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The psychological origins of science fiction

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A B S T R A C T

Science fiction has become very popular across all mediatic forms (e.g., in short stories, in novels, in movies, in TV series). The cultural success of this genre is both geographically widespread and rather recent in history. Although such observations seem consensual, many problems remain and are debated in science fiction study, notably (1) the defining characteristics of the genre, (2) the reasons for its late emergence, and (3) the interindividual variability of its appeal. Previous attempts to solve such puzzles focused on proximate How-questions (e.g., How did the genre emerge?). The article presents a contribution from cognitive and evolutionary sciences, which make it possible to ask Why-questions (e.g., Why did the genre emerge?). We hypothesize that science fiction, with its emphasis on new and innovative features (e.g., new civilizations, innovative technologies, futuristic worlds), appeals to the human desire for new abstract information. We review research in neuroscience, evolutionary psychology, and behavioral ecology, showing that some specialized biological mechanisms in human cognition prompt exploratory preferences for such information. We show that this hypothesis can explain (1) why science fiction works are perceived as homogenous and different from works of fiction of other genres, (2) why science fiction emerged and became culturally successful rather late in literary history, and (3) why the preference for science fiction varies across time, across space, and across individuals. We provide empirical testable predictions that should be tested in the future to confirm this hypothesis.

1. Introduction

This article presents a new hypothesis to causally explain the emergence of science fiction by examining the cognitive reasons for its appeal. This hypothesis builds upon existing theories of science fiction, which generally fall into two categories: (1) those that focus on the influence of science and technology on the content of science fictional works, explaining how human culture and symbolic systems generate specific ideas, codes, themes, or myths for the genre (Langlet, 2006); and (2) those that study how previous fictional works influence subsequent works, which is akin to Bakhtinian dialogic theory, theories of intertextuality (with Genette's concept of hypertextuality), or again what researchers in computational sciences of culture and digital humanities refer to as cultural evolution, which is the process of selecting and refining both the content and formal aspects of fictional works over time (Sobchuk, 2022).

Such frameworks therefore try to answer "how" questions (e.g., "How did science-fiction emerge?", "How do fictional works influence subsequent ones?"). Our goal is to provide answers to the "why" questions: Why did science fiction emerge? Why are humans so receptive to it? Why does this interest in science fiction vary from one individual to another? Why are genre-specific themes so popular now, and not earlier in literary history? Our hypothesis is directly based on the theoretical work that defines the contours of

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science fiction thanks to founding concepts of science fiction theories

Our hypothesis is built on the foundational theories of science fiction that help us understand the genre. Such theories provide the framework for our understanding of science fiction and its defining characteristics. For instance, science fiction is often defined as the kinds of fiction that prompt "cognitive distancing" with novel and sometimes disturbing content features called *novum* by Suvin (Suvin, 1979). It is also proposed that such fictional works leads to a *sense of wonder.* Finally, some researchers focused on the amount and structure of fictional information, through the concept "xeno-encyclopedia", adapted from Umberto Eco's theory (Saint-Gelais, 1999).

The idea behind our hypothesis is that these concepts indeed capture fictional elements that are attractive to the human mind in general: information, objects, societies, complex systems of knowledge, which have the common quality of being novel and innovative. The *sense of wonder* that they therefore induce is, according to our theory, associated with a boarder appetite for new knowledge that makes the unknown more predictable (on this epistemic drive, see: Bellagamba et al., 2018; Fingerhut & Prinz, 2018; Gottlieb et al., 2018; Picholle, 2021; Shiota et al., 2017). This is the hypothesis that we will defend in the rest of this article, based on recent research in cognitive science, behavioral ecology, and evolutionary psychology.

Our goal is to continue this line of reasoning which is motivated by the desire to understand the origin of the human appetite for science fiction. An important conceptual distinction in the evolutionary and behavioral sciences can help to better understand the level of analysis we adopt to further our hypothesis: the distinction between proximate causes and ultimate causes.

At the proximate level, scientific analyses focus on the cognitive or cultural events that immediately cause a phenomenon. Why do humans like sugar? Why do humans have sex? At the proximate level, the response will be that sugar tastes good and that sex is pleasurable. This level is descriptive: it makes it possible to understand how the taste of sugar is pleasant, for example by studying the way in which taste receptors are connected to the reward system in the brain. These types of explanation are to be distinguished from ultimate explanations.

The ultimate reasonings are interested in the deep reasons for which a phenomenon emerges. Why does sugar taste good? Why are the taste receptors dedicated to sugar associated with the pleasure system? Why does the sexual orgasm exist? It is possible to provide answers to these ultimate questions with evolutionary theory, which explains how natural selection promotes the spread of genes coding for cognitive or physiological mechanisms that increase an organism's chances of survival and reproduction. Ancestral organisms which, by chance, as a result of a mutation, were endowed with an increased preference for sugar, or an increased sense of pleasure in sexual intercourse, were able to survive longer (thanks to the energy gain from glucose ingestion) or reproduce more (through an intrinsic motivation to seek sexual orgasm). Therefore, the genes encoding such mechanisms have, over hundreds of thousands of years, spread throughout the human population.

While the whole set of cultural theories intending to explain the emergence of science fiction is, we argue, situated at the proximal level, our objective is to propose an ultimate explanation of the cognitive mechanisms that are responsible for the human preference for science fiction. This is why our hypothesis is different from the previous ones, and why it can still be compatible with them.

If we take it for granted that the science fiction genre is broadly seen as a genre of fictions that include new and surprising elements of content and form, the question becomes: Why do such features fascinate some humans? What evolved mechanisms is responsible for the human fascination for stories in which humans interact in different ways (e.g., with societies structured in districts, in *Hunger Games*), travel in new engines (e.g., spaceships, in *Star Wars*), use non-existent powerful technologies (e.g., teleportation portals or time machines, in *Dark*) or inhabit different environments (e.g., different planets, in *Avatar*)? And why do our folk intuitions make us feel like such works belong to a homogeneous category? To answer these ultimate questions, it seems essential to us to mobilize theoretical concepts and empirical results from psychology, anthropology, and neuroscience, because they can shed light on what, in the human mind, reacts positively to some fictional content features.

First, we will present the dopaminergic system, its role in the human appeal for the unknown, and the evolutionary reasons why this cognitive attraction has been selected during the evolutionary history of mobile organisms. Then, we will put forward the hypothesis according to which the existence in the human mind of functionally specialized cognitive mechanisms makes it possible to explain the widespread perception of the existence of fairly homogeneous fictional genres. We will thus propose that science fiction is a category which brings together works that stimulate a rather homogenous set of cognitive mechanisms, hence the appearance of homogeneity or the 'family resemblance'. Finally, we will try to explain how the sensitivity of these mechanisms fluctuates adaptively depending on the environment in which the organism finds itself, what evolutionary and behavioral scientists call 'phenotypic plasticity'. We will attempt to demonstrate that the flexibility of human cognition makes it possible to account for the variability of preferences for science fiction, and therefore for the diverse content and cultural evolution of science fiction.

2. The dopaminergic system

The objective of this first section is to clarify the link between a specific biological system of human cognition and the subjective appeal for the unknown. Dopamine is a kind of neurotransmitter, that is, a chemical compounds in the brain that allow communication between neurons and more broadly within the whole nervous system. Dopamine is present in non-human animals, including insects such as Drosophila, or "fruit fly" (Riemensperger et al., 2011). In humans, as in other mammals, it plays a role in risk-taking and exploration within the mesocorticolimbic system, which notably includes the ventral tegmental area (where dopamine is produced), the limbic system (which plays an important role in emotions such as fear or pleasure, but also in the formation of memory), and the frontal cortex (which is involved in reasoning, language, and voluntary movement). One recent hypothesis is that the function of the dopaminergic system is to prompt exploration, broadly defined as the transformation of the "unknown" into the "known" (DeYoung, 2013; Peterson, 1999).

What is ‘unknown’ is uncertain to the mind and can be defined in terms of *psychological entropy*. Coming from thermodynamics where it designates the degree of disorder or randomness of matter, the term entropy is derived here from an extension of its meaning: it was used to describe the degree of disorganization of an information system (Shannon, 1948). Psychological entropy is thus defined in neurosciences and psychology as the “amount” of uncertainty, or the degree of unpredictability, of an action or a context, measured intuitively and unconsciously by the brain (DeYoung, 2015).

Uncertainty can relate to perceptual or abstract representations, and thus concern very diverse stimuli, such as: a forest that one has never walked through, a city that one discovers for the first time, an object the function of which is unknown, a person you have never met, unknown concepts, or even more broadly new scientific knowledge. All of these observable manifestations are stimuli (i.e., “events” for the brain) that increase the level of psychological entropy, as the human brain struggles to answer the questions “What’s going on?” or “What should I do?” (DeYoung, 2015).

Psychological entropy can be both aversive and attractive for the human mind. It is aversive because uncertainty involves short-term risks, for the reason that one cannot understand what is happening nor predict what will happen. However, it is also associated with the reward system *via* dopaminergic pathways (Bromberg-Martin & Hikosaka, 2009; Bromberg-Martin et al., 2010). Why? From an evolutionary point of view, dealing with uncertainty is adaptive, because it allows the acquisition of new information and therefore *reduces* psychological entropy for the future.

In other words, while the human mind automatically and unconsciously rewards actions that lead to the achievement of evolutionarily programmed goals (e.g., eating, making love, or socializing; i.e., *consummatory rewards*), it also rewards automatically and unconsciously actions that increase the probability of achieving such goals in the future (e.g., information about which resources to collect; i.e., *incentive rewards*). This is what is more commonly called curiosity: new information in itself is rewarding for the brain (Bromberg-Martin & Hikosaka, 2009). This is why humans are sometimes attracted to novel stimuli (Bunzeck & Düzel, 2006; Chakroun et al., 2020; Costa et al., 2014; Horvitz et al., 1997; Kakade & Dayan, 2002; Kidd & Hayden, 2015; Koster et al., 2016; Reed & Adams, 1996; Wittmann et al., 2007) .

Organisms endowed with this dopaminergic system are thus rewarded when they acquire new information. However, to acquire new information, and thus reduce the level of psychological entropy, it is necessary to tolerate an *increase* in the level of psychological entropy in the short term. The analogy with space exploration is evocative: it is necessary to cross unknown territories to discover new information about them. This is consistent with the fact, at first sight paradoxical, that the dopaminergic system rewards *the increase* in the level of psychological entropy (DeYoung, 2015).

Dopaminergic functions not only influence what an individual does when faced with the unknown, but also how actively they seek out the unknown. From an evolutionary point of view, intrinsically motivated exploration is also advantageous for acquiring knowledge about one’s environment (e.g., about the quantity of food or about the presence of predators). In fact, the *voluntary increase in the level of psychological entropy* is functional *to reduce it* for the future in the medium or long term (DeYoung, 2013; Hirsh et al., 2012). Going back to the proximate level for a moment, this reasoning explains the pleasure one experiences while reducing psychological entropy following a voluntary increase (e.g., the cognitive satisfaction of “Eurekas”, or “awe”, after reading a difficult scientific essay; Goldy & Piff, 2022).

Such exploratory preferences have therefore evolved to solve an adaptive problem, that of making the decision between exploring and exploiting, for example, between exploring an unknown environment and exploiting a known environment (Cohen et al., 2007; Delton & Robertson, 2016; Mehlhorn et al., 2015). This evolutionary trade-off can be thought of as a natural selection pressure that has resulted in the evolution of specific behavioral and cognitive skills in all mobile organisms (e.g., in fish: Broglio et al., 2003).

We propose the ultimate hypothesis that the specific pleasure that some humans derive from consuming science fiction is explained by the presence of this dopaminergic system in their brain, which motivates humans to reduce entropy. In certain particular circumstances, notably in a context of security and abundance (see last section), the dopaminergic system makes *the increase* in psychological entropy cognitively pleasant, because it motivates the organism to confront the unknown in order to acquire new information.

It is precisely this cognitive system that the elements of science fiction stimulate, whether it is a ‘word-fiction’, that is, a word that only exists in fictions like the *hralz* (Langlet, 2006), an unknown civilization, or a strange machine. Such fictional elements are as many perceived opportunities for acquiring new information, that is, for reducing psychological entropy: the new concept will be disambiguated, the springs of this new civilization will be assimilated, or this new machine will be mastered. This view is consistent with Loewenstein’s theory, who proposed to conceive of curiosity as the feeling evoked by the realization of a gap in one’s subjectively perceived level of knowledge (Golman & Loewenstein, 2012; Loewenstein, 1994): any event in the environment that provokes the phenomenology of an epistemic gap leads to an increase in psychological entropy, which motivates any endeavor that would lead to its reduction.

A first question arises. Why would learning purely fictional facts, which teach nothing about the real world, arouse our curiosity? The answer to that question lies in evolutionary theory. The strategy of exploring the unknown was selected by evolution because it increased organisms’ chances of survival and reproduction. This cognitive mechanism called “curiosity” therefore evolved over the hundreds of millions of years that preceded the advent of modern humans, and thus long before human communication reached the level of subtlety necessary for the emergence of narrative fictions (Hills, 2006).

It is therefore stimulated by any external event, at an intuitive level which, crucially, does not take the border between fiction and reality into account. For the non-reflective part of the human mind, encompassing all intuitive mechanisms and emotions, fiction is just like a window on a distant possible world, nothing more (Dubourg & Baumard, 2022b). Thus, in the same way that a monster on television can stimulate the evolved cognitive mechanism of fear, and the reading of a tragedy can stimulate the cognitive mechanisms of sadness, elements in science fiction can stimulate the cognitive mechanism of curiosity. Of course, it does not mean that the fiction/non-fiction distinction is superficial. Rather, it means that our preferences are not influenced by this distinction.

The second question raised by this general hypothesis is that of variability: there are obviously great differences in the sensitivity of this mechanism of curiosity between individuals within the human species. This question will be addressed in the last section.

Finally, the last important question to which this hypothesis leads is: Why do science fiction consumers turn to science fiction, and not to science? What is the 'advantage' of science fiction over other similar cultural productions that increase psychological entropy and leads our curious minds to be motivated to explore?

Following our broader hypothesis, we propose that the more impactful and the more rapid the reduction of psychological entropy, the stronger the phenomenological feeling, and the more intense the physiological and emotional reaction (e.g., *awe*). This is due to the relevance of powerful cognitive effect (compared to the effort invested): it is, in our opinion, very close to what English speakers call *insight*, or Eureka, that is, the sudden and gratifying realization of a causal relationship (Bellagamba et al., 2018; Picholle, 2021).

According to this hypothesis, the entire scientific production would be the result of an evolved motivation to explore the links of cause and effect in the environment, in order to reduce the psychological entropy and thus reduce the errors of prediction of future events. Science fiction has a crucial advantage over science: it is not limited by the constraints of reality. The creators of science fiction (but also of thrillers, for example) can therefore imagine narrative elements and sequences that make the realization of (fictional) cause and effect relationships even more impactful and rewarding.

3. Specific evolved mechanisms

We have seen that natural selection has favored the evolution of a cognitive system whose function is to make uncertainty appealing in some specific conditions, in order to gain new information. However, all fiction involves uncertainty: even in a romance novel or in an action film, the characters are new, the actions are surprising, and the plot is to some extent unpredictable (Tobin, 2018). It does not seem to be a matter of degree.

What then is the specificity of the unknown to which science fiction exposes us? Some hypotheses in cultural and narratological studies focus on the idea that science fiction works are different from other fictional productions because they offer more 'rational' representations of unfamiliar reality (Suvin, 1979; but see Mather, 2007). Our hypothesis is that science fiction exposes us to very specific novel, bizarre, or original elements that activate particular specialized mechanisms of the human mind.

The human cognitive architecture is formed by multiple distinct mechanisms selected during evolution. One of the contributions of evolutionary psychology has been to propose ways of understanding and empirically testing how these specialized mechanisms are indeed distinct in terms of their function and functioning (Barrett, 2015; Tooby & Cosmides, 1992). The crucial point is that such mechanisms have evolved as biological adaptations to specific and all different ancestral problems. Therefore, these cognitive adaptations function to detect specific classes of environmental cues, in order to respond to them in ways that, on average, increased the organism's chances of survival and reproduction.

For example, intuitive physics, which evolved in human cognition to address the adaptive problem of understanding physical laws and adapting behaviors to them (Kubricht et al., 2017; Lewry et al., 2021; Perez & Feigenson, 2021; Spelke, 1990), is different from intuitive biology, which is a biological adaptation to the ancestral problem of understanding and classifying biological entities (Atran, 1998; Mahr & Csibra, 2021; Wertz, 2019). The accumulated evidence to distinguish and understand them comes from anthropological studies in hunter-gatherer societies, developmental psychology studies on children, and cross-cultural studies in experimental psychology (Barrett, 2015).

To take just one example: we know that children, even before they can walk (here at five months), perceive physical objects as unitary, delimited, and persistent entities. One empirical evidence of that comes from experimental developmental psychology: researchers compared the time babies look at both intuitive physical phenomena (an object colliding with another object) and supposedly counter-intuitive physical phenomena (the object passes through another object). Children look significantly longer at the second situation, suggesting that they are surprised and therefore had very early *intuitive expectations* regarding the *permanence* of physical objects (Baillargeon et al., 1985).

Research in psychology has provided ample experimental evidence that this approach can explain the success in the history of fiction of many fictional content features, because they differ from what one intuitively expects (e.g., a ghost who can cross walls and disappear is surprising for our intuitive physics; Banerjee et al., 2013; Norenzayan et al., 2006; Stubbersfield & Tehrani, 2013). Such

Table 1
Example of adaptive problems (first column) which, acting as selection pressures, favored the emergence of cognitive mechanisms (second column). These cognitive adaptations are evolutionarily programmed to react to external types of events. These "events", or stimuli, have equivalents in fiction, of which we give some intuitive examples (third column). We also give an example of science fiction works that include these types of content elements that stimulate the associated cognitive mechanisms (fourth column).

Adaptive problem	Mechanism cognitive	Example of fictional elements stimulating the mechanism	Example work
Understand physical laws	Intuitive physics (Baillargeon et al., 1985)	Returns in time (Nahin, 1999)	*Stargate*
Classify biological entities	Intuitive biology (Atran, 1998)	Supernatural creatures (Slonczewski & Levy, 2003)	*Frankenstein*
Understand and manipulate tools	Tool reasoning (Osiurak & Reynaud, 2019)	Nanotechnology (Taillandier, 2017)	*Star Wars*
Understand environments	Spatial navigation (Hills et al., 2015)	New environments (Dubourg & Baumard, 2022a)	*The Expanse*
Understanding causal relationships	Search for explanation (Liquin & Lombrozo, 2022)	"Didactic segments" (Saint-Gelais, 1999)	*Dark*

features increase the level of psychological entropy: we pass from what was intuitively predictable (e.g., the two objects stumble against each other) to the unpredicted (e.g., the two objects cross each other). This activates the dopaminergic system which directs our attention to what is now identified by the human mind as a source of uncertainty, precisely because new information seems available. This information leads to lower level of psychological entropy.

Our hypothesis is that content features which are rather specific to science fiction are those that engage functionally specific cognitive mechanisms, that are not engaged (or not as much) by other fictions from other genres. We identify five of them: intuitive physics, intuitive biology, tool reasoning, spatial navigation, and search for explanation (see Table 1). In a review of the literature in evolutionary and cognitive psychology, we have identified more than 70 specialized cognitive mechanisms that can be stimulated by narrative fictions from all genres throughout history (Dubourge et al., n,d.). This makes science fiction rather specific, if science fiction works do repeatedly activate only five of them. This leads to a testable prediction: after having specified, in a large database of fictional stories, which stories stimulate which cognitive mechanisms, we predict that an unsupervised clustering method (i.e., a technique that naturally groups stories together based on their similarities without prior labelling) will bring out a fairly homogeneous cluster of works categorized in the science fiction genre.

4. Phenotypic plasticity

We have reported evidence accumulating over the past few decades that suggests that evolution has shaped the dopaminergic system to make the unknown interesting and motivate us to explore new events in our environments: this would explain the intrinsic appeal for science fiction. We also hypothesized that science fiction is a generic category that brings together fictional works that have the common characteristic of activating specific and universal mechanisms of human cognition, namely intuitive physics, intuitive biology, technological reasoning, environmental curiosity, and the search for explanation. We therefore tried to explain the origin of science fiction through universal cognitive predispositions.

However, science fiction is not universal: its emergence is quite recent, its popularity varies greatly from one country to another, and, even within the same country, not everybody has a strong taste for it: some love science fiction, others are mixed, and still others have an aversion to this genre. A cognitive and evolutionary explanation of the origin of science fiction should also be able to explain the variability of its power of attraction between individuals, between societies, and across time.

As we have sometimes implied it, to be adaptive, curiosity should be more or less sensitive depending on certain cues in the environment: in an environment without danger and with an abundant amount of resource, it is more interesting to explore, because the evolutionary costs associated with explorative behaviors (e.g., collection risks, opportunity costs) are reduced. Conversely, it is too risky for an organism in an unpredictable and resource-poor environment to explore. It is better for it to exploit the resources already available, and not to base its survival on the potential benefits of exploration, which only happen, as we have seen, in the medium or long term (Katz & Naug, 2015; van Schaik et al., 2016; Verdolin, 2006). In other words, in a dangerous and resource-poor environment, the time and energy invested in exploration are evolutionarily too costly (Boon-Falleur et al., 2021; Mell et al., 2021).

Evolutionary biologists speak of adaptive *phenotypic plasticity* to explain how our phenotype, and in particular the sensitivity of our cognitive mechanisms, are indeed determined in a very plastic way by our direct environment (Frankenhuis & Nettle, 2020; West--Eberhard, 2003). Consistently, we argue that curiosity is not fixed to a certain level: it has evolved to vary according to the level of security and affluence of the local environment, in an adaptive way. This has already been demonstrated in many species, such as in black-capped chickadees (Rojas-Ferrer et al., 2020), in vampire bats (Carter et al., 2018), in bees (Katz & Naug, 2015), in spotted hyenas (Benson-Amram & Holekamp, 2012) and in orangutans (van Schaik et al., 2016). The most parsimonious assumption is that this is also the case in humans as well (Baumard, 2019).

Curiosity is notably assimilated to a psychological trait identified in personality psychology, called *Openness to experience,* and which can be defined as a stable appeal for novelty, originality, difference, and adventure (DeYoung, 2011; McCrae, 1993). It constitutes one of the five dimensions within the Big Five, the descriptive model of human personality (McCrae & John, 1992). The five dimensions that compose it (i.e., Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism) have been designed to capture the variability of human personalities and behaviors: humans differ in the personality "scores" associated with each of these dimensions, calculated using psychological questionnaires. The Big Five is considered the most widely accepted model of human personality today (Nettle & Penke (2010); see Wright & Jackson (2022), for a study of the individual stability of Big Five traits with 21, 616 participants; see Durkee et al. (2020), for a cross-cultural study in 115 countries and with 685,089 participants; see Schmitt et al. (2007), for a cross-cultural study in 56 countries and with 17,837 participants; see Bainbridge et al. (2022), for a study showing that among 1039 psychological scales, between 71 and 83 % are in fact associated with the Big Five).

Recently, psychologists have been interested in the sources of variability of these personality traits at the inter-individual level. Openness to experience scores vary depending on several factors, including the local environment. At the individual level, there is empirical evidence that people living in more affluent families have higher Openness to experience scores (Menardo et al. (2017); Zhang et al. (2018)), and that in these conditions these scores are less likely to decline over the lifespan (Oh et al., 2022). At the level of societies, recent studies using the World Values Survey (combining data from 100 different countries) show that, across the world, people living in wealthier countries have higher levels of openness to change and new experiences (Inglehart, 2020; Korotayev et al., 2019). Finally, a recent study shows that *between-countries* differences in levels of causal learning and pretend play in children (i.e., the United-States vs. Peru) are similar to *within-countries* due to different socio-economic statuses (i.e., mixed-SES United-States vs. low-SES United-States; Wente et al. (2022)).

In addition, there is also empirical evidence that attraction to science fiction is positively correlated with scores of Openness to experience (see Michelson (2014), for an essay on the links between all the traits of the Big Five and fictional experiences). With 3.5

million participants, people who 'liked' science fiction movies on Facebook have been shown to have significantly higher levels of Openness to experience (Nave et al., 2020). And with a database of over 50,000 individuals, it has also been shown that people with a higher Openness to experience score are more likely to like science fiction literature (Cantador et al., 2013). This means that people's standard of living makes it possible to predict, on average, their level of Openness to experience, and thus their taste for science fiction.

As we have shown, Openness to experience has neurobiological correlates (the dopaminergic system underlies the Openness personality trait; DeYoung (2013)) and the trait is exceptionally stable throughout life after the critical period of childhood. These empirical observations suggest that Openness, and the other four Big Five personality traits, can be thought of as constellations of preferences and behaviors that these underlying factors cause, and from which their scores are often inferred (see Dubois et al. (2020), for other scientific evidence supporting this hypothesis). Following this model, we therefore hypothesize that the observed correlations are due to actual causal processes. The late appearance, and only in a few countries, of content features that seem to define the genre of science fiction can therefore be explained by the flexibility of the sensitivity of human curiosity. For a long time, people's level of curiosity was too low to give rise to the production of works of science fiction. Economic developments made certain populations on average more curious about new and strange stimuli, and it was only then that certain elements that characterize science fiction could be appreciated by a large enough audience, and then taken up and refined.

Let's take the example of worlds of science fiction, which are deemed 'complex' and 'consistent' (Besson, 2015), and which we argue greatly increase consumers' level of psychological entropy. Such science fiction universes first appeared in the United Kingdom (Wolf, 2013), which was then the first country in terms of GDP per capita (Manning (2017); GDP being one of the only measuring instruments to quantify the general level affluence of a society). These worlds then met with popular success in the Euro-American sphere, then in Japan in the 1950s (Bolton et al., 2007; Takayuki, 2000) and in Taiwan and Hong Kong in the 1980s and 1990s (Gaffric, 2017), after their economic development in the 1970s. On the other hand, if Jules Verne was first translated into Chinese at the beginning of the 20th century and inspired Chinese writers to write science fiction stories at the end from the Qing dynasty and the beginning of the Republican era (Aloisio, 2017), they remained marginal and timorous in Chinese literature throughout the 20th century (Jiang, 2013; Aloisio, 2017). Science fiction really became popular in mainland China at the turn of the new millennium, that is, 20 years after the Chinese economy took off (Song, 2013).

The rest of this research program involves testing the many predictions that derive from it, using experimental or observational studies, in order to consolidate the correlational evidence, and to provide causal evidence. In particular, we can test that: (1) in history, science fiction novels appear systematically after an improvement in living conditions, with statistical studies testing the prediction that the rise in affluence *precedes* the emergence of science fiction (see Martins & Baumard (2021), for an example of this method); (2) synchronously, the variability in the popularity of science fiction across countries is explained by the variability in their levels of affluence and relative safety. The direction of causality can be tested with statistical models involving exogenous shocks (see Baumard et al. (2022), for an example of this method). At the individual level, we predict that (3) individuals who have grown up and live in better living conditions are on average more attracted to science fiction rather than other fictional genres; and that (4) the individuals' Openness score is a mediating variable in the causal model which associates their standard of living with their preference for science fiction (in statistics, mediation is a model which makes it possible to explain the causal relationship between two variables by the presence of an intermediate variable: a specific statistical test would therefore make it possible to test this prediction; see Dubourge et al. (n,d.), for an example of this method).

5. Conclusion

The essential idea of this broad theoretical framework is that psychological predispositions characteristic of the human brain underlies any cultural evolutionary process and account for lasting traditions, cultural norms, and symbolic productions (Sperber, 1996; Sperber & Hirschfeld, 2004; Morin, 2016). This idea is not new. In fiction study, Jean-Marie Schaeffer has written that the success of fiction is based on "psychological hooks" (Schaeffer, 1999), and Vincent Jouve that the pleasure provided by fiction is "induced by the activity of the cognitive apparatus" (Jouve, 2019). Many literary critics or cultural anthropologists have adopted this idea (Boyd, 2010; Carroll, 2012; Grodal, 2017; Jobling, 2001; Nettle, 2005; Singh, 2019; Dubourg et al., 2021; Dubourg & Baumard, 2022b), making it possible to explain the appeal for fictions by making clearer the specialized mechanisms that they trigger. The sensitivity of these mechanisms varies from one individual to another. This is what generates the cultural recurrence of some fictional inventions (Acerbi et al., 2019; Sperber & Hirschfeld, 2004), but also the variability of a cultural tastes across individuals, across countries, across social classes, and across time.

This approach makes it possible to answer questions related to science fiction with ultimate explanations, that is, with causes explaining why the human brain is organized as it is organized and works as it works. Why is science fiction fun and interesting for some humans? Because the human brain is endowed with a dopaminergic system that has evolved to be interested and even to seek the unknown, in order to reduce the psychological entropy for the future. Why is there a generic category of science fiction homogeneous enough to be identified and used by readers and researchers? Because all these works trigger specific cognitive mechanisms that are not as much stimulated by other fictions, such as intuitive physics and technological reasoning. Finally, why does science fiction appeal to some people, but not to all? Because the will to voluntarily seek uncertainty and therefore raise psychological entropy is flexible, notably *via* phenotypic plasticity: the more favorable the environment, the more sensitive the organism's level of curiosity.

Of course, this model does not explain all of the variance in the differences in preference for science fiction between individuals. In other words, under equivalent living conditions, the preference for science fiction still varies enormously from one individual to another. This is not inconsistent with our general hypothesis, which specifically predicts that an individual in an affluent environment with no imminent danger is *more likely* to like science fiction (in a probabilistic fashion). The fact that this preference still varies after having considered the living conditions of individuals makes it clear that there are other causal factors which contribute to explaining it, in different proportions of explained variance. Several avenues, which go beyond the scope of this article, could be considered to find other causal factors: for example, genetic inheritance (which sets a certain level of dopamine which differs between individuals depending on their parents' genome; Penke & Jokela (2016); Bouchard & Loehlin (2001)) or age (following recent results in developmental psychology and studies focusing on life history theory in behavioral biology: Blanco & Sloutsky (2020, 2021); Del Giudice (2014); Kaplan & Gangestad (2015)).

Crucially, this approach differs from the approaches that want to explain the emergence of and interest in science fiction with the emergence of and interest in science. According to our hypothesis, the emergence of science cannot causally explain the emergence of science fiction: it is rather the same common cognitive bases that explain both phenomena. On the other hand, it explains why they are concomitant, without necessarily being causally linked (see Fig. 1). Our model calls into question the idea that a technological advance is necessarily interesting and pleasant once it is invented: for science fiction to be able to discuss it without being rejected in the bench of forgotten works, it is necessary that readers find this technology interesting and are curious to "learn" more about it (see Taillandier (2017), for an article on the appearance of nanotechnology in Japanese science fiction in the 1990s) .

If both science fiction and science emerge from the same cognitive bases, does this mean they are both evolutionary adaptations? Delving into this matter, there is a wider debate in the evolutionary research on fiction concerning fiction's evolutionary function. Some researchers argue that our inclination to create or enjoy stories is the direct result of a biological adaptation. They suggest various potential functions for this, ranging from fostering social cohesion to teaching moral lessons (Sugiyama, 2021; Mar & Oatley, 2008; van Mulukom & Clasen, 2021; Smith et al., 2017). Others, however, argue that our interest in fiction might just be a side effect of other cognitive mechanisms we evolved over time. For example, according to (Pinker, 1997) and Tooby and Cosmides (2001), our attraction to certain art forms, including literature, might exploit cognitive systems that evolved for different primary purposes (e.g., language, an adaptation that did not evolve for humans to be able to tell fictional stories). In a recent article, we proposed another alternative, which views fiction as a kind of technology. We suggested humans began crafting stories because the attention from these stories provided them tangible benefits, like improving their social reputation or passing down important information (Dubourg & Baumard, 2022b).

Regardless of the stance one adopts, it is undeniable that the human inclination towards fiction employs a myriad of cognitive faculties and preferences that evolved for diverse reasons. Thus, our penchant for science fiction, and fiction in general, would not be an adaptation. Considering this perspective, our approach aspires to pioneer the emergence of a new line of research. While this program is rooted in the legacy of Literary Darwinism, it endeavors to go a step further. We aim to provide more nuanced explanations by studying the evolutionary and psychological foundations of *variable* preferences. By probing into concepts like genetic variability and phenotypic plasticity, we bridge insights from personality, developmental and behavioral psychology. Evolution not only molds our psychological mechanisms, but also their changing sensitivity level, and these mechanisms, in turn, influence how we create and consume fictional narratives. Moving forward, we anticipate that this framework will pave the way for clearer ultimate explanations of

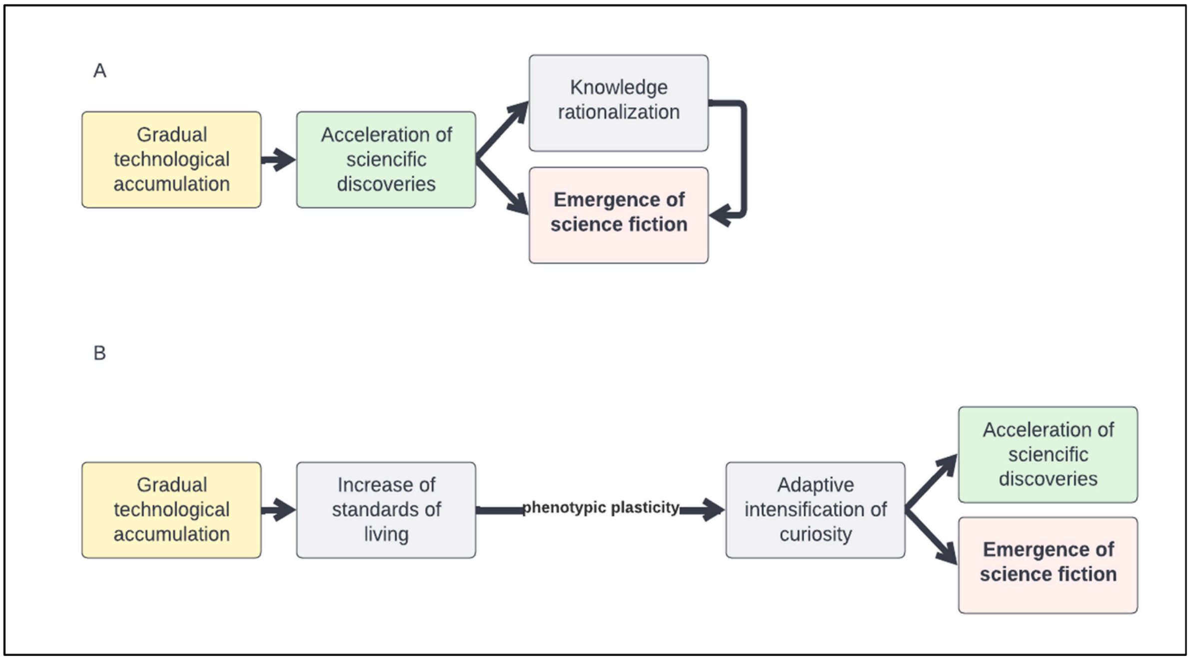

Fig. 1. Each arrow represents a causal link. A. Proposed diagram of the standard model explaining the causal stages of the emergence of science fiction. B. Diagram of the cognitive and evolutionary model explaining the causal stages of the emergence of science fiction. In Model B, scientific discoveries have no causal impact on the emergence of science fiction.

our highly diverse cultural tastes.

6. Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT in order to improve the writing style of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

None.

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