing trend towards automation, and creativity as a final frontier for Artificial Intelligence (AI)—the future of human work will be shaped by the phenomenon that is creativity (Prasch & Bengler, 2019). To research the demands put on humans by a constant requirement for creativity and the definition of rules that can ensure continued well-being for workers must therefore be a focal point for HFE in the years to come. After all, the discipline has been fairly successful at this in the domain of manual labor in the past. This is especially true not only for retrospective measurement but proactive design of systems that humans will interact with in the future (*prospective ergonomics*; Bubb, 2012). As was the case with manual labor, development of comprehensive measurement instruments lies at the beginning of this journey. The approach presented within this thesis, Creativity Assessment via Novelty and Usefulness (CANU), provides one starting point. Generally, the concept of automated scoring on large samples to overcome manual scoring drawbacks is increasingly being tested in contemporary studies (e.g. D. H. Cropley & Marrone, 2021; Olson et al., 2021). As described, the initial version of the CANU was still rather crude and unable to properly quantify creative output. For the second iteration, however, participants already agreed that creativity was necessary to perform well. This concept of iteration, or learning from previous results (and mistakes), is inherent to the scientific process, modern project management, and creativity itself.

The tendency to make mistakes is a characteristic feature that sets humans apart from machines. Deviating from regular behavior is one of the key features of our creative capacity. Just as in nature, where random permutations of lifeforms occur and the survival of the fittest leads to continuous improvements, humans can learn from mistakes and progress (Amabile & Pratt, 2016; Bubb, 2006). This capacity to adopt and acquire new skills is the reason why human labor has prevailed (Frey & Osborne, 2017; Goldin & Katz, 2018), and the world of work has not—despite doomsayers, both old and new (e.g. Keynes, 1930; Susskind, 2020)—eliminated the human element. To neglect the trend towards, and enormous potential of automation, however, would be foolish. In order to reap the rewards of automation and its phenomenal potential to increase productivity, but also leverage humans and their capacity for complex critical thinking, social intelligence and creative problem solving, interaction between both parties is imperative (Bubb, 2006). This, however, requires a stronger focus on human-machine interaction with the goal of creative output, especially from the discipline HFE. This long-standing endeavor, called Intelligence Augmentation (IA) (Engelbart, 1962) has often been in competition with AI. For creativity and its unique properties, however, a synthesis of the two, Artificial Intelligence Augmentation (AIA), seems appropriate (Carter & Nielsen, 2017). First results of this emerging field are machines that purposefully make mistakes (Knight, 2021). In a recent approach, McIlroy-Young et al. (2020) created an AI that aligns an algorithmic approach with the human one in the domain of chess. By predicting human errors, the authors hope to eventually facilitate the exchange of humans and AI as partners. In order to develop systems like these for creative performance though, a better understanding of the role of error in creative problem-solving is required (Mumford et al., 2006). Along the way, errors are bound to be made. These, when properly analyzed and learned from, however, might facilitate creativity, the very phenomenon necessary to promote itself as a research subject.

the danger of computers becoming like humans
is not as great as the danger of humans
becoming like computers

—— *Konrad Zuse*

Acknowledgements

As is the nature of the scientific process, a thesis like this can never be the work of a singular person. Not unlike many before me, I have seen further by standing on the shoulders of giants. Besides the giants who have contributed to this dissertation through their scientific achievements, some additional—no less great—contributions must be mentioned separately. First and foremost, I would like to thank my supervisor, Prof. Klaus Bengler for his trust in me and his willingness to let me walk off the beaten track. Only this freedom to pursue a topic that I was truly interested in enabled the present research. Additionally, I would like to thank Prof. Sebastian Pfotenhauer for being available as a second examiner of this thesis.

Secondly, I want to shout out all the great colleagues that I have met at the Chair of Ergonomics over the years—some of which have become dear friends. It was truly inspiring to work in an environment so full of vibrant enthusiasm, unrestricted support, and willingness to discover. To start an (incomplete) list of names, I would like to thank my mentor (and constant, necessary nuisance) Patrick Gontar. If it were not for your relentless questions on the status of my thesis, I would probably never have started writing, not to mention actually finished it. The "old guard" of Moritz Körber, Jonas Schmidtler, and Markus Zimmermann, who welcomed me with open arms and taught me a thing or two about science, the bigger picture, and life in general. And of course Caroline Adam, Philipp Maruhn, and Jakob Reinhardt for motivation, discussion (sometimes less of a scientific nature), and making my time at the Chair as wholesome to remember as it is.

Over the years, I had the pleasure of working with and teaching countless students that have inspired me immensely. From student theses[*], over developing, maintaining, and restructuring a massive open online course[†], to starting a new project format focused on teaching creativity[‡], I have learned to trust in their work, let the reigns loose, and appreciate the powerful motivator that is a common goal.

Lastly, my friends and family. Stefan Tretter for motivating me to get into academia in the first place (after all, how hard can it be?). My mom and my dad—thank you for all the support you have given me over the years. From learning Latin vocabulary (sorry about that), to instilling in me a dare to think for myself and ask the fundamental questions. And my sister Johanna, who is not only a scientific force of nature, but also the most rigorous reviewer I happened to know as a baby. To all of you: so long, and thanks for all the fish!

[*] Adrian Abele, Michael Drexler, Marcel Brünn, Julia Büttler, Hedwig Kursawe, Sebastian Pütz, Marlene Schlorf, Lena aus dem Bruch, Jonas Bender, Mariangela Scotto di Carlo, and Miriam Thelen

[†] David Schopf, Niklas Lütteken, Nicolas Härtwig, Peter Eliseenkov, Christina Rosenmöller, Gideon Kloss, Kristina Strobl, Moritz Rettinger, Tim Westhoff, Sebastian Schmeiser, Jonas Bender, Christian Barthelme, Franziska Buck, and Benedict Gruber

[‡] Sophie Sikora, Luis Monleón, and Max Rost

Acronyms

A&V	Adjectives and Values Scale
ACL	Adjective Check List
AI	Artificial Intelligence
AIA	Artificial Intelligence Augmentation
APA	American Psychological Association
API	Application Programming Interface
APM	Advanced Progressive Matrix
ASI	Achieving Styles Inventory
BFI	Big Five Inventory
BICB	Biographical Inventory of Creative Behaviors
CAT	Consensual Assessment Technique
CANU	Creativity Assessment via Novelty and Usefulness
CAQ	Creative Achievement Questionnaire
CBI	Creative Behavior Inventory
CCQ	Creative Climate Questionnaire
CDQS	Creativity Development Quick Scan
CDQ-R	Revised Creativity Domain Questionnaire
CPS	Creative Personality Scale
CPSS	Creative Product Semantic Scale
CSS	Creativity Support System
CUCEI	College and University Classroom Environment Inventory
CSDS	Creative Solution Diagnosis Scale
CSI	Creativity Support Index
ECCI-m	Epstein Creativity Competencies Inventory for Managers
HCAY	How Creative Are You
HCI	Human Computer Interaction
HFE	Human Factors/Ergonomics
ICAA	Inventory of Creative Activities and Achievements
JIB	Jones Inventory of Barriers
KEYS	KEYS: Assessing the Climate for Creativity

IA	Intelligence Augmentation
MuPeT	Multi-Perspective Thinking
MSI	Mode Shifting Index
OAI	Organizational Assessment Instrument
SOQ	Situational Outlook Questionnaire
SSSI	Siegel Scale of Support for Innovation
TCI	Team Climate Inventory
TTCT	Torrance Test of Creative Thinking
UCD	User-Centered Design
UI	User Interface
VUCA	Volatility, Uncertainty, Complexity and Ambiguity
WES	Work Environment Scale
WKCT	Wallach-Kogan Creativity Test

Figures

Tables

Bibliography

Abraham, A. (2016). Gender and creativity: an overview of psychological and neuroscientific literature. *Brain Imaging and Behavior*, *10*(2), 609–618. https://doi.org/10.1007/s11682-015-9410-8

Acar, S., & Runco, M. A. (2014). Assessing Associative Distance Among Ideas Elicited by Tests of Divergent Thinking. *Creativity Research Journal*, *26*(2), 229–238. https://doi.org/10.1080/10400419.2014.901095

Acemoglu, D., & Restrepo, P. (2018a). Artificial Intelligence, Automation and Work. *SSRN Electronic Journal*, (May), 197–236. https://doi.org/10.2139/ssrn.3098384

Acemoglu, D., & Restrepo, P. (2018b). The Race between Man and Machine: Implications of Technology for Growth, Factor Shares, and Employment. *American Economic Review*, *108*(6), 1488–1542. https://doi.org/10.1257/aer.20160696

Ai, X. (1999). Creativity and Academic Achievement: An Investigation of Gender Differences. *Creativity Research Journal*, *12*(4), 329–337. https://doi.org/10.1207/s15326934crj1204_11

Albert, R. S., & Runco, M. A. (1999). A history of research on creativity. *Handbook of Creativity*, *2*(0502167), 16–34. https://doi.org/10.1017/CBO9780511807916.004

Alipour, L., Faizi, M., Moradi, A. M., & Akrami, G. (2018). A review of design fixation: research directions and key factors. *International Journal of Design Creativity and Innovation*, *6*(1-2), 22–35. https://doi.org/10.1080/21650349.2017.1320232

Althuizen, N., & Wierenga, B. (2014). Supporting Creative Problem Solving with a Case-Based Reasoning System. *Journal of Management Information Systems*, *31*(1), 309–340. https://doi.org/10.2753/MIS0742-1222310112

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

Amabile, T. M. (1988). A model of creativity and innovation in organizations. *Research in organizational behavior*, *10*(1), 123–167.

Amabile, T. M. (1996). *Creativity in Context: Update to the social psychology of creativity* (1st). Routledge. https://doi.org/10.4324/9780429501234

Amabile, T. M. (1997). Motivating Creativity in Organizations: On Doing What You Love and Loving What You Do. *California Management Review*, *40*(1), 39–58. https://doi.org/10.2307/41165921

Amabile, T. M. (1998). How to Kill Creativity. *Harvard Business Review*, *76*(5), 76–87.

Amabile, T. M. (2012). Componential theory of creativity. *Harvard Business School*, *12*(96), 1–10.

Amabile, T. M., Barsade, S. G., Mueller, J. S., & Staw, B. M. (2005). Affect and Creativity at Work. *Administrative Science Quarterly*, *50*(3), 367–403. https://doi.org/10.2189/asqu.2005.50.3.367

Amabile, T. M., Conti, R., Coon, H., Lazenby, J., & Herron, M. (1996). Assessing the Work Environment for Creativity. *Academy of Management Journal*, *39*(5), 1154–1184. https://doi.org/10.5465/256995

Amabile, T. M., & Gryskiewicz, N. D. (1989). The Creative Environment Scales: Work Environment Inventory. *Creativity Research Journal*, *2*(4), 231–253. https://doi.org/10.1080/10400418909534321

Amabile, T. M., Hadley, C. N., & Kramer, S. J. (2002). Creativity under the gun. *Harvard business review*, *80*(8), 52–61, 147. http://www.ncbi.nlm.nih.gov/pubmed/12195920

Amabile, T. M., & Mueller, J. S. (2008). Assessing Creativity and Its Antecedents: An Exploration of the Componential Theory of Creativity. In J. Zhou & C. E. Shalley (Eds.), *Handbook of organizational creativity* (pp. 33–64). Lawrence Erlbaum Associates. http://library1.nida.ac.th/termpaper6/sd/2554/19755.pdf

Amabile, T. M., & Pillemer, J. (2012). Perspectives on the social psychology of creativity. *Journal of Creative Behavior*, *46*(1), 3–15. https://doi.org/10.1002/jocb.001

Amabile, T. M., & Pratt, M. G. (2016). The dynamic componential model of creativity and innovation in organizations: Making progress, making meaning. *Research in Organizational Behavior*, *36*, 157–183. https://doi.org/10.1016/j.riob.2016.10.001

Amabile, T. M., Schatzel, E. A., Moneta, G. B., & Kramer, S. J. (2004). Leader behaviors and the work environment for creativity: Perceived leader support. *The Leadership Quarterly*, *15*(1), 5–32. https://doi.org/10.1016/j.leaqua.2003.12.003

Anderson, N., & West, M. A. (1996). The team climate inventory: Development of the tci and its applications in teambuilding for innovativeness. *European Journal of Work and Organizational Psychology*, *5*(1), 53–66. https://doi.org/10.1080/13594329608414840

Andrews, J., & Smith, D. C. (1996). In search of the marketing imagination: Factors affecting the creativity of marketing programs for mature products. *Journal of Marketing Research*, *33*(2), 174–187. https://doi.org/10.2307/3152145

Andriopoulos, C. (2001). Determinants of organisational creativity: a literature review. *Management Decision*, *39*(10), 834–841. https://doi.org/10.1108/00251740110402328

Araujo, T. (2018). Living up to the chatbot hype: The influence of anthropomorphic design cues and communicative agency framing on conversational agent and company perceptions. *Computers in Human Behavior*, *85*, 183–189. https://doi.org/10.1016/j.chb.2018.03.051

aus dem Bruch, L. (2020). *Kreativitätsunterstützende Systeme im beruflichen Kontext* [Master's Thesis]. Technical University of Munich.

Autor, D. H., Levy, F., & Murnane, R. J. (2003). The Skill Content of Recent Technological Change: An Empirical Exploration. *The Quarterly Journal of Economics*, *118*(4), 1279–1333. https://doi.org/10.1162/003355303322552801

Auzmendi, E., Villa, A., & Abedi, J. (1996). Reliability and Validity of a Newly Constructed Multiple-Choice Creativity Instrument. *Creativity Research Journal*, *9*(1), 89–95. https://doi.org/10.1207/s15326934crj0901_8

Backerra, H., Malorny, C., & Schwarz, W. (2020). *Kreativitätstechniken: kreative Prozesse anstoßen Innovationen fördern* (4th). Hanser. https://www.amazon.de/-/en/Hendrik-Backerra/dp/3446412336

Baer, J. (2016). Creativity Doesn't Develop in a Vacuum. *New Directions for Child and Adolescent Development*, *2016*(151), 9–20. https://doi.org/10.1002/cad.20151

Baer, J., & Kaufman, J. C. (2008). Gender differences in creativity. *Journal of Creative Behavior*, *42*(2), 75–105. https://doi.org/10.1002/j.2162-6057.2008.tb01289.x

Baer, J., & McKool, S. S. (2009). Assessing creativity using the consensual assessment technique. *Handbook of Research on Assessment Technologies, Methods, and Applications in Higher Education*, 65–77. https://doi.org/10.4018/978-1-60566-667-9.ch004

Baer, J., & McKool, S. S. (2014). The Gold Standard for Assessing Creativity. *International Journal of Quality Assurance in Engineering and Technology Education*, *3*(1), 81–93. https://doi.org/10.4018/ijqaete.2014010104

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

Barbot, B., Hass, R. W., & Reiter-Palmon, R. (2019). Creativity assessment in psychological research: (Re)setting the standards. *Psychology of Aesthetics, Creativity, and the Arts*, *13*(2), 233–240. https://doi.org/10.1037/aca0000233

Barbot, B., & Reiter-Palmon, R. (2019). Creativity assessment: Pitfalls, solutions, and standards. *Psychology of Aesthetics, Creativity, and the Arts*, *13*(2), 131–132. https://doi.org/10.1037/aca0000251

Barron, F. (1955). The disposition toward originality. *The Journal of Abnormal and Social Psychology*, *51*(3), 478–485. https://doi.org/10.1037/h0048073

Batey, M. (2007). *A psychometric investigation of everyday creativity* [Doctoral dissertation, University College London (University of London)].

Batey, M. (2012). The Measurement of Creativity: From Definitional Consensus to the Introduction of a New Heuristic Framework. *Creativity Research Journal*, *24*(1), 95–104. https://doi.org/10.1080/10400419.2012.649181

Batey, M., & Furnham, A. (2006). Creativity, Intelligence, and Personality: A Critical Review of the Scattered Literature. *Genetic, Social, and General Psychology Monographs*, *132*(4), 355–429. https://doi.org/10.3200/MONO.132.4.355-430

Batey, M., & Furnham, A. (2008). The relationship between measures of creativity and schizotypy. *Personality and Individual Differences*, *45*(8), 816–821. https://doi.org/10.1016/j.paid.2008.08.014

Batey, M., Furnham, A., & Safiullina, X. (2010). Intelligence, general knowledge and personality as predictors of creativity. *Learning and Individual Differences*, *20*(5), 532–535. https://doi.org/10.1016/j.lindif.2010.04.008

Becker, M. (1995). Nineteenth-Century Foundations of Creativity Research. *Creativity Research Journal*, *8*(3), 219–229. https://doi.org/10.1207/s15326934crj0803_2

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

Bender, J. (2021). *Development of a measuring instrument for the analysis of creativity* [Master's Thesis]. Technical University of Munich.

Benedek, M., Mühlmann, C., Jauk, E., & Neubauer, A. C. (2013). Assessment of divergent thinking by means of the subjective top-scoring method: Effects of the number of top-ideas and time-on-task on reliability and validity. *Psychology of Aesthetics, Creativity, and the Arts*, *7*(4), 341–349. https://doi.org/10.1037/a0033644

Bengler, K., Rettenmaier, M., Fritz, N., & Feierle, A. (2020). From HMI to HMIs: Towards an HMI Framework for Automated Driving. *Information*, *11*(2), 61. https://doi.org/10.3390/info11020061

Bennett, N., & Lemoine, G. J. (2014). What a difference a word makes: Understanding threats to performance in a VUCA world. *Business Horizons*, *57*(3), 311–317. https://doi.org/10.1016/j.bushor.2014.01.001

Berg, J. M. (2014). The primal mark: How the beginning shapes the end in the development of creative ideas. *Organizational Behavior and Human Decision Processes*, *125*(1), 1–17. https://doi.org/10.1016/j.obhdp.2014.06.001

Berns, S., & Colton, S. (2020). Bridging Generative Deep Learning and Computational Creativity. *Proceedings of the 11th International Conference on Computational Creativity*, 406–409. https://twitter.com/mmariansky/status/1226756838613491713

Besemer, S. P., & Treffinger, D. J. (1981). Analysis of Creative Products: Review and Synthesis*. *The Journal of Creative Behavior*, *15*(3), 158–178. https://doi.org/10.1002/j.2162-6057.1981.tb00287.x

Besold, T. R., Schorlemmer, M., & Smaill, A. (2015). *Computational Creativity Research: Towards Creative Machines* (T. R. Besold, M. Schorlemmer, & A. Smaill, Eds.; Vol. 7). Atlantis Press. https://doi.org/10.2991/978-94-6239-085-0

Binnewies, C., Ohly, S., & Niessen, C. (2008). Age and creativity at work (M. Peeters, Ed.). *Journal of Managerial Psychology*, *23*(4), 438–457. https://doi.org/10.1108/02683940810869042

Boden, M. A. (1996). Creativity. In *Artificial intelligence* (pp. 267–291). Elsevier. https://doi.org/10.1016/B978-012161964-0/50011-X

Boden, M. A. (2004). *The Creative Mind*. Routledge. https://doi.org/10.4324/9780203508527 cited By 17.

Bonnardel, N., & Pichot, N. (2020). Enhancing collaborative creativity with virtual dynamic personas. *Applied Ergonomics*, *82*(September 2019), 102949. https://doi.org/10.1016/j.apergo.2019.102949

Bonnardel, N., & Zenasni, F. (2010). The impact of technology on creativity in design: An enhancement? *Creativity and Innovation Management*, *19*(2), 180–191. https://doi.org/10.1111/j.1467-8691.2010.00560.x

Botella, M., Nelson, J., & Zenasni, F. (2019). It Is Time to Observe the Creative Process: How to Use a Creative Process Report Diary (CRD). *The Journal of Creative Behavior*, *53*(2), 211–221. https://doi.org/10.1002/jocb.172

Botella, M., Zenasni, F., & Todd, L. I. (2018). What Are the Stages of the Creative Process? What Visual Art Students Are Saying. *Frontiers in Psychology*, *9*(11), 2266:1–13. https://doi.org/10.3389/fpsyg.2018.02266

Brophy, D. R. (1998). Understanding, measuring, and enhancing individual creative problem-solving efforts. *Creativity Research Journal*, *11*(2), 123–150. https://doi.org/10.1207/s15326934crj1102_4

Brown, T. (2008). Design Thinking. *Hardvard Business Review*, *86*(6), 1–9.

Brünn, M. (2019). *Development of an Application to Measure Creative Performance* [Bachelor's Thesis]. Technical University of Munich.

Brynjolfsson, E., & McAfee, A. (2011). *Race Against the Machine: how the digital revolution is accelerating innovation, driving productivity, and irreversibly transforming employment and the economy*. Digital Frontier Press.

Bubb, H. (2006). A consideration of the nature of work and the consequences for the human-oriented design of production and products (L. Nadel, Ed.). *Applied Ergonomics*, *37*(4 SPEC. ISS.), 401–407. https://doi.org/10.1016/j.apergo.2006.04.004

Bubb, H. (2012). *Information Ergonomics* (M. Stein & P. Sandl, Eds.). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-25841-1

Büttler, J., Kursawe, H., Pütz, S., & Schlorf, M. (2019). *Validierung des CANU als objektives Messinstrument zur Erfassung von Kreativität* [Interdisciplinary Project]. Technical University of Munich.

Cardoso, C., & Badke-Schaub, P. (2011). Fixation or Inspiration: Creative Problem Solving in Design. *The Journal of Creative Behavior*, *45*(2), 77–82. https://doi.org/10.1002/j.2162-6057.2011.tb01086.x

Carroll, E. A., & Latulipe, C. (2009). The creativity support index. *Proceedings of the 27th international conference extended abstracts on Human factors in computing systems - CHI EA '09*, 4009. https://doi.org/10.1145/1520340.1520609

Carson, S. H., Peterson, J. B., & Higgins, D. M. (2003). Decreased Latent Inhibition Is Associated With Increased Creative Achievement in High-Functioning Individuals. *Journal of Personality and Social Psychology*, *85*(3), 499–506. https://doi.org/10.1037/0022-3514.85.3.499

Carson, S. H., Peterson, J. B., & Higgins, D. M. (2005). Reliability, Validity, and Factor Structure of the Creative Achievement Questionnaire. *Creativity Research Journal*, *17*(1), 37–50. https://doi.org/10.1207/s15326934crj1701_4

Carter, S., & Nielsen, M. (2017). Using Artificial Intelligence to Augment Human Intelligence. *Distill*, *2*(12). https://doi.org/10.23915/distill.00009
https://distill.pub/2017/aia.

Cave, S., Dihal, K., & Dillon, S. (2020). *AI narratives: A history of imaginative thinking about intelligent machines*. Oxford University Press.

Ceylan, C., Dul, J., & Aytac, S. (2008). Can the office environment stimulate a manager's creativity? *Human Factors and Ergonomics in Manufacturing*, *18*(6), 589–602. https://doi.org/10.1002/hfm.20128

Chan, J., Dow, S. P., & Schunn, C. D. (2018). Do the Best Design Ideas (Really) Come from Conceptually Distant Sources of Inspiration? In *Engineering a better future* (pp. 111–139, Vol. 51). Springer International Publishing. https://doi.org/10.1007/978-3-319-91134-2_12

Chaves, A. P., & Gerosa, M. A. (2021). How Should My Chatbot Interact? A Survey on Social Characteristics in Human–Chatbot Interaction Design. *International Journal of Human–Computer Interaction*, *37*(8), 729–758. https://doi.org/10.1080/10447318.2020.1841438

Cherry, E., & Latulipe, C. (2014). Quantifying the Creativity Support of Digital Tools through the Creativity Support Index. *ACM Transactions on Computer-Human Interaction*, *21*(4), 1–25. https://doi.org/10.1145/2617588

Chiu, I., & Shu, L. H. (2012). Investigating effects of oppositely related semantic stimuli on design concept creativity. *Journal of Engineering Design*, *23*(4), 271–296. https://doi.org/10.1080/09544828.2011.603298

Cho, S. H., Nijenhuis, J. T., Vianen, A. E., Kim, H.-B., & Lee, K. H. (2010). The Relationship Between Diverse Components of Intelligence and Creativity. *The Journal of Creative Behavior*, *44*(2), 125–137. https://doi.org/10.1002/j.2162-6057.2010.tb01329.x

Clegg, B., & Birch, P. (2007). *Instant Creativity: simple techniques to ignite innovation and problem solving* (2nd ed.). Kogan Page.

Coleman, A. (2017). Why Uncertainty Means Just One Thing To Entrepreneurs: Opportunity. Retrieved May 25, 2021, from https://www.forbes.com/sites/deloitte/2021/05/13/how-stakeholders-can-make-or-break-companies-sustainability-efforts/

Colton, S., & Wiggins, G. A. (2012). Computational Creativity: The Final Frontier? *Proceedings of the 20th European Conference on Artificial Intelligence*, *242*, 21–26. https://doi.org/10.3233/978-1-61499-098-7-21

Costa, P. T., & McCrae, R. R. (2008). The Revised NEO Personality Inventory (NEO-PI-R). In *The sage handbook of personality theory and assessment: Volume 2 — personality measurement and testing* (pp. 179–198, Vol. 2). SAGE Publications Ltd. https://doi.org/10.4135/9781849200479.n9

Couger, J. D. (1995). *Creative problem solving and opportunity finding*. Boyd & Fraser Publishing. https://archive.org/details/creativeproblemsoocoug

Crilly, N. (2019). Creativity and fixation in the real world: A literature review of case study research. *Design Studies*, *64*, 154–168. https://doi.org/10.1016/j.destud.2019.07.002

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

Cropley, A. J., & Cropley, D. H. (2008). Resolving the paradoxes of creativity: an extended phase model. *Cambridge Journal of Education*, *38*(3), 355–373. https://doi.org/10.1080/03057640802286871

Cropley, D. H., & Cropley, A. J. (2018). *Die Psychologie der organisationalen Innovation*. Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-17389-0

Cropley, D. H., & Kaufman, J. C. (2012). Measuring Functional Creativity: Non-Expert Raters and the Creative Solution Diagnosis Scale. *The Journal of Creative Behavior*, *46*(2), 119–137. https://doi.org/10.1002/jocb.9

Cropley, D. H., Kaufman, J. C., & Cropley, A. J. (2011). Measuring Creativity for Innovation Management. *Journal of technology management & innovation*, *6*(3), 13–30. https://doi.org/10.4067/S0718-27242011000300002

Cropley, D. H., & Marrone, R. L. (2021). Automated Scoring of Figural Creativity using a Convolutional Neural Network. https://doi.org/10.31234/osf.io/8qe7y

Cseh, G. M., & Jeffries, K. K. (2019). A scattered CAT: A critical evaluation of the consensual assessment technique for creativity research. *Psychology of Aesthetics, Creativity, and the Arts*, *13*(2), 159–166. https://doi.org/10.1037/aca0000220

Csikszentmihalyi, M. (1999). Implications of a systems perspective for the study of creativity. In *Handbook of creativity.* (pp. 313–335). Cambridge University Press.

Csikszentmihalyi, M. (2014). Society, Culture, and Person: A Systems View of Creativity. In *The systems model of creativity* (pp. 47–61). Springer Netherlands. https://doi.org/10.1007/978-94-017-9085-7_4

Dalsgaard, P. (2014). Pragmatism and design thinking. *International Journal of Design*, *8*(1), 143–155.

Daly, S. R., Seifert, C. M., Yilmaz, S., & Gonzalez, R. (2016). Comparing Ideation Techniques for Beginning Designers. *Journal of Mechanical Design*, *138*(10), 1–12. https://doi.org/10.1115/1.4034087

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, *125*(6), 627–668. https://doi.org/10.1037/0033-2909.125.6.627

Deci, E. L., & Ryan, R. M. (2004). *Handbook of self-determination research*. University Rochester Press.

de Jong, J. P. J., & Kemp, R. (2003). Determinants of Co-Workers' Innovative Behaviour: An Investigation into Knowledge Intensive Services. *International Journal of Innovation Management*, *07*(02), 189–212. https://doi.org/10.1142/S1363919603000787

Dewett, T. (2007). Linking intrinsic motivation, risk taking, and employee creativity in an R&D environment. *R&D Management*, *37*(3), 197–208. https://doi.org/https://doi.org/10.1111/j.1467-9310.2007.00469.x

Diedrich, J., Benedek, M., Jauk, E., & Neubauer, A. C. (2015). Are creative ideas novel and useful? *Psychology of Aesthetics, Creativity, and the Arts*, *9*(1), 35–40. https://doi.org/10.1037/a0038688

Diedrich, J., Jauk, E., Silvia, P. J., Gredlein, J. M., Neubauer, A. C., & Benedek, M. (2018). Assessment of real-life creativity: The inventory of creative activities and achievements (ICAA). *Psychology of Aesthetics, Creativity, and the Arts*, *12*(3), 304–316. https://doi.org/10.1037/aca0000137

Digman, J. M. (1990). Personality Structure: Emergence of the Five-Factor Model. *Annual Review of Psychology*, *41*(1), 417–440. https://doi.org/10.1146/annurev.ps.41.020190.002221

Dillon, J. T. (1982). Problem Finding and Solving. *The Journal of Creative Behavior*, *16*(2), 97–111. https://doi.org/10.1002/j.2162-6057.1982.tb00326.x

Dilts, R. (1994). *Strategies of Genius: Sigmund Freud, Leonardo da Vinci, Nikola Tesla.* (Vol. 3). Meta Publications. https://www.pdfdrive.com/strategies-of-genius-volume-one-d185665985.html

Dix, A., Finlay, J., Abowd, G. D., & Beale, R. (2004). *Human-Computer Interaction* (3rd ed.). Pearson Education.

Dollinger, S. J., & Clancy, S. M. (1993). Identity, Self, and Personality: II. Glimpses Through the Autophotographic Eye. *Journal of Personality and Social Psychology*, *64*(6), 1064–1071. https://doi.org/10.1037/0022-3514.64.6.1064

Dollinger, S. J., Urban, K. K., & James, T. A. (2004). Creativity and Openness: Further Validation of Two Creative Product Measures. *Creativity Research Journal*, *16*(1), 35–47. https://doi.org/10.1207/s15326934crj1601_4

Domino, G. (1994). Assessment of Creativity With the ACL: An Empirical Comparison of Four Scales. *Creativity Research Journal*, *7*(1), 21–33. https://doi.org/10.1080/10400419409534506

Drexler, M. (2019). *Entwicklung eines Messwerkzeuges für Kreativität* [Master's Thesis]. Technical University of Munich.

Dreyfus, S. E., & Dreyfus, H. L. (1980). *A five-stage model of the mental activities involved in directed skill acquisition*. University of California (Berkeley) Operations Research Center.

Drucker, P. F. (1999). Knowledge Worker Productivity: The Biggest Challenge. *California Management Review*, *41*(2), 79–85.

Dul, J. (2011). Human factors in business: creating people-centric systems. *RSM Discovery - Management Knowledge*, *5*(1), 4–7.

Dul, J. (2019). The Physical Environment and Creativity: A theoretical framework. In J. C. Kaufman & R. J. Sternberg (Eds.), *The cambridge handbook of creativity* (2nd ed., pp. 481–509). Cambridge University Press. https://doi.org/10.1017/9781316979839.025

Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W. S., Wilson, J. R., & van der Doelen, B. (2012). A strategy for human factors/ergonomics: developing the discipline and profession (L. Nadel, Ed.). *Ergonomics*, *55*(4), 377–395. https://doi.org/10.1080/00140139.2012.661087

Dul, J., & Ceylan, C. (2011). Work environments for employee creativity. *Ergonomics*, *54*(1), 12–20. https://doi.org/10.1080/00140139.2010.542833

Dul, J., & Ceylan, C. (2014). The Impact of a Creativity-supporting Work Environment on a Firm's Product Innovation Performance. *Journal of Product Innovation Management*, *31*(6), 1254–1267. https://doi.org/10.1111/jpim.12149

Dul, J., Ceylan, C., & Jaspers, F. (2011). Knowledge workers' creativity and the role of the physical work environment. *Human Resource Management*, *50*(6), 715–734. https://doi.org/10.1002/hrm.20454

Dul, J., & Neumann, W. P. (2009). Ergonomics contributions to company strategies. *Applied Ergonomics*, *40*(4), 745–752. https://doi.org/10.1016/j.apergo.2008.07.001

Eder, P., & Sawyer, J. E. (2007). A meta-analytic examination of employee creativity. *22nd annual conference, society of industrial and organizational psychology (SIOP), New York, NY, April*.

Egan, T. M. (2005). Factors Influencing Individual Creativity in the Workplace: An Examination of Quantitative Empirical Research (L. Nadel, Ed.). *Advances in Developing Human Resources*, *7*(2), 160–181. https://doi.org/10.1177/1523422305274527

Eisenberger, R., & Cameron, J. (1996). Detrimental effects of reward: Reality or myth? *American Psychologist*, *51*(11), 1153–1166. https://doi.org/10.1037/0003-066X.51.11.1153

Eisenberger, R., & Cameron, J. (1998). Reward, intrinsic interest, and creativity: New findings. *American Psychologist*, *53*(6), 676–679. https://doi.org/10.1037/0003-066X.53.6.676

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

Eisenman, R. (1990). Creativity, preference for complexity, and physical and mental illness. *Creativity Research Journal*, *3*(3), 231–236. https://doi.org/10.1080/10400419009534355

Ekvall, G. (1983). *Climate, Structure and Innovativeness of Organizations: A Theoretical Framework and an Experiment*. {The Swedish Council for Management and Organizational Behaviour}.

Ellström, P.-E. (2001). Integrating learning and work: Problems and prospects. *Human Resource Development Quarterly*, *12*(4), 421. https://doi.org/10.1002/hrdq.1006

Engelbart, D. C. (1962). *Augmenting Human Intellect: A Conceptual Framework* (tech. rep.).

Ensor, J., Pirrie, A., & Band, C. (2006). Creativity work environment: do UK advertising agencies have one? *European Journal of Innovation Management*, *9*(3), 258–268. https://doi.org/10.1108/14601060610678130

Epstein, R., Kaminaka, K., Phan, V., & Uda, R. (2013). How is Creativity Best Managed? Some Empirical and Theoretical Guidelines. *Creativity and Innovation Management*, *22*(4), 359–374. https://doi.org/10.1111/caim.12042

Eysenck, H. J. (1993). Creativity and Personality: Suggestions for a Theory. *Psychological Inquiry*, *4*(3), 147–178. https://doi.org/10.1207/s15327965pli0403_1

Feist, G. J. (1993). A Structural Model of Scientific Eminence. *Psychological Science*, *4*(6), 366–371. https://doi.org/10.1111/j.1467-9280.1993.tb00583.x

Feist, G. J. (1998). A Meta-Analysis of Personality in Scientific and Artistic Creativity. *Personality and Social Psychology Review*, *2*(4), 290–309. https://doi.org/10.1207/s15327957pspr0204_5

Fischer, G. (2004). Social creativity. *Proceedings of the eighth conference on Participatory design Artful integration: interweaving media, materials and practices - PDC 04*, *1*, 152. https://doi.org/10.1145/1011870.1011889

Florida, R. (2002). *The Rise of the Creative Class*. Basic Books. https://doi.org/10.1080/20421338.2016.1256596

Ford, C. M. (1996). A theory of individual creative action in multiple social domains. *Academy of Management Review*, *21*(4), 1112–1142. https://doi.org/10.5465/AMR.1996.9704071865

Forgionne, G., & Newman, J. (2007). An experiment on the effectiveness of creativity enhancing decision-making support systems. *Decision Support Systems*, *42*(4), 2126–2136. https://doi.org/10.1016/j.dss.2006.05.009

Foss, L., Woll, K., & Moilanen, M. (2013). Creativity and implementations of new ideas: Do organisational structure, work environment and gender matter? (D. Gry Agnete Alsos, Professor Ulla Hy, Ed.). *International Journal of Gender and Entrepreneurship*, *5*(3), 298–322. https://doi.org/10.1108/IJGE-09-2012-0049

Fowler, M., Highsmith, J., et al. (2001). The Agile Manifesto. *Software Development*, *9*(8), 28–35.

Frederiksen, N., & Ward, W. C. (1978). Measures for the Study of Creativity in Scientific Problem-Solving. *Applied Psychological Measurement*, *2*(1), 1–24. https://doi.org/10.1177/014662167800200101

Fredrickson, B. L. (1998). What Good Are Positive Emotions? *Review of General Psychology*, *2*(3), 300–319. https://doi.org/10.1037/1089-2680.2.3.300

Freedman, K. (2010). Rethinking Creativity: A Definition to Support Contemporary Practice. *Art Education*, *63*(2), 8–15. https://doi.org/10.1080/00043125.2010.11519056
Frey, C. B., & Osborne, M. A. (2017). The future of employment: How susceptible are jobs to computerisation? *Technological Forecasting and Social Change*, *114*, 254–280. https://doi.org/10.1016/j.techfore.2016.08.019
Frich, J., MacDonald Vermeulen, L., Remy, C., Biskjaer, M. M., & Dalsgaard, P. (2019). Mapping the Landscape of Creativity Support Tools in HCI. *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–18. https://doi.org/10.1145/3290605.3300619
Frich, J., Mose Biskjaer, M., & Dalsgaard, P. (2018). Twenty Years of Creativity Research in Human-Computer Interaction. *Proceedings of the 2018 Designing Interactive Systems Conference*, 1235–1257. https://doi.org/10.1145/3196709.3196732
Friedman, B., & Hendry, D. (2012). The Envisioning Cards: A Toolkit for Catalyzing Humanistic and Technical Imaginations. *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems - CHI '12*, 1145. https://doi.org/10.1145/2207676.2208562
Frith, E., Elbich, D. B., Christensen, A. P., Rosenberg, M. D., Chen, Q., Kane, M. J., Silvia, P. J., Seli, P., & Beaty, R. E. (2021). Intelligence and creativity share a common cognitive and neural basis. *Journal of Experimental Psychology: General*, *150*(4), 609–632. https://doi.org/10.1037/xge0000958
Fuchs-Beauchamp, K. D., Karnes, M. B., & Johnson, L. J. (1993). Creativity and Intelligence in Preschoolers. *Gifted Child Quarterly*, *37*(3), 113–117. https://doi.org/10.1177/001698629303700303
Furnham, A., Batey, M., Anand, K., & Manfield, J. (2008). Personality, hypomania, intelligence and creativity. *Personality and Individual Differences*, *44*(5), 1060–1069. https://doi.org/10.1016/j.paid.2007.10.035

Gabora, L. (2002). Cognitive mechanisms underlying the creative process. *Proceedings of the fourth conference on Creativity and Cognition*, (January 2002), 126–133. https://doi.org/10.1145/581710.581730
Gabriel, A., Monticolo, D., Camargo, M., & Bourgault, M. (2016). Creativity support systems: A systematic mapping study. *Thinking Skills and Creativity*, *21*, 109–122. https://doi.org/10.1016/j.tsc.2016.05.009
Gagné, R. M., & Smith, E. C. (1962). A study of the effects of verbalization on problem solving. *Journal of Experimental Psychology*, *63*(1), 12–18. https://doi.org/10.1037/h0048703
Galasiu, A. D., & Veitch, J. A. (2006). Occupant preferences and satisfaction with the luminous environment and control systems in daylit offices: a literature review. *Energy and Buildings*, *38*(7), 728–742. https://doi.org/10.1016/j.enbuild.2006.03.001
Gamper, V. (2019). *Motivational Design for Computer-Supported Collaborative Ideation* [Doctoral dissertation, Technical University Munich (TUM)].
Gardner, H. (1988). Creativity: An interdisciplinary perspective. *Creativity Research Journal*, *1*(1), 8–26. https://doi.org/10.1080/10400418809534284
Garfield, M. J., Taylor, N. J., Dennis, A. R., & Satzinger, J. W. (2001). Research Report: Modifying Paradigms—Individual Differences, Creativity Techniques, and Exposure to Ideas in Group Idea Generation. *Information Systems Research*, *12*(3), 322–333. https://doi.org/10.1287/isre.12.3.322.9710
Garvin, D. A. (1984). What Does Product Quality Mean.
George, J. M., & Zhou, J. (2001). When job dissatisfaction leads to creativity : encouraging the expression of voice. *Academy of Management Journal*, *1892*(713), 682–696.

Gerhardt-Powals, J. (1996). Cognitive engineering principles for enhancing human-computer performance. *International Journal of Human-Computer Interaction*, *8*(2), 189–211. https://doi.org/10.1080/10447319609526147

Gero, J. S., & Kannengiesser, U. (2004). The situated function-behaviour-structure framework. *Design Studies*, *25*(4), 373–391. https://doi.org/10.1016/j.destud.2003.10.010

Gero, J. S., & Milovanovic, J. (2020). A framework for studying design thinking through measuring designers' minds, bodies and brains. *Design Science*, *6*(May), e19. https://doi.org/10.1017/dsj.2020.15

Geschka, H., Schaude, G. R., & Schlicksupp, H. (1976). Modern Techniques for Solving Problems. *International Studies of Management & Organization*, *6*(4), 45–63. https://doi.org/10.1080/00208825.1976.11656211

Getzels, J. W. (1975). Problem-Finding and the Inventiveness of Solutions. *The Journal of Creative Behavior*, *9*(1), 12–18. https://doi.org/10.1002/j.2162-6057.1975.tb00552.x

Gilhooly, K. J., Fioratou, E., & Henretty, N. (2010). Verbalization and problem solving: Insight and spatial factors. *British Journal of Psychology*, *101*(1), 81–93. https://doi.org/10.1348/000712609X422656

Glăveanu, V. P., & Beghetto, R. A. (2021). Creative Experience: A Non-Standard Definition of Creativity. *Creativity Research Journal*, *33*(2), 75–80. https://doi.org/10.1080/10400419.2020.1827606

Glăveanu, V. P. (2013). Rewriting the Language of Creativity: The Five A's Framework. *Review of General Psychology*, *17*(1), 69–81. https://doi.org/10.1037/a0029528

Glăveanu, V. P. (2019). Measuring creativity across cultures: Epistemological and methodological considerations. *Psychology of Aesthetics, Creativity, and the Arts*, *13*(2), 227–232. https://doi.org/10.1037/aca0000216

Glover, J. A. (1979). Levels of Questions Asked in Interview and Reading Sessions by Creative and Relatively Noncreative College Students. *The Journal of Genetic Psychology*, *135*(1), 103–108. https://doi.org/10.1080/00221325.1979.10533421

Goldberg, L. R. (1990). An alternative "description of personality": The Big-Five factor structure. *Journal of Personality and Social Psychology*, *59*(6), 1216–1229. https://doi.org/10.1037/0022-3514.59.6.1216

Goldin, C., & Katz, L. F. (2018). *The race between education and technology*. Routledge.

Gough, H. G. (1976). Studying creativity by means of word association tests. *Journal of Applied Psychology*, *61*(3), 348–353. https://doi.org/10.1037/0021-9010.61.3.348

Gough, H. G. (1979). A creative personality scale for the Adjective Check List. *Journal of Personality and Social Psychology*, *37*(8), 1398–1405. https://doi.org/10.1037/0022-3514.37.8.1398

Gough, H. G. (2000). Adjective Checklist. In *Encyclopedia of psychology, vol. 1.* (pp. 36–37). American Psychological Association. https://doi.org/10.1037/10516-014

Greenberg, E. (1994). The Importance of Autonomy in Encouraging Creativity: Managerial Implications from a Study in Fashion Design. *Creativity and Innovation Management*, *3*(3), 167–176. https://doi.org/10.1111/j.1467-8691.1994.tb00170.x

Gruszka, A., & Tang, M. (2017). The 4P's Creativity Model and its Application in Different Fields. In M. Tang & C. H. Werner (Eds.), *Handbook of the management of creativity and innovation* (pp. 51–71). https://doi.org/10.1142/9789813141889_0003

Guilford, J. P. (1950). Creativity. *The American Psychologist*, *5*(9), 444–54. https://doi.org/10.1037/h0063487

Guilford, J. P. (1967). The nature of human intelligence.

Haase, J., Hoff, E. V., Hanel, P. H. P., & Innes-Ker, Å. (2018). A Meta-Analysis of the Relation between Creative Self-Efficacy and Different Creativity Measurements. *Creativity Research Journal*, *30*(1), 1–16. https://doi.org/10.1080/10400419.2018.1411436

Hall, A. (2020). Some 30% of British adults 'don't know how to be' artistic, according to new poll. Retrieved April 19, 2021, from https://www.independent.co.uk/news/british-adults-creativity-artistic-cooking-photography-hobbies-b716443.html

Haner, U.-E. (2005). Spaces for Creativity and Innovation in Two Established Organizations. *Creativity and Innovation Management*, *14*(3), 288–298. https://doi.org/10.1111/j.1476-8691.2005.00347.x

Harris, M. M., & Schaubroek, J. (1988). a Meta-Analysis of Self-Supervisor, Self-Peer, and Peer-Supervisor Ratings. *Personnel Psychology*, *41*(1), 43–62. https://doi.org/10.1111/j.1744-6570.1988.tb00631.x

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In *Advances in psychology* (pp. 139–183, Vol. 52). https://doi.org/10.1016/S0166-4115(08)62386-9

Harteis, C., Bauer, J., & Gruber, H. (2008). The culture of learning from mistakes: How employees handle mistakes in everyday work. *International Journal of Educational Research*, *47*(4), 223–231. https://doi.org/10.1016/j.ijer.2008.07.003

Hatcher, L., Ross, T. L., & Collins, D. (1989). Prosocial Behavior, Job Complexity, and Suggestion Contribution Under Gainsharing Plans. *The Journal of Applied Behavioral Science*, *25*(3), 231–248. https://doi.org/10.1177/0021886389253002

Hender, J. M., Dean, D. L., Rodgers, T. L., & Nunamaker Jr, J. F. (2002). An Examination of the Impact of Stimuli Type and GSS Structure on Creativity: Brainstorming Versus Non-Brainstorming Techniques in a GSS Environment. *Journal of Management Information Systems*, *18*(4), 59–85. https://doi.org/10.1080/07421222.2002.11045705

Hennessey, B. A., & Amabile, T. M. (2010). Creativity (2010 Annual Review of Psychology). *Annual Review of Psychology*, *61*, 569–598. https://doi.org/10.1146/annurev.psych.093008.100416

Hilf, H. (1976). *Einführung in die Arbeitswissenschaft.* De Gruyter.

Hillier, A., Alexander, J. K., & Beversdorf, D. Q. (2006). The Effect of Auditory Stressors on Cognitive Flexibility. *Neurocase*, *12*(4), 228–231. https://doi.org/10.1080/13554790600878887

Hocevar, D. (1979). The Development of the Creative Behavior Inventory (CBI).

Hocevar, D. (1981). Measurement of Creativity: Review and Critique. *Journal of Personality Assessment*, *45*(5), 450–464. https://doi.org/10.1207/s15327752jpa4505_1

Hoff, A. (2013). Ambiguity equals opportunity: The story of the new HBS application. Retrieved May 25, 2021, from https://www.amerasiaconsulting.com/blog/2013/6/3/ambiguity-equals-opportunity-the-story-of-the-new-hbs-application

Hoff, E. V., & Öberg, N. K. (2015). The role of the physical work environment for creative employees – a case study of digital artists. *The International Journal of Human Resource Management*, *26*(14), 1889–1906. https://doi.org/10.1080/09585192.2014.971842

Holford, W. D. (2019). The future of human creative knowledge work within the digital economy. *Futures*, *105*(October), 143–154. https://doi.org/10.1016/j.futures.2018.10.002

Hong, E., & Milgram, R. M. (2010). Creative Thinking Ability: Domain Generality and Specificity. *Creativity Research Journal*, *22*(3), 272–287. https://doi.org/10.1080/10400419.2010.503535

Horn, D., & Salvendy, G. (2006). Consumer-based assessment of product creativity: A review and reappraisal. *Human Factors and Ergonomics In Manufacturing*, *16*(2), 155–175. https://doi.org/10.1002/hfm.20047

Hornecker, E. (2010). Creative Idea Exploration Within the Stucture of a Guiding Framework: The Card Brainstorming Game. *Proceedings of the fourth international conference on Tangible, embedded, and embodied interaction - TEI '10*, 101. https://doi.org/10.1145/1709886.1709905

Howard, T., Culley, S., & Dekoninck, E. (2008). Describing the creative design process by the integration of engineering design and cognitive psychology literature. *Design Studies*, *29*(2), 160–180. https://doi.org/10.1016/j.destud.2008.01.001

Hunter, S. T., Bedell, K. E., & Mumford, M. D. (2007). Climate for Creativity: A Quantitative Review. *Creativity Research Journal*, *19*(1), 69–90. https://doi.org/10.1080/10400410709336883

Insel, P. M., & Moos, R. H. (1974). Psychological environments: Expanding the scope of human ecology. *American Psychologist*, *29*(3), 179–188. https://doi.org/10.1037/h0035994

Interanational Ergonomics Association. (2021). What Is Ergonomics? Retrieved May 26, 2021, from https://iea.cc/what-is-ergonomics/

Isaksen, S. G., Lauer, K. J., & Ekvall, G. (1999). Situational Outlook Questionnaire: A Measure of the Climate for Creativity and Change. *Psychological Reports*, *85*(2), 665–674. https://doi.org/10.2466/pro.1999.85.2.665

Isaksen, S. G., & Treffinger, D. J. (2004). Celebrating 50 years of Reflective Practice: Versions of Creative Problem Solving. *The Journal of Creative Behavior*, *38*(2), 75–101. https://doi.org/10.1002/j.2162-6057.2004.tb01234.x

Issahaka, A. W., & Lines, R. (2019). Knowledge Workers: How Are They Different? (And Why Does It Matter?) *Academy of Management Proceedings*, *2019*(1), 15232. https://doi.org/10.5465/AMBPP.2019.15232abstract

Janssen, O. (2000). Job demands, perceptions of effort-reward fairness and innovative work behaviour. *Journal of Occupational and Organizational Psychology*, *73*(3), 287–302. https://doi.org/10.1348/096317900167038

Jansson, D. G., & Smith, S. M. (1991). Design fixation. *Design Studies*, *12*(1), 3–11. https://doi.org/10.1016/0142-694X(91)90003-F

Jastrzebowski, W. (2000). *An Outline of Ergonomics, or the Science of Work Based upon the Truths Drawn from the Science of Nature 1857*. Central Institute for Labour Protection.

Jauk, E., Benedek, M., Dunst, B., & Neubauer, A. C. (2013). The relationship between intelligence and creativity: New support for the threshold hypothesis by means of empirical breakpoint detection. *Intelligence*, *41*(4), 212–221. https://doi.org/10.1016/j.intell.2013.03.003

Jennings, K. E. (2010). Developing Creativity: Artificial Barriers in Artificial Intelligence. *Minds and Machines*, *20*(4), 489–501. https://doi.org/10.1007/s11023-010-9206-y

Jing Zhou, Shin, S. J., & Cannella, A. A. (2008). Employee Self-Perceived Creativity After Mergers and Acquisitions. *The Journal of Applied Behavioral Science*, *44*(4), 397–421. https://doi.org/10.1177/0021886308328010

Kadir, B. A., Broberg, O., & da Conceição, C. S. (2019). Current research and future perspectives on human factors and ergonomics in Industry 4.0. *Computers & Industrial Engineering*, *137*(December 2018), 106004. https://doi.org/10.1016/j.cie.2019.106004

Kalff, Y. (2017). The knowledge worker and the projectified self: domesticating and disciplining creativity. *Work Organisation, Labour & Globalisation*, *11*(1), 10. https://doi.org/10.13169/workorgalaboglob.11.1.0010

Karwowski, W. (2006). The Discipline of Ergonomics and Human Factors. In *Handbook of human factors and ergonomics* (pp. 1–31). John Wiley & Sons, Inc. https://doi.org/10.1002/0470048204.ch1

Kaufman, J. C., Plucker, J. A., & Baer, J. (2008). Essentials of creativity assessment. Essentials of psychological assessment series.

Kaufman, J. C. (2014). Measuring Creativity - the Last Windmill? Retrieved June 3, 2021, from https://learningfirst.org/measuring-creativity-last-windmill

Kaufman, J. C., & Baer, J. (2012). Beyond New and Appropriate: Who Decides What Is Creative? *Creativity Research Journal*, *24*(1), 83–91. https://doi.org/10.1080/10400419.2012.649237

Kaufman, J. C., Baer, J., Cole, J. C., & Sexton, J. D. (2008). A comparison of expert and nonexpert raters using the consensual assessment technique. *Creativity Research Journal*, *20*(2), 171–178. https://doi.org/10.1080/10400410802059929

Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The four C model of creativity. *Review of General Psychology*, *13*(1), 1–12. https://doi.org/10.1037/a0013688

Kaufman, J. C., Cole, J. C., & Baer, J. (2009). The Construct of Creativity: Structural Model for Self-Reported Creativity Ratings. *The Journal of Creative Behavior*, *43*(2), 119–134. https://doi.org/10.1002/j.2162-6057.2009.tb01310.x

Keynes, J. M. (1930). Economic Possibilities for our Grandchildren. *Essays in Persuasion*, 358–373. http://www.econ.yale.edu/smith/econ116a/keynes1.pdf

Kim, K. H. (2005). Can Only Intelligent People Be Creative? *Journal of Secondary Gifted Education*, *16*(2), 57–66. http://kkim.wmwikis.net/file/view/Can%20Only%20Intelligent%20People%20Creative.pdf

Knight, W. (2021). A New Artificial Intelligence Makes Mistakes—on Purpose. Retrieved June 4, 2021, from https://www.wired.com/story/new-artificial-intelligence-mistakes-purpose-chess/

Kohn, N. W., Paulus, P. B., & Korde, R. M. (2011). Conceptual Combinations and Subsequent Creativity. *Creativity Research Journal*, *23*(3), 203–210. https://doi.org/10.1080/10400419.2011.595659

Kolder, S. (2019). KOLD - The Creative Process [Video File]. https://youtu.be/LAq_AL9TXOc

Kreuzer, C., & Weber, S. (2020). Apprentices' Errors in Intrapreneurship: Findings from a Large-Scale Assessment. *Vocations and Learning*, *13*(2), 341–366. https://doi.org/10.1007/s12186-020-09241-5

Krippendorff, K. (2018). *Content analysis: An introduction to its methodology*. Sage publications.

Kristensen, T. (2004). The Physical Context of Creativity. *Creativity and Innovation Management*, *13*(2), 89–96. https://doi.org/10.1111/j.0963-1690.2004.00297.x

Kubat, M. (2017). *An Introduction to Machine Learning*. Springer International Publishing. https://doi.org/10.1007/978-3-319-63913-0

Kurtzberg, T. R. (2005). Feeling Creative, Being Creative: An Empirical Study of Diversity and Creativity in Teams. *Creativity Research Journal*, *17*(1), 51–65. https://doi.org/10.1207/s15326934crj1701_5

Lee, J. H., Ha, E. J., Kim, D., Jung, Y. J., Heo, S., Jang, Y.-h., An, S. H., & Lee, K. (2020). Application of deep learning to the diagnosis of cervical lymph node metastasis from thyroid cancer with CT: external validation and clinical utility for resident training. *European Radiology*, *30*(6), 3066–3072. https://doi.org/10.1007/s00330-019-06652-4

Lee, Y. S. (2016). Creative workplace characteristics and innovative start-up companies. *Facilities*, *34*(7/8), 413–432. https://doi.org/10.1108/F-06-2014-0054

Lipman-Blumen, J. (1991). *Individual and organizational achieving styles: A conceptual handbook for researchers and human resource professionals*. Achieving Styles Institute.

Livingstone, L. P., Nelson, D. L., & Barr, S. H. (1997). Person-environment fit and creativity: An examination of supply-value and demand-ability versions of fit. *Journal of Management*, *23*(2), 119–146. https://doi.org/10.1177/014920639702300202

Lubart, T. I. (1999). Creativity Across Cultures. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 339–350). Cambridge University Press.

Lubart, T. I. (2001). Models of the creative process: Past, present and future. *Creativity Research Journal*, *13*(3-4), 295–308. https://doi.org/10.1207/s15326934crj1334_07

Lubart, T. I. (2005). How can computers be partners in the creative process: Classification and commentary on the Special Issue. *International Journal of Human Computer Studies*, *63*(4-5 SPEC. ISS.), 365–369. https://doi.org/10.1016/j.ijhcs.2005.04.002

Lubart, T. I., & Thornhill-Miller, B. (2019). Creativity: An Overview of the 7C's of Creative Thought. In R. J. Sternberg & J. Funke (Eds.), *The psychology of human thought: An introduction* (pp. 277–305). Heidelberg University Publishing. https://doi.org/10.17885/heiup.470.c6678

Ma, H.-H. (2009). The Effect Size of Variables Associated With Creativity: A Meta-Analysis. *Creativity Research Journal*, *21*(1), 30–42. https://doi.org/10.1080/10400410802633400

Mack, O., Khare, A., Krämer, A., & Burgartz, T. (2016). *Managing in a VUCA World* (O. Mack, A. Khare, A. Krämer, & T. Burgartz, Eds.). Springer International Publishing. https://doi.org/10.1007/978-3-319-16889-0

Madjar, N., Greenberg, E., & Chen, Z. (2011). Factors for radical creativity, incremental creativity, and routine, noncreative performance. *Journal of Applied Psychology*, *96*(4), 730–743. https://doi.org/10.1037/a0022416

Madjar, N., & Oldham, G. R. (2006). Task Rotation and Polychronicity: Effects on Individuals' Creativity. *Human Performance*, *19*(2), 117–131. https://doi.org/10.1207/s15327043hup1902_2

Madjar, N., Oldham, G. R., & Pratt, M. G. (2002). There's No Place like Home? The Contributions of Work and Nonwork Creativity Support to Employees' Creative Performance. *Academy of Management Journal*, *45*(4), 757–767. https://doi.org/10.5465/3069309

Magadley, W., & Birdi, K. (2009). Innovation Labs: An Examination into the Use of Physical Spaces to Enhance Organizational Creativity. *Creativity and Innovation Management*, *18*(4), 315–325. https://doi.org/10.1111/j.1467-8691.2009.00540.x

Maiden, N., Zachos, K., Brown, A., Apostolou, D., Holm, B., Nyre, L., Tonheim, A., & van den Beld, A. (2020). Digital creativity support for original journalism. *Communications of the ACM*, *63*(8), 46–53. https://doi.org/10.1145/3386526

Maiden, N., Zachos, K., Brown, A., Brock, G., Nyre, L., Nygård Tonheim, A., Apsotolou, D., & Evans, J. (2018). Making the News: Digital Creativity Support for Journalists. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 1–11. https://doi.org/10.1145/3173574.3174049

Malaga, R. A. (2000). The effect of stimulus modes and associative distance in individual creativity support systems. *Decision Support Systems*, *29*(2), 125–141. https://doi.org/10.1016/S0167-9236(00)00067-1

Manske, M. E., & Davis, G. A. (1968). Effects of Simple Instructional Biases upon Performance in the Unusual Uses Test. *The Journal of General Psychology*, *79*(1), 25–33. https://doi.org/10.1080/00221309.1968.9710449

Manske, S., Omar Álvarez-Márquez, J., Omar, J., Márquez, Á., Giemza, A., Hoppe, H. U., Álvarez Márquez, J. O., Giemza, A., & Hoppe, H. U. (2014). MuPeT: A framework for enabling multi-perspective problem elaboration. *Proceedings of the 22nd International Conference on Computers in Education*, (January 2014), 218–223. https://www.researchgate.net/publication/286349409

Marakas, G. M., & Elam, J. J. (1997). Creativity Enhancement in Problem Solving: Through Software or Process? *Management Science*, *43*(8), 1136–1146. https://doi.org/10.1287/mnsc.43.8.1136

Marsick, V. J., Watkins, K. E., Callahan, M. W., & Volpe, M. (2008). *Informal and incidental learning in the workplace*. Routledge.

Martens, Y. (2011). Creative workplace: instrumental and symbolic support for creativity (B. P. Haynes, Ed.). *Facilities*, *29*(1/2), 63–79. https://doi.org/10.1108/02632771111101331

Massetti, B. (1996). An Empirical Examination of the Value of Creativity Support Systems on Idea Generation. *MIS Quarterly*, *20*(1), 83. https://doi.org/10.2307/249543

Mathisen, G. E., & Einarsen, S. (2004). A Review of Instruments Assessing Creative and Innovative Environments Within Organizations. *Creativity Research Journal*, *16*(1), 119–140. https://doi.org/10.1207/s15326934crj1601_12

Matud, M. P., Rodríguez, C., & Grande, J. (2007). Gender differences in creative thinking. *Personality and Individual Differences*, *43*(5), 1137–1147. https://doi.org/10.1016/j.paid.2007.03.006

Maudet, N., Jalal, G., Tchernavskij, P., Beaudouin-Lafon, M., & Mackay, W. E. (2017). Beyond Grids:Interactive Graphical Substrates to Structure Digital Layout. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 5053–5064. https://doi.org/10.1145/3025453.3025718

Mayring, P. (2004). Qualitative content analysis. In U. Flick, E. von Kardorff, & I. Steinke (Eds.), *A companion to qualitative research* (pp. 266–269, Vol. 1). Sage Publications.

McCarthy, J., Minsky, M. L., Rochester, N., & Shannon, C. E. (1955). *A proposal for the dartmouth summer research project on artificial intelligence* (tech. rep.).

McCarthy, M., Chen, C. C., & McNamee, R. C. (2018). Novelty and Usefulness Trade-Off: Cultural Cognitive Differences and Creative Idea Evaluation. *Journal of Cross-Cultural Psychology*, *49*(2), 171–198. https://doi.org/10.1177/0022022116680479

McCoy, J. M., & Evans, G. W. (2002). The Potential Role of the Physical Environment in Fostering Creativity. *Creativity Research Journal*, *14*(3-4), 409–426. https://doi.org/10.1207/S15326934CRJ1434_11

McCrae, R. R., & Ingraham, L. J. (1987). Creativity, Divergent Thinking, and Openness to Experience. *Journal of Personality and Social Psychology*, *52*(6), 1258–1265. https://doi.org/10.1037/0022-3514.52.6.1258

McFadzean, E. (1998). The Creativity Continuum: Towards a Classification of Creative Problem Solving Techniques. *Creativity and Innovation Management*, *7*(3), 131–139. https://doi.org/10.1111/1467-8691.00101

McIlroy-Young, R., Sen, S., Kleinberg, J., & Anderson, A. (2020). Aligning Superhuman AI with Human Behavior. *Proceedings of the 26th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining*, 1677–1687. https://doi.org/10.1145/3394486.3403219

Mednick, S. (1962). The associative basis of the creative process. *Psychological Review*, *69*(3), 220–232. https://doi.org/10.1037/h0048850

Mehta, R., & Zhu, R. ((2009). Blue or Red? Exploring the Effect of Color on Cognitive Task Performances. *Science*, *323*(5918), 1226–1229. https://doi.org/10.1126/science.1169144

Mehta, R., Zhu, R. (, & Cheema, A. (2012). Is Noise Always Bad? Exploring the Effects of Ambient Noise on Creative Cognition. *Journal of Consumer Research*, *39*(4), 784–799. https://doi.org/10.1086/665048

Meinel, M., Maier, L., Wagner, T. F., & Voigt, K.-I. (2017). Designing Creativity-Enhancing Workspaces: A Critical Look at Empirical Evidence. *Journal of Technology and Innovation Management*, *1*(1), 1–12.

Merten, T., & Fischer, I. (1999). Creativity, personality and word association responses: associative behaviour in forty supposedly creative persons. *Personality and Individual Differences*, *27*(5), 933–942. https://doi.org/10.1016/S0191-8869(99)00042-2

Mirowsky, J., & Ross, C. E. (2007). Creative Work and Health. *Journal of Health and Social Behavior*, *48*(4), 385–403. https://doi.org/10.1177/002214650704800404

Mueller, F., Gibbs, M. R., Vetere, F., & Edge, D. (2014). Supporting the creative game design process with exertion cards. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2211–2220. https://doi.org/10.1145/2556288.2557272

Mueller, J. S., Melwani, S., & Goncalo, J. A. (2012). The bias against creativity: Why people desire but reject creative ideas. *Psychological Science*, *23*(1), 13–17. https://doi.org/10.1177/0956797611421018

Mumford, M. D. (2003). Where Have We Been, Where Are We Going? Taking Stock in Creativity Research. *Creativity Research Journal*, *15*(2-3), 107–120. https://doi.org/10.1080/10400419.2003.9651403

Mumford, M. D., Blair, C., Dailey, L., Leritz, L. E., & Osburn, H. K. (2006). Errors in Creative Thought? Cognitive Biases in a Complex Processing Activity. *The Journal of Creative Behavior*, *40*(2), 75–109. https://doi.org/10.1002/j.2162-6057.2006.tb01267.x

Mumford, M. D., & Gustafson, S. B. (1988). Creativity syndrome Integration, application, and innovation -Mumford, Michael D.; Gustafson, Sigrid B. 1988.pdf. *Psychological Bullettin*, *103*(1), 27–43.

Nielsen, J. (1994a). Enhancing the explanatory power of usability heuristics. *Proceedings of the SIGCHI conference on Human factors in computing systems celebrating interdependence - CHI '94*, 152–158. https://doi.org/10.1145/191666.191729

Nielsen, J. (1994b). Guerrilla HCI: Using discount usability engineering to penetrate the intimidation barrier. *Cost-justifying usability*, 245–272. http://www.nngroup.com/articles/guerrilla-hci/

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

Ohly, S., Sonnentag, S., & Pluntke, F. (2006). Routinization, work characteristics and their relationships with creative and proactive behaviors. *Journal of Organizational Behavior*, *27*(3), 257–279. https://doi.org/10.1002/job.376

Oldham, G. R., & Cummings, A. (1996). Employee Creativity: Personal and Contextual Factors at Work. *Academy of Management Journal*, *39*(3), 607–634. https://doi.org/10.5465/256657

Olson, J. A., Nahas, J., Chmoulevitch, D., Cropper, S. J., & Webb, M. E. (2021). Naming unrelated words predicts creativity. *Proceedings of the National Academy of Sciences*, *118*(25), e2022340118. https://doi.org/10.1073/pnas.2022340118

Olszak, C. M., & Kisielnicki, J. (2018). A conceptual framework of information systems for organizational creativity support. lessons from empirical investigations. *Information Systems Management*, *35*(1), 29–48. https://doi.org/10.1080/10580530.2017.1416945

O'Quin, K., & Besemer, S. P. (1989). The development, reliability, and validity of the revised creative product semantic scale. *Creativity Research Journal*, *2*(4), 267–278. https://doi.org/10.1080/10400418909534323

Osborn, A. F. (1953). *Applied imagination*. Scribner. https://openlibrary.org/books/OL6138374M/Applied_imagination

Osborn, A. F. (1952). *Wake up your mind: 101 ways to develop creativeness*. Scribner.

Palmer, C. (2015). *Berufsbezogene Kreativitätsdiagnostik. Entwicklung und Validierung eines Verfahrens zur Erfassung der personalen Voraussetzungen von Innovationen* [Dissertation]. Universität Hohenheim. https://d-nb.info/1072146649/34

Park, G., Lubinski, D., & Benbow, C. P. (2007). Contrasting Intellectual Patterns Predict Creativity in the Arts and Sciences. *Psychological Science*, *18*(11), 948–952. https://doi.org/10.1111/j.1467-9280.2007.02007.x

Piffer, D. (2012). Can creativity be measured? An attempt to clarify the notion of creativity and general directions for future research. *Thinking Skills and Creativity*, *7*(3), 258–264. https://doi.org/10.1016/j.tsc.2012.04.009

Pisturi, J. (2018). The Future of Human Work Is Imagination, Creativity, and Strategy. Retrieved May 19, 2021, from https://hbr.org/2018/01/the-future-of-human-work-is-imagination-creativity-and-strategy

Plucker, J. A., Beghetto, R. A., & Dow, G. T. (2004). Why Isn't Creativity More Important to Educational Psychologists? Potentials, Pitfalls, and Future Directions in Creativity Research. *Educational Psychologist*, *39*(2), 83–96. https://doi.org/10.1207/s15326985ep3902_1

Plucker, J. A., Makel, M. C., & Qian, M. (2010). Assessment of Creativity. In *The cambridge handbook of creativity* (pp. 44–68). Cambridge University Press. https://doi.org/10.1017/9781316979839.005

Prasch, L., aus dem Bruch, L., & Bengler, K. (2021). User Needs for Digital Creativity Support Systems in an Occupational Context. In N. L. Black, W. P. Neumann, & I. Noy (Eds.), *Proceedings of the 21st congress of the international ergonomics association (iea 2021)* (pp. 667–674). Springer International Publishing. https://doi.org/10.1007/978-3-030-74614-8_83

Prasch, L., & Bengler, K. (2019). Ergonomics in the Age of Creative Knowledge Workers – Define, Assess, Optimize. In *Advances in intelligent systems and computing* (pp. 349–357, Vol. 821). https://doi.org/10.1007/978-3-319-96080-7_41

Prasch, L., Maruhn, P., Brünn, M., & Bengler, K. (2020). Creativity Assessment via Novelty and Usefulness (CANU) - Approach to an Easy to Use Objective Test Tool. *Proceedings of the Sixth International Conference on Design Creativity (ICDC 2020)*, 019–026. https://doi.org/10.35199/ICDC.2020.03

Prentky, R. A. (2001). Mental Illness and Roots of Genius. *Creativity Research Journal*, *13*(1), 95–104. https://doi.org/10.1207/S15326934CRJ1301_11

Pringle, A., & Sowden, P. T. (2017). The Mode Shifting Index (MSI): A new measure of the creative thinking skill of shifting between associative and analytic thinking. *Thinking Skills and Creativity*, *23*, 17–28. https://doi.org/10.1016/j.tsc.2016.10.010

Puccio, G. J., & Cabra, J. F. (2012). Idea Generation and Idea Evaluation. In M. D. Mumford (Ed.), *Handbook of organizational creativity* (pp. 189–215). Elsevier. https://doi.org/10.1016/B978-0-12-374714-3.00009-4

Ramírez, Y. W., & Nembhard, D. A. (2004). Measuring knowledge worker productivity. *Journal of Intellectual Capital*, *5*(4), 602–628. https://doi.org/10.1108/14691930410567040

Rammstedt, B., & John, O. P. (2007). Measuring personality in one minute or less: A 10-item short version of the Big Five Inventory in English and German. *Journal of Research in Personality*, *41*(1), 203–212. https://doi.org/10.1016/j.jrp.2006.02.001

Raudsepp, E. (1981). *How creative are you?* Perigee Books.

Raven, J. C., Raven, J., & Court, J. H. (1998). *Raven's progressive matrices and vocabulary scales*. Oxford pyschologists Press.

Remy, C., Macdonald Vermeulen, L., Frich, J., Biskjaer, M. M., & Dalsgaard, P. (2020). Evaluating creativity support tools in HCI research. *DIS 2020 - Proceedings of the 2020 ACM Designing Interactive Systems Conference*, 457–476. https://doi.org/10.1145/3357236.3395474

Resnick, M., Myers, B., Nakakoji, K., Shneiderman, B., Pausch, R., Selker, T., & Eisenberg, M. (2005). *Design Principles for Tools to Support Creative Thinking* (tech. rep.). National Science Foundation. Washington DC.

Rhodes, M. (1961). An Analysis of Creativity. *The Phi Delta Kappan*, *42*(7), 305–310. https://doi.org/10.2307/20342603

Rickards, T., & Jones, L. J. (1991). Towards the identification of situational barriers to creative behaviors: The development of a self-report inventory. *Creativity Research Journal*, *4*(4), 303–315. https://doi.org/10.1080/10400419109534408

Runco, M. A. (2004). Everyone has creative potential. In *Creativity: From potential to realization.* (pp. 21–30). American Psychological Association. https://doi.org/10.1037/10692-002

Runco, M. A. (2007). A hierarchical framework for the study of creativity. *New Horizons in Education*, *55*(3), 1–9.

Runco, M. A. (2008). Commentary: Divergent Thinking Is Not Synonymous With Creativity. *Psychology of Aesthetics, Creativity, and the Arts*, *2*(2), 93–96. https://doi.org/10.1037/1931-3896.2.2.93

Runco, M. A. (2014). “Big C, Little c” Creativity as a False Dichotomy: Reality is not Categorical. *Creativity Research Journal*, *26*(1), 131–132. https://doi.org/10.1080/10400419.2014.873676

Runco, M. A., & Albert, R. S. (1986). The threshold theory regarding creativity and intelligence: An empirical test with gifted and nongifted children. *Creative Child and Adult Quarterly*, *11*(4), 212–218.

Runco, M. A., & Charles, R. E. (1993). Judgments of originality and appropriateness as predictors of creativity. *Personality and Individual Differences*, *15*(5), 537–546. https://doi.org/10.1016/0191-8869(93)90337-3

Runco, M. A., & Jaeger, G. J. (2012). The Standard Definition of Creativity. *Creativity Research Journal*, *24*(1), 92–96. https://doi.org/10.1080/10400419.2012.650092

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037//0003-066x.55.1.68

Rybowiak, V., Garst, H., Frese, M., & Batinic, B. (1999). Error orientation questionnaire (EOQ): reliability, validity, and different language equivalence. *Journal of Organizational Behavior*, *20*(4), 527–547. https://doi.org/10.1002/(SICI)1099-1379(199907)20:4<527::AID-JOB886>3.0.CO;2-G

Said-Metwaly, S., den Noortgate, W. V., & Kyndt, E. (2017). Approaches to Measuring Creativity: A Systematic Literature Review. *Creativity. Theories – Research - Applications*, *4*(2), 238–275. https://doi.org/10.1515/ctra-2017-0013

Sailer, K. (2011). Creativity as social and spatial process (B. P. Haynes, Ed.). *Facilities*, *29*(1/2), 6–18. https://doi.org/10.1108/02632771111101296

Samani, S. A., Rasid, S. Z. B. A., & bt Sofian, S. (2014). A Workplace to Support Creativity. *Industrial Engineering and Management Systems*, *13*(4), 414–420. https://doi.org/10.7232/iems.2014.13.4.414

Samani, S. A., Rasid, S. Z. B. A., & Sofian, S. B. (2015). Individual Control over the Physical Work Environment to Affect Creativity. *Industrial Engineering and Management Systems*, *14*(1), 94–103. https://doi.org/10.7232/iems.2015.14.1.094

Santanen, E. L., Briggs, R. O., & De Vreede, G. J. (2004). Causal Relationships in Creative Problem Solving: Comparing Facilitation Interventions for Ideation. *Journal of Management Information Systems*, *20*(4), 167–198. https://doi.org/10.1080/07421222.2004.11045783

Sarkar, A. (2016). We live in a VUCA World: the importance of responsible leadership. *Development and Learning in Organizations: An International Journal*, *30*(3), 9–12. https://doi.org/10.1108/DLO-07-2015-0062

Sarkar, P., & Chakrabarti, A. (2007). Development of a method for assessing design creativity. *International Conference on Engineering Design ICED 07*, (August), 1–12.

Sarkar, P., & Chakrabarti, A. (2008). Studying engineering design creativity. *Workshop on Studying Design Creativity*. http://johngero.com/conferences/sdc08/papers/Chakrabarti.pdf

Sarkar, P., & Chakrabarti, A. (2011). Assessing design creativity. *Design Studies*, *32*(4), 348–383. https://doi.org/10.1016/j.destud.2011.01.002

Savransky, S. D. (2000). *Engineering of creativity: Introduction to TRIZ methodology of inventive problem solving*. CRC press.

Sawyer, R. K. (2012). *Explaining creativity: The science of human innovation*. Oxford University Press.

Schlorf, M. (2020). *Einfluss der wahrgenommenen sozial-organisatorischen und physikalischen Arbeitsumgebung auf die kreative Leistung von Wissensarbeitenden in Deutschland* [Master's Thesis]. Technical University of Munich.

Scotney, V. S., Weissmeyer, S., Carbert, N., & Gabora, L. (2019). The Ubiquity of Cross-Domain Thinking in the Early Phase of the Creative Process. *Frontiers in Psychology*, *10*(JUN), 1–10. https://doi.org/10.3389/fpsyg.2019.01426

Scott, S. G., & Bruce, R. A. (1994). Determinants of Innovative Behavior: A Path Model of Individual Innovation in the Workplace. *Academy of Management Journal*, *37*(3), 580–607. https://doi.org/10.5465/256701

Scotto di Carlo, M. (2021). *Development and evaluation of digital creativity assistants as supplemental tools for brainstorming* [Master's Thesis]. Technical University of Munich.

Senders, J. W., & Moray, N. P. (1991). *Human error: Cause, prediction, and reduction*. CRC Press.

Serrat, O. (2017). The Five Whys Technique. In *Knowledge solutions* (pp. 307–310). Springer Singapore. https://doi.org/10.1007/978-981-10-0983-9_32

Shalley, C. E., Gilson, L. L., & Blum, T. C. (2000). Matching Creativity Requirements and the Work Environment: Effects on Satisfaction and Intentions to Leave. *Academy of Management Journal*, *43*(2), 215–223. https://doi.org/10.5465/1556378

Shalley, C. E., Gilson, L. L., & Blum, T. C. (2009). Interactive Effects of Growth Need Strength, Work Context, and Job Complexity On Self-Reported Creative Performance. *Academy of Management Journal*, *52*(3), 489–505. https://doi.org/10.5465/amj.2009.41330806

Shalley, C. E., Zhou, J., & Oldham, G. R. (2004). The Effects of Personal and Contextual Characteristics on Creativity: Where Should We Go from Here? *Journal of Management*, *30*(6), 933–958. https://doi.org/10.1016/j.jm.2004.06.007

Shannon, C. E. (1948). A Mathematical Theory of Communication. *Bell System Technical Journal*, *27*(3), 379–423. https://doi.org/10.1002/j.1538-7305.1948.tb01338.x

Shibata, S., & Suzuki, N. (2004). Effects of an indoor plant on creative task performance and mood. *Scandinavian Journal of Psychology*, *45*(5), 373–381. https://doi.org/10.1111/j.1467-9450.2004.00419.x

Shneiderman, B. (2000). Creating creativity: User Interfaces for Supporting Innovation. *ACM Transactions on Computer-Human Interaction*, *7*(1), 114–138. https://doi.org/10.1145/344949.345077

Shneiderman, B. (2002). Creativity support tools. *Communications of the ACM*, *45*(10), 116–120. https://doi.org/10.1145/570907.570945

Shneiderman, B. (2007). Creativity support tools: accelerating discovery and innovation. *Communications of the ACM*, *50*(12), 20–32. https://doi.org/10.1145/1323688.1323689

Shneiderman, B. (2009). Creativity Support Tools: A Grand Challenge for HCI Researchers. In *Engineering the user interface* (pp. 1–9). Springer London. https://doi.org/10.1007/978-1-84800-136-7_1

Shneiderman, B., Fischer, G., Czerwinski, M., Myers, B., Candy, L., Edmonds, E., Eisenberg, M., Giaccardi, E., Hewett, T., University, D., Jennings, P., Kules, B., Nakakoji, K., Nunamaker, J., Pausch, R., Selker, T., Sylvan, E., & Terry, M. (2005). Creativity Support Tools: A workshop sponsored by the National Science Foundation. *International Journal of Human-Computer Interaction*, *20*(2), 1–83. http://www.cs.umd.edu/hcil/CST/creativitybook_final.pdf

Shneiderman, B., Fischer, G., Czerwinski, M., Resnick, M., Myers, B., Candy, L., Edmonds, E., Eisenberg, M., Giaccardi, E., Hewett, T., Jennings, P., Kules, B., Nakakoji, K., Nunamaker, J., Pausch, R., Selker, T., Sylvan, E., & Terry, M. (2006). Creativity Support Tools: Report From a U.S. National Science Foundation Sponsored Workshop. *International Journal of Human-Computer Interaction*, *20*(2), 61–77. https://doi.org/10.1207/s15327590ijhc2002_1

Siegel, S. M., & Kaemmerer, W. F. (1978). Measuring the perceived support for innovation in organizations. *Journal of Applied Psychology*, *63*(5), 553–562. https://doi.org/10.1037/0021-9010.63.5.553

Siemon, D., Eckardt, L., & Robra-Bissantz, S. (2015). Tracking Down the Negative Group Creativity Effects with the Help of an Artificial Intelligence-Like Support System. *2015 48th Hawaii International Conference on System Sciences*, 236–243. https://doi.org/10.1109/HICSS.2015.37
no control condition??

Silvia, P. J. (2008). Creativity and intelligence revisited: A latent variable analysis of Wallach and Kogan (1965). *Creativity Research Journal*, *20*(1), 34–39. https://doi.org/10.1080/10400410701841807

Silvia, P. J., Wigert, B., Reiter-Palmon, R., & Kaufman, J. C. (2012). Assessing creativity with self-report scales: A review and empirical evaluation. *Psychology of Aesthetics, Creativity, and the Arts*, *6*(1), 19–34. https://doi.org/10.1037/a0024071

Simonton, D. K. (1975). Age and Literary Creativity. *Journal of Cross-Cultural Psychology*, *6*(3), 259–277. https://doi.org/10.1177/002202217563001

Simonton, D. K. (1988). Age and outstanding achievement: What do we know after a century of research? *Psychological bulletin*, *104*(2), 251.

Simonton, D. K. (1995). Exceptional personal influence: An integrative paradigm. *Creativity Research Journal*, *8*(4), 371–376.

Simonton, D. K. (2000). Creativity: Cognitive, personal, developmental, and social aspects. *American Psychologist*, *55*(1), 151–158. https://doi.org/10.1037/0003-066X.55.1.151

Smit, D., Grah, T., Murer, M., van Rheden, V., & Tscheligi, M. (2018). MacroScope: First-Person Perspective in Physical Scale Models. *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction*, 253–259. https://doi.org/10.1145/3173225.3173276

Smola, A., & Vishwanathan, S. V. N. (2008). Introduction to machine learning. *Cambridge University, UK*, *32*(34), 2008.

Snyder, H. T., Hammond, J. A., Grohman, M. G., & Katz-Buonincontro, J. (2019). Creativity measurement in undergraduate students from 1984-2013: A systematic review. *Psychology of Aesthetics, Creativity, and the Arts*, *13*(2), 133–143. https://doi.org/10.1037/aca0000228

Soriano de Alencar, E. M., & Bruno-Faria, M. F. (1997). Characteristics of on Organizational Environment which Stimulate and Inhibit Creativity*. *The Journal of Creative Behavior*, *31*(4), 271–281. https://doi.org/10.1002/j.2162-6057.1997.tb00799.x

Statistisches Bundesamt. (2018). *Bildungsstand der Bevölkerung* (Vol. 49).

Stefl, M., & Rohm, A. (2017). Is the internet killing your creative potential? *Graziadio Business Report*, *20*(1). https://gbr.pepperdine.edu/2017/04/is-the-internet-killing-your-creative-potential/

Steidle, A., & Werth, L. (2013). Freedom from constraints: Darkness and dim illumination promote creativity (L. Nadel, Ed.). *Journal of Environmental Psychology*, *35*, 67–80. https://doi.org/10.1016/j.jenvp.2013.05.003

Stein, M. I. (1953). Creativity and Culture. *The Journal of Psychology*, *36*(2), 311–322. https://doi.org/10.1080/00223980.1953.9712897

Stein, M. I. (1974). *Stimulating creativity (Vol. 1)*. Academic Press.

Steiner, G. (2006). Innovative Performance of Organizations as a Result of their Physical Environment. *XVIth World Congress on Sociology "The Quality of Social Existance in a Globalistic World"*, 1–14. http://www.unizar.es/sociocybernetics/congresos/DURBAN/papers/steiner.pdf

Sternberg, R. J. (1999). A Propulsion Model of Types of Creative Contributions. *Review of General Psychology*, *3*(2), 83–100. https://doi.org/10.1037/1089-2680.3.2.83

Sternberg, R. J. (2000). *Handbook of Intelligence* (R. J. Sternberg, Ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511807947

Sternberg, R. J. (2006). RETRACTED ARTICLE: The Nature of Creativity. *Creativity Research Journal*, *18*(1), 87–98. https://doi.org/10.1207/s15326934crj1801_10

Sternberg, R. J. (2020). "The Nature of Creativity": Retraction. https://doi.org/10.1080/10400419.2019.1647690

Sternberg, R. J., & Lubart, T. I. (1991). An Investment Theory of Creativity and Its Development. *Human Development*, *34*(1), 1–31. https://doi.org/10.1159/000277029

Sternberg, R. J., & Lubart, T. I. (1996). Investing in creativity. *American Psychologist*, *51*(7), 677–688. https://doi.org/10.1037/0003-066X.51.7.677

Sternberg, R. J., & Lubart, T. I. (1999). The concept of creativity: Prospects and paradigms. *Handbook of creativity*, *1*, 3–15.

Stokols, D., Clitheroe, C., & Zmuidzinas, M. (2002). Qualities of Work Environments That Promote Perceived Support for Creativity. *Creativity Research Journal*, *14*(2), 137–147. https://doi.org/10.1207/S15326934CRJ1402_1

Stone, N. J. (2003). Environmental view and color for a simulated telemarketing task. *Journal of Environmental Psychology*, *23*(1), 63–78. https://doi.org/10.1016/S0272-4944(02)00107-X

Streumer, J., & Kho, M. (2006). The World Of Work-Related Learning. In *Work-related learning* (pp. 3–49). Kluwer Academic Publishers. https://doi.org/10.1007/1-4020-3939-5_1

Strohmann, T., Siemon, D., & Robra-Bissantz, S. (2017). brAInstorm: Intelligent Assistance in Group Idea Generation. In A. Maedche, J. vom Brocke, & A. Hevner (Eds.), *Designing the digital transformation* (pp. 457–461). Spinger. https://doi.org/10.1007/978-3-319-59144-5_31

Susskind, D. (2020). *A world without work: Technology, automation and how we should respond*. Penguin UK.

Switzer, C. (2008). Time for change: empowering organizations to succeed in the knowledge economy. *Journal of Knowledge Management*, *12*(2), 18–28. https://doi.org/10.1108/13673270810859488

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. https://doi.org/10.5116/ijme.4dfb.8dfd

Taylor, F. W. (1914). *The Principles of Scientific Management*. Harper & Brothers.

Taylor, I. A., & Sandler, B. E. (1972). Use of a creative product inventory for evaluating products of chemists. *Proceedings of the Annual Convention of the American Psychological Association*.

Tierney, P., Farmer, S. M., & Graen, G. B. (1999). An examination of leadership and employee creativity: The relevance of traits and relationships. *Personnel psychology*, *52*(3), 591–620. https://doi.org/10.1111/j.1744-6570.1999.tb00173.x

Toker, U., & Gray, D. O. (2008). Innovation spaces: Workspace planning and innovation in U.S. university research centers. *Research Policy*, *37*(2), 309–329. https://doi.org/10.1016/j.respol.2007.09.006

Torrance, E. P. (1966). The Torrance Tests of Creative Thinking-Norms-Technical Manual Research Edition-Verbal Tests. *Forms A and B-Figural Tests, Forms A and B.*

Toynbee, A. (1962). Has America Neglected Her Creative Minority? *Sooner Magazine*, 7–9.

Treagust, D. F., & Fraser, B. J. (1986). Validation and Application of the College and University Classroom Environment Inventory (CUCEI).

Treffinger, D. J., Isaksen, S. G., & Stead-Dorval, K. B. (2005). *Creative problem solving: An introduction*. Prufrock Press Inc.

Tseng, I., Moss, J., Cagan, J., & Kotovsky, K. (2008). The role of timing and analogical similarity in the stimulation of idea generation in design. *Design Studies*, *29*(3), 203–221. https://doi.org/10.1016/j.destud.2008.01.003

Tupes, E. C., & Christal, R. E. (1992). Recurrent Personality Factors Based on Trait Ratings. *Journal of Personality*, *60*(2), 225–251. https://doi.org/10.1111/j.1467-6494.1992.tb00973.x

Turing, A. M. (1937). On Computable Numbers, with an Application to the Entscheidungsproblem. *Proceedings of the London Mathematical Society*, *s2-42*(1), 230–265. https://doi.org/10.1112/plms/s2-42.1.230

Unsworth, K. (2001). Unpacking Creativity. *Academy of Management Review*, *26*(2), 289–297. https://doi.org/10.5465/amr.2001.4378025

Unsworth, K., Brown, H., & McGuire, L. (2000). Employee Innovation: The roles of Idea Generation and Idea Implementation. *SIOP Conference 2000*, 1–12. http://eprints.qut.edu.au/3034/

Valgeirsdottir, D., Onarheim, B., & Gabrielsen, G. (2015). Product creativity assessment of innovations: considering the creative process. *International Journal of Design Creativity and Innovation*, *3*(2), 95–106. https://doi.org/10.1080/21650349.2014.954626

Van de Ven, A. H., & Ferry, D. L. (1980). *Measuring and Assessing Organizations.* Wiley Interscience. https://doi.org/10.2307/2392488

Van Gundy, A. B. (2005). *101 activities for teaching creativity and problem solving*. John Wiley & Sons.

Vartanian, O., Beatty, E. L., Smith, I., Forbes, S., Rice, E., & Crocker, J. (2019). Measurement matters: the relationship between methods of scoring the Alternate Uses Task and brain activation. *Current Opinion in Behavioral Sciences*, *27*, 109–115. https://doi.org/10.1016/j.cobeha.2018.10.012

Vasconcelos, L. A., & Crilly, N. (2016). Inspiration and fixation: Questions, methods, findings, and challenges. *Design Studies*, *42*, 1–32. https://doi.org/10.1016/j.destud.2015.11.001

Veitch, J. A., & Gifford, R. (1996). Choice, percieved control, and performance in the physical environment. *Journal of Environmental Psychology*, *16*(3), 269–276. https://doi.org/10.1006/jevp.1996.0022

Venkatesh, V. (2000). Determinants of Perceived Ease of Use: Integrating Control, Intrinsic Motivation, and Emotion into the Technology Acceptance Model. *Information Systems Research*, *11*(4), 342–365. https://doi.org/10.1287/isre.11.4.342.11872

Ventura, D. (2015). The Computational Creativity Complex. In *Computational creativity research: Towards creative machines* (pp. 65–92). Springer. https://doi.org/10.2991/978-94-6239-085-0_4

Vithayathawornwong, S., Danko, S., & Tolbert, P. (2003). The Role of the Physical Environment in Supporting Organizational Creativity. *Journal of Interior Design*, *29*(1-2), 1–16. https://doi.org/10.1111/j.1939-1668.2003.tb00381.x

von Hippel, E. (2006). *Democratizing Innovation* (Vol. 6). MIT Press. http://library.oapen.org/handle/20.500.12657/26093

Wallach, M. A., & Kogan, N. (1965). Modes of thinking in young children.

Wallas, G. (1926). *The Art of Thought.* London.

Wang, H.-C., Fussell, S. R., & Cosley, D. (2011). From diversity to creativity: Stimulating group brainstorming with cultural differences and conversationally-retriebed pictures. *Proceedings of the ACM 2011 conference on Computer supported cooperative work - CSCW '11*, 265. https://doi.org/10.1145/1958824.1958864

Wang, K., & Nickerson, J. V. (2017). A literature review on individual creativity support systems. *Computers in Human Behavior*, *74*, 139–151. https://doi.org/10.1016/j.chb.2017.04.035

Wang, K., & Nickerson, J. V. (2019). A Wikipedia-based Method to Support Creative Idea Generation: The Role of Stimulus Relatedness. *Journal of Management Information Systems*, *36*(4), 1284–1312. https://doi.org/10.1080/07421222.2019.1661095

Ward, M. (2020). Victorian Fictions of Computational Creativity. In S. Cave, K. Dihal, & S. Dillon (Eds.), *Ai narratives: A history of imaginative thinking about intelligent machines* (pp. 144–164). Oxford University Press.

Warwick-Ching, L. (2013). Currency wars: Volatility provides profit opportunity. *The Financial Times*, *25*, 3. Retrieved May 25, 2021, from https://www.ft.com/content/e17e1ab0-8714-11e2-9dd7-00144feabdc0#axzz2r3QHfbxW

Wierenga, B., & van Bruggen, G. H. (1998). The Dependent Variable in Research into the Effects of Creativity Support Systems: Quality and Quantity of Ideas. *MIS Quarterly*, *22*(1), 81. https://doi.org/10.2307/249679

Wolfradt, U., & Pretz, J. E. (2001). Individual differences in creativity: personality, story writing, and hobbies. *European Journal of Personality*, *15*(4), 297–310. https://doi.org/10.1002/per.409

Woodman, R. W., Sawyer, J. E., & Griffin, R. W. (1993). Toward a Theory of Organizational Creativity. *Academy of Management Review*, *18*(2), 293–321. https://doi.org/10.5465/amr.1993.3997517

Zeng, L., Proctor, R. W., & Salvendy, G. (2011). Can traditional divergent thinking tests be trusted in measuring and predicting real-world creativity? *Creativity Research Journal*, *23*(1), 24–37. https://doi.org/10.1080/10400419.2011.545713

Zhou, J. (2003). When the presence of creative coworkers is related to creativity: Role of supervisor close monitoring, developmental feedback, and creative personality. *Journal of Applied Psychology*, *88*(3), 413–422. https://doi.org/10.1037/0021-9010.88.3.413