“Embodied Creativity in the Era of AI:

a Comparative Study involving Neural Style Transfer Technologies”

by

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Table of Contents

List of Figures

List of Tables

Abstract

The emergence of artificial intelligence (AI) significantly impacted the creative world, not only in terms of providing new resources and platforms for artistic expression but also in transforming the way people experience creativity. As new technologies and applications are being developed, embodied creativity and AI are two concepts that are becoming increasingly intertwined in contemporary discourse on creativity. However, within the framework of embodied cognition, the precise impact of physical participation in an of AI-based intervention on creativity is still an area of ongoing research with limited amount of empirical research conducted on this particular topic. Our study aims to provide insights into pre- and post-changes in the creativity level between eighteen high school students who participated in an interactive art project that uses Neural Style Transfer technology (NST) and nineteen high school students who passively observed art. Students' level of creativity was assessed using the Torrance Test of Creative Thinking (TTCT) – Figural version. For the group that participated in an AI installation, we found an increase in scores for Resistance to Premature Closure in the scores by age-based norm and decrease in measure for Elaboration in the scores by grade-based norm. Additionally, in the measures of Fluency, Originality, Creative Strengths Checklist scores assessed by grade-based norm, and Fluency, Originality, and Elaboration evaluated on the basis of age-based norms level there were significant differences in scores between the pre-test and post-test for all participants, regardless of whether they were in the Passive Art Observation or Interactive AI Installation group. Our results demonstrate how the emergence of AI-based interventions can have both positive and negative effects on different aspects of creativity. Specifically, our findings indicate that active participation in the installation had a positive impact on participants' resistance to premature closure, enhancing their ability to remain open-minded and generate

original ideas. However, it also had a negative impact on their elaboration skills, reducing their ability to delve deeply into concepts and provide intricate and detailed perspectives. The results obtained from this study provide valuable insights into how physical experiences can shape an individual's creativity in the context of embodied cognition. More specifically, by examining the effect of participation in an interactive AI-powered activity, we can better understand how engaging with AI creativity tools can enhance a person's creative thinking abilities. We anticipate that the findings from this study will serve as a foundation for further research on the topic for professionals in various fields.

Keywords: Art, Artificial Intelligence, creativity, embodied creativity, embodied cognition, Neural Style Transfer, RECS

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.

CHAPTER 2: RESEARCH METHODOLOGY

Introduction

This study sought to assess the changes in creativity levels among high school students who (1) participated in an AI intervention (2) passively observed art. The research question of how the creativity levels of participants changed were answered by analyzing the results of the

Torrance Test of Creative Thinking Figural versions A and B that were given before and after the intervention as a pre-test and post-test respectively. In this chapter of our study, we will address the overall research design, participants and setting for the study, materials, study procedures, and data analysis processes.

Research Design

This study adopts an empirical approach, which employs quantitative methods to address the research hypothesis and explain and predict the phenomenon through numerical data. We employed a "pretest-posttest design with two treatment groups" study design in order to compare the effects of two different interventions and evaluate the effectiveness of the treatments. The independent variable for this study was the type of intervention the participants received: either the passive art observation through a slideshow or an interactive AI installation.

The decision to choose a quantitative design for this study was justified by the aim of quantifying and comparing changes in creativity levels between the two groups (interactive art project vs. passive art observation) using standardized tests, such as TTCT. This approach involved collecting numerical data on creativity scores or indicators before and after the interventions and conducting statistical analyses to determine the significance of the observed differences. By adopting a quantitative approach, it was possible to investigate potential cause-effect relationships, measure effect sizes, and generalize findings to a larger population of high school students. This method provided a systematic and objective means to comprehend the impact of embodiment on creativity levels.

The study consisted of two phases spanning over a two-week period. The participants were divided into two treatment groups: Passive Art Observation Group and Interactive AI Installation Group. Both groups were administered a pre-test using Torrance Test of Creative

Thinking (TTCT) – Figural Form A. Pre-test lasted 30 minutes, after which the tests were collected by the principal investigator. In the second phase, the Passive Art Observation Group viewed a slideshow video while the Interactive AI Installation Group participated in an interactive Artificial Intelligence installation that incorporated NST. Both activities will be discussed in more detail in the Materials and the Procedures section of this document. After ten minutes, both groups were asked to stop the activities and were given a post-test using TTCT - Figural Form B, which lasted 30 minutes. The collected forms were then sent to the Scholastic Testing Service, Inc., where they were evaluated by trained professionals. After the principal investigator received the results, the collected data was subjected to statistical analysis using the Statistical Package for the Social Sciences (SPSS; IBM Corp. 2023). The analysis techniques employed in this study included descriptive statistics, Multivariate Analysis of Variance (MANOVA), independent samples t-test, and paired samples t-test. We will address these statistical analyses and the results in more detail in the Data Analysis section and the Results sections of our study.

Participants

The researched involved 37 respondents (16 boys and 21 girls) (See Table 1) who were high school students enrolled in Lycée Aline Mayrisch, a high school in Luxembourg City, in southern Luxembourg. The age of the participants ranged from 16 to 18 (M = 16.68, SD = 0.530). (See Table 2). The selection of participants and the group assignments were randomized.

Their participation in the study was voluntary. The study excluded three participants who were unable to participate in the second phase of the experiment, resulting in a total of 37 participants.

Table 1. Subject's Sex

Sex 1 = Male 2 = Female

	N	%
1	16	43.2%
2	21	56.8%

Table 2. Subjects' Age in Years

Age in Years

	N	%
16	13	35.1%
17	23	62.2%
18	1	2.7%

Setting

The data collection for the study was carried out at Lycée Aline Mayrisch, a high school located in southern Luxembourg City. The primary investigator collaborated with the teachers to schedule the study during the students' regular class time. To maintain a comfortable and familiar environment, the study was conducted in the students' regular classrooms, with each student having access to their personal tablet. The teachers were present during the study sessions but did not interact with the students. The classrooms were equipped with computer screens mounted on the walls, which displayed PowerPoint slides containing instructions in both French and English. The TTCT - Figural were completed by the participants using pencils for the pre-test and post-

test, respectively. At the conclusion of each session, the completed forms were collected by the primary investigator.

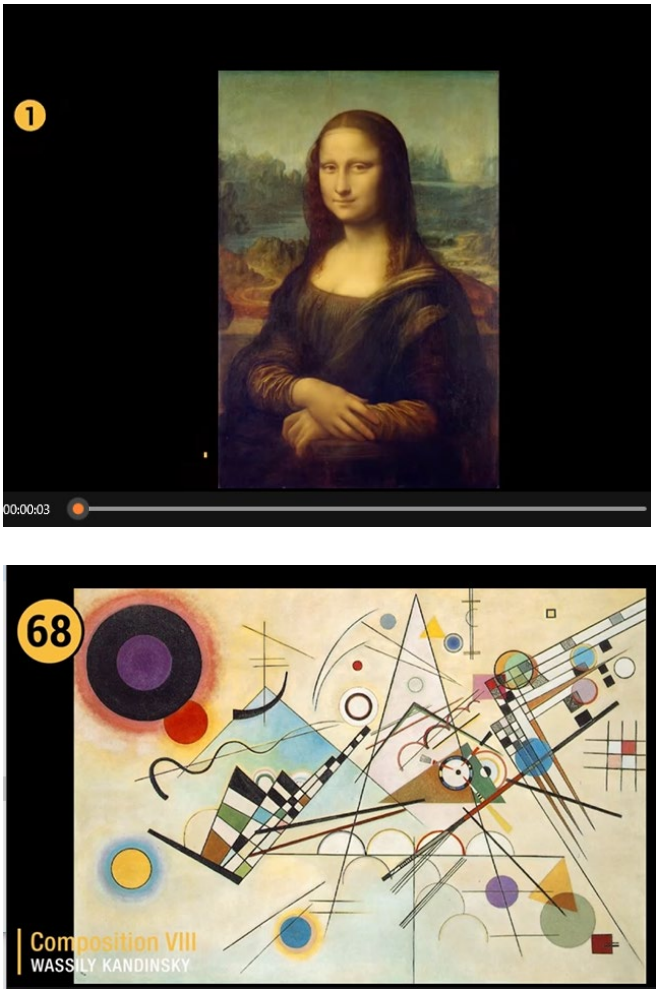
Materials

This section of the study pertains to the materials employed in the research. We will discuss a slideshow video presented to the Passive Art Observation Group and an AI art installation utilizing NST that was used for the Interactive AI Installation Group. Furthermore, we address the selection of the Torrance Tests of Creative Thinking - Figural form as the assessment tool and provide the rationale behind choosing this specific test.

Art slideshow video

In the present study, the Passive Art Observation Group participants were exposed to a passive intervention consisting of a compilation of photographs in a form of a video featuring a variety of art pieces spanning multiple eras, ranging from the Renaissance to modern times. The primary objective of this intervention was to provide a control condition that did not entail active participation and did not incorporate the use of NST technology, thus enabling a comparison between the effects of passively viewing traditional artwork versus actively participating in an intervention that utilized NST. The use of diverse art pieces from various eras in the slideshow was intended to ensure that the Passive Art Observation Group experienced a broad range of artistic styles and techniques. In order to access and watch the video, the subjects provided with the link that they had to click.

Figure 1. Screenshots of a video



AI Intervention featuring Neural Style Transfer

For the AI intervention part for the Interactive AI Installation Group, we used NST technology which is made possible by convolutional neural network (CNN) (Gatys et al., 2015b). NST is an optimization technique where a style reference image, such as a piece of art by a well-known painter and a content image are combined using the optimization approach known as NST to create an output image that resembles the content image but has been "painted" in the manner of the style reference image. This is done by optimizing the output image to match the style reference image's and the content image's statistics for both content and style. This technique

involves training a CNN on a pair of images, one representing the content and the other representing the style.

As depicted in Figure 1, CNNs have demonstrated an ability to learn and extract high-level image content using standard image features. This feature extraction capability has been observed across diverse datasets and even in other visual information processing tasks such as texture recognition and artistic style classification, provided that sufficient labeled data is available for training the network on specific tasks. During the training process, the neural network adjusts the weights of its layers to minimize the loss function. After the network has been trained, we may use it to generate new images by fusing the style and content of different photos. Figures 2 *(Gatys et al., 2015b)* and Figure 3 *(Vanden Berghe et al., 2022)* provide visual representations of the process, delineating the sequential stages entailed in converting a photograph into a painted rendition that mimics the stylistic attributes of a specific painting. The figures portray the initial photograph, an accompanying painting employed as a stylistic benchmark, and the ultimate output image that has been adjusted to mirror the style exhibited in the referenced painting.

Figure 2. Neural Style Transfer Architecture

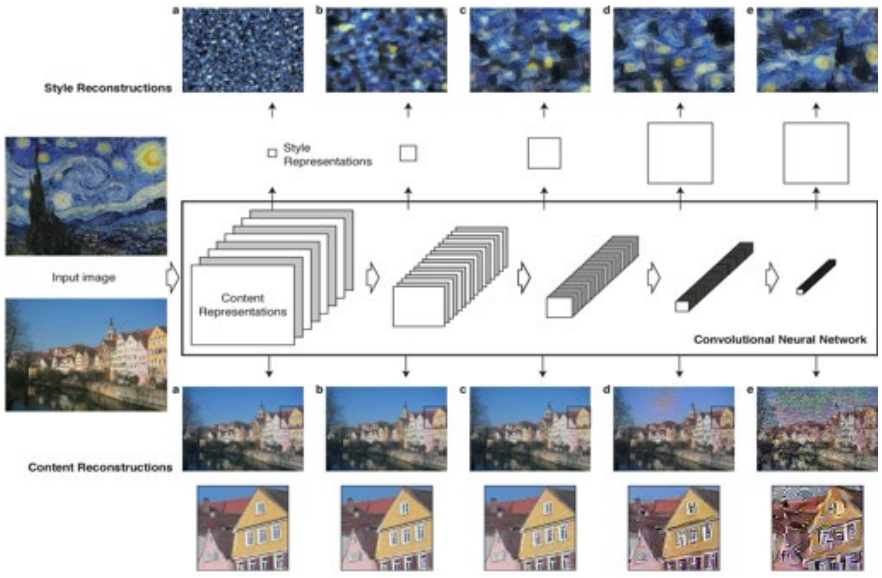


Figure 3. Neural Style Output example

During the experiment which lasted ten minutes, the participants physically interacted with the interactive installation through their tablets, accessing it via a provided link. This hands-on engagement allowed them to directly participate in the creative process. Upon accessing the installation, participants were presented with the option to either upload pre-existing photos from their device or capture new ones specifically for the purpose of the experiment. This flexibility allowed participants to select images that they found personally relevant to their creative expression. In addition, by utilizing their tablets, participants had a tangible tool through which they could access and manipulate the selected images, enhancing their sense of embodiment within the artistic experience. Once the participants had chosen their content images, they were

presented with a curated list of various artistic styles to choose from. This selection of styles encompassed a range of visual aesthetics, allowing participants to explore different artistic expressions and find a style that resonated with their creative vision. The chosen style could then be applied to the selected images, transforming them into artworks. By actively choosing images that held personal meaning to them, participants were physically and cognitively engaged in the process, connecting their own experiences and emotions to the creative endeavor. Furthermore, the active transformation of the selected visual content according to their creative intentions allowed the participants to embody the role of an artist. This merging of physical and cognitive elements created a holistic and immersive experience, where participants could fully engage their senses and creative abilities in the interactive artistic process.

Torrance Tests of Creative Thinking - Figural

The assessment of creativity poses a challenging endeavor due to its multifaceted and subjective nature. Given the specific requirements of our study design, the selection of an appropriate measurement tool was crucial. We sought a tool that offered two distinct testing forms, enabling us to conduct both pre and post testing assessments. Furthermore, it was imperative that the chosen tool demonstrated high levels of reliability and validity, ensuring the accuracy and consistency of the obtained results. By employing such a robust measuring instrument, we aimed to enhance the credibility and rigor of our study's findings.

Albeit there exist various tests to measure creativity, for our study we chose Torrance Tests of Creative Thinking (TTCT), developed in the 1960s by psychologist E. Paul Torrance. One of the reasons for this selection is that those tests are regarded as the foremost widely used and extensively evaluated assessment tools for measuring divergent thinking. (Yamada & Tam, 1996) The tests stem from the work of J.P. Guilford on divergent and convergent thinking. They

gauge creative thinking through both verbal and pictorial means and measures creative potential of an individual in terms of fluency, originality, abstractness of titles, elaboration and resistance to premature closing. (Harris, 2016). The overall score in the TTCT, called Creative Index was esteemed to be the best predictor for adult creative achievement. Currently, its copyright belongs to the Scholastic Testing Service, Inc. The TTCT comes in two versions: the TTCT-Verbal and the TTCT-Figural, which are comprised of Form A and Form B.

It is crucial to acknowledge that the Torrance Test of Creative Thinking (TTCT) Verbal and Figural tests assess distinct aspects of creative abilities. While the fluency and originality components are common to both the Figural and Verbal Forms of the TTCT, the correlation between performance on the Verbal and Figural measures is minimal (Alabbasi et al., 2022).

To evaluate the changes in creativity levels in our study, we used the Figural form of the TTCT form A for the pre-test and form B for the post-test. This choice was guided by various considerations. One important factor is the cultural fairness of the Figural Form compared to the Verbal Form, which is particularly relevant in our multicultural school environment. The Figural Form reduces the reliance on writing skills, allowing for a more inclusive assessment of creativity across diverse populations. Furthermore, our decision to use the Figural form was supported by a recent empirical study conducted by (Kim, 2017) examining 994 participants ranging from preschool children to adults. The research provided evidence supporting the notion that the TTCT-Figural is a more comprehensive measure of creativity than the Verbal form. Therefore, by utilizing the Figural form of TTCT, we were hoping to capture a broader range of creative abilities while minimizing potential biases associated with language and cultural backgrounds.

TTCT - Figural is a standardized test designed to measure five norm-referenced measures of creativity such as fluency, originality, abstractness of titles, elaboration and resistance to premature closing. (1) Fluency represents the number of relevant ideas and shows an ability to produce a number of figural images. It is based on the total number of relevant responses, is a crucial aspect of the test since all other scores depend on it. No further scores can be given in other areas unless a response is considered relevant first. The (2) Originality score is based on the statistical rarity and uniqueness of the response, and it determines if the student produced many ordinary, typical responses or uncommon and remarkably imaginative responses. Combining two or more figures into one picture carries more weight in the score. (3) Abstractness of Titles score evaluates the subject's ability to synthesize and organize information to produce a title that captures the essence of the picture. Another important measure of TTCT is (4) Elaboration, which is the score based on the idea that imagination and attention to detail are indicative of creative ability. The last score, (5) Resistance to Premature Closure, reflects a person's ability to delay closure and keep their mind open long enough to develop original ideas. Less creative individuals tend to rush to conclusions without fully considering the available information, which hinders their ability to create powerful and original images.

In addition to the aforesaid five norm-referenced measures, TTCT contains thirteen criterion-referenced measures. As per Torrance Tests of Creative Thinking - Interpretive Manual (2018), those measures are: (1) Emotional Expressiveness measures a subject's ability to communicate feelings and emotions verbally or nonverbally through drawings, titles, and speech of the figures in the drawings. (2) Storytelling Articulateness indicates a subject's ability to clearly and powerfully communicate an idea or tell a story by providing some kind of environment and sufficient detail to put things in context. (3) Movement or Action judges a

person's perception of movement through titles and the speech and bodily posture of figures in the drawings. (4) Expressiveness of Titles notes a person's use of titles that go beyond simple description and communicate something about the pictures that the graphic cues themselves do not express without the title. (5) Synthesis of Incomplete Figures reflects the combination of two or more figures, which is quite rare and points out an individual whose thinking departs from the commonplace and established, who is able to see relationships among rather diverse and unrelated elements, and who, under restrictive conditions, utilizes whatever freedom is allowed. (6) Synthesis of Lines (Form A: Circles, Form B) is the same as (5) above, except it involves the combination of sets of parallel lines or circles. (7) Unusual Visualization points out an individual who sees things in new ways as well as old ways and who can repeatedly perceive a commonplace object or situation in different ways. (8) Internal Visualization indicates subject's ability to visualize beyond exteriors and pay attention to the internal, dynamic workings of things. (9) Extending or Breaking Boundaries suggests that a person is able to remain open long enough to permit the mind to make mental leaps away from the obvious and commonplace, and to open up or extend the boundaries or limits imposed upon the stimulus figure. (10) Humor suggests that an individual perceives and depicts conceptual and perceptual incongruity, unusual combinations, and surprise. (11) Richness of Imagery reflects a subject's ability to create strong, sharp, distinct mental pictures in the mind of the beholder. (12) Colorfulness of Imagery reflects a subject's ability to excite and appeal to the senses. (13) Fantasy accesses a person's use of fantasy imagery in responding to the test tasks.

The assessments of the TTCT-Figural are categorized into three non-verbal exercises: Picture Construction, Picture Completion, and Lines and Circles (repeated figures). To complete all three exercises, a total working time of 30 minutes is needed, with 10 minutes allotted for

each activity. To obtain an overall score known as Creative Index (CI), standard scores of five variables, including fluency, originality, elaboration, abstractness of titles, and resistance to premature closure, are used. Raw scores are converted to standard scores with a mean of 100 and standard deviation of 20. The standard scores for each subscale fall within the range of 40-154 for fluency, and 40-160 for originality, elaboration, abstractness of titles, and resistance to premature closure. The average of the standard scores for the five measures produces an overall indicator of creative potential. For the frequency of creative strengths, a scoring guide is used to award a + or ++. The number of +s is added to the averaged standard scores to yield a Creative Index. (Torrance, 2018).

The scores are categorized by age-based and grade-based norms due to the fact that creativity develops differently across different age groups and educational levels. The categorization of scores by grade and age is essential due to the varying developmental trajectories of creativity across different age groups and educational levels. Grade-based scores are utilized to evaluate the average performance of individuals within specific educational grade levels on a national level. By grouping scores by grade, we can examine and compare the creativity of individuals in different educational stages. The grade-based norm tables are provided for grades kindergarten through grade 12. For adults, it is advisable to use “grade 13” table. Age-based scores, on the other hand, allow for comparisons of creativity among individuals of the same age on a national level, enabling insights into age-related patterns of creative abilities. The age-based scoring tables are typically provided for ages 5-20 with the age 20 norms to be used for all ages above 20. The tables are used to convert raw scores of individual components and composite measures into national percentiles and obtain the standard scores. (Torrance, 2018).

When interpreting scores obtained from any measurement instrument, it is necessary to utilize "derived" or "normative" scores to enable comparisons of performance within a specific group. This applies to the TTCT Figural assessment, which measures different dimensions of creativity and involves two types of comparisons. The scores are expressed in terms of percentile ranking, which indicates the individual's position relative to others in the group. For example, a percentile rank of 60 indicates that the individual's score is higher than 60 percent of the scores of other group members. Normalized standard scores are obtained directly from percentile ranks and are suitable for use in statistical analyses such as averaging and correlating. In the TTCT, a normalized standard score is employed with a mean of 100 and a standard deviation of 20.

Just like any assessment tool, it is crucial to select a testing instrument that possesses robust statistical reliability and validity. In terms of reliability, the TTCT-Figural Manual of 1990 states that the interrater reliability among the scorers for Scholastic Testing Service, Inc., was greater than 0.90, while test-retest reliability coefficients ranged from 0.50 to 0.93. The latter one being not so high could be explained by the fact that “motivational conditions affect the measurement of creative functioning, which could explain the low test–retest reliability.” However, it was concluded that due to the complexity of creative thinking, the level of reliability can be considered reasonable for research applications. In addition, the TTCT-Figural has a high predictive validity over a wide age range. Concurrent validity of the test was examined by comparing its scores with the Spatial Test of Primary Mental Abilities (PMA) and the Gordon Test of Visual Imagery Control. The findings demonstrated significant correlations between imagery and various aspects of creative thinking. In individuals with an IQ above 120, there was a strong correlation of 0.36 ($p < 0.001$) between originality and PMA scores, as well as a correlation of 0.30 ($p < 0.01$) between originality and scores on the Gordon test. Moreover, there

was a correlation of 0.33 ($p < 0.001$) between resistance to premature closure and PMA, and a correlation of 0.26 ($p < 0.01$) between resistance to premature closure and the Gordon test. As for construct validity, there exist conflicting results concerning its dimensionality. Some researchers view divergent thinking as multidimensional, suggesting that creativity consists of distinct traits. However, other studies indicate high correlations among the subscales, which implies that there is insufficient justification to consider creativity as composed of separate and distinct traits. (Kyung Hee Kim, 2006). This divergence in findings highlights the ongoing debate surrounding the underlying structure of creativity as a construct.

Procedures

The study participants were recruited through the assistance of two Art teachers, who willingly allocated time from their schedules for this activity. The study was carried out in two distinct classes, with identical procedures followed in each. Given that the majority of the students were minors, parental consent was required. The consent forms were distributed to the legal guardians through the teachers. Signed consent forms were collected in person or electronically by the teachers and were returned to the primary investigator.

First phase

In the initial session, the students were presented with the PowerPoint that introduced the primary investigator and provided background information on their academic qualifications. The students were also informed that the study was part of the master's thesis. They were then briefed on the study's timeline, which spanned two days, with a two-week interval between the sessions. They were informed that it was comprised of two phases: the first one consisting of an introduction and a pre-test and the second one consisting of the participating in a specific activity followed by a post-test.

Through random selection, a group of students was separated into two cohorts, the Passive Art Observation Group and the Interactive AI Installation Group. Prior to commencing the experiment, both groups were administered a pre-test in the form of a TTCT - Figural Form A. The test was distributed by the main investigator, the instructions for the test were posted on the computer screen and were read out loud.

Second phase

Following a two-week interval, the second phase of the experiment was initiated using the same group of students. In the second phase of the experiment, the Passive Art Observation Group was instructed to access a slideshow video by clicking on a hyperlink. They were then directed to click on a "play" button to initiate the slideshow, which featured a collection of art pieces for viewing. Participants were allowed ten minutes to view the presentation. Simultaneously, the Interactive AI Installation Group was invited to participate in an interactive Artificial Intelligence installation that incorporated NST. The study participants accessed the installation through a provided link using their tablets. They were given the choice to either upload existing photos from their device or capture new ones for use in the experiment. After selecting the content images, participants were presented with a list of available artistic styles to choose from and apply to their selected images. The experimental exercise lasted for a duration of ten minutes. After both groups completed their tasks, they were administered the post-test using the TTCT - Figural Form B. The tests were then collected by the primary investigator.

Post-intervention phase

The test results were submitted to Scholastic Testing Service, Inc. and evaluated by trained professionals. This approach was selected based on the TTCT - Figural manual, which

reported an inter-rater reliability exceeding 0.90 (Torrance, 2018). This finding suggests that the likelihood of errors was minimized by selecting this method.

Data analysis

In order to assess what are the effects of engaging high school students in an interactive art project utilizing NST on changes in creativity levels, in contrast to the impact of passive art observation, the completed TTCT - Figural forms A and B were sent to Scholastic Testing Service, Inc. and evaluated by trained professionals. The obtained results were subsequently analyzed using the Statistical Package for the Social Sciences (SPSS; IBM Corp. 2023) software. Paired samples t-test was applied to identify the variations in scores between the pre-test and post-test within each group. Additionally, independent samples t-test was utilized to examine the potential difference in the extent of score changes in the post-test between the two groups. Moreover, Multivariate Analysis of Variance (MANOVA) was used to evaluate the variations between the pre-test and post-test scores for all participants, as well as between the groups.

CHAPTER 3: RESULTS

Introduction

In this chapter of our report, we will present the findings obtained from the study. The scores provided in this report are divided into two primary categories: "Scores of measures based on grade-based norms" and "Scores of measures based on age-based norms." Within each category, we will first present the statistically significant findings specific to particular groups, followed by a comprehensive overview of the results across all groups. Additionally, we also address the non-significant data.

The category of "Scores of measures based on grade-based norms" refers to the assessment scores that have been evaluated according to the specific grade level of the participants. These scores take into account the academic expectations and developmental stage associated with each grade. By using grade-based norms, it becomes possible to gauge how well individuals are performing in relation to their peers within the same grade level. This category allows for a more focused examination of performance within the educational context. On the other hand, the category of "Scores of measures based on age-based norms" involves the assessment scores that have been analyzed based on the participants' age groups. Age-based norms consider the natural progression of development and learning abilities over time. These scores provide a broader perspective by allowing comparisons among individuals of different ages. By using age-based norms, it becomes possible to gain insights into performance trends across various stages of development.

It is worth noting that, according to Torrance's Interpretive Manual (Torrance, 2018), grade-based scores are more commonly employed in research studies compared to age-based scores. However, in our study, we opted to include both approaches to provide a more comprehensive analysis of the similarities and differences observed in the results. By considering both grade-based and age-based norms, we aim to gain a comprehensive understanding of the impact embodiment on creativity, allowing us to draw more robust conclusions and contribute valuable insights to the existing literature in this field. Additionally, it is important to mention that the norms were developed based on the normative sample based on 60,917 students from 1,300 schools in 35 United States of America states.

In the following table, we present a summarized overview of the research findings and in the following section, we will provide a detailed presentation of these results.

Table 3. Summary of the Results

Measures	Scores by grade-based norms	Scores by age-based norms
Elaboration	Decrease for AI Installation Group	Decrease for both groups
Resistance to Premature Closure	No significant results	Increase for AI Installation Group
Fluency	Increase for both groups	Increase for both groups
Originality	Decrease for both groups	Decrease for both groups
Abstractness of Titles	No significant results	No significant results
Average	No significant results	No significant results
Checklist of Creative Strengths	Increase for both groups	No significant results
Creativity Index	No significant results	No significant results

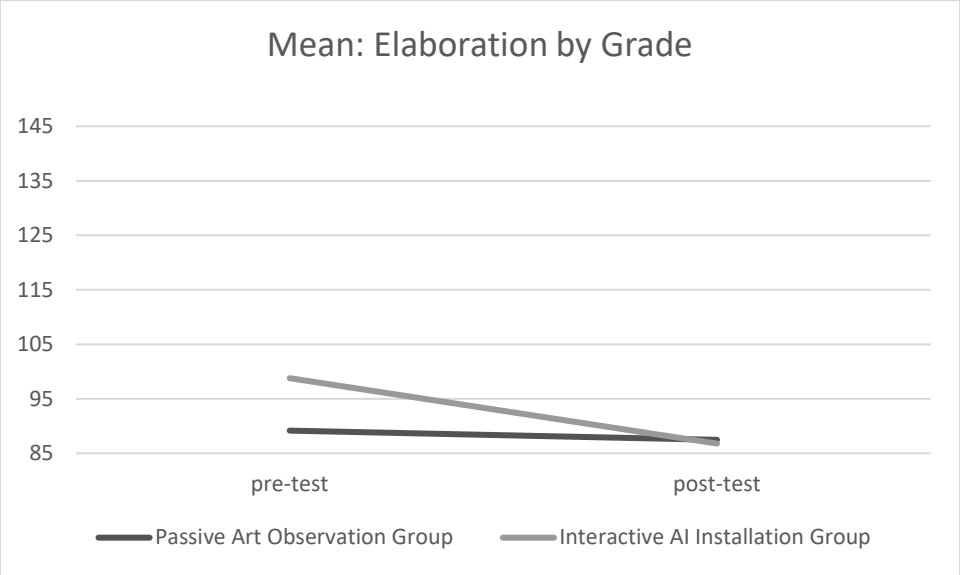
Scores of Measures by Grade-Based Norm

Decrease in Elaboration for Interactive AI Installation Group

For the Elaboration measure, our analysis revealed that both Passive Art Observation Group and Interactive AI Installation Groups showed a decrease in mean scores, with the post-test scores being lower for the Passive Art Observation Group: M = 89.16 to 87.47; Interactive AI Installation Group: M = 98.78 to 86.78. The decrease in scores was higher for the Passive Art Observation Group (-11.9 points) than for the Interactive AI Installation Group (-1.7 points). While there were about 10 points between the two groups at pre-test, there was no difference between them at post-test. Using paired samples t-test, we can infer that there is no significant difference in scores between the pre-test and post-test for the Passive Art Observation Group $t(18) = 0.527$, $p = 0.302$. However, the difference in score for the Interactive AI Installation Group was significant $t(17) = 3.452$, $p < 0.05$. Using independent samples t-test, we can

conclude that the two groups do not differ in their pre-test scores $t(35) = -1.551$, $p = 0.065$ and their post-test scores $t(35) = 0.094$, $p = 0.463$. Nevertheless, MANOVA showed a significant difference between the pre-test and post-test scores for all subjects $F(1, 35) = 8.369$, $p < 0.01$. The interaction with the group is also significant $F(1, 35) = 1.178$, $p = 0.285$, meaning that the difference between the pre-test and post-test is not the same between the two groups. Indeed, the graph visually confirms those results.

Table 4. Mean of the Measure of Elaboration by Grade-Based Norm

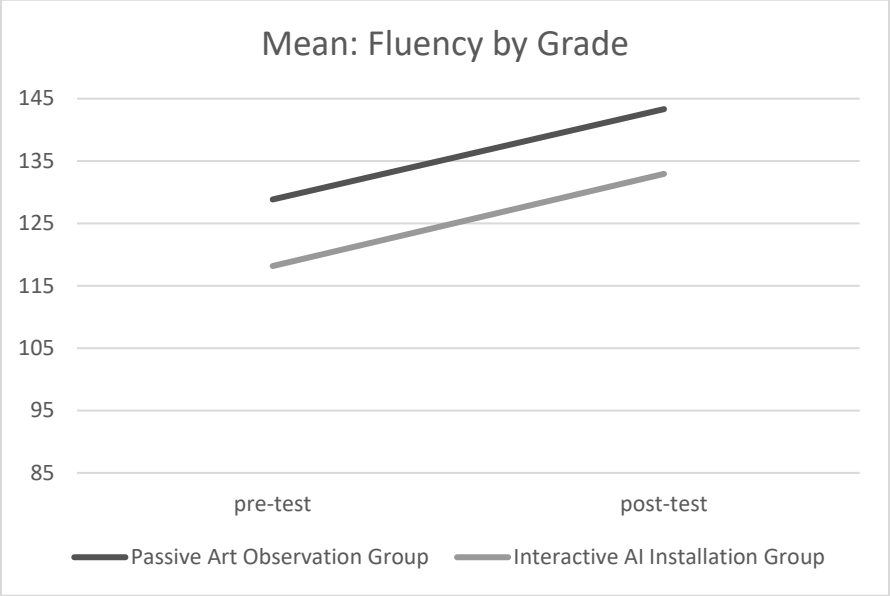


Increase in Fluency, Creative Strengths Checklist for Both Groups

For the Fluency measure, our analysis revealed several findings. Both the Passive Art Observation Group and the Interactive AI Installation Group showed an increase in mean scores, with the post-test scores being significantly higher than the pretest scores for both groups: Passive Art Observation Group: Mean (M) = 128.84 to 143.32; Interactive AI Installation Group: M = 118.17 to 132.94. The increase in scores was similar in both groups, with an average of around 14 points. Using paired samples t-tests, we could infer that there was a significant difference in scores between the pre-test and post-test within each group: Passive Art

Observation Group $t(18) = -3.559$, $p < 0.05$ and the Interactive AI Installation Group $t(17) = -5.556$, $p < 0.05$. Using independent samples t-tests, we concluded that there was a significant difference in the magnitude of change in Fluency scores between the two groups in the pre-test $t(35) = 1.805$, $p < 0.05$ and post-test $t(25) = 1.863$, $p < 0.05$. Using MANOVA, we found a significant difference between the pre-test and post-test scores for all subjects $F(1, 35) = 35.390$, $p < 0.05$. However, there was no significant difference in pre-test and post-test scores between the two groups $F(1, 35) = 0.004$, $p = 0.951$.

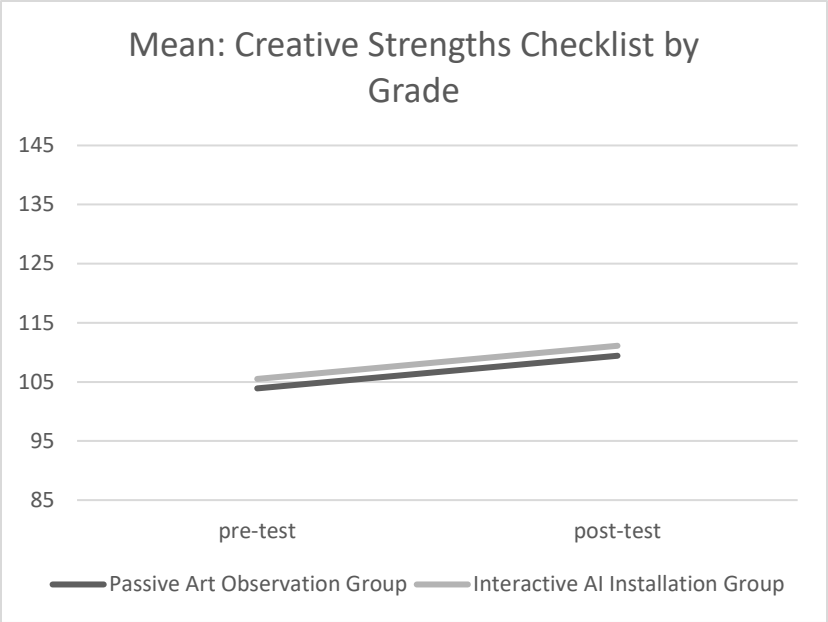
Table 5. Mean of the Measure of Fluency by Grade-Based Norms



Regarding the Creative Strengths Checklist measure, the study found that both groups showed a similar increase in mean scores of around 5.5 points: Passive Art Observation Group: $M = 103.9$ to 109.42; Interactive AI Installation Group: $M = 105.5$ to 111.11. Using paired samples t-test, the study found that there is a significant difference in scores between the pre-test and post-test for the Passive Art Observation Group $t(18) = -2.048$, $p < 0.05$ and for the Interactive AI Installation Group $t(17) = -1.721$, $p < 0.05$. Finally, using independent samples t-test, the study concludes that the two groups do not differ in their pre-test scores $t(35) = -0.416$, p

= 0.340 nor their post-test scores $t(35) = -0.299$, $p = 0.384$. There was a significant difference between the pre-test and post-test scores for all subjects that was discovered using MANOVA $F(1, 35) = 7.077$, $p < 0.05$. However, overall, there was no significant difference in pre-test and post-test scores between the two groups $F(1, 35) = 0.028$, $p = 0.867$.

Table 6. Mean of the Measure of Creative Strengths Checklist by Grade-Based Norms

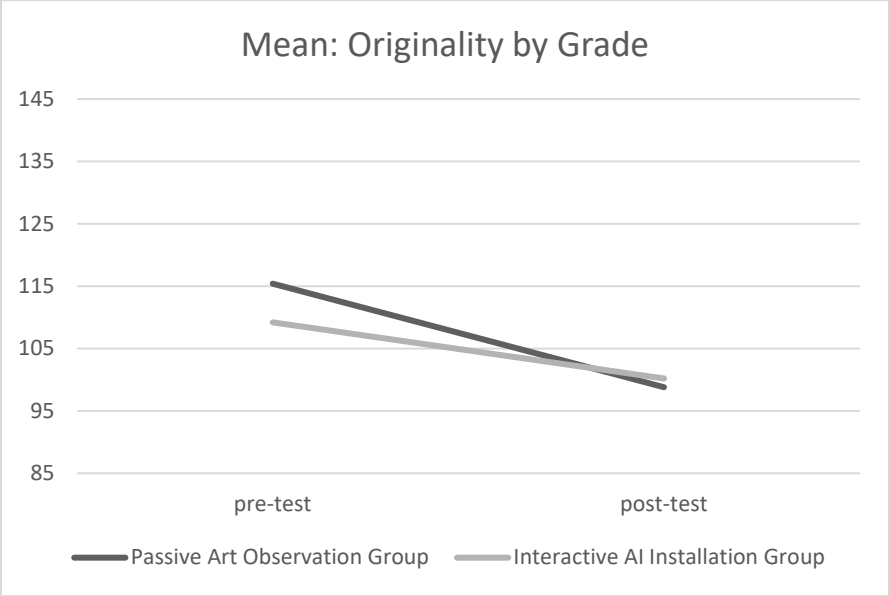


Decrease in Originality for Both Groups

For the Originality measure, both groups showed a decrease in mean scores, with the post-test scores being lower than the pretest scores for both groups: Passive Art Observation Group: $M = 115.4$ to 98.8; Interactive AI Installation Group: $M = 109.2$ to 100.2. The decrease in scores was higher for the Passive Art Observation Group (-16 points) than for the Interactive AI Installation Group (-9 points). Using paired samples t-test, we can infer that there is a significant difference in scores between the pre-test and post-test for the Passive Art Observation Group $t(18) = 3.353$, $p < 0.05$ but not for the Interactive AI Installation Groups $t(17) = 1.828$, p

= 0.06. Using independent samples t-test, we concluded that the two groups do not differ in their pre-test scores $t(35) = 0.941$, p=0.177 or their post-test scores $t(35) = -0.221$, $p = 0.413$. Finally, using MANOVA, our analysis showed that there was a significant difference between the pre-test and post-test scores for all subjects $F(1, 35) = 13.413$, $p < 0.001$. However, there was no significant difference in pre-test and post-test scores between the two groups $F(1, 35) = 1.178$, $p = 0.285$.

Table 7. Mean of the Measure of Originality by Grade-Based Norm



Some Statistically significant values for Titles, Resistance to Premature Closure

For the Titles measure, we found a significant difference in means of the paired Passive Art Observation Group on the pre-test and post-test $t(18) = 2.336$, $p < 0.05$. However, this difference was not consistent across all dependent variables. Regarding the Resistance to Premature Closure, we found a significant difference in means of the paired Interactive AI Installation Group on the pre-test and post-test $t(17) = -2.635$, $p < 0.05$. Additionally, according to the independent samples t-test, there is a difference in mean scores for the pre-test $t(35) = 1.024$, $p < 0.05$, however there was a no difference in the mean scores for the post-test $t(35) = -$

0.382, $p = 0.352$. The MANOVA analysis conducted for both measures did not yield any statistically significant results.

No Statistically Significant Values for Average and Creativity Index

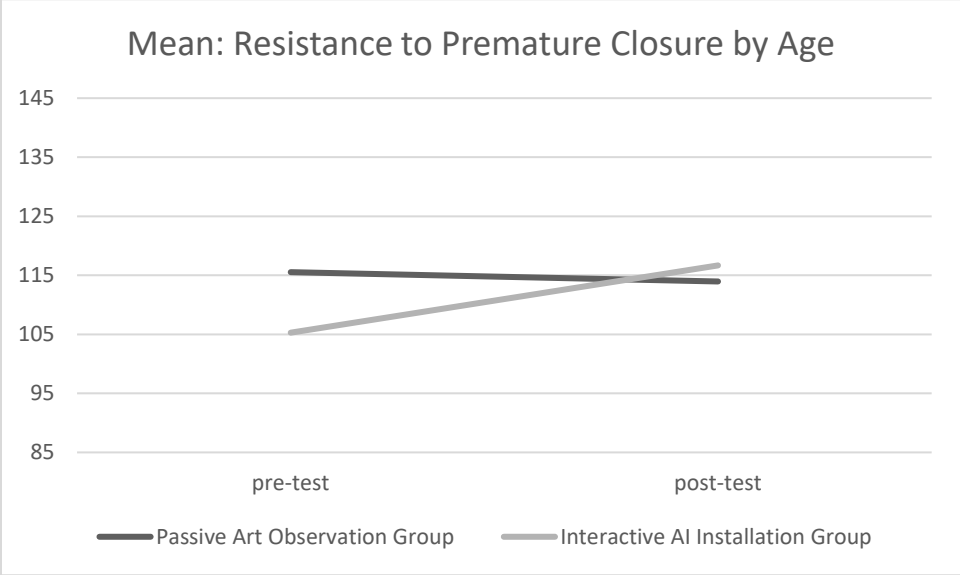
For the Average and Creativity Index, we found that there were no statistically significant results.

Scores of Measures by Age-Based Norm

Increase in Resistance to Premature Closure for Interactive AI Installation Group

Regarding the Resistance to Premature Closure measure, the Passive Art Observation Group did not show any difference between pre-test and post-test scores, while the Interactive AI Installation Group had an increase of 11 points (Passive Art Observation Group: M =115.53 to 113.95; Interactive AI Installation Group: M = 105.28 to 116.67). The paired samples t-test revealed that the decrease in scores for the Passive Art Observation Group was not significant $t(18) = 0.323$, $p = 0.375$, but the increase for the Interactive AI Installation Group was significant $t(17) = -3.073$, $p < 0.05$. Additionally, the independent samples t-test on the pre-test $t(35) = 1.891$, $p < 0.05$ indicated that the groups differ significantly. Nevertheless, the post-test scores showed that there was no significant difference between the two groups $t(35) = -0.407$, $p = 0.343$, meaning that the associated population means were not significantly different. The MANOVA within subject test indicates that there is no difference between the pre-test and post-test for all subjects, with $F(1, 35) = 2.514$, $p = 0.122$. However, the interaction of the measure Resistance to Premature Closure and Group was significant $F(1, 35) = 4.393$, $p < 0.05$, indicating that the difference between the pre-test and post-test is not the same between the two groups. The graph confirms those findings.

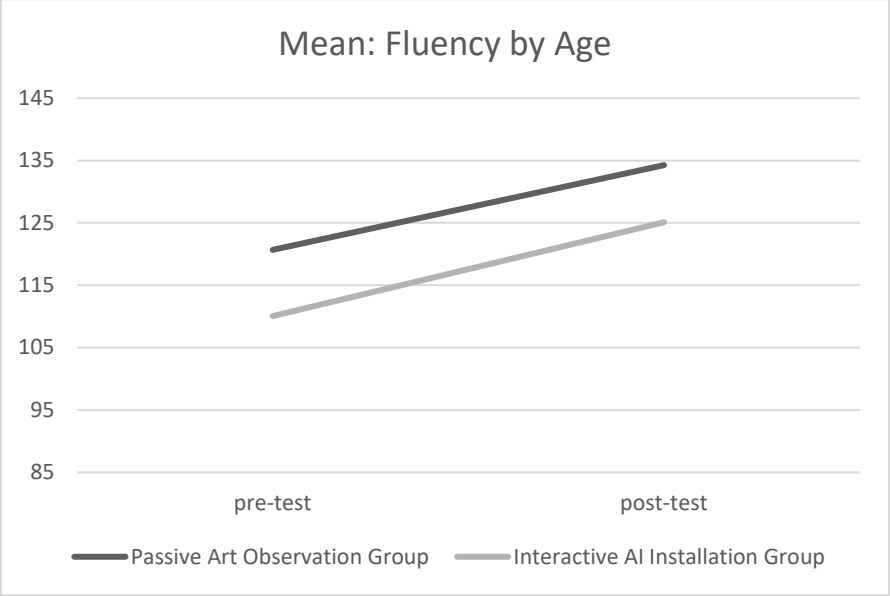
Table 8. Mean of the Measure of Resistance to Premature Closure by Grade-Based Norm



Increase in Fluency for Both Groups

Regarding the Fluency measure, both the Passive Art Observation Group (M = 120.68 to 134.26) and Interactive AI Installation Group (M = 110.06 to 125.11) showed a similar increase in mean scores, with an average gain of around 14.5 points. Using paired samples t-test, we can infer that there is a significant difference in scores between the pre-test and post-test for both the Passive Art Observation Group $t(18) = -3.208$, $p < 0.05$ and the Interactive AI Installation Group $t(17) = -5.129$, $p < 0.05$. Furthermore, using independent samples t-test, we conclude that the two groups do not differ in their pre-test scores $t(35) = 1.608$, $p = 0.058$ nor their post-test scores $t(35) = 1.510$, $p = 0.071$. The results of the MANOVA showed a significant difference between the pre-test and post-test scores for all subjects $F(1, 35) = 30.268$, $p < 0.001$. However, there was no significant difference in pre-test and post-test scores between the two groups $F(1, 35) = 0.998$, $p = 0.778$.

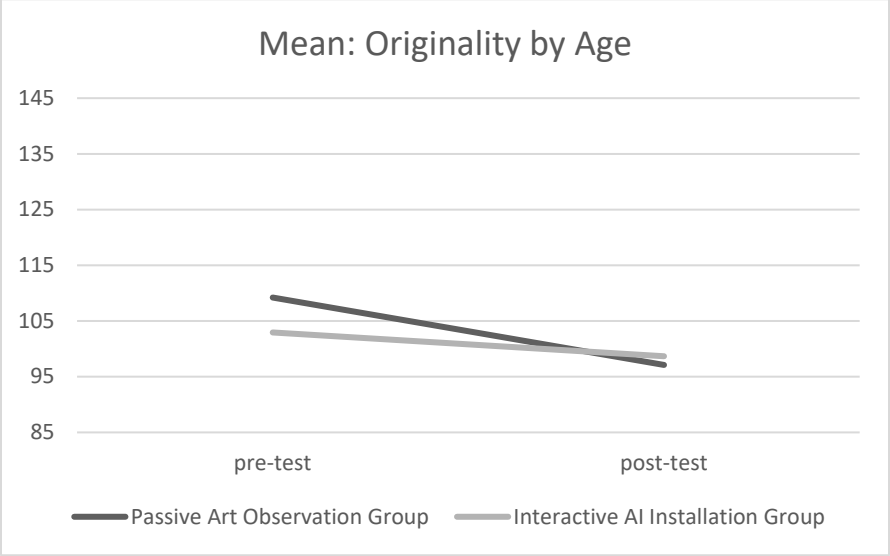
Table 9. Mean of the Measure of Fluency by Age-Based Norms



Decrease in Originality and Elaboration for Both Groups

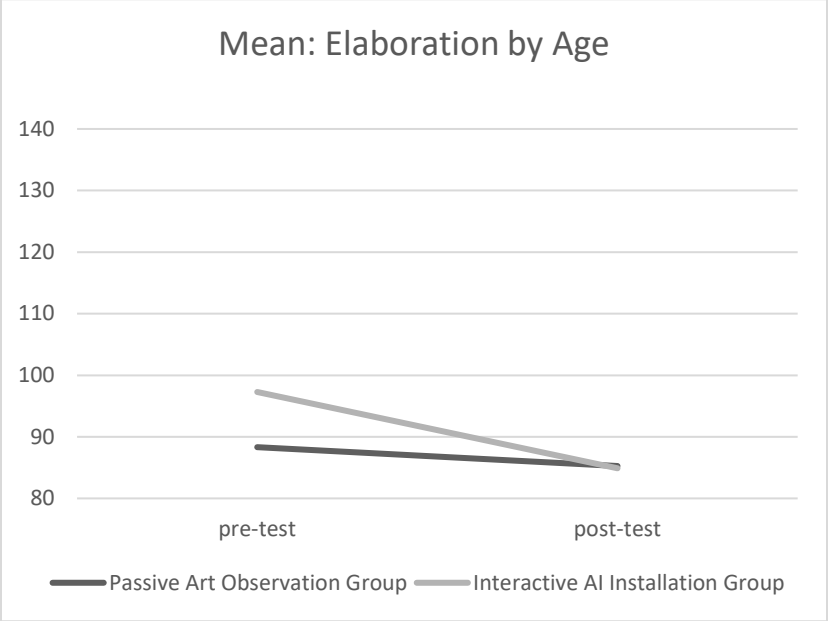
As for the Originality measure, both the Passive Art Observation Group (M = 109.21 to 97.11) and Interactive AI Installation Group (M = 102.94 to 98.67) showed a decrease in mean scores, with the decrease in scores higher for the Passive Art Observation Group (-12 points) than for the Interactive AI Installation Group (-4 points). Using paired samples t-test, we can infer that there is a significant difference in scores between the pre-test and post-test for the Passive Art Observation Group $t(18) = 2.499$, $p < 0.05$ but not for the Interactive AI Installation Group $t(17) = 0.867$, $p = 0.199$. In addition, using independent samples t-test, we conclude that the two groups do not differ in their pre-test $t(35) = 0.957$, $p = 0.173$ or their post-test scores $t(35) = -0.261$, $p = 0.398$. The results of the MANOVA indicate a significant difference between the pre-test and post-test scores for all subjects $F(1, 35) = 5.610$, $p < 0.05$. However, there was no significant difference in pre-test and post-test scores between the two groups $F(1, 35) = 1.281$, $p = 0.265$.

Table 10. Mean of the Measure of Originality by Age-Based Norms



Concerning the Elaboration measure, both groups showed a decrease in mean scores (Passive Art Observation Group: $M = 88.32$ to 85.26; Interactive AI Installation Group: $M = 97.28$ to 84.89). The decrease in scores was higher for the Interactive AI Installation Group (-12.39 points) than for the Passive Art Observation Group (-3.05 points). Using paired samples t-test, we can infer that there is no significant difference in scores between the pre-test and post-test for the Passive Art Observation Group $t(18) = 4.286$, $p = 0.170$. However, the difference in score for the Interactive AI Installation Group is significant $t(17) = 4.286$, $p < 0.05$. Additionally, using independent samples t-test, we conclude that the two groups do not differ in their pre-test $t(35) = -1.492$, $p = 0.072$ or post-test scores $t(35) = 0.053$, $p = 0.479$. The results of the MANOVA showed a significant difference between the pre-test and post-test scores for all subjects $F(1, 35) = 5.610$, $p = 0.024$. However, the interaction with the group is not significant $F(1, 35) = 1.281$, $p = 0.265$, meaning that the difference between the pre-test and post-test is the same between the two groups.

Table 11. Mean of the Measure of Elaboration by Age-Based Norms



Some Statistically Significant Values for Titles

As for the measure Titles, there was a significant difference in means of the paired Passive Art Observation Group on the pre-test and post-test $t(18) = 2.081$, $p < 0.05$. However, this difference is not reflected in the MANOVA results with no significant difference between the pre-test and post-test scores for all subjects: $F(1, 35) = 2.406$, $p = 0.130$ and no significant difference in pre-test and post-test scores between the two groups: $F(1, 35) = 2.314$, $p = 0.13$.

No Statistically Significant Values for Average, Creative Strengths Checklist and Creativity Index

Finally, the measures of Average, Creative Strengths Checklist, and Creativity Index showed no statistically significant values.

Conclusion

The findings of our study suggest that the overall Creativity Index, when analyzed based on grade-based or age-based norms, did not show any significant differences between the

participants who engaged in an interactive AI installation and those who passively observed art. However, a closer examination of individual creativity measures revealed some interesting patterns. Specifically, when using grade-based norms, active participation in the interactive AI installation was associated with a decrease in scores for the Elaboration measure. Conversely, when considering age-based norms, both intervention groups exhibited a decrease in scores for Elaboration. Interestingly, the group that engaged with the AI installation showed an increase in scores for Resistance to Premature Closure when assessed using age-based norms. Furthermore, both intervention groups experienced an increase in scores for Fluency, for both grade-based and age-based norms. There was also a decrease in scores for Originality, as assessed by both grade-based and age-based norms. Additionally, there was no significant difference in improvement between the two intervention conditions when considering the Creative Strengths Checklist measure assessed with grade-based norms. Both groups demonstrated an increase in scores, suggesting that the interventions did not have a significantly greater impact on participants' identification of their creative strengths.

In the next chapter, we will delve into a more detailed discussion of these findings and explore their implications.

CHAPTER 4: DISCUSSION

Introduction

Chapter 4 of our report focuses on the interpretation of the results obtained from our study, which aimed to examine the changes in creativity levels among high school students who engaged in an interactive art project utilizing AI-driven technology, compared to those who

passively observed art. In this chapter, we will discuss the implications of our findings, explore the limitations of the study, and provide insights into the theoretical and practical implications of our research. Additionally, we will highlight the opportunities for future research in this field and discuss the contributions our study makes to the existing literature.

Interpretation of Results

Overview

Regarding the interpretation of the TTC-Figural results obtained through this study, we draw upon the insights gained from Gubenko and Houssemand's (2022) application of the 4E framework to the interpretation of the Alternative Uses Task test. The 4E theory, as stated by van der Schyff et al. (2018), provides a framework that can enhance our comprehension of creativity by elucidating how individuals and social groups, through interactive and embodied processes, collectively generate rich and meaningful experiences. By applying the 4E framework to the TTCT-Figural results, we seek to explore how the test assesses creative thinking considering the dynamic interactions between the individual's cognitive processes and embodied experiences. Although we tested and focused on the role of the bodily experience in a creative process, we will address the role of the environment (social and cultural context) as well as the tools and actions undertaken by the subjects.

In our study, we opted for a comprehensive assessment approach and considered both grade-based and age-based norms in order to provide a more nuanced understanding of individual’s performance. The interpretation of the results is based on grade-based norms focuses on grade 11, which encompasses individuals aged 16-18. This allows us to compare the performance of our subjects within their specific grade level, regardless of their age. On the other hand, the interpretation of the results based on age-based norms involves comparing our subjects

to others in their respective age groups. For instance, a 16-year-old participant's performance is compared to the other subjects of the same age. This approach enables us to assess their performance relative to individuals of similar age, irrespective of their grade level. Therefore, depending on which norms were utilized as basis for grading, differences in assessment results are to be expected.

The choice of norms can influence the interpretation and comparison of scores, as it provides a reference point for evaluating individuals' performance. The measure which is scored by grade-based norms accounts for the expected cognitive abilities and developmental milestones associated with specific grade levels. It can be extrapolated that if the students did not perform on the test at the level expected for their grade, their scores for this measure will be lower. At the same time, an older student with the more developed cognitive skills who is assessed at the same level, as other student in his grade could obtain higher scores. Conversely, measuring creativity by age considers the development of an individual over time taking into account individual's experience and cognitive development that are not solely tied to grade level. With age, individuals generally acquire knowledge and develop their cognitive abilities. For instance, certain individuals may possess cognitive capabilities that surpass the typical expectations for their grade. Through their involvement in the interactive art activity, their cognitive abilities may have been further enhanced, leading to higher scores on the age-based measure compared to their peers in the same grade. Additionally, we must consider educational and cultural differences, as the normative sample used for test development was collected in the United States.

When analyzing the results of the Creativity Index, which serves as an overall assessment of creativity, we found that neither the interactive intervention nor the passive art observation

intervention had a noticeable impact on the participants' creativity levels. This finding was observed when evaluating the scores using both grade-based and age-based norms. Nevertheless, it is of interest to analyze each creativity measure separately, as they contribute unique aspects to the composite creativity assessment.

Upon examining the specific measures that comprise the Creativity Index, we identified several measures that exhibited statistical significance. Specifically, active participation in an interactive AI Installation resulted in a decrease in the Elaboration measure when evaluated using grade-based norms. However, when considering the scores evaluated using age-based norms, both intervention groups exhibited a decrease in scores for this particular measure. Interestingly, the group that engaged with the AI Installation demonstrated an increase in scores for Resistance to Premature Closure when assessed using age-based norms. It is noteworthy that Torrance's Technical Manual indicates a "low to moderate correlation" between the measure of Resistance to Premature Closure and the measures of Fluency ($r = 0.566$) and Originality ($r = 0.417$). Additionally, Fluency and Originality show a "highly correlated" relationship with each other, with a correlation coefficient of $r = 0.703$. Given these correlations, one might expect to see similar patterns in the scores of Resistance to Premature Closure, Fluency, and Originality in our study. However, our findings do not align with these expectations. We noted that both intervention groups experienced an increase in Fluency scores and a decrease in Originality scores, as assessed by both grade-based and age-based norms. This implies that engaging with art, regardless of interactivity, can influence these particular aspects of creativity regardless how the results are scored. Additionally, there was no significantly greater improvement in the embodied cognition condition since both groups demonstrated an increase in scores for the Creative Strengths Checklist measure when evaluated using grade-based norms.

Below we will discuss potential explanations for the observed findings.

No Significant Effect on Creativity Index (Grade-Based and Age-Based Norms) for Both Groups

First, we would like to address the results for the Creativity Index, a composite score derived from multiple measures, which aims to provide a comprehensive evaluation of an individual's creative potential. The statistical analysis based on the scores obtained for both grade-based and age-based norms revealed that neither the interactive intervention, which involved physical engagement with the art installation, nor the passive art observation intervention exerted a discernible influence on the participants' creativity levels. This outcome suggests that despite the potential for embodiment to play a role in facilitating creative thinking, inclusion of embodied interactions in one condition of this study, there was no discernible impact on the participants' creativity levels as measured by the TTCT-Figural.

There are several possible explanations for these findings. From the standpoint of embodied cognition, it is plausible to consider that the level of bodily engagement exhibited by the subjects in the study may not have reached a sufficiently active level to exert a notable influence on their creativity. In the study, the participants primarily utilized their fingers to interact with the tablet interface, involving the selection of photos and artistic styles. However, it is conceivable that this level of bodily engagement may not have been dynamic enough to stimulate significant changes in their creative thinking processes.

From enactive cognition perspectives, while the interactive intervention involved physical engagement with the art installation, the short ten-minute duration of physically engaging with the AI-powered intervention and viewing the artistic pieces might not have

provided enough time for participants to fully immerse themselves and experience a substantial impact on their creative thinking.

Additionally, from embedded cognition perspective, the structured school environment in which the study took place could have influenced participants' perception of their own creativity. The participants may have felt restricted or inhibited in expressing their creativity due to the formal and regulated atmosphere of the school setting. This constraint might have limited their ability to fully engage with the interventions and manifest their creative potential. Furthermore, the concept of extended cognition, which emphasizes the role of external resources, suggests that the tools provided in the form of interventions may not have been strong enough stimuli to elicit significant changes in the Creativity Index.

Another factor to consider is the sample size and composition of the study which could have influenced the statistical power to detect meaningful effects. In our study, we had a total of 38 participants. While this sample size is not uncommon in research studies, it is relatively small and may limit the generalizability of the findings. Additionally, the composition of the sample, including factors such as age range, educational background, and prior experience with art, may have influenced the results. A more diverse and larger sample size could potentially provide a more representative picture of the population and enhance the statistical power to detect any effects of the interventions.

Decrease in Elaboration Scores (Grade-Based Norms) for AI Installation Group and in Elaboration Scores (Age-Based Norms) for Both Groups

Elaboration measure focuses on developing, embroidering, embellishing or otherwise elaborating on ideas in a detailed and intricate manner (Torrance, 2018). While scoring it, one must take into account the fluency and originality of the ideas generated, as well as the level of

elaboration and detail provided in each response. Higher scores indicate a greater ability to delve deeply into concepts, offering intricate and multifaceted perspectives.

Analysis of the scores by grade-based norms indicated that the participation in the Interactive AI Installation had a negative impact on the measure of Elaboration, while passive art observation did not influence this measure. While analyzing the scores by age-based norms, we can state that there was a notable decrease in scores for both AI Installation and Passive Art Observation groups. The results suggest that only comparing the subjects' results by grade we can observe this statistically significant value for the group exposed to embodied activity. By considering the concepts of the RECS framework, we can gain a deeper understanding of the factors that influenced the results of the study.

When examining the scores based on grade-based measures, taking into account the perspective of embodied cognition, it is possible that the physical engagement in the interactive AI installation may have affected the participants' capacity to generate complex and elaborate ideas during the post-test. The bodily involvement in the installation might have led participants to prioritize the visual and sensory aspects, potentially diverting their attention away from engaging in profound cognitive elaboration.

From the perspective of enactive cognition, it can be hypothesized that the active physical engagement with NST technologies resulted in a decrease in the participants' ability to elaborate on ideas. This could be attributed to the participants relying on the AI technology to develop their ideas, as the process of uploading images and applying artistic styles was performed by the technology itself, minimizing the participants' active involvement in the creative process.

Another factor to consider is the potential influence of the AI component in the installation. Since according to the extended cognition, the cognitive processes can extend beyond the boundaries of the brain through the incorporation of external resources, the presence of AI may have led participants to rely on the system's creativity, limiting their independent thinking. This reliance on external guidance could have hindered their ability to generate highly elaborated responses at a later stage of the experiment.

Furthermore, through the lens of embedded cognition, which highlights the influence of environment, it is important to acknowledge the role of environmental factors and individual differences. Due to their background, not all participants may have found the Interactive AI Installation to be conducive to their creative thinking process. Some individuals may have thrived in more traditional, open-ended environments that allow for greater exploration and elaboration. Hence why it could be that the Passive Art Observation group experienced an insignificant decrease in scores in comparison to the group that participated in an AI installation.

However, when analyzing the scores based on age-based measures we notice that both physically participating in an artistic process, as well as viewing art had a negative impact on the Elaboration measure. It can be stipulated that the novelty and engagement provided by the installations may have diverted participants' attention away from generating detailed and intricate ideas during the post-test.

Increase in Resistance to Premature Closure Scores (Age-Based Norms) for AI Installation Group

Resistance to Premature Closure assesses an individual's capacity to remain open-minded and avoid hasty conclusions, allowing for the mental leap necessary to generate original ideas. Individuals with lower levels of creativity often have a tendency to prematurely jump to conclusions without fully considering the available information, thereby limiting their opportunities to develop more innovative and impactful concepts.

The results of the statistical analysis demonstrate that the Interactive AI Installation Group experienced a significant improvement in the Resistance to Premature Closure measure scored for the age-based norm, while the Passive Art Observation Group did not show a substantial change. It is noteworthy that this difference is only observed if the scores are analyzed on the basis of the age. This indicates that in comparison to their peers of the same age, the subjects' ability to delay closure of figures has improved. However, this difference is not observed when the scores are compared to the performance of the subjects from the same grade on a national level. These results highlight the potential effectiveness of embodied artistic activity in fostering individuals' capacity to maintain openness and delay closure in their thinking, leading to more innovative and flexible cognitive processes. The observed difference in this measure between two groups when scored on the basis of age-based norm can be attributed to various factors.

From the perspective of embodied cognition, it can be proposed that when individuals actively engage in creative activities guided by AI, it promotes a reflection in their cognitive processes. The interactive element of the AI installation offers novel approaches for dealing with images, such as uploading a photo and selecting a preferred artistic style. This process of actively

engaging with the technology requires individuals to pause and consider different possibilities before reaching a final result, thus discouraging hasty conclusions and promoting a more thoughtful approach to the creative process.

Reframing the results in the concept of embedded cognition, the interactive AI art installation likely provided affordances for the participants to engage in exploratory thinking and challenge their assumptions. This in turn might have enabled them to explore variations of the artistic outcomes before choosing one, which was reflected in the improved performance in this measure. The socio-cultural environment, including the educational context and peer comparison, also may have influenced the observed differences in cognitive performance. It can be that the variations in cognitive development within a single grade level might not be as significant compared to those observed across different age groups. As a result, when scoring based on grade-based norms, the educational context and peer comparison might have attenuated the observed improvement in this measure, as the focus shifts more towards academic performance rather than individual cognitive development.

According to enactive cognition, it is that actions aid us to make sense of our environment. Therefore, it could be said that the interactive nature of the AI art installation encouraged the participants to engage in meaningful actions, such as experimenting with different approaches when choosing the art styles. These actions allowed them to explore alternative possibilities before reaching conclusions, leading to improved cognitive performance and an increase in the scores for the measure of Resistance to Premature Closure.

In addition, analyzing the performance through extended cognition view, the interactive AI art installation expanded the cognitive system beyond the individual's body by incorporating the AI technology through the interactive elements of the installation. These external elements

became integral to the participants' cognitive processes and potentially contributed to the observed improvement in the discussed measure.

As for the Passive Art Observation Group, the lack of significant change in the Resistance to Premature Closure measure could be due to the absence of interactive elements in the artistic observation activity.

Increase in Fluency (Grade-Based and Age-Based Norms) for Both Groups

Fluency score is considered one of the most critical aspects of the test. No subsequent scores may be given in other dimensions unless a response is first to be relevant (Torrance, 2018). The results of the study suggest that regardless of which intervention individuals participated in, both the grade-based and age-based groups demonstrated an improvement in generating a large number of figural images, as indicated by the scores for the measure of Fluency. Conversely, no statistically significant improvement was observed in the condition associated with embodied cognition. Based on this outcome we can stipulate that physical implication in the artistic process did not have an effect on this particular measure.

The increase in the measure of Fluency can be due to the role of the environment, specifically, exposure to diverse visual imagery that can stimulate the brain leading to an increase in the generation of diverse ideas. This aligns with the concept of embedded cognition, which suggests that cognition is shaped by the environment and the affordances it provides.

From an enactive cognition perspective, engagement with art, whether through visual observation or combined visual and physical interaction, may enhance individuals' capacity to establish connections between seemingly disparate concepts. Furthermore, it is plausible to propose that art possesses the ability to elicit potent emotional responses (Tinio & Gartus, 2018)

which can perhaps fuel the creative process and enhance individual's ability to produce large quantity of ideas. However, as stated previously, there was no observed difference in the results for the group that was actively engaged with the AI installation. Therefore, active physical engagement in creative activity did not have a direct effect on this measure.

Lastly, the tools used in the experiment, whether it was a video or an interactive installation, can be viewed, when considering extended cognition, as important artifacts that play a significant role in creative cognition. It can be argued that their use contributed to the increase in subject's abilities to produce numerous figural images.

Decrease in Originality Scores (Grade-Based and Age-Based Norms) for Both Groups

Despite the high correlation between the measures of Fluency, representing the quantity and Originality, representing quality ($r = 0.703$), the artistic intervention did not have the same effect on the measure of Originality. Our results indicate a decrease in post-test scores for all subjects. According to the TTCT Streaming Scoring Guide (2018), increase in Fluency in combination with low scores for Originality implies that participants in both the grade-based and age-based groups, produced many relatively trite, common responses. We can conclude that from an embodied cognition view, the embodiment did not play a role in the decrease of scores for this measure. Additionally, in the context of enactive cognition, active engagement with the installation also did not play a role in the decrease in Originality scores. It can be stipulated that the short duration of the intervention did not provide enough time for the activity to have an effect. It could also be that the exposure to art imagery, rather than the physical participation caused a decline in the ability to produce "unusual" responses.

From the perspective of embedded cognition, this decrease in Originality scores could be attributed to physical and socio-cultural factors, such as the influence of established artistic

norms on participants' cognition. Despite efforts to expose participants to varied artworks and train the interactive installation's NST model, the results remained aligned with existing artistic conventions. Therefore, the exposure to this type of art may not have sufficiently pushed participants' boundaries and stimulated the generation of highly original ideas.

An alternative explanation can be offered by considering the extended cognition framework. According to this perspective, the items in our environment become incorporated into our cognitive system. In this case, we must consider the impact of the TTCT-Figural test on the obtained scores. Although the specific forms of the TTCT (A and B) used for pre- and post-assessment differed, the overall nature of the test remained the same. It is plausible that participants may have exhausted their repertoire of unique ideas due to the inherent nature of the test itself. Also, the decrease in Originality scores could be explained by participants' familiarity with the artistic stimuli. It is possible that participants had prior exposure to the artworks and had previously interacted with NST applications on their phones or tablets. Consequently, they may have lacked the inspiration to create more unique responses.

Increase in Creative Strengths Checklist Scores (Grade-Based Norms) for Both Groups

Our results indicate that regardless of which intervention individuals participated in, both groups demonstrated an improvement in the Creative Strengths Checklist Scores evaluated on grade-based norm. According to the TTCT Streamlined Scoring Guide, (Torrance, 2018), Checklist of Creative Strengths consists of thirteen criterion-referenced measures that identify specific markers of creative strengths in individuals. These markers indicate areas of strength that can be leveraged for the development of instructional methods tailored to each individual's unique creative abilities. By identifying and nurturing these specific strengths, educators and

practitioners can design instructional approaches that effectively support and enhance creative thinking in individuals.

Analyzing the observed increase in the Creative Strengths Checklist scores within the RECS framework sheds light on the underlying mechanisms. Interestingly, from embodied cognition perspective, while physical interaction with installations may not have directly affected the measured creative strengths, the overall exposure to art positively influenced individuals' creative abilities. This suggests that engaging with artistic interventions, both visually and physically, can lead to transformative changes in cognitive processes and an expansion of creative capacities. However, direct physical involvement in the interactive activity does not play a role in an increase of scores for this measure.

Summary

Overall, the perspectives provided by the RECS framework, namely embodiment, embedded cognition, enactive cognition, and extended cognition, shed light on the mechanisms through which engaging with art can lead to improvements in creative abilities. In our study, we discovered that physical engagement with an AI-powered installation resulted in a decrease in the measure of Elaboration and an increase in the measure of Resistance to Premature Closure. While our focus was primarily on embodied experience, it is important to acknowledge the potential contributions of the other frameworks in shaping creativity. These frameworks highlight the interplay between the body, environment, actions, and cognitive processes, providing a comprehensive understanding of the observed outcomes in the context of artistic interventions. Future research endeavors could delve into the specific roles of each framework, investigating how they interact and influence creative processes.

Limitations

As with any scientific investigation, our study is not without limitations that are essential to acknowledge and address to ensure the validity and generalizability of the findings.

Although we addressed the possible causes of increase and decrease in measures scores within the framework of 4E (embodied, embedded, enactive, and extended cognition), our study did not specifically examine the individual contributions of each cognitive aspect, with the exception of embodiment. Our study primarily focused on the embodied cognition component, and while we provided insights into its impact, we did not comprehensively evaluate the specific contributions of the other cognitions—embedded, enactive, and extended. Consequently, further investigation is warranted to thoroughly assess the interpretations of the environment, action, and the tools employed in our experiment. Additionally, it is worth noting that the initial concept for our study involved the utilization of deepfake technology in combination with NST, which would have allowed the subjects to engage in a more interactive experience than with just NST. Deepfake technology, renowned for its ability to convincingly alter a person's appearance in videos, held the potential to enhance the participants' engagement by changing their visual representation and providing real-time video footage of their actions within the artistic installation. This additional interactive element could have potentially stimulated a deeper sense of engagement with the installation potentially influencing subjects' cognitive processes resulting in changes in creativity levels. However, due to technical restrictions, we were unable to ran the experiment as initially planned and thus had to resort solely to the use of NST.

The absence of a control group is a significant limitation of our study. In the absence of a control group, it is challenging to draw definitive conclusions about whether the observed differences between the two treatment groups were due to the treatments themselves or other factors that may have influenced the results. The lack of a control group increases the risk of

confounding variables influencing the results. While we can analyze the differences between the two treatment groups, it is important to interpret the findings with caution, as there could be an alternative explanation for the observed effects.

Another limitation of our study is the relatively small sample size. With only 37 participants, the generalizability of the findings may be limited, and the statistical power to detect significant effects could be reduced. A larger sample size would have provided more robust results and increased the representativeness of the findings to the broader population. The small sample size rendered our statistical analyses less powerful and increased the risk of errors. For MANOVA, a smaller sample size reduced the ability to detect differences between groups and treatments and could increase the risk of Type I errors, meaning that the test could have detected a significant difference when there is none. For t-tests, the precision of estimates is reduced, and the variability of the data is increased. In addition, with a limited sample size, the representativeness of the sample to the larger population may be compromised. This can impact the generalizability of the findings and limit the ability to draw conclusions about the broader population.

It is important to note that for our study we focused on high school students ages 16 to 18, situated in Luxembourg. The age range of 16 to 18 represents a relatively narrow segment of the overall population, and creativity and cognitive processes can vary across different age groups. Therefore, the findings of our study may not be applicable to individuals outside this specific age range. Additionally, our study was conducted exclusively within the context of high school in Luxembourg. Cultural, educational, and environmental factors specific to this region could have influenced the participants' experiences and responses to the interventions. Therefore, caution should be exercised when extrapolating our results to other geographic locations or educational systems, as the effects of the interventions may differ in diverse cultural and educational settings.

Fourth limitation is that our study solely utilized the TTCT in its figural form. The decision to use only the figurative form of the TTCT in our study was influenced by the diverse linguistic backgrounds of our participants. We recognized that participants' varying levels of language proficiency and familiarity with the test language could introduce confounding factors and potentially influence their performance in the verbal section of the test. To minimize this potential bias, we opted to focus solely on the figurative form, which allowed us to assess participants' creative thinking abilities through non-verbal means. By doing so, we aimed to ensure that the results obtained from the TTCT were more directly indicative of participants' creative capabilities, independent of their linguistic backgrounds or language-related factors. While this decision allowed us to include participants with diverse linguistic backgrounds, it does narrow the scope of our assessment of creativity, as the verbal section could provide additional insights into participants' creative thinking abilities. Including a comprehensive assessment battery would have allowed for a more comprehensive understanding of creativity.

Additionally, it is important to mention TTCT distribution in normative sample used for the development of the test. The current norms for Figural Forms A and B were established based on a sample of 60,917 students from 1,300 schools across 35 states in the United States of America with the scoring done by the Scholastic Testing Service, Inc. Therefore, when evaluating the test results of the TTCT in Luxembourg, it is important to keep in mind cultural and educational differences between the two countries. Furthermore, the distribution by Grade indicates the widespread use of the instrument in the lower and middle grades, with a more limited use at the secondary and adult levels. For example, in the 11th Grade, a total of 168 students completed TTCT-Figural Form A, and 192 students completed Form B. In contrast, there were 7,134 students from grade 1 who were administered Form A, and 2,862 students who completed Form

B. Although the sample size remains relatively robust, it suggests that the results from lower grades may yield more precise interpretations compared to the secondary and adult levels.

Another limitation was that the specific measurement instrument we employed: TTCT in its figurative version, may have its own limitations. While it is a widely used measure of creativity, it may not capture the full complexity of creative thinking, and its validity in assessing creativity across diverse populations and contexts has been debated. The reliance on a single test instrument raises concerns about the construct validity and generalizability of our findings. Supplementing the TTCT-Figurative with other established measures or alternative assessments could have provided a more comprehensive and robust evaluation of creativity. Also, empirical validation is still needed to confirm the accuracy of comprehensive longitudinal models that incorporate current theories of creativity and cognition in explaining creative achievement. (Plucker, 1999).

Finally, a sixth limitation is that the duration of the treatments lasted only 10 minutes, which may not have been sufficient to cause significant changes in creative thinking. With a brief intervention period, participants may not have had enough time to fully engage with the materials and explore the creative processes stimulated by the treatments. The brevity of the treatments in our study limits the depth and breadth of insights that can be drawn from the results. It is possible that longer exposure to the interventions could have yielded different or more pronounced outcomes.

Overall, these limitations should be considered when interpreting the results of our study, and future research should strive to address them in order to enhance the validity and generalizability of the findings.

Future Research Opportunities

The limitations of our study present exciting opportunities for future research in the realm of creativity and cognition within the framework of the 4E perspectives. While we provided valuable insights into the impact of embodied cognition, further investigation is needed to explore the specific influences of the other cognitive aspects—embedded, enactive, and extended—in the context of creativity. Future research endeavors could delve deeper into understanding the interpretations of the environment, action, and the tools employed in experimental settings. By conducting comprehensive studies that systematically examine each of these cognitive dimensions, we would contribute to a more comprehensive and holistic understanding of the interplay between cognition and creative processes.

The idea of incorporating deepfake technology in addition to NST into future experiments remains an intriguing avenue for future research. Deepfake creates interaction with virtual artistic expression in a manner that closely resembles real-life interaction. Exploring the impact of deepfake technology in future studies would undoubtedly provide valuable insights into the potential of advanced virtual technologies to enhance creative engagement and push the boundaries of embodied experiences in the context of AI-powered interventions. Additionally, creating a more immersive and physically demanding interactions that involve incorporating gestures, whole-body movements, and tactile experiences that elicit a greater level of bodily engagement, could provide exciting research opportunities.

In subsequent research it would be advisable to include a control group to establish a baseline for comparison. A control group would enable researchers to isolate the effect of the treatment and determine whether the observed differences in outcomes were due to the treatment itself or to other factors. As a control trial is considered a standard in research practice,

conducting this type of study including a control group would potentially establish causality, reduce risk of confounding variables influencing the results and increase the internal validity of the study for research population.

Sample size is another important consideration in future research. Increasing the sample size can improve the representativeness of the findings and enhance the statistical power of the study by minimizing errors and improving the ability to detect the effect of treatments on the groups. In addition, to increase the generalizability of the findings, it is important to include participants from diverse age ranges, cultural backgrounds and geographic locations in order to understand how creativity and cognitive processes vary across different groups. By examining these variations, researchers can gain insights into the influence of cultural, educational, and environmental factors on creativity and cognitive processes. Additionally, an important step towards inclusivity and comprehensive understanding would involve including individuals with developmental disabilities. This would shed light on the unique experiences and perspectives of individuals with neurodevelopmental disorders.

Researchers should also consider including a comprehensive assessment battery to evaluate creativity. While the TTCT is a widely used measure of creativity, it has its limitations and may not capture the full complexity of creative thinking. By including other well-established measures or alternative assessments that tap into different aspects of creativity, researchers can enhance the breadth and depth of the evaluation, ensuring a more comprehensive and robust understanding of creative abilities. For instance, they could use Guilford's Alternative Uses or Consequences tests that assess individual's ability to think beyond conventional associations and anticipate and evaluate the potential outcomes of specific actions. This multi-measure approach

would ensure a more comprehensive and robust assessment of an individual's multifaceted nature of creativity.

A potential avenue for future research lies in examining the applicability and validity of the TTCT-Figural in diverse cultural and educational contexts. While the current norms for Figural Forms A and B were developed based on a large sample of students from schools in the United States, it is crucial to investigate the generalizability of these norms to other countries, such as Luxembourg. This would involve considering the cultural and educational differences between the two contexts and exploring whether these variations impact the interpretation of creativity scores. Additionally, future studies could explore the utilization of the TTCT across different grade levels, particularly focusing on secondary and adult levels.

Finally, researchers should consider the duration of the treatment when designing studies. A brief intervention period may not be sufficient to cause significant changes in creative thinking. Researchers should aim for a longer exposure to the interventions to allow participants to fully engage with the materials and explore the creative processes stimulated by the treatments. One approach to explore the impact of intervention duration is to organize various groups with different exposure times to interactive installations. For instance, researchers could assign groups to participate in interactive installations for 10, 20, 30 minutes, or even longer. This would enable the investigation of the potential dose-response relationship between intervention duration and its impact on creative thinking. By comparing the outcomes across these different time periods with the control group, researchers can gain insights into the optimal duration needed to elicit significant changes in creativity. Furthermore, it would be intriguing to investigate the effects of interventions that span over more extended periods, such as a whole class period or even an entire semester. By providing participants with prolonged engagement in

the interventions, researchers can examine how sustained exposure and immersion in creative activities impact the development and enhancement of creative thinking skills. This longitudinal approach allows for a comprehensive exploration of how creativity evolves and matures over an extended duration, providing valuable insights into the long-term effects of interventions on creative cognition.

Overall, further exploration and refinement of interventions that incorporate embodiment in the context of creativity research could shed light on the complex interplay between physical engagement, cognitive processes, and creative outcomes.

Conclusion

The research conducted by the primary investigator aimed to contribute to the field of embodied cognition, specifically focusing on the effects of physical participation in an interactive installation featuring AI technologies on creativity levels. To elaborate further, the purpose of this study was to explore the potential changes in creativity levels among high school students who actively participated in an interactive art project using NST and those who observed traditional art objects such as paintings in a passive manner through a video.

The theoretical implications of the research findings based on 4E cognition framework indicate that active involvement in an interactive AI installation did not cause changes in the overall Creativity Index, as indicated by the results obtained from the study. However, depending on whether the results were graded using grade-based or age-based norms, we noticed the impact of embodiment on creativity measures. When examining the measures separately, it became evident that physical immersion in an interactive creative activity can foster openness and flexible thinking, as evidenced by improvements in the measure of Resistance to Premature

Closure. This aligns with the theoretical perspective of embodied cognition, which emphasizes the role of the body in shaping cognitive processes.

However, this physical engagement also hindered the participants ability to develop or elaborate on ideas, resulting in a decrease in the measure of Elaboration. This raises theoretical questions regarding the complex interplay between the embodiment and elaboration. In addition, the study found that artistic interventions, regardless of the type, can lead to improvements in Fluency and Creative Strengths but may result in a decrease in Originality and Elaboration. Those findings prompt theoretical discussion on how different dimensions of creativity may respond to embodied interactions. However, the absence of a control group limits the certainty of attributing these changes solely to artistic interventions, highlighting the need for further investigation. Overall, even though the overall impact of intervention on Creativity Index might not be significant, the findings indicate the need to analyze and interpret each measure of creativity independently, as their response to intervention may vary.

As the impact of AI on our lives continues to grow, it is important to continue exploring the potential benefits and drawbacks of the interplay between embodied creativity and AI with a balanced perspective. In doing so, we can continue to expand our understanding of this interaction and design new ways to enhance creativity. From a practical perspective, understanding the impact of embodiment on creativity has interdisciplinary implications, spanning various fields such as education, business, and the arts. It is widely recognized that creativity can be nurtured and there is currently a dearth of identified pedagogical practices aimed at fostering it. (Malinin, 2019). Therefore, when designing interventions aimed at fostering creativity, one must consider the role of the body in shaping an individual's creativity, particularly in the context of engaging with AI-powered creativity tools. For example, creating

interactive installations that combine AI technology with physical elements, such as gesture recognition or tactile feedback, that can provide users with a more embodied creative experience. The duration of the intervention and perhaps repeated exposure must be also carefully considered to ensure sufficient time for individuals to fully engage with the tools. As shown in our study, short interventions might not be sufficient to elicit important changes in creativity levels. Additionally, one can foresee developing a personalized AI-powered interventions that could provide guidance to individuals with their creative strengths and weaknesses. AI systems could analyze individual performance and offer tailored activities that would enhance persons' creativity. Overall, those types of interventions can be implemented in various settings allowing widespread access to potential creativity training tools for a broad audience.

In summary, our research findings serve as a valuable starting point for considering positives and negatives of the interaction between embodied creativity and AI. We hope that continued research in this domain will allow us to develop strategies that optimize the benefits while mitigating any potential drawbacks, leading to the advancement in the field of creative practices.

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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 12. 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