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The impact of watching science fiction on the creativity of individuals: The role of STEM background

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ABSTRACT

This paper delves into the intersection of science fiction, creativity, and individuals' backgrounds, with a special emphasis on STEM (Science, Technology, Engineering, Mathematics) education. We investigate if individuals with a STEM background show a more pronounced creative impact from watching science fiction compared to their non-STEM counterparts. We conducted an experimental study involving 204 university students from various disciplines, both STEM and non-STEM, randomly assigned to one of two conditions—watching a science fiction TV episode or a non-science fiction episode—followed by a creative task. The solutions proposed by the students were assessed for their level of creativity. Our findings reveal that the students with a STEM background were more creatively impacted by the exposure to science fiction. These insights hold significant implications for educators, policy-makers, and professionals interested in fostering creativity, suggesting the need for tailored approaches based on an individual's background and a potential role for science fiction in stimulating creative thinking.

1. Introduction

Science fiction (sci-fi), as a genre, has captivated audiences for centuries, transporting them to imaginative realms and presenting futuristic concepts that challenge the boundaries of human knowledge and understanding. Beyond entertainment, there is a growing body of research suggesting that exposure to sci-fi can have a profound impact on the creativity of individuals, enhancing their capacity to contribute to innovation (Michaud, 2021; Schwarz et al., 2014; Michaud and Appio, 2022). While the existence of a positive influence of watching sci-fi on human creativity has already been established, the factors that amplify or hinder this influence remain unclear. In this paper, we explore the relationship between watching sci-fi and individual creativity, with a particular focus on the role of an individual's characteristics, specifically a STEM (Science, Technology, Engineering, and Mathematics) background (Toubia and Netzer, 2017).

Creativity is a fundamental aspect of human cognition and problem-solving, allowing individuals to generate novel and valuable ideas, perspectives, and solutions (Anderson et al., 2014). Sci-fi, with its ability to depict speculative and futuristic scenarios, has the potential to stimulate the creative thinking process (Muscio, 2023). By exposing individuals to alternative realities, advanced technologies, and complex scientific concepts, sci-fi offers a unique platform for expanding imagination and pushing the boundaries of conventional thinking (Wu, 2013). This has contributed to the development of techniques for the development of creativity based on sci-fi, such as sci-fi prototyping (Potstada and Zybura, 2014) or sci-fi-based technology scenarios (Idier, 2000).

Not all individuals, however, can be expected to be equally sensitive to the stimuli of sci-fi under any circumstances. Individual and environmental factors can affect how the relationship between sci-fi and creativity manifests itself in practice (Potstada and Zybura, 2014). This can result in very different outcomes in terms of creativity depending on the individual and the situation (Lin et al., 2013). Understanding the factors that intervene in the relationship between sci-fi and creativity is crucial for optimizing the creative potential that sci-fi can offer. By identifying the variables that interact with the viewing experience, we can further explore the underlying mechanisms through which sci-fi influences creativity.

One such factor that may contribute to the differential impact of sci-fi on creativity is an individual's background (Jessen et al., 2020; Lin et al., 2013). A person's educational and professional experiences, interests, and prior knowledge shape his/her cognitive framework and perception

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of reality. It is plausible to assume that individuals with a STEM background, characterized by their exposure to scientific and technological concepts, may experience sci-fi in a unique and potentially more impactful manner, relative to individuals without a similar background. However, research into the impact of sci-fi consumption on creativity is still in its infancy (Michaud, 2021). There are few empirical studies on the topic. The causal relationships investigated by prior studies are simple, and relevant moderation or mediation effects such as the individual's background are rarely considered. There is, therefore, a double gap in the literature: (i) in general, empirical studies are needed that investigate the relationship between sci-fi consumption and creativity; (ii) in particular, these studies need to analyze the complexity of such a causal relationship by investigating the role of variables such as an individual's background.

Against this background, the paper answers the following research question: *How does an individual's background, specifically in STEM or non-STEM disciplines, moderate the impact of watching science fiction on the creativity of ideas?* In doing so, we consider that individuals with a STEM background will exhibit a stronger impact of watching sci-fi on their creativity. The rationale behind this statement is grounded in the assumption that individuals with STEM training possess a solid foundation of scientific principles and are more likely to engage deeply with the scientific and technological concepts depicted in sci-fi (Honey and Kanter, 2013). Consequently, their exposure to sci-fi may enhance their ability to generate novel and innovative ideas.

To answer our research question, we conducted an experiment (Saunders et al., 2007) involving university students from various disciplines, including both STEM and non-STEM backgrounds. A total of 204 students were randomly assigned to one of the two experimental conditions (i.e., watching an episode of a TV series - sci-fi *versus* no sci-fi episode) and then solving a task. The solutions proposed by students were evaluated in terms of the creativity they expressed. The results of the experiment confirm a stronger impact of watching sci-fi on the creativity of students with a STEM background.

The outcome of our study is useful for scholars and professionals interested in creativity and how it can be stimulated. In fact, the study underlines that different approaches are necessary as the background of the interested subjects varies. In the same way, our results are useful for scholars in the field of education and for policy-makers as they highlight aspects relevant to the education of individuals, particularly in terms of creativity.

This paper is structured as follows: Section 2 provides a review of the existing literature on the impact of sci-fi on creativity. Section 3 outlines the methodology employed in our study, including participant selection, experimental design, and data collection and analysis methods. Section 4 presents the results obtained from our analysis and statistical tests. In Section 5, we discuss the implications of our findings. Conclusion, limitations, and directions for future research conclude the paper.

2. Theoretical development

In the evolving landscape of creativity research, recent studies have further elucidated the relationship between sci-fi exposure and creative thinking. Henriksen et al. (2016) examine the role of interdisciplinary learning in fostering creativity, particularly emphasizing the impact of narrative media like sci-fi on cognitive flexibility and innovative thinking. This perspective is enriched by Reboud and Mazzarol (2023), who explore the benefits of sci-fi writing in stimulating entrepreneurial students' imagination and future-oriented thinking. Additionally, Cropley and Cropley (2020) address the cognitive mechanisms through which sci-fi influences creative thinking, particularly in STEM fields, underscoring the role of imaginative narratives in stimulating divergent thinking.

Root-Bernstein and Root-Bernstein (2017) highlight how sci-fi can serve as a catalyst for creative ideation and problem-solving, a view supported by Zheng and Callaghan (2018), who discuss the concept of 'diegetic innovation templating' in Chinese SMEs, illustrating the stimulating role of sci-fi and fantasy in innovation. Furthermore, Wiseman and Watt (2022) contribute to this discourse with a targeted literature review on experiencing the impossible and creativity, emphasizing the broader implications of sci-fi on societal and cultural creativity. Finally, Vorderer et al. (2004) provide empirical evidence of the relationship between sci-fi and creativity by suggesting a positive correlation between regular exposure to sci-fi narratives and enhanced creative thinking skills, particularly in contexts requiring innovative solutions.

In the following two paragraphs, we delve into the relationship between sci-fi and creativity, exploring the impact of this genre on innovative outputs. Additionally, we examine the role of creativity in innovation and its connection with individuals' backgrounds.

2.1. Science-fiction, creativity and innovation

In the realm of fiction, the generation of innovative ideas and exploration is not merely a critique or imitation of the process of scientific discovery, nor is it solely an indication of potential technological and scientific developments. With greater creativity and risk-taking, sci-fi has the potential to disrupt our current understanding of science while contemplating a vast range of possibilities, including those that have been envisioned but not yet adopted by mainstream scientific communities. In essence, sci-fi transcends its role as a mere auxiliary to the scientific method, possessing the capacity to initiate unique occurrences that may subsequently be legitimized through traditional scientific validation (Appel et al., 2016).

According to Lee (2019), firstly, sci-fi employs an established theory, which may be widely accepted, contentious, or unproven, and offers its own reinterpretation of a possibility that may or may not prompt reconsideration of the current scientific understanding. Secondly, the scientific narrative is typically direct, with innovation arising in the form of potential technological advancements derived from directing scientific knowledge toward technological possibilities. Thirdly, sci-fi embraces a concept deemed implausible within the constraints of reality and creates a world where such a possibility becomes attainable, although the mechanism for enabling these possibilities may be detailed to varying extents. The development of a scientific concept within the fictional realm may sow the seeds for constructing a scientific rationale that originates in fiction before being translated into mathematical language and integrated into experimentation. This third scenario parallels the notion of models as fiction, developed to emulate and represent scientific epistemologies and practice (Godfrey-Smith, 2009; Fine, 2009; Suárez, 2008). Lastly, sci-fi extrapolates from a contemporary idea to simulate a potential outcome that may materialize should the projected scenario become experimentally feasible.

The first and second scenarios are content with drawing inspiration from the scientific world without challenging the prevailing paradigms of Kuhnian normal science (Kuhn, 2012). In other words, the portrayal of scientific artifacts in these instances is unlikely to significantly defy the dominant scientific principles of the era, although the second scenario may still lead to unforeseen technologies. Conversely, the third and fourth scenarios imply that sci-fi could assume a more proactive role in the creation of scientific knowledge and the generation of innovative discoveries.

Stanislaw Lem (1984) posits that sci-fi inadvertently generates an eerie realm through the elicitation of suspended judgment via the subversion of anticipations, thus differentiating the genre's portrayal of science as a distinct entity from a logically inflected, fact-based narration of science (Latour, 1999). William Bainbridge (1986) contends that sci-fi serves as a creative construal of scientific and technological concepts for the purpose of conveying to a broad readership the ideas that shape our civilization's future. Gerard Klein (2000) proposes that sci-fi narratives ought to encompass semblances of images (eikons) and depictions (eidons). For a work to be classified as sci-fi, the image must constitute the central aspect of the science, to the extent that the

narrative would disintegrate without said image, thereby deeming the work as sci-fi. Klein further asserts that qualifying an elaborate image as sci-fi necessitates an emphasis on the fictional component, wherein the image must have experienced additional imaginative augmentation beyond a mere literal portrayal of the science. In turn, a true-to-life representation of the scientific community and science itself signifies that the work is not science fiction. Eikons, despite their potent theoretical ties, possess their own distinct voice and emotive allure, while eidons gravitate towards abstraction - although the abstraction of the latter does not preclude its capacity to stimulate vivid narratives involving tangible subjects.

Science fiction's interjection into the realm of science, originating from a creative vantage point, may not always garner universal approval and could potentially provoke unease (Solomon, 2009). Nevertheless, sci-fi serves as a fecund domain for examining the role of narratives in science, whether as motivational stories or as rigorous engagement in the generation of scientific knowledge. This examination is essential for unifying disparate components that may lack cohesion, whether they are fragments of theories or evidence from various sources (Morgan and Wise, 2017). Within the realm of fictional development, sci-fi is both inspired by and invents narratives that relate to diverse scientific theories, albeit not necessarily adhering to what is conventionally regarded as a legitimate scientific methodology. Even if a work of sci-fi fails to provoke innovative perspectives on science, it still paves the way for contemplating how scientific concepts can offer fresh insights into envisioned futures and imagined technologies, emphasizing the potentialities derived from science rather than the novelty embodied by science itself, and thus stimulating creativity.

The impact of sci-fi on individuals presents a captivating subject not only for social researchers but also for scholars in the natural sciences and humanities. Numerous technological advancements experience a preliminary existence within the realm of fiction before their eventual adoption by people and societies. For instance, flying apparatuses, spacecraft, and submarines inhabited the imaginative worlds of Jules Verne long before their real-life invention (e.g., From Earth to the Moon; Robur the Conquerer; Twenty Thousand Leagues under the Sea). Multiple other instances exist in which fictionalized renditions of technology predated real-world innovations (e.g., radar, TV, cf. Gernsback, 2000). Plausibly, due to their fascination with (and professional expertise in) technology and science, sci-fi authors may possess the ability to predict future developments (although numerous prognostications have proven incorrect). However, sci-fi could also exert a causal influence on tangible technological innovation.

At least two causal pathways can be conceived regarding how technologies introduced in sci-fi might potentially affect real-life technologies: firstly, on the supply side, sci-fi works could influence inventors and scientists - either by providing useful information or – more plausibly – by motivating individuals to investigate a specific issue or embark on a scientific career. For example, Crouch (1982) offers compelling case studies about aeronautics pioneers who drew inspiration from fictional narratives of interstellar voyages. Subsequently, Bailenson et al. (2007) discussed how cyberpunk sci-fi spurred research inquiries for virtual reality scholars and established benchmarks in the progression of virtual reality systems. Secondly, on the demand side, sci-fi could potentially affect those who encounter new technologies and frequently determine the success or failure of innovation: the average consumer, recipient, or citizen.

In recent times, a considerable amount of research has investigated the impact of fictional narratives on recipient variables, encompassing recipients' comprehension of real-world matters (e.g., Dahlstrom, 2012, 2014; Marsh et al., 2003), attitudes and convictions (e.g., Appel and Richter, 2007), behavioral inclinations (Appel and Mara, 2013), self-perception (e.g., Djikic et al., 2009; Richter et al., 2014), and theory of mind (e.g., Fong et al., 2013; Kidd and Castano, 2013). The impact of narratives is frequently ascribed to the distinct experiential state during reading, listening, or viewing a story. This phenomenological attribute of engaging with a narrative or watching a film encompasses the absorption and diminished detachment, as well as the involvement that recipients often encounter. Various terminology has been employed to delineate and explicate experiential states during media consumption.

In sum, both the narrative structure and plot conventions foster perceptions of coherence and interconnectedness in the world around us. Furthermore, recipients frequently become deeply engrossed and invested in the story's universe, resulting in a robust connection between the self and the fictional elements. Delving into the realm of sci-fi enables recipients to cultivate interpretive frameworks for future technologies that might otherwise be incomprehensible or evoke feelings of estrangement. Sci-fi instills a more lucid understanding of what to anticipate from future technology and links the recipient's self to emerging technology.

2.2. Creativity and individuals' background

Creativity and innovation serve as the bedrock for organizations' competitive advantage. Organizational creativity encompasses the generation of novel and valuable outcomes, including ideas, solutions, processes, and products, a definition widely accepted among creativity and innovation scholars (Amabile and Pratt, 2016; van Knippenberg, 2017). Novelty refers to the uniqueness of an outcome compared to existing organizational outcomes, while usefulness denotes the potential value of an outcome for the organization (Shalley et al., 2004).

Building upon our exploration of creativity within the realm of sci-fi, it becomes crucial to address the classification of creativity and the methodologies for measuring creative performance. This inquiry, while not exhaustive due to the scope of this paper, aims to provide a general understanding of the realm of creativity research. Recognizing the multifaceted nature of creativity, which manifests in various forms and contexts, is essential. A pivotal distinction in this field is between individual and collective creativity. Individual creativity often originates from the novel ideas of a single person, whereas collective creativity emerges from group dynamics and collaboration, as highlighted by Paulus and Nijstad (2003). This dichotomy is crucial in understanding how creativity operates across different social and professional settings.

Another important aspect is domain-specific creativity, referring to the unique forms of creativity within specific fields or disciplines. For instance, artistic creativity differs significantly from innovative thinking in technological fields, a concept explored by Baer (2012). Moreover, the process of creative thinking is often categorized into divergent and convergent thinking. Divergent thinking involves generating multiple novel ideas, while convergent thinking focuses on refining these ideas, as elaborated by Cropley (2006). The Four C Model of Creativity, proposed by Kaufman and Beghetto (2009), categorizes creativity into four distinct levels: Mini-c, Little-c, Pro-C, and Big-C, representing different scales and impacts of creative work.

Recent contributions to this field include Dietrich's (2019) discussion on types of creativity, Glück et al.'s (2002) exploration of how creatives define creativity, and Dietrich and Zakka's (2023) work on education, neuroscience, and types of creativity. Cools et al. (2017) investigate the role of management control in stimulating different types of creativity. Additionally, Cropley et al. (2011) focus on measuring creativity for innovation management, while Silvia et al. (2012) and Leutner et al. (2017) assess creativity with self-report scales and image-based response scales, respectively. Kerr and Gagliardi (2003) also contribute to the discussion on measuring creativity in research and practice.

In this study, we adopt West and Farr's (1990: 9) definition of innovation as "the intentional introduction and application within a role, group, or organization of ideas, processes, products, or procedures, new to the relevant unit of adoption, designed to significantly benefit the individual, the group, organization, or wider society." This definition distinguishes creativity, or idea generation, from innovation, which encompasses idea implementation. However, much of the research on

organizational creativity extends beyond idea generation to include enacted ideas, resulting in considerable overlap between creativity and innovation in research practice (van Knippenberg, 2017). Creative employees often catalyze innovation within organizations. Creativity has been extensively studied as both a precursor to performance and as an outcome in itself (e.g., Agnihotri et al., 2014). Despite the existence of multiple definitions, novelty remains the central concept (Andrews and Smith, 1996; Coelho et al., 2011). Amabile (1983) posits that, besides being novel, something is creative if it meets two criteria: 1) it represents an appropriate, useful, correct, or valuable response to the task at hand, and 2) it is heuristic rather than algorithmic.

Creative performance can lead to competitive advantage (Shalley et al., 2004). Amabile's (1983) framework suggests that the creative process relies on the interaction between environmental and personal factors. In the present study, we focused on the latter with a specific focus on individuals' backgrounds. Thus, in the quest to better understand the nexus of creativity and personal backgrounds, particularly with regard to the hypothesis that an individual with a STEM background may possess a heightened sense of creativity, a plethora of recent scholarly literature has been published (Plucker et al., 2017; Cropley, 2020). Although the concept of creativity has been studied for decades, the focus on STEM fields as a potential catalyst for creative growth has emerged as a contemporary research interest (Stemler et al., 2012; Sawyer, 2017). This burgeoning area of study is crucial, as it provides insight into the interplay between creativity and personal backgrounds, with a particular focus on individuals in STEM fields (Mann et al., 2017).

A comprehensive understanding of creativity necessitates the acknowledgment of its multi-dimensional nature. In fact, creativity can be conceptualized as the product of the interplay between domain-relevant skills, creative thinking skills, and intrinsic task motivation (Amabile, 1983). This tripartite perspective is essential in examining the relationship between creativity and STEM backgrounds (Snyder et al., 2018) and, especially, the role of cognitive and motivational aspects of creativity within the context of STEM fields (Plucker et al., 2017). As demonstrated by recent studies (Charyton et al., 2008; Weisberg, 2013), individuals with a STEM background tend to display enhanced problem-solving skills, which, in turn, may foster heightened levels of creativity. For instance, Charyton et al. (2008) observed that engineers exhibited greater creative potential than individuals from non-STEM backgrounds, as they were more adept at generating original and feasible solutions to complex problems. Additionally, Weisberg (2013) found that individuals who have excelled in STEM fields tend to possess an innate ability to think divergently, which is closely associated with heightened creative potential.

Furthermore, the interdisciplinary nature of STEM fields has been posited as a contributing factor to the development of creativity (Root-Bernstein and Root-Bernstein, 2017). The integration of scientific, technological, engineering, and mathematical principles fosters a unique environment that encourages the synthesis of seemingly disparate concepts (Henriksen et al., 2016). This fusion of ideas and perspectives has been shown to stimulate cognitive flexibility and enhance creative problem-solving abilities (Sternberg, 2003; Sawyer, 2017). In addition to cognitive factors, motivational factors have also been implicated in the relationship between creativity and STEM backgrounds (Eisenberger and Rhoades, 2001). Individuals who pursue STEM careers are often intrinsically motivated to explore novel ideas and embrace challenges (Eisenberger and Rhoades, 2001). This intrinsic motivation has been linked to increased creativity, as it fosters a drive to engage in self-directed learning and experimentation (Amabile, 1983).

Despite the growing body of evidence supporting the hypothesis that a STEM background has a positive impact on creativity, some researchers have called attention to the potential confounding factors that may influence this relationship (Sawyer, 2017; Sternberg, 2003). For instance, Sternberg (2003) has argued that the relationship between creativity and personal backgrounds is likely to be bidirectional, with the environment and the individual mutually influencing one another. Moreover, the impact of cultural and socio-economic factors on creativity should not be overlooked, as these factors have been shown to play a significant role in shaping an individual's creative potential (Beghetto, 2010; Glăveanu, 2013). Indeed, the relationship between creativity and personal backgrounds, particularly within the context of STEM fields, remains a complex and challenging phenomenon. Moreover, it is important to recognize that creativity is not exclusive to STEM fields. Creativity can be observed across various domains, and individuals from diverse backgrounds can exhibit high levels of creative potential (Kaufman and Beghetto, 2009). As such, while the current body of literature suggests that individuals with a STEM background may possess a heightened sense of creativity, it is crucial to explore the potential influence of personal backgrounds on creativity across a broad range of disciplines (Sawyer, 2017; Henriksen et al., 2016).

The relationship between creativity and sci-fi has been a subject of interest in recent years, particularly in regard to the hypothesis that viewing sci-fi television series may bolster creativity in individuals with STEM backgrounds (Vorderer et al., 2004). Sci-fi as a genre has long been recognized for its ability to inspire creative thinking and innovative ideas, often pushing the boundaries of what is considered possible by imagining alternative worlds and technological advancements (Westfahl, 2000; Kaku, 2012). This unique characteristic of sci-fi raises the question of whether exposure to sci-fi television series may have a tangible impact on individuals' creative potential, particularly for those with a STEM background.

Existing literature on the psychological effects of media exposure suggests that the content of television programs can influence cognitive processes, including creativity (Greenfield et al., 1984; Huesmann and Taylor, 2006). For example, studies have found that watching television programs that promote creative problem-solving can lead to increases in creative thinking and ideation among viewers (Pichot et al., 2022; Cropley and Cropley, 2008). In the context of sci-fi, researchers have posited that exposure to imaginative narratives and depictions of futuristic technologies may stimulate creative thinking by encouraging individuals to consider novel ideas and question conventional assumptions (Vorderer et al., 2004).

Moreover, individuals with STEM backgrounds may be particularly primed to benefit from the creative inspiration offered by sci-fi television series. As individuals in STEM fields are often required to engage in problem-solving and innovative thinking, they may be more receptive to the imaginative possibilities presented by sci-fi narratives (Root-Bernstein and Root-Bernstein, 2017). Additionally, the interdisciplinary nature of STEM fields may facilitate a deeper understanding and appreciation of the scientific concepts explored in sci-fi, potentially fostering a greater sense of creative engagement with the content (Snyder et al., 2018). In conclusion, the current scientific literature suggests that there may be a positive relationship between exposure to sci-fi television series and creativity in individuals with STEM backgrounds. The imaginative and futuristic nature of sci-fi content has the potential to inspire creative thinking and innovative ideas, and individuals in STEM fields may be particularly well-suited to benefit from this creative stimulation.

3. Method

3.1. Sample size considerations, participants, and procedure

This research employed an experimental design to examine our research framework (Fig. 1). We established the number of participants in advance to ensure a minimum of 25 participants per group, as recommended by Simmons et al. (2011) to avoid false positive results. Our planned sample size for a one-factor experiment with two conditions was fifty, which is considered adequate for many studies in experimental psychology, even though it could be considered small. Our study consisted of a main experimental session lasting approximately 1 h and a follow-up survey. The predetermined sample size was based on the

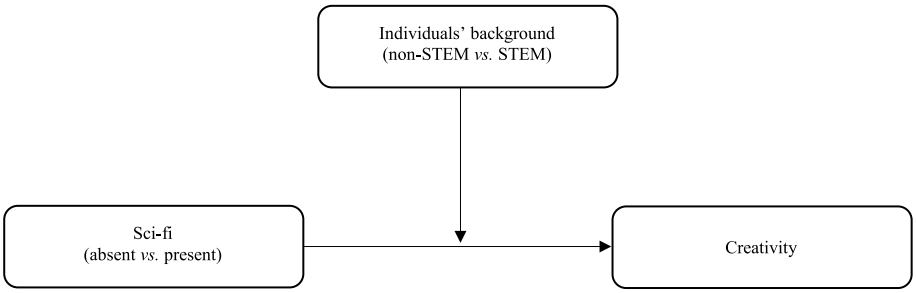

Fig. 1. The research framework.

difficulty of recruiting enthusiastic participants. For this reason, we involved in our study a sample of 248 undergraduate students at a large European University who completed the experiment in exchange for course credit. Of these, fifteen had prior experience with the TV show (followed the series/had seen the pilot episode); five participants did not complete the survey part, while fourteen participants were outliers on all four criteria, then were discarded. The final sample was N = 204 (55.4% female, M_{age} = 21.42 SD_{age} = 3.45).

Since two TV series episodes were used as treatment manipulation, the experiment followed a one-factorial between-subjects design (treatment: TV series episodes' condition – sci-fi *vs.* no sci-fi). Each participant was randomly assigned to one of the two experimental conditions. After randomization, participants were accompanied to the room in which the pilot episode was screened. Each participant watched the pilot episode together with other participants (group sizes varied from 10 to 20). After watching the pilot episode, participants in both conditions worked on a task (see Appendix for the details of the task). Since in both conditions we kept constant the possibility of gaining the credit score, in this way, we kept constant motivation in the task.

We also administered manipulation checks related to sci-fi treatment. In particular, we used a bipolar item (i.e., "Please, indicate to which extent you think the episode you just saw is based on Science Fiction: 1 = not at all, 7 = very much"). Moreover, participants' experience with sci-fi was measured. Specifically, participants indicated their familiarity with sci-fi through 3 seven-point Likert scale items (example items include "I watch/read science fiction films, TV shows, and books on a regular basis" and "I'm passionate about science fiction") adapted from Black and Barnes (2021) and used to calculate a mean sci-fi enjoyment score. The final page entailed participants' demographics, the indication of the course of study (i.e., our proposed moderator variable), and questions about whether or not they had seen the movie before.

3.2. Stimuli

Participants watched approximately 45 min of the pilot episode of one of two TV series, *The Rig* (the long pilot required pausing the show at 46.5 min, which coincides with a good stopping point), or *The Expanse* (watched in its entirety – 45 min).

The Rig was selected as no sci-fi stimulus. *The Rig* is a TV series about a group of oil rig workers who become trapped on the rig after an explosion. As they struggle to survive, tensions rise, and secrets are revealed among the crew. The pilot episode introduces the main characters and sets up the series' premise, which will focus on the aftermath of the disaster and the following investigation. *The Expanse* was selected as the sci-fi stimulus. *The Expanse* is a sci-fi TV series set in a future where humanity has colonized the solar system. The series follows the crew of a spaceship as they investigate the disappearance of a young woman, who they later discover is connected to a larger conspiracy involving a powerful corporation and a terrorist group. The pilot episode introduces the main characters and the complex political landscape of the series, setting the stage for the following conflict and adventure. Specifically, the selection of TV series to be used as stimuli for our experiment has happened in such a way that the stimuli, although well distinguished in terms of genre (i.e., sci-fi and not sci-fi), had key points in common. A brief description of shared communities appears below.

In terms of setting (space/marine setting), both series are set in extreme and dangerous environments. *The Expanse* is set in deep space, in a distant future where humanity has settled throughout the solar system. The series explores the social and economic implications of space colonization and highlights tensions between the different human factions that have settled in different parts of the solar system. *The Rig*, on the other hand, is set on an isolated offshore oil platform off the coast of Scotland. The series explores the lives of platform workers, the challenges and threats they must face in their work, and the social and economic implications of offshore oil extraction. Furthermore, as far as conflicts and tensions between characters are concerned, both series feature characters who must navigate tensions and conflicts between them, which can be heightened by the isolation and claustrophobia of the setting. In *The Expanse*, the main characters belong to different political and governmental factions and must try to collaborate to face a common threat. There are also personal conflicts between characters, such as tensions between the captain of the Rocinante, James Holden, and the security officer, Naomi Nagata. In *The Rig*, platform workers are forced to live and work together in a confined space and must manage personal conflicts and cultural differences that emerge. In terms of suspense and intrigue, both *The Expanse* and *The Rig* feature plots that include suspense, mysteries, and intrigues involving the characters. In *The Expanse*, the plot revolves around a vast conspiracy involving various political and governmental factions, as well as a mysterious form of alien life. The series also presents several mysteries to be solved, such as the discovery of an abandoned ship with advanced alien technology. In *The Rig*, the plot is centered on the tension between the platform workers and the oil company that employs them. There are also elements of suspense and mystery in the series, such as the mysterious incident that threatens to destroy the platform. Finally, both *The Expanse* and *The Rig* touch on political and social issues. *The Expanse* addresses issues such as class and power dynamics, government corruption, and the consequences of colonization and imperialism. *The Rig* deals with the economic and environmental impact of the oil industry, as well as issues of workplace safety and corporate responsibility.

3.3. Measures

In terms of measuring creativity, various methodologies have been developed. Psychometric tests like the Torrance Tests of Creative Thinking (TTCT) evaluate creative potential and divergent thinking capabilities (Torrance, 1972). The Consensual Assessment Technique (CAT), described by Amabile (1982), involves expert evaluation of creative work. Other methods include biographical inventories, assessing creativity based on an individual's history and achievements, and sociometric techniques that measure creativity through peer assessments and social network analysis. The Remote Associates Test (RAT) evaluates convergent thinking by challenging participants to find

connections between unrelated words. Furthermore, in order to measure creative performance, output-based measures quantify the number of creative products or ideas generated, while impact measures evaluate the broader influence of creative work. Qualitative analysis offers in-depth insights into the creative process and the final product, often utilized in case studies. Longitudinal studies provide a dynamic view of creativity by tracking its development over time.

In this study, general creativity was assessed with the Divergent Thinking tests (e.g., Zeng et al., 2011), which originated from the psychometric tradition of creativity research, and are the primary tool used to assess an individual's potential for creativity. According to previous research on creativity (e.g., Silvia et al., 2008; Zeng et al., 2011), the Divergent Thinking tests are the primary type of psychometric tool used for creativity assessment since Divergent Thinking involves generating a variety of ideas in a problem context and is considered a crucial aspect of creativity, as recalled in the previous theoretical section. Thanks to the Divergent Thinking tests, it is possible to provide quantifiable measures of an individual's creative potential, indicating their likelihood of producing creative solutions in a problem context (Zeng et al., 2011). Among the various Divergent Thinking tests present in the literature (see Guilford, 1967; Torrance, 1987; Wallach and Kogan, 1965), the Torrance Test of Creative Thinking (Torrance, 1966) is the most widely used and accepted test (e.g., Almeida et al., 2008; Kim, 2006). According to Torrance (1966, p. 6), creativity is "a process of becoming sensitive to problems, deficiencies, gaps in knowledge, missing elements, disharmonies, and so on; identifying the difficulty; searching for solutions, making guesses, or formulating hypotheses about the deficiencies." Specifically, starting on this definition, the author stresses the relevance of identifying challenges, exploring potential solutions, making assumptions, and developing hypotheses about inadequacies as the foundation for developing the Torrance Test of Creative Thinking. Then, in our research, we used an adapted version of the Torrance Test of Creative Thinking, by asking to carry out a task in which a problem of a social nature was described; then, participants were asked to indicate how many solutions could be devised to solve the problem. The manner in which instructions are provided to participants during the Divergent Thinking tests may also impact their performance. Two commonly used instruction types in the field are explicit instructions and quantity instructions. Explicit instructions emphasize the production of responses that differ from the common ones (e.g., "provide creative responses"), whereas quantity instructions do not specifically stress any criterion besides generating as many responses as possible (Said-Metwaly et al., 2020). In our study, we decided to give only quantity instruction (i.e., "propose as many ideas and solutions as possible").

The scoring mechanism of the level of ideas' creativity was based on four criteria (e.g., Runco and Pritzker, 2020): originality (statistically uncommon when compared to responses to the overall data set – "How would you rate the originality of the proposed ideas?"), fluency (the number of relevant ideas – "How would you rate the number of proposed ideas?), flexibility (the number of fields which the responses fall into - "How would you rate the flexibility of the proposed ideas?"), and elaboration (amount of details for the ideas – "How would you rate the elaboration of the proposed ideas?"). Specifically, three independent judges evaluated the proposed ideas using 7-point Likert items (1 = very low, 7 = very high) on all four criteria. Then, a mean creativity score was calculated to conduct the analyses.

4. Results

4.1. Preliminary analyses

Data were entered into IBM SPSS Statistics (version 25, SPSS Inc., Chicago, IL, USA), and data accuracy was checked throughout the process. Since the scoring mechanism of the level of ideas' creativity was based on four criteria (i.e., originality, fluency, flexibility, and elaboration) through three independent judges, we first checked the reliability of the construct. The three independent evaluations used to measure the ideas' originality showed a Cronbach alpha of 0.89, and item-to-total correlations were $\geq$0.73 for all the judges. Then, an average score of originality was created. The three independent evaluations used to measure the ideas' fluency showed a Cronbach alpha of 0.94, and item-to-total correlations were $\geq$0.84 for all the judges. Then, an average score of fluency was created. The three independent evaluations used to measure the ideas' flexibility showed a Cronbach alpha of 0.86, and item-to-total correlations were $\geq$0.62 for all the judges. Then, an average score of flexibility was created. The three independent evaluations used to measure the ideas' elaboration showed a Cronbach alpha of 0.89, and item-to-total correlations were $\geq$0.71 for all the judges. Then, an average score of flexibility was created. Finally, we tested the reliability of the creativity construct by using the average score of all four criteria. Results showed a Cronbach alpha of 0.88, and item-to-total correlations were $\geq$0.66 for all the items. Therefore, an average score of creativity was created and used for the analyses.

Additionally, we tested the reliability of the three items used to measure familiarity with sci-fi. The results showed a Cronbach alpha of 0.88, and item-to-total correlations $\geq$0.74 for all the items. Therefore, an average score of sci-fi familiarity was created.

To check the proposed manipulations, we ran a one-way analysis of variance (ANOVA) on the sci-fi variable, considering the sci-fi manipulation (absent *vs.* present) as the independent variable. The results indicated that the manipulation was successful, as participants in the sci-fi condition perceived the episode saw as significantly more science-fiction than participants in the no sci-fi condition ($M_{\text{sci-fi present}} = 5.47$, $SD_{\text{sci-fi present}} = 1.42$; $M_{\text{sci-fi absent}} = 3.50$, $SD_{\text{sci-fi absent}} = 1.61$; $F(1, 202) = 84.12$, $p < 0.000$).

4.2. Main results

To address our research question (i.e., the moderating role of individuals' background on the relationship between sci-fi and creativity), we coded the proposed moderator variable (i.e., individuals' background) as 1 for the students enrolled in STEM disciplines (Science, Technology, Engineering, and Mathematics), and 0 for the students enrolled in non-STEM (other disciplines).

Then, we run a two-way ANCOVA by considering creativity as the dependent variable, sci-fi (absent *vs.* present) as the independent variable, individuals' background (non-STEM *vs.* STEM) as the moderator variable, and sci-fi familiarity as a covariate variable. The results on creativity showed a non-significant effect of sci-fi ($M_{\text{sci-fi present}} = 2.98$, $SD_{\text{sci-fi present}} = 0.23$; $M_{\text{sci-fi absent}} = 2.68$, $SD_{\text{sci-fi absent}} = 0.10$; $F(1, 199) = 1.45$, $p = 0.23$), a non-significant effect of individuals' background ($M_{\text{STEM}} = 2.97$, $SD_{\text{STEM}} = 0.23$; $M_{\text{Non-STEM}} = 2.70$, $SD_{\text{Non-STEM}} = 0.09$; $F(1, 199) = 1.25$, $p = 0.26$), and a non-significant effect of sci-fi familiarity ($F(1, 199) = 0.81$, $p = 0.37$), More importantly, we found a significant sci-fi $\times$ individuals' background interaction ($F(1, 199) = 14.86$, $p < 0.000$). Planned comparisons revealed that when individuals' background is STEM, watching sci-fi led to more creative outputs than watching no sci-fi ($M_{\text{sci-fi present}} = 3.60$, $SD_{\text{sci-fi present}} = 0.44$; $M_{\text{sci-fi absent}} = 2.34$, $SD_{\text{sci-fi absent}} = 0.12$; $F(1, 199) = 7.38$, $p < 0.000$). When individuals' background is non-STEM, watching sci-fi led to less creative outputs than watching no sci-fi ($M_{\text{sci-fi present}} = 2.37$, $SD_{\text{sci-fi present}} = 0.11$; $M_{\text{sci-fi absent}} = 3.02$, $SD_{\text{sci-fi absent}} = 0.15$; $F(1, 199) = 12.89$, $p < 0.000$). These results provide support to our research question and are represented in Fig. 2.

5. Discussion and conclusion

The purpose of this research was to answer the following research question: *How does an individual's background, specifically in STEM or non-STEM disciplines, moderate the impact of watching science fiction on the creativity of ideas they generate?* Although there were no main effects of the TV series genre (sci-fi *versus* no sci-fi) on our outcome variable,

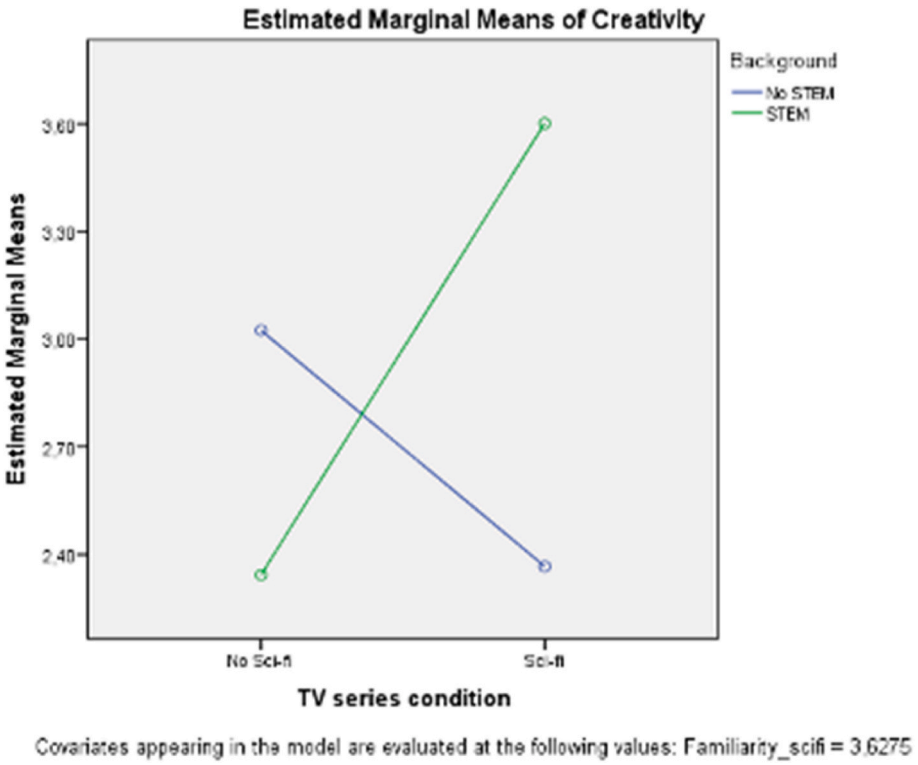

Fig. 2. The moderating role of students' background on the relationship between sci-fi and creativity.

results allowed us to answer our research question highlighting what background individuals need to develop to take advantage of science-fiction-based methods. In particular, our results have provided evidence that the different individuals' backgrounds may change the effects of sci-fi on creativity. The findings demonstrated that when individuals' background is in STEM (Science, Technology, Engineering, and Mathematics), watching sci-fi (*versus* no sci-fi) can lead to more creative outputs; while when individuals' background is in non-STEM, watching sci-fi (*versus* no sci-fi) can lead to less creative outputs.

These findings suggest that the effects of sci-fi exposure on creativity are contingent on an individual's personal background. This is consistent with previous research demonstrating that individual differences, such as personality traits and cognitive abilities, along with environmental factors, can moderate the relationship between sci-fi and creativity (Charyton et al., 2008; Lin et al., 2013; Potstada and Zybura, 2014; Weisberg, 2013). In particular, according to the results of the present study, the complementarity between sci-fi exposure and STEM background appears to enhance creativity.

It is possible to formulate several explanations to justify this result. Firstly, sci-fi exposure may activate and engage individuals' existing STEM knowledge, skills, and professional experiences. This is consistent with previous research demonstrating that creativity is often based on the recombination of existing ideas, concepts, and knowledge (Sawyer, 2017; Xiao et al., 2022). Therefore, sci-fi exposure may provide a new context in which STEM skills can be emphasized and exploited, thus leading to increased creativity. As STEM individuals often possess a strong foundation in various scientific and technical disciplines, exposure to sci-fi may encourage them to think beyond traditional boundaries and integrate ideas from different fields, fostering interdisciplinary thinking and creativity.

Secondly, another possible explanation is that sci-fi exposure may provide inspiration and motivation for individuals with a STEM background to think more creatively. Sci-fi often presents futuristic, imaginative scenarios that require a flexible and open-minded approach to problem-solving. This type of exposure may encourage individuals to think beyond the constraints of their existing knowledge and skills, leading to more creative solutions. Moreover, the structured and rigorous nature of STEM disciplines may create a need for a mental escape from the confines of analytical thinking, and sci-fi, with its imaginative and speculative scenarios, may serve as a playground for STEM-based individuals' minds. This exposure may enhance their imaginative faculties, contributing to a more holistic cognitive profile. In turn, STEM-based individuals – who are more comfortable with scientific principles and more used to confronting themselves with complex technological concepts (Honey and Kanter, 2013) – may find sci-fi stimulating in this respect.

Finally, since our measure of individual creativity was based on a divergent thinking test (namely, the Torrance Test of Creative Thinking – Torrance, 1966), the obtained results seem to indicate that exposure to sci-fi and its imaginative narratives stimulates divergent thinking in individuals with a STEM background, thus leading to enhanced creativity. In this, our study suggests a possible link between prior literature investigating, on the one side, the relevance of divergent thinking for individuals with a STEM background (Weisberg, 2013) and, on the other side, the impact of sci-fi on individuals' divergent thinking (Cropley and Cropley, 2020).

Similarly, the finding that individuals without a STEM background provided solutions characterized by a lower level of creativity when exposed to sci-fi TV series is also notable. It is possible that sci-fi exposure may be overwhelming or confusing for individuals without a STEM background, leading to decreased creativity. In fact, non-STEM individuals may not be accustomed to the analytical and problem-solving thinking patterns prevalent in STEM disciplines. The cognitive processes required to navigate complex scientific concepts in sci-fi may be unfamiliar and challenging for them, potentially inhibiting their creative exploration. Furthermore, individuals without a STEM background might find it challenging to grasp the technical concepts and futuristic scenarios often presented in sci-fi and may perceive sci-fi as a cognitive barrier. This interpretation is consistent with previous research demonstrating that the complexity of creative tasks can affect the

creativity of individuals with different levels of expertise and with different learning orientations (Gong and Choi, 2016).

At the same time, it cannot be excluded that a selection bias may occur in this case. In fact, very likely the choice of academic career is determined by inner personal traits, with individuals who find themselves uncomfortable with the complexity and rational thinking of scientific disciplines to prefer non-STEM disciplines. Given their academic preferences, it cannot be excluded that non-STEM individuals – especially those involved in humanities or social sciences – may have a preference for realistic and tangible scenarios, grounded in everyday experiences. By contrast, sci-fi often is connected to speculative and futuristic realms that may seem detached from reality, leading to a potential decrease in engagement and creative inspiration. Under these circumstances, exposure to sci-fi may represent a stressful event for non-STEM students, which may reinforce their aversion towards complex tasks, thus leading to reduced creativity. However, in this case, it is the inner personal traits that impact creativity levels, not individuals' non-STEM backgrounds. An individual's academic background acts, in this case, as tangible evidence of a latent attitude or trait. The current study has important implications for the use of sci-fi as a tool for enhancing creativity. Our findings suggest that sci-fi exposure is most beneficial for individuals with a STEM background and may not be effective for individuals without a STEM background. Therefore, when using sci-fi as a tool for creativity training, it is important to consider the individual's personal background and tailor the approach accordingly.

Fig. 3 shows a diagram that illustrates the results in light of the discussed literature.

5.1. Managerial implications

Our findings yield significant managerial implications. From an organizational perspective, the results underline the potential benefits of diversity in team composition. If creativity is the goal, businesses should strive for teams with a rich blend of individuals with varying backgrounds. Particularly, individuals with STEM and non-STEM backgrounds should be encouraged to mingle, share, and cross-pollinate ideas. This could stimulate the generation of novel and innovative solutions, enhancing the overall creativity of the team.

The findings of this study also offer valuable insights for managers involved in innovation and product development. Techniques such as sci-fi prototyping (Potstada and Zybura, 2014) and science fiction-based technology scenarios (Idier, 2000) offer unique ways to stimulate creativity in the ideation and design phases. By integrating these techniques into their innovation processes, companies can potentially spark novel and innovative ideas, especially when these methods are used by employees with a STEM background. By so doing, they can harness the predictive and imaginative power of sci-fi to anticipate future technological trends and consumer needs, thereby gaining a competitive edge in the rapidly evolving marketplace. Therefore, organizations may consider investing in the development of these skills, possibly through targeted training and professional development programs, which may ultimately boost their innovative capacity and overall competitiveness. Examples of SMEs having adopted sci-fi to stimulate creativity in product design and marketing campaigns (Zheng and Callaghan, 2018) are promising in this respect.

Integrating science fiction-based tools into HR management programs may offer a novel approach to cultivating creativity and innovation, particularly among employees with a STEM background. For this purpose, companies may introduce immersive workshops or training sessions that involve sci-fi scenarios relevant to organizational challenges. These sessions should encourage participants to explore speculative solutions, fostering interdisciplinary thinking by blending scientific principles with imaginative possibilities. Furthermore, incorporating elements of gamification, such as scenario-based simulations inspired by sci-fi, can engage STEM employees in collaborative problem-solving. This not only enhances their analytical skills but also sparks creative thinking as they navigate futuristic challenges. Ultimately, an HR management program infused with science fiction-based tools may become a catalyst for innovation, transforming STEM-oriented employees into forward-thinking problem solvers who thrive in the dynamic landscape of emerging technologies and future challenges.

Similarly, HR recruitment processes may implement tools that allow the identification and selection of candidates with a positive attitude toward sci-fi. Not only could sci-fi literature or film discussions be

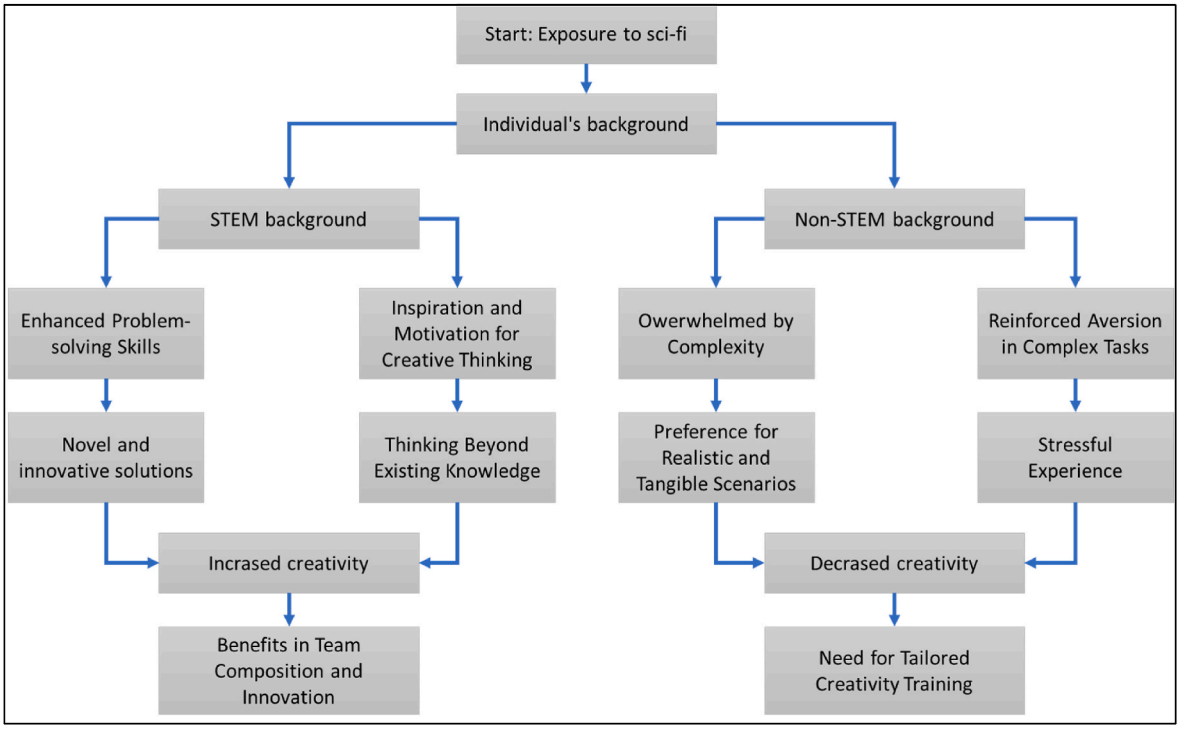

Fig. 3. Impact of Science Fiction on Creativity: A STEM vs. Non-STEM Perspective.

incorporated as part of the recruitment process, but more complex solutions might be adopted for this purpose. For instance, sci-fi-themed questions could be incorporated in interviews or assessments, estimating candidates' familiarity and enthusiasm for speculative narratives. This approach assesses their openness to unconventional ideas and their ability to think beyond traditional boundaries, crucial for innovative thinking and creativity. In a similar vein, scenario-based assessments inspired by sci-fi concepts could be employed, allowing candidates to showcase their problem-solving skills in imaginative contexts. This not only identifies their capacity for creative thinking but also provides insights into how they apply their STEM knowledge to unconventional challenges. Recruitment events or hackathons could also be organized with a sci-fi twist, in order to stimulate candidates to collaborate on futuristic projects. By doing so, HR management may assess candidates' ability to work in a team and identify those who thrive in speculative and dynamic problem-solving environments, and who eventually may show stronger creativity capabilities.

The findings also have considerable implications for the realm of education. It has been traditionally assumed that a strict distinction between STEM and non-STEM curricula is optimal for student learning. However, the findings suggest that cross-contamination between these fields can potentially stimulate creative thinking (Charalambos et al., 2015). Furthermore, the inclusion of topics related to sci-fi within the curriculum may play a pivotal role in nurturing creativity among students. By challenging students' assumptions and encouraging them to think beyond the confines of current knowledge, sci-fi can act as a catalyst for the generation of creative ideas.

Lastly, these findings also extend to executive education. While traditional programs have focused on developing specific technical and managerial competencies, the results suggest that integrating these programs with stimuli from sci-fi could enhance creativity. By exposing executives to narratives that explore the boundaries of technological possibilities, sci-fi can inspire creative and innovative thinking, thereby fostering the development of novel solutions to complex business problems.

5.2. Limitations and future research

It is important to consider potential limitations and complexities in the relationship between sci-fi exposure and creativity in individuals with STEM backgrounds. First of all, since this study analyses the relationship between sci-fi and creativity, considering the background of the participants (i.e., STEM) as a possible moderator of this relationship, it is crucial to recognize possible alternative explanations or factors that might affect how STEM backgrounds impact creativity in the context of sci-fi. For instance, personal hobbies, interests, or exposure to other forms of imaginative media could play a significant role in the creative impact individuals experience, possibly lessening the impact of their STEM knowledge. Likewise, the individual's cognitive style (i.e., the individual's manner of thinking, perceiving, and retaining information, or his favored method of utilizing information when addressing problems – Mampadi et al., 2011) could be an alternative explanation of the relationship between sci-fi and creativity. These concerns, by highlighting the need for a more detailed investigation, suggest that future research could thoroughly explore the various factors that contribute to how sci-fi affects creativity, beyond just the influence of STEM backgrounds.

Also, while we addressed the enhanced impact of sci-fi on creativity in individuals with a STEM background, we acknowledge that this does not preclude the potential for sci-fi to inspire creativity in those with non-STEM backgrounds. Future research could explore the unique ways in which sci-fi might stimulate creativity in non-STEM individuals, perhaps through different cognitive processes or inspirational pathways. Despite this, our argument remains valid in the context of STEM education, as it specifically examines the unique cognitive processes stimulated by STEM knowledge when interacting with sci-fi. This specificity, however, does not negate the broader potential of sci-fi as a tool for creative inspiration across various disciplines.

Moreover, the extent to which sci-fi television series may boost creativity could be influenced by factors such as the quality and complexity of the narratives, the degree to which the content resonates with viewers' personal interests, and the frequency and duration of exposure to the content (Vorderer et al., 2004). Furthermore, researchers have argued that the impact of media exposure on cognitive processes, including creativity, is likely to be multifaceted and contingent upon a range of individual and contextual factors (Greenfield et al., 1984; Huesmann and Taylor, 2006).

However, further research is necessary to elucidate the nuances of this relationship and to examine the potential influence of other factors, such as the quality of the content and individual differences in receptivity to sci-fi narratives (Vorderer et al., 2004). By exploring the interplay between sci-fi exposure and creativity, researchers can contribute to a deeper understanding of the factors that foster creative thinking and potentially inform educational and occupational practices aimed at nurturing creativity in STEM fields (Mann et al., 2017; Runco and Pritzker, 2020).

Future research should employ longitudinal and quasi-experimental designs to assess the causal relationship between sci-fi exposure and creativity among individuals with STEM backgrounds, taking into account potential moderating and mediating factors (Cropley and Cropley, 2008). Specifically, longitudinal research could assist in measuring the lasting effects of STEM education on creative thinking, shaped by sci-fi. By conducting longitudinal assessments, it becomes possible to explore the consistency of creative influence over time and uncover latent effects that might not be immediately noticeable. While, performing a quasi-experimental pre-test and post-test design (Campbell and Stanley, 2015) with which the dependent variable (i.e., creativity) is measured once before the treatment (i.e., sci-fi) is implemented and once after it is implemented, could assist in measuring the effectiveness of watching sci-fi on students' creativity and problem-solving.

Moreover, it would be worthwhile to investigate the impact of different forms of sci-fi media, such as novels, films, and interactive media, on creativity, as these various formats may offer distinct experiences that could differentially affect creative thinking.

Additionally, researchers should explore the role of individual differences in the relationship between sci-fi exposure and creativity. For example, variables such as cognitive style, personality traits, and prior knowledge may influence the degree to which individuals are receptive to the creative inspiration offered by sci-fi content (Root-Bernstein and Root-Bernstein, 2017). Understanding these individual differences may provide valuable insights into how to optimize the potential benefits of sci-fi exposure for promoting creativity in STEM fields.

Finally, it is important to consider the broader implications of the relationship between sci-fi exposure and creativity for educational and occupational practices. For instance, incorporating sci-fi content into STEM curricula could serve as a powerful tool for sparking creative thinking and fostering innovative problem-solving among students (Henriksen et al., 2016; Mann et al., 2017). Similarly, organizations in STEM industries may benefit from leveraging sci-fi narratives as a source of creative inspiration for employees, encouraging them to envision bold new ideas and challenge conventional wisdom (Cropley, 2020; Snyder et al., 2018).

In summary, the relationship between exposure to sci-fi television series and creativity among individuals with STEM backgrounds is a promising area of inquiry with potential implications for fostering creativity and innovation in STEM fields. Further research is needed to explore the complexities of this relationship and to elucidate the optimal conditions for leveraging sci-fi as a catalyst for creative inspiration. By continuing to investigate the interplay between sci-fi exposure and creativity, researchers can contribute to a richer understanding of the factors that promote creative thinking and inform evidence-based practices for nurturing creativity in STEM fields and beyond.

CRediT authorship contribution statement

Veronica Marozzo: Conceptualization, Formal analysis, Methodology, Project administration, Software, Writing – original draft, Writing – review & editing, Data curation, Supervision, Validation, Visualization. **Antonio Crupi:** Conceptualization, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Tindara Abbate:** Conceptualization, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Fabrizio Cesaroni:** Conceptualization, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Vincenzo Corvello:** Conceptualization, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Data availability

Data will be made available on request.

Appendix

A1. Task administered to participants

Thank you for your cooperation!

In the next screen, you will be asked to perform a task. Please read carefully the task objective and the instructions to complete it.

Waste management refers to the policies, procedures, or methodologies aimed at managing the entire waste process, from production to final disposal. The process includes the collection, transportation, treatment (recovery or disposal), and reuse/recycling of waste materials produced by human activities, in an effort to reduce their impact on health and the environment.

The correct management of hazardous and non-hazardous waste, both urban and special, is based on principles set out in specific regulations and directives of the European Union. However, translating theory into a practical application of the legislation is not always straightforward.

Task objective: Identify ideas and solutions to improve the management of the entire waste process in your city.

Instructions: In the box below, propose as many ideas and solutions as possible that come to mind to improve the management of the entire waste process (collection, transportation, treatment - recovery or disposal - and reuse/recycling of waste materials). The proposed ideas and solutions should not already be present in your city.

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