“Embodied Creativity in the Era of AI:

a Comparative Study involving Neural Style Transfer Technologies”

by

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CHAPTER 1: INTRODUCTION

Introduction

Creativity, as elusive as the mythical muses of ancient Greece, has been an unseen but very present companion to the humankind since the dawn of civilization. Its profound influence can be observed in various forms throughout history, from the captivating cave paintings of Lascaux to the ethereal sculptures of ancient Rome, from the majestic Great Pyramid of Giza to the groundbreaking Apollo 11 rocket that propelled humanity to the moon. In the modern era, Artificial Intelligence has added a new dimension to this rich tapestry of creativity. These diverse examples serve as a poignant reminder that creative expression transcends time and cultural boundaries, binding us together through our shared humanity. It represents an innate and universal human impulse, continuously evolving and serving as a dynamic area of research. The increasing recognition of its significance in multiple domains, including education, business, healthcare, and the arts, further highlights the ever-growing importance and relevance of creativity in our rapidly changing world.

Research on creativity in psychology aims to understand the cognitive and psychological processes involved in generating novel and valuable ideas or products. This includes examining individual differences in creativity, such as personality traits and cognitive abilities, as well as environmental and contextual factors that influence creative thinking and problem-solving. However, despite numerous studies, the discussion regarding the definition, components and assessment of creativity has been subjects of ongoing debate among researchers for decades.

One of the pioneering studies on creativity was conducted by Guilford (1950), who identified several key characteristics of creative individuals, including sensitivity to problems, fluency of ideas, mental flexibility, divergent thinking, and the ability to redefine familiar objects

and concepts. Further research has shown positive associations between creativity and traits such as humor and complex temperament (Rhodes, 1961). More recent studies have also emphasized the importance of contextual factors in fostering creativity. For instance, a supportive and positive work environment, exposure to diverse perspectives and experiences, and opportunities for autonomy and exploration have all been found to enhance creativity (Amabile, 1998; Csikszentmihalyi, 1997). Moreover, cognitive processes involved in creativity can also be influenced by external factors such as culture, education, and social norms (Glăveanu, 2013). The interplay between embodied cognition and AI has brought yet another new dimensions to the exploration of creativity, forging a connection between human expression and technological innovation.

Consequently, there exists a significant scholarly interest in studying the underlying mechanisms of creativity, fostering its development, and leveraging it to address the challenges of contemporary society. In psychology, the research on the topic of creativity focuses on understanding the cognitive and psychological processes involved in generating novel and valuable ideas or products. This entails examining individual differences in creativity, such as personality traits and cognitive abilities, as well as environmental and contextual elements that influence creative thinking and problem-solving.

Statement of the Problem

Consider the following scenarios: when you are bored in class or attend yet another unnecessary work meeting, do you find yourself doodling on a scrap of paper or fidgeting with a pen? When faced with writer's block or facing a particularly difficult problem, do you go for a walk to help you come up with a creative solution? Our bodies play crucial roles in how we perceive the world around us and engage with it. Throughout our lives, it is through our bodies

we experience the environment around us by interacting with our surroundings, connecting with others, exploring, learning and creating. They can be used as powerful tools for expression and exploration when we engage in creative activities, such as art, music, dance, or writing. For instance, someone who has experienced a traumatic event may use art or writing to process their feelings and make sense of their experiences, while someone who has traveled extensively may draw inspiration from different cultures and perspectives.

In recent years, the notion of embodied cognition, which focuses on the interdependence of physical experiences and cognitive processes, has become an important concept in cognitive science and neuroscience. Yet, the research into embodied creativity is still in its early stages despite the shift away from viewing creativity as a solely cognitive process towards seeing it more as an activity (Glaveanu et al., 2013). According to Griffith (2021), Although the field of embodied cognition has faced criticism within psychology, the researchers do not deny its existence as a theoretical framework. Instead, the critique primarily revolves around methodological challenges, including a scarcity of experimental research studies and limited direct replication, which have hindered the field's progress. Further exploration is necessary to enhance our understanding of the intricate mechanisms and implications of embodied cognition.

The advent of artificial intelligence (AI) added yet another dimension to this topic through the emergence of new opportunities for artistic expression marking the intersection between embodied creativity and AI as a topic of contemporary discourse. Although ongoing research and development in this area is underway, the exact impact of active participation in AI-based interventions on creativity remains uncertain as empirical research on the subject is limited.

In discussions surrounding the intersection of AI and creativity, the predominant focus often revolves around two key aspects: the potential creative capabilities of AI systems and the notion of co-creation between humans and AI (Wingström et al., 2022). Scientists also aim to use AI technologies to explore human creativity. For example examine the application of AI techniques in modeling human aesthetics and creativity (Utz & DiPaola, 2020). Nevertheless, the majority of studies on the topic of AI and creativity are conducted within the field of computer science, where researchers often use pre-planned empirical settings and rarely question the underlying concepts of creativity (Gobet & Sala, 2019). Moreover, the existing studies predominantly focus on technical aspects rather than the underlying cognitive and psychological processes of creativity.

Our goal is to address these gaps in research regarding the influence of physical experiences on creative processes and explore the impact of AI-based interventions on creative thinking. We seek to contribute valuable insights that address both theoretical frameworks and practical applications, providing a foundation for further research.

Literature Review

Overview

The literature review section provides an overview of key concepts and research findings related to creativity, embodied creativity, and the impact of AI on creative processes. In the first part of the literature review, the concept of creativity is explored, encompassing a wide range of definitions and perspectives from researchers in the field. This section aims to provide a brief understanding of creativity by highlighting its key components, while addressing the involvement of cognitive processes. The second part focuses on embodied creativity, an emerging field of research that examines the role of the body and environment in the creative

cognitive processes. The section presents current studies that demonstrate the impact of embodied movements on creative ideation and problem-solving. The final part of this literature review explores the influence of AI on creativity. We examine the potential of AI to enhance creative thinking abilities and presents studies that have explored the positive effects of engaging with AI-powered creativity tools. It is primary's investigator's hope that providing this understanding of abovementioned concepts will enhance comprehension of embodied cognition and creativity, fostering a deeper understanding of the current study and emphasizing the importance of future research in the field of embodied creativity and AI.

Components of Creativity

Although there exist various definitions of creativity, the general consensus among the researchers is that it must have two main components: it has to be original and task-appropriate. In other words, it must fulfill the prerequisites for whatever it is trying to accomplish. (Kaufman & Glăveanu, 2021). Beyond that, according to various researchers, this definition also includes a wide range of other elements. According to (Rhodes, 1961), creativity can be understood as a phenomenon in which an individual generates and communicates a novel idea or concept, which serves as the end product. Implicit in this definition is the involvement of cognitive processes that enable the creation of something new. Additionally, it is assumed that the individual operates within social, cultural, and environmental context, which provides a certain level of influence on the creative process. However, this description leaves unanswered questions regarding the originality and novelty of the generated idea. Dr. E. Paul Torrance, a prominent educational researcher, addresses this gap by defining creativity as a process that involves identifying a problem, searching for solutions, testing and modifying hypotheses, and finally communicating the results. (Kyung Hee Kim, 2006). In addition to these definitions, some

researchers propose that creativity involves the integration of various cognitive processes, such as divergent and convergent thinking, analogical and metaphorical thinking, mental imagery, and analogical reasoning. In modern times, the updated Bloom's Taxonomy characterizes creativity as the most intricate and advanced cognitive process within the hierarchy of knowledge, necessitating the utilization of higher-level cognitive functions supported by the executive control network. These functions include working memory, inhibitory control, goal-oriented behaviors, and cognitive flexibility (Romance et al., 2023, p. 11).

Embodied cognition view of creativity

In the field of psychology, a traditional view of creativity as a cognitive process centered on generating new ideas and products prevailed until recently. Leschziner and Brett, (2019) highlighted how this emphasis on controlled cognition has led to the perception of creativity as an exceptional phenomenon, separate from nonconscious thinking and habitual actions. The authors pointed out that existing frameworks and studies in psychology often overlook the role of the body in creativity, with limited consideration given to its connection with affect and emotions. By primarily associating the body with the brain's thoughts and perceptions, the body is positioned as a passive responder rather than an active generator of creative ideas. Leschziner and Brett (2019) argued that this focus on the mind has led to a neglect of the body and sensory experiences in the creative process. They suggested that the body itself can play a significant role in generating new ideas and creative actions. Indeed, over the past few decades, embodiment theory has had a significant impact on creativity research. This theory studies the role of the body in the creative cognitive process, including how physical experiences such as movement and gesture can facilitate the generation of new and innovative ideas. The embodied approach recognizes the interconnectedness of the brain and body and how they form part of a larger

cognitive system. This perspective explores how actions influence perception and cognition and posits a complementary relationship between action and perception (Bruin et al., 2018). According to this framework, the body and environmental information involve a broad range of actions that can be utilized to facilitate creative thinking (Koch et al., 2014). As per Malinin, (2019), this research field can be divided into two distinct streams. The first stream focuses on conducting experimental studies that explore the role of embodied metaphors in creative thinking. These investigations typically assess how the enactment of metaphors through specific bodily movements can impact the generation of ideas. In contrast, the second stream takes a dynamical systems perspective, considering creativity as an emergent phenomenon that arises through the interactions between individuals and the material environment, including artifacts. This approach often employs qualitative or mixed methods to understand the entire creative process, from problem finding to implementation, by integrating observation, sensors, and interviews to capture the dynamic interplay between people and artifacts.

Multiple studies have provided evidence that physical actions can boost the generation of creative ideas. For instance, research conducted by Oppezzo and Schwartz (2014) demonstrated that engaging in physical activity such as walking, particularly in outdoor settings, led to a significant increase in creative thinking. Similarly, Andolfi et al., (2017) found that adopting expansive or open postures, such as standing with arms outstretched, can increase the likelihood of producing original and imaginative ideas. In the realm of music, Raposo et al., (2021) explored the biologically mediated meaning grounded in the human body and brain, and leverages this understanding to develop a statistical computational model that learns semiotic correlations between music audio and dance video, demonstrating its effectiveness in cross-modal retrieval tasks. Additionally, Romance et al., (2023), revealed a correlation between

moderate-vigorous physical activity and cognitive fluency, originality, and cognitive flexibility. Frith (2019) conducted a study containing multiple experiments to explore the relationship between exercise and creativity, ultimately finding that acute, moderate-intensity treadmill exercise coupled with anagram problem-solving had a statistically significant priming effect on subsequent RAT completion compared to a non-exercise condition. These findings suggest that combining exercise with priming may be an effective approach for enhancing verbal convergent creativity. In addition, a systematic review of 20 studies exploring the impact of motion on creativity concluded that embodied movement robustly enhanced creativity in nearly all studies (90%), with no studies showing any negative effect. These findings suggest that physical actions and movements have significant potential to enhance creative idea generation and should be explored further as a viable strategy for promoting creativity (Frith, 2019). However, it is important to note that the body itself does not exist in a vacuum. Creative development occurs through the active interaction of an individual's body with their surrounding environment.

According to 4E cognition approach, human cognition is a dynamic system that encompasses the interconnectedness of the brain/mind, body, and the surrounding world (Gubenko & Houssemand, 2022). As individuals interact with their surroundings, they encounter stimuli and acquire knowledge, skills, and experiences that contribute to their creative development. To effectively address creative cognition across different domains, it is crucial to comprehend the mental and environmental factors that can either enhance or hinder creative thinking processes (Romance et al., 2023). Gaining insight into these factors is essential for developing comprehensive models that capture the complexities of creativity. Nevertheless, according to Griffith (2021), despite the emerging evidence of the importance of the role of the body and environment, the question of whether embodiment requires complex coupling between

brain, body, and environment, or whether it is reducible to neural representations, remains a central issue in debates about cognition.

Artificial Intelligence

Traditionally, creative arts have been considered as the domain of human creative processes. However, recent developments in the field of AI have introduced a paradigm shift in this perspective. The rise of AI has revolutionized the creative landscape, offering new resources for artistic expression and reshaping our perception of creativity. The integration of digital and networking technologies has significantly influenced our perception of creativity, enabling new forms of creation, collaboration, and dissemination (Henriksen et al., 2016). AI-powered technologies, such as deep learning algorithms and machine learning systems are now being used to create digital art, music, and other types of creative output. Artists and engineers have harnessed the power of AI to generate amazing works in the domains of visual arts, literature, cinema, music, and many other fields.

AI has the ability to impact creative processes in multitude of ways. For example, AI can be used to automate repetitive tasks and allow creative individuals to focus on more artistic tasks. It can be used to analyse data and provide insights that can prompt new ideas, as it was done by Refik Anadol, a Turkish-born media artist known for his works with AI. In his project "Melting Memories," (2018) Anadol used AI algorithms to process and visualize data collected from millions of flight routes and projected the results onto scultptural forms creating an immersive environment representing the patterns of air travel. Beyond Anadol's work, others have explored the integration of AI algorithms into various domains. For example, scientists have explored the use of AI algorithms in creation of original musical compositions (Raposo et al., 2021), dancing routines (Zeng, 2022), and even fashion (Luce, 2019). In some instances, AI systems, such as

AIVA (Artificial Intelligence Virtual Artist) have been built to react in real-time to the movements, given rise to new forms of participatory and improvisational art. This interactive aspect introduces a new dimension of embodiment, where the AI system becomes an active participant in the creative process, responding to and influencing human expression.

However, despite the growing attention given to creativity and the evidence highlighting the influence of AI technologies on creative processes, the scholarly investigations in this domain generally exhibit a scarcity of explicitly defined constructs related to creativity and frequently lack comprehensive descriptions of the observed effects (Gubenko et al., 2021). Nevertheless, preliminary findings suggest that the utilization of AI-powered creativity tools holds the potential to augment an individual's creative thinking capabilities. For example, in a study conducted by Eteokleous et al. (2018), it was discovered that the implementation of a non-formal robotics curriculum resulted in a notable enhancement of creative abilities among 32 primary school students, as measured by the TTCT. Likewise, Hendrik et al. (2020) observed a positive impact on Figural Creativity among 40 elementary school students who participated in a robotics intervention consisting of seven weekly lessons, as evaluated through the TTCT. These studies shed light on the potential role of AI technologies in facilitating creative processes. However, further research is needed to establish a more comprehensive understanding of the specific mechanisms and effects of AI technologies on creativity.

Definition of Key Terms

1. Creativity: According to (Rhodes, 1961), the term "creativity" refers to the act of communicating a new concept or idea, with the underlying implication of mental activity and societal influence. It encompasses the capacity to generate original and valuable ideas, products, or problem-solving approaches (Amabile, 2019).

Specifically, it involves both divergent thinking, which entails generating a range of diverse ideas, and convergent thinking, which involves evaluating and selecting the most promising ideas. (Runco & Jaeger, 2012).

2. Embodied cognition: Embodied cognition is a prominent theoretical framework positing that cognitive processes are intricately intertwined with the physical body and its dynamic interactions with the surrounding environment. It emphasizes that cognition extends beyond the confines of the brain, as the actions, perceptions, and sensations of the body play a fundamental role in shaping and influencing cognitive phenomena (Shapiro & Spaulding, 2021). “Embodiment refers to how the body contributes to cognitive process and is based on the premise that the brain and body evolved together and are therefore intrinsically coupled. It considers the brain as part of a larger cognitive system, including the body’s nervous system and sensorimotor capabilities” (Malinin, 2019).
3. Embodied creativity: is a theoretical framework that emphasizes the role of the body and its interactions with the environment in the creative process. It suggests that cognitive processes involved in creativity are not solely limited to the brain but are influenced by bodily actions, perceptions, and sensations. This perspective highlights the interplay between the body, mind, and environment in shaping and facilitating creative thinking and expression.
4. Artificial Intelligence (AI): AI, an expansive domain within computer science and technology, encompasses the development of intelligent machines with the capacity to undertake tasks conventionally associated with human intelligence. Its multifaceted nature incorporates subdisciplines such as machine learning, natural language

processing, computer vision, and robotics, among a diverse array of others (Nilsson, 1996).

5. Neural Style Transfer (NST): NST is a is a technique that combines the content of one image with the artistic style of another image to create a new image that preserves the underlying content while adopting the visual style of the reference image (Gatys et al., 2015a).

Contributions to Current Literature

This study aimed to contribute to the existing literature on the influence of physical experiences on individual's creativity. As the capabilities of the human body are increasingly harnessed to enhance AI systems, it becomes imperative to investigate the impact of AI on creativity. Specifically, the primary investigator aimed to explore the effects of active participation in an interactive art project using NST and compare them to those who passively observed art. By examining how engagement with AI-powered creativity tools can enhance creative thinking abilities, this study seeks to provide valuable insights into the field of embodied cognition, AI, and creativity. The findings from this research are anticipated to inform future developments in this area, expanding our understanding of the relationship between physical experiences, AI, and individual creativity. In addition, the primary investigator believes that this research will contribute to the current debates about embodied cognition and the disagreements between behaviorists and cognitivists regarding the role of the body and environment in creativity.

Summary

The literature review section of this study highlights the evolving understanding of creativity, the importance of embodiment in the creative process, and the transformative role of

AI in expanding creative possibilities. The primary investigator hopes that it provides a comprehensive overview of the current state of research in the field of creativity by encompassing the discussions on traditional definitions of creativity, the role of embodiment in creative cognition, and the transformative influence of AI on creative processes. By synthesizing key concepts and research findings, we hope to contribute to a deeper understanding of the complex dynamics underlying creativity and set the stage for further exploration and investigation in these evolving areas of study.

Purpose of the Study

At present, there exists a limited number of empirical research studies examining the impact of physical experiences with AI technologies on an individual's creative process. More specifically, the purpose of this study was to investigate the effect of actively engaging art activity featuring NST technology on high school students' creativity level. The study's objective was to investigate the changes in creativity level among high school students before and after their participation in an interactive art project that incorporates NST and to compare the results to a group of students who observed art passively.

The primary investigator hopes that the findings of this study will offer valuable insights into the potential of physical experiences, particularly those involving AI-powered creativity tools, to enhance creative thinking abilities. In addition, the author hopes that this research will contribute to the existing literature on the influence of AI technologies on creativity and will serve as a foundation for future studies in various fields.

Theoretical Framework

This study utilizes the framework of embodied cognition, and more specifically the Radical Embodied Cognitive Science (RECS) perspective which draws on the 4E cognition

framework which highlight the importance of embodied interaction in a socio-cultural environment for creative process.

Embodied Cognition

Embodied cognition is a widely recognized theoretical framework that suggests a close relationship between cognitive processes and the physical body, as well as its dynamic interactions with the environment. This perspective highlights the idea that cognition is not limited to the brain alone but is influenced by the body's actions, perceptions, and sensations, which significantly contribute to shaping and impacting cognitive phenomena (Shapiro & Spaulding, 2021).

Radical Embodied Cognitive Science

According to RECS approach, cognition cannot be understood in isolation from the body and environment, and our bodily experiences and sensory-motor systems play a significant role in how we reason. According to Malinin (2019), the Radical Embodied Cognitive Science (RECS) theory challenges traditional approaches to cognitive science and contends that cognition should be viewed as a dynamic system that includes the brain, body, and environment. RECS asserts that human cognition is an embodied and situated activity, representing a dynamic system that encompasses the brain, body, and the external world. The framework of RECS is commonly articulated through the lens of 4E cognition, which highlights the embodied, embedded, enactive, and extended nature of the mind. More specifically, embodied cognition recognizes the role of the body in cognition, embedded cognition highlights the influence of environments on cognition, enactive cognition emphasizes cognition's connection to action, and extended cognition suggests that cognitive processes can extend beyond the boundaries of the brain through the incorporation of external resources. This perspective acknowledges that

cognition is not confined solely to the brain, but rather involves the active participation of the body and its interactions within the surrounding environment (Malinin, 2019).

Traditionally, cognition is viewed as an isolated abstract process confined to the brain. As a result, conventional investigations into perception primarily center around the processing of sensory information in specific cortical regions associated with different sensory modalities, as well as considerations regarding cognitive influence. According to Gubenko and Houssemand (2022) "the interpretation of important cognitive processes underlying the creative performance … has evolved mainly around associative and divergent-convergent accounts. These explanations might be viewed as "disembodied" since they disregard how ideas could be translated into actions and vice versa". In contrast, the proponents of 4E cognition place considerable emphasis on the role of embodied action and propose that perception is fundamentally oriented toward action. They challenge and critique the functionalist view that cognitive phenomena are solely determined by their functional role and exist as an independent level of analysis (Bruin et al., 2018).

The 4E approach emphasizes that cognition involves extracranial bodily processes, departing from the view that the brain is the sole basis of cognitive processes. This involvement of extracranial processes can be understood in strong and weak ways, either constituting cognitive processes or causally depending on them. Additionally, extracranial processes can be bodily, involving the brain-body unit, or extrabodily, involving the brain-body-environment unit (Bruin et al., 2018). The 4E framework elucidates the mechanisms by which teams actively participate in the creative process, fostering the development of collaborative creative outputs through dynamic interactions. Moreover, it enables us to explore creativity beyond the limitations of individual processes or the final product (Griffith, 2021).

Research Question and Hypothesis

In order to expand upon the current body of research on embodied cognition and explore the effects of active engagement in an interactive art installation that utilizes AI-powered technology on creativity, it was essential to investigate the treatment outcomes resulting from the implementation of AI intervention. Consequently, the research question for this study was formulated as follows:

> **RQ:** How does the engagement of high school students in an interactive art project utilizing NST influence their creativity levels, in comparison to the impact of passive art observation?

Based on this research question our hypothesis is as follows:

> **Hypothesis:** Subjects (16-18) who participated in an interactive AI centered art project that uses NST will score higher on the Creativity Index, as assessed by TTCT-Figural, compared to those who passively observed traditional art objects, such as paintings.

By examining the effects of active engagement in the interactive art project utilizing NST on creativity levels and comparing it to the effects of passive art observation, this research aims to provide insights into the role of embodiment in influencing creativity among high school students.

References

Anadol, R. (2018). Melting Memories [Installation]. Public Art Istanbul, Turkey.

Alabbasi, A. M. A., Paek, S. H., Kim, D., & Cramond, B. (2022). What do educators need to know about the Torrance Tests of Creative Thinking: A comprehensive review. *Frontiers in Psychology*, *13*. https://www.frontiersin.org/articles/10.3389/fpsyg.2022.1000385

Amabile, T. M. (1998). How to Kill Creativity. *Harvard Business Review*, *76*(5), 76–87. https://hbr.org/1998/09/how-to-kill-creativity

Amabile, T. M. (2019). *Creativity In Context: Update To The Social Psychology Of Creativity*. Routledge. https://doi.org/10.4324/9780429501234

Andolfi, V. R., Di Nuzzo, C., & Antonietti, A. (2017). Opening the mind through the body: The effects of posture on creative processes. *Thinking Skills and Creativity*, *24*, 20–28. https://doi.org/10.1016/j.tsc.2017.02.012

Bruin, L. de, Newen, A., & Gallagher, S. (Eds.). (2018). *The Oxford Handbook of 4E Cognition*. Oxford University Press.

Csikszentmihalyi, M. (1997). *Creativity: Flow and the psychology of discovery and invention* (pp. viii, 456). HarperCollins Publishers.

Frith, E. M. (2019). *Acute Exercise and Creativity: Embodied Cognition Approaches* [University of Mississippi]. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://core.ac.uk/download/pdf/288063329.pdf

Gatys, L. A., Ecker, A. S., & Bethge, M. (2015a). A Neural Algorithm of Artistic Style. *ArXiv:1508.06576 [Cs, q-Bio]*. http://arxiv.org/abs/1508.06576

Gatys, L. A., Ecker, A. S., & Bethge, M. (2015b). *A Neural Algorithm of Artistic Style* (arXiv:1508.06576). arXiv. https://doi.org/10.48550/arXiv.1508.06576

Glaveanu, V., Lubart, T., Bonnardel, N., Botella, M., de Biaisi, P.-M., Desainte-Catherine, M., Georgsdottir, A., Guillou, K., Kurtag, G., Mouchiroud, C., Storme, M., Wojtczuk, A., & Zenasni, F. (2013). Creativity as action: Findings from five creative domains. *Frontiers in Psychology*, *4*. https://www.frontiersin.org/articles/10.3389/fpsyg.2013.00176

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

Gobet, F., & Sala, G. (2019). How Artificial Intelligence Can Help Us Understand Human Creativity. *Frontiers in Psychology*, *10*, 1401. https://doi.org/10.3389/fpsyg.2019.01401

Griffith, A. (2021). Embodied creativity in the fine and performing arts. *Journal of Creativity*, *31*, 100010. https://doi.org/10.1016/j.yjoc.2021.100010

Gubenko, A., & Houssemand, C. (2022). Alternative Object Use in Adults and Children: Embodied Cognitive Bases of Creativity. *Frontiers in Psychology*, *13*, 893420. https://doi.org/10.3389/fpsyg.2022.893420

Gubenko, A., Kirsch, C., Smilek, J. N., Lubart, T., & Houssemand, C. (2021). Educational Robotics and Robot Creativity: An Interdisciplinary Dialogue. *Frontiers in Robotics and AI*, *8*. https://www.frontiersin.org/articles/10.3389/frobt.2021.662030

Harris, A. (2016). *Creativity and Education*. Palgrave Macmillan UK. https://doi.org/10.1057/978-1-137-57224-0

Henriksen, D., Mishra, P., & Fisser, P. (2016). Infusing Creativity and Technology in 21st Century Education: A Systemic View for Change. *Journal of Educational Technology & Society*, *19*(3), 27–37. https://www.jstor.org/stable/jeductechsoci.19.3.27

Kaufman, J., & Glăveanu, V. P. (2021). *An Overview of Creativity Theories* (pp. 17–30). https://doi.org/10.1017/9781108776721.003

Kim, K. H. (2017). The Torrance Tests of Creative Thinking - Figural or Verbal: Which One Should We Use? *Creativity. Theories – Research - Applications*, *4*(2), 302–321. https://doi.org/10.1515/ctra-2017-0015

Koch, S., Kunz, T., Lykou, S., & Cruz, R. (2014). Effects of dance movement therapy and dance on health-related psychological outcomes: A meta-analysis. *The Arts in Psychotherapy*, *41*(1), 46–64. https://doi.org/10.1016/j.aip.2013.10.004

Kyung Hee Kim. (2006). Can We Trust Creativity Tests? A Review of the Torrance Tests of Creative Thinking (TTCT). *Creativity Research Journal*, *18*(1), 3–14. https://doi.org/10.1207/s15326934crj1801_2

Leschziner, V., & Brett, G. (2019). Beyond Two Minds: Cognitive, Embodied, and Evaluative Processes in Creativity. *Social Psychology Quarterly*, *82*(4), 340–366. https://doi.org/10.1177/0190272519851791

Luce, L. (2019). *Artificial intelligence for fashion: : How AI is revolutionizing the fashion industry /*. Apress. https://doi.org/10.1007/978-1-4842-3931-5

Malinin, L. H. (2019). How Radical Is Embodied Creativity? Implications of 4E Approaches for Creativity Research and Teaching. *Frontiers in Psychology*, *10*. https://www.frontiersin.org/article/10.3389/fpsyg.2019.02372

Nilsson, N. J. (1996). Artificial intelligence: A modern approach: Stuart Russell and Peter Norvig, (Prentice Hall, Englewood Cliffs, NJ, 1995); xxviii + 932 pages. *Artificial Intelligence*, *82*(1), 369–380. https://doi.org/10.1016/0004-3702(96)00007-0

Oppezzo, M., & Schwartz, D. L. (2014). Give your ideas some legs: The positive effect of walking on creative thinking. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *40*, 1142–1152. https://doi.org/10.1037/a0036577

Plucker, J. A. (1999). Is the proof in the pudding? Reanalyses of Torrance's (1958 to present) longitudinal data. *Creativity Research Journal*, *12*, 103–114. https://doi.org/10.1207/s15326934crj1202_3

Raposo, F. A., Martins de Matos, D., & Ribeiro, R. (2021). Assessing kinetic meaning of music and dance via deep cross-modal retrieval. *Neural Computing & Applications*, *33*(21), 14481–14493. https://doi.org/10.1007/s00521-021-06090-8

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

Romance, R., Nielsen-Rodríguez, A., Mendes, R. S., Dobado-Castañeda, J. C., & Dias, G. (2023). The influence of physical activity on the creativity of 10 and 11-year-old school children. *Thinking Skills and Creativity*, *48*, 101295. https://doi.org/10.1016/j.tsc.2023.101295

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

Shapiro, L., & Spaulding, S. (2021). Embodied Cognition. In *The Stanford Encyclopedia of Philosophy* (Winter 2021). https://plato.stanford.edu/archives/fall2011/entries/embodied-cognition/

Tinio, P. P. L., & Gartus, A. (2018). Chapter 15 - Characterizing the emotional response to art beyond pleasure: Correspondence between the emotional characteristics of artworks and

viewers' emotional responses. In J. F. Christensen & A. Gomila (Eds.), *Progress in Brain Research* (Vol. 237, pp. 319–342). Elsevier. https://doi.org/10.1016/bs.pbr.2018.03.005

Torrance, E. P. (2018). *Torrance Tests of Creative Thinking—Interpretive Manual*. Scholastic Testing Service, Inc.

Utz, V., & DiPaola, S. (2020). Using an AI creativity system to explore how aesthetic experiences are processed along the brain's perceptual neural pathways. *Cognitive Systems Research*, *59*, 63–72. https://doi.org/10.1016/j.cogsys.2019.09.012

van der Schyff, D., Schiavio, A., Walton, A., Velardo, V., & Chemero, A. (2018). Musical creativity and the embodied mind: Exploring the possibilities of 4E cognition and dynamical systems theory. *Music & Science*, *1*, 2059204318792319. https://doi.org/10.1177/2059204318792319

Vanden Berghe, A., Fathi, F. Z., & Nouzri, S. (2022). *Poster: Art Installation "Mirror, Mirror" featuring*.

Wingström, R., Hautala, J., & Lundman, R. (2022). Redefining Creativity in the Era of AI? Perspectives of Computer Scientists and New Media Artists. *Creativity Research Journal*, 1–17. https://doi.org/10.1080/10400419.2022.2107850

Yamada, H., & Tam, A. Y.-W. (1996). Prediction study of adult creative achievement: Torrance's longitudinal study of creativity revisited. *The Journal of Creative Behavior*, *30*, 144–149. https://doi.org/10.1002/j.2162-6057.1996.tb00764.x

Zeng, Z. (2022). Research on Multimodal Dance Movement Recognition Based on Artificial Intelligence Image Technology. *Computational Intelligence and Neuroscience*, *2022*, 1–8. https://doi.org/10.1155/2022/4785333

Appendices

Appendix A. Letter to Parents and Consent Form (FR)

Chers parents,

Dans le cadre de mon master en Psychologie : Evaluation and Assessment, je réalise un mémoire ayant comme sujet « Effets des technologies Deepfake et Neural Style Transfer sur les aspects cognitifs de la créativité ». Afin de répondre à cette question, j'ai choisi un test sur la créativité que j'aimerai faire passer à la classe 3B à Lycée Aline Mayrisch, Luxembourg.

Pour cette recherche, j'aurais besoin d'environ 20 étudiants. La recherche prendra environ 1 heure. Les étudiants recevront un pré-test, puis ils se livreront à une installation artistique via un ordinateur portable, tablet ou téléphone mobile et recevront ensuite un post-test.

Grâce à ce test, je pourrais constater si technologies de l'intelligence artificielle ont des effets sur les aspects cognitifs de la créativité ou pas. La participation sera évidemment anonyme et aucune information importante ne sera divulguée.

Suite à cela, je voulais vous demander si vous étiez d'accord que votre enfant participe à mon mémoire en complétant ce formulaire.

Anastasia T. Vanden Berghe

Étudiante en master Psychologie :

Evaluation and Assessment

– ►

Prénom de l'enfant : ………………………………………..

☐ Je soussigné, parents de ……………………………………………………………, donne mon accord à la participation de l'activité pour la rédaction du mémoire.

☐ Je soussigné, parents de ………………………………………………………., *ne* donne *pas* mon accord à la participation de l'activité pour la rédaction du mémoire.

Annexe

Deepfake

- L'image ou la vidéo d'une personne est prise et transformée via un algorithme en quelqu'un d'autre d'une manière qui donne à la vidéo un aspect authentique.

Pour l'installation, l'image du célèbre portrait a été prise. Le participant regardera l'ordinateur portable avec une caméra où il verra le portrait. Au fur et à mesure qu'ils bougent leur visage et leurs expressions, le portrait imitera ce qu'ils font.

Neural Style Transfer
- Le contenu et l'image de style (illustration) sont pris, mélangés ensemble, ce qui fait que l'image finale est l'image de contenu apparaissant comme si elle avait été faite dans le style de l'image de style.

Le participant se fera prendre en photo via un ordinateur avec un appareil photo. Leur image sera transformée, comme si elle était peinte à la manière d'un tableau.

Si vous souhaitez en savoir plus sur la technologie ou le processus, n'hésitez pas à me contacter : anastasia.tavares.001@student.uni.lu

Appendix B. Correlation of Creativity Measures

Table 1. Table – Correlations of Measures

		FLRS	**ORRS**	**ELRS**	**TIRS**	**CLRS**	**CKLS**	**GIDX**
	FLRS	1	0 .703	0 .278	0 .179	0 .566	0 .156	0 .697
	ORRS		1	0 .314	0 .196	0 .417	0 .228	0 .675
	ELRS			1	0 .492	0 .27	0 .588	0 .68
	TIRS				1	0 .336	0 .476	0 .628

	CLRS					1	0.306	0.723
	CKLS						1	0.637
	GIDX							1