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Why Imaginary Worlds?

The psychological foundations and cultural evolution of fictions with imaginary worlds

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Short abstract: Why do fiction makers spend much time and money building imaginary worlds? Why are fictions with such imaginary worlds so widely popular? Current views in cultural evolution do not explain this massive cultural phenomenon. In this paper, we hypothesize that imaginary worlds tap into preferences for exploration which have evolved in a wide range of species to propel individuals toward new sources of reward. After reviewing research on exploratory behavior and preferences and the sources of their variability, we argue that this hypothesis explains the way imaginary worlds evolved culturally, their shape and content, their recent striking success, and their distribution across time and populations.

Long abstract: Imaginary worlds are extremely successful. The most popular fictions produced in the last decades contain such a fictional world. They can be found in all fictional media, from novels (e.g., *Lord of The Ring*, *Harry Potter*) to films (e.g., *Star Wars*, *Avatar*), video games (e.g., *The Legend of Zelda*, *Final Fantasy*), graphic novels (e.g., *One piece*, *Naruto*) and TV series (e.g., *Star Trek*, *Game of Thrones)*, and they date as far back as ancient literature (e.g., the Cyclops Islands in *The Odyssey*, 850 BCE). Why such a success? Why so much attention devoted to nonexistent worlds? In this article, we propose that imaginary worlds co-opt our preferences for exploration, which have evolved in humans and non-human animals alike, to propel individuals toward new environments and new

sources of reward. Humans would find imaginary worlds very attractive for the very same reasons, and under the same circumstances, as they are lured by unfamiliar environments in real life. After reviewing research on exploratory preferences in behavioral ecology, environmental aesthetics, neuroscience, and evolutionary and developmental psychology, we focus on the sources of their variability across time and space, which we argue can account for the variability of the cultural preference for imaginary worlds. This hypothesis can therefore explain the way imaginary worlds evolved culturally, their shape and content, their recent striking success, and their distribution across time and populations.

Keywords: cognitive attraction, cultural evolution, curiosity, exploration, fiction, imaginary worlds, novelty, reward

1. Introduction

The world around, fictions with imaginary worlds draw acclaim from the public, the critics and the industry, making them both best-selling and most-appreciated fictions (e.g., top-ranked in online ranking websites). For instance, *The Lord of the Ring* novels are among the best-selling novels ever written, with more than 150 million copies sold in 38 different languages. The screen adaptations by Peter Jackson grossed each around 1 billion dollars in box-office worldwide, making them among the highest-grossing films ever produced. They received universal critical acclaim and won 17 Academy Awards. *The Return of the King* alone won 11 of them, setting the current record of the most Oscars won by a single movie. This sequel is the 5th film in the "all-time top-rated movies" list from IMDb, the biggest user-generated ranking dataset on films. Producers of fictions know just how lucrative this kind of fiction can be: after a competitive bid against HBO and Netflix, Amazon bought the rights to produce TV programs based on Tolkien's imaginary world for 250 million dollars, which is by far the most expensive script idea ever sold. Tolkien's world has also been adapted into theatre, radio, board games, video games and role-playing games (e.g., *Dungeon and Dragons* and *Middle-Earth Role Playing*).

Many other fictions can be mentioned: *Star Wars*, the most successful fiction merchandising franchise of all time (Block & Wilson, 2010) and arguably the most influential movie in the history of films (Canet, 2016); *Harry Potter*, the best-selling book series in history, translated into 80 languages; *Game of Thrones*, whose final episode set the all-time audience record for a TV series with 16,4 million people watching it live and 15 million people streaming it later; *The Legend of Zelda*, one of

the best-selling video game series worldwide, with over 100 millions video games sold since the first one; and the Marvel Cinematic Universe, a shared imaginary world including a series of super hero films with common settings and characters, which cumulates several records in the history of cinema, including the highest opening week gross (*Avengers: Endgame*), the biggest opening week-end (*Avengers: Infinity War*) and, more significatively, the highest-grossing movie of all time (*Avengers: Endgame*). A more quantitative approach confirms that fictions with imaginary worlds are highly successful in recent times: the numbers of novels with imaginary worlds and the number of films with imaginary worlds have considerably increased in the last hundred years, both in absolute terms and relatively to the global levels of production of novels and films (Dubourg et al., 2021).

The examples of *The Lord of the Ring*, *Star Wars* and *Harry Potter* are startling, because they are without any doubt the most popular fictions worldwide and, at the same time, the fictions which may have pushed the building of imaginary worlds the furthest, notably if we consider the amount of background information generated by their creators. Tellingly, in cultural studies, it has been argued that "more and more, storytelling has become the art of worldbuilding, as artists create compelling environments that cannot be fully explored or exhausted within a single work or even a single medium" (Jenkins, 2006, p. 117; see also Besson, 2015; Saler, 2012; Wolf, 2013, 2017, 2021). This goes to the point that imaginary worlds without any narrative have become to appear. One compelling example is the *Codex Seraphinianus*, an encyclopedia of an imaginary world with no story nor protagonist (Luigi Serafini, 1981). Imaginary worlds are also invading mainstream literature with novels like *The Possibility of an Island* by Michel Houellebecq which blurs the lines between science-fiction, alternative history, and highbrow general fiction.

This cultural phenomenon is not at all limited to the United-States and the English-speaking Western countries. *Harry Potter*, *Star Wars* and *The Lord of the Rings* are highly popular all around the world and in fact, these franchises make most of their revenues outside North America (Kuipers & de Kloet, 2009). Also, many imaginary worlds consumed all around the world are produced outside the English-speaking world, from the Japanese manga *One Piece*, which has become the best-selling manga series in history with its 470 million copies sold in 43 different countries, to Liu Cixin's best-seller *The Three-Body Problem*, the first Asian novel to win the American Hugo Award (Chau, 2018). In this sense, a psychological and evolutionary understanding of the appeal for imaginary worlds is long overdue.

2. Imaginary worlds and world-dominant fictions

Fictions differ in the degree to which they distinguish themselves from the real world. For instance, in Balzac's novels, the fictional environment depicted is identical to France from the author's period and, while Balzac added approximately 3,000 fictional individuals, we intuitively picture the protagonists within the real world (Pavel, 2017). We infer much information derived from our folk knowledge of the real world, such as the country in which the fiction takes place, its geography, its political institutions, and the technology available. In fiction study, this idea is captured by the notion of 'principle of minimal departure' (Ryan, 1991; Searle, 1975) or 'reality principle' (Pavel, 2017; Walton, 1993). Conversely, Tolkien's "subcreated" world, Arda, is ostentatiously different from any environment in the real world (Tolkien & Tolkien, 2006), and so is *One Piece* world, with its imaginary planet with only one continent called the Red Line. Both imaginary worlds are populated by humans but also many other imaginary races, and both include many elements that do not exist in the real world.

Following these examples, the key determinant of our definition of an imaginary world is the background knowledge required to understand the fiction, because it differs from the knowledge of the real world. Imaginary worlds are fictional environments that the recipients of the fiction could not have possibly explored in real life, be it far removed islands, locations in the future or the distant past, other planets, or environments in alternative history. In fact, in the example of Tolkien, the background information is commonly considered by literary critics as the most important feature (Jourde, 1991). In 1956, Tolkien wrote a letter which displays the crucial interest of his readers for background information:

Most people want more (and better) maps; some wish more for geological indications than place-names; many want more specimens of Elvish, with structural and grammatical sketches; others ask for metrics and prosodies, not only of the Elvish, but of the "translations" that are in unfamiliar modes—such as those composed in the strictest forms of Anglo-Saxon verse (e.g., the fragment on the Battle of Pelennor, Book Five, vi, 124). Musicians want tunes and musical notations. Archaeologists enquire about ceramics, metallurgy, tools and architecture. Botanists desire more accurate descriptions of the mallorn, of elanor, niphredil, alfirin and mallos, and of symbelmynë. (…) Historians require more details about the social and political structure of Gondor, and the contemporary monetary system. (Letter to H. Cotton Minchin, 16 April 1956).

To sum up, by definition, a fiction based on an imaginary world is a fiction in which the consumer will learn a lot of novel information about the fictional environment (also called the 'chronotope' in literary theory and philosophy of language; Bakhtin & Emerson, 1984). For example, *Harry Potter* has Hogwarts and many other magical locations, Jules Verne's *From the Earth to the Moon* has the Moon (which had obviously not yet been explored at the time of the author), the *Odyssey* has the Cyclops Islands, Aiaia, the Fortunate Islands, the Siren Island and the Lotophages, to name only a few invented islands, and The *Lord of the Ring* is set in a complex alternate world with hundreds of invented locations. It is worth noting that religious narratives also involve unknown worlds that are, in a way, imaginary, with different physical laws and spatial structures, for instance. However, religious narratives cannot be considered as fictions. In this paper, we will limit our study to fictional worlds, mostly because non-fictional worlds such as religious worlds are likely to be culturally stabilized for reasons (e.g., authority) that differs from pure entertainment (Boyer, 2001).

Genre	Definition	Examples
Fantasy	Includes elements and beings originating from or inspired by traditional stories, such as mythical creatures (dragons, elves, dwarves, and fairies, for example), magic, witchcraft, potions, etc.	*The Lord of the Rings, Dungeons and Dragons, The Legend of Zelda, Harry Potter, A Song of Ice and Fire, Magic: The Gathering, Kafka on the Shore, World of Warcraft*
Science fiction	Features technologies and other elements that do not exist in real life but may be supposed to be created or discovered in the future through scientific advancement, such as advanced robots, interstellar travel, aliens, time travel, mutants and cyborgs.	*The Time Machine, I, Robot, Dune, Star Trek, 2001: A Space Odyssey, Swamp Thing, Black Mirror, Star Wars, Blade Runner, Jurassic Park, The Hitchhiker's guide to the galaxy*
Adventure fictions	Features a fast-paced, action-packed plot in which the hero has to complete a quest or a task. The adventure story usually takes place elsewhere, and uses maps, intriguing backgrounds to interest the reader.	*The Odyssey, Gulliver's Travels, Robinson Crusoe, The Jungle Book, Treasure Island, Two Years' Vacation, Michel Strogoff, Lord of the Flies, Up, The Revenant*
Uchronia	Focuses on historical events as if they happened in a different way, and their implications in the present.	*The Man in the High Castle, The Last Starship from Earth, Once Upon a Time… in Hollywood*
Utopian	Takes place in a highly desirable society, often presented as advanced, happy, intelligent or even perfect or problem-free.	*Utopia, Island, Ecotopia, 17776, A Modern Utopia, Men Like Gods, Eutopia*
Dystopian	Takes place in a highly undesirable society, often plagued with strict control, violence, chaos, brainwashing or other negative elements.	*Brave New World, 1984, The Handmaid's Tale, A Clockwork Orange, The Hunger Games*
Superhero	Centers on superheroes (i.e., heroes with extraordinary abilities or powers) and their fight against evil forces such as supervillains.	DC Universe, Marvel Cinematic Universe, *Naruto, Kamen Rider, X-Men, Super Sentai, Power Rangers*
Supernatural	Exploits as plot devices or themes some contradictions of the commonplace natural world and materialist assumptions about it.	*The Castle of Otranto, Stranger Things, Paranormal Activity, Dark, Fallen, The Vampire Diaries, Charmed*
Apocalyptic	Takes place before and during a massive, worldwide catastrophe.	*On the Beach, Threads, The Day After Tomorrow, 2012, World War Z*
Post-apocalyptic	Focuses on groups of survivors after massive worldwide disasters.	*The Stand, Mad Max, Waterworld, Fallout, Metroid Prime, Metro 2033, The Walking Dead*

Table 1. Fictional genres of the broad category of speculative fictions, conducive to the building of imaginary worlds, with the definitions from Wikipedia and some modern examples.

Note that fictions with imaginary worlds are not the only fictions in which the background information is central. One could also mention historical novels such as Umberto Eco's *The Name of the Rose* and social realistic novels such as Zola's *Germinal*, where the environments, be it a medieval Benedictine monastery or as industrial mine complex, play a central role in the fiction, although it resembles the real world. Thus, fictions with imaginary worlds belong to the broader category of 'world-dominant fictions', as opposed to 'story-dominant fictions' (Ryan, 2017). It is also important to note that our understanding of fictions with imaginary worlds is very close to the category of 'speculative fictions', which encompasses any fictional genre typically containing some background elements that do not exist in the real world (**Table 1**). Yet, it does not totally overlap with it. Indeed, not all speculative fictions require extensive background information to be appreciated. For instance, Edgar Poe's and Franz Kafka's fantastic tales in which there is only one element of supernatural do not offer much to explore. The appeal of these speculative fictions, in which the world is either relatively unimportant or very similar to the real world, would rely on the blurring of the boundaries between what is real and what is unreal (Todorov, 2015). Nonetheless, speculative fictions, being recorded and tagged online, can be used as a proxy for fictions with imaginary worlds (Dubourg et al., 2021).

Fantasy and science fiction are recent fictional genres, but imaginary worlds are much more ancient (Scholes & Rabkin, 1977). A huge number of ancient fictions set an imaginary world, in ancient epic poems about heroes' journeys, travelers' tales from the exploration age, adventure fictions, utopias and dystopias (Wolf, 2013). For instance, the ancient Mesopotamian *The Epic of Gilgamesh* (1800 BCE) and *The Odyssey* (850 BCE) are often mentioned as precursors of fantasy fiction. Some scholars have tried to map the faraway lands and islands visited by Odysseus (Clay, 2007). Other imaginary locations from this period were directly described without any narration (e.g., Arimaspi, the imaginary world from Herodotus' *Histories*). Lucian of Samosata's *True History* is evidence that such travelers' tales from this ancient time were considered as imaginary by their audience, as it is clearly stated in the introduction: "I see no reason for resigning my right to that inventive freedom others enjoy […]. My subject is, then, what I have neither seen, experienced, nor been told, what neither exists nor could conceivably do so. I humbly solicit my readers' incredulity." (Lucian of Samosata, 150 C.E.). Other ancient imaginary worlds are mentioned to strengthen this argument (**Table 2**).

Location name	Title	Author	Date	Region
Anpu's Country	*Tale of Two Brothers*	Undetermined	1200 BCE*	Egypt
Odysseus Islands	*The Odyssey*	Homer	900 BCE*	Greece
Islands of the Sun	*Islands of the Sun*	Iambulus	100 BCE*	Greece
Island of Anostus	*Varia Historia*	Claudius Aelianus	175*	Rome
The Otherworld	*The Voyage of Bran*	Undetermined	750*	Ireland
Magical islands	*Sinbad the Sailor*	Undetermined	800*	Middle East
The Moon	*The Tale of the Bamboo Cutter*	Undetermined	950*	Japan
Brocéliande	*Yvain, the Knight of the Lion*	Chrétien de Troyes	1180	France
Cockaigne	*Le Dit de Cocagne*	Undetermined	1250*	France
Hell	*The Divine Comedy*	Dante	1321	Italy
Devil's Island and other islands	*Amadís de Gaule*	Undetermined	1508	France
Utopia	*Utopia*	Thomas More	1516	England
Prospero's Island	*The Tempest*	William Shakespeare	1623	England
Lilliput, Laputa, Brobdingnag, etc.	*Gulliver's Travels*	Jonathan Swift	1726	Ireland

Table 2. Examples of imaginary worlds in non-contemporary fictions, with their invented toponyms, extracted from the broadly inclusive list of imaginary worlds put forward by Mark J.-P. Wolf (2013) (* Dates are approximative).

All this suggests that, in fictions, imaginary worlds are highly appealing. It raises many questions. Why this urge to create new fictional locations from scratch? The same stories could take place in faithful representations of the real world and it would considerably reduce the costs of fiction making (e.g., economic costs related to special effects in films with imaginary worlds). Why are we captivated by fictions with imaginary worlds, and seemingly more and more so? The timing of their success suggests that we are more predisposed to appreciate such fictions in modern societies, or we would have invented more imaginary worlds much earlier. Why are best-rated video games those with large open worlds (e.g., *Zelda*, *Assassin's Creed*, *No Man's Sky*)? Why Baum (*The Wizard of Oz*), Tolkien (*The Lord of the Ring*), Lucas (*Star Wars*), Cameron (*Avatar*), Rowling (*Harry Potter*) and developers from Hello Games Studio (*No Man's Sky*), to name only a few, were willing to devote multiple years of their lives building extensive imaginary worlds? In a nutshell: Why imaginary worlds?

3. The psychological foundations and cultural evolution of fictions

To understand the human's interest in imaginary worlds, we first need to clarify why humans produce and consume fictions. At the proximate level, evolutionary and cognitive approaches to fictions have demonstrated that fictions tend to recycle and exaggerate the most attention-grabbing and fitness-relevant stimuli in real life (Boyd, 2018; Carroll, 2012; Gottschall, 2012; Gottschall &

Wilson, 2005; Mar & Oatley, 2008; Saad, 2012; Schaeffer, 1999), such as romantic relationship (Alberti, 2013; Baumard et al., 2021; Cox & Fisher, 2009; Martins & Baumard, 2021; Salmon & Symons, 2004; Vanderbeke, 2019), cooperation and cheating (Singh, 2019), social status (Nettle, 2005a, 2005b), and political rivalries (Jobling, 2001). In other words, fictions constitutes 'intensified stimuli' or 'superstimuli' in the sense that they are crafted to artificially grab the consumers' attention, just like masks artificially trigger the human face detection capacity, and cuisine artificially triggers the nutrients detector systems (Boyer, 2018; Buss, 2015; Nettle, 2005a; Sperber, 1996; Sperber & Hirschfeld, 2004; Verpooten & Nelissen, 2010). Triggering people's attention is indeed the most important element of success of fictions. Such an evolutionary and cognitive approach of fiction therefore predicts that to answer the question "Why do people enjoy fictions?" is very close to answering the question "Why do people enjoy life?" (Bloom, 2010; Pinker, 1997).

A common view in behavioral sciences is that the capacity to tell stories is adaptive. This capacity would have evolved either to convey and teach new information (S. Sugiyama, 1996, 2001) or to simulate the real world (Mar & Oatley, 2008; Morin et al., 2019; Zunshine, 2006). Here we rather assume that humans did not specifically evolve the capacity to tell stories, but they rather create fictions thanks to a range of other adaptations (e.g., language, capacity to simulate, theory of mind; Mellmann, 2012). Yet, because they are highly attractive, fictions can be used to fulfill any evolutionary relevant purpose that needs others' attention to be caught, be it signaling one's values to potential mates (Miller, 2001) or cooperative partners (André et al., 2020; André & Baumard, 2020; Bourdieu, 2010; Nettle, 2005b; Singh, 2019, 2020; Veblen, 1899), transmitting knowledge (Nakawake & Sato, 2019; Schniter et al., 2018; M. Sugiyama, 2021), communicating social norms (Ferrara et al., 2019; Mar & Oatley, 2008), or selling products (Saad, 2012; Saad & Gill, 2000). Thus, to use a standard term, we do not consider fictions as 'by-products', because they clearly confer benefits to both the producers and the consumers (André et al., 2020). At the same time, fictions are definitely artificial. Hence, it is probably more appropriate to say that fictions (e.g., novels, films, video games) are a kind of cultural technology primarily designed for entertainment (Dubourg & Baumard, 2021; N. Paige, 2018; N. D. Paige, 2020; Singh, 2020).

To conclude, because we hypothesize that fictions are created mostly to attract attention, we do not hypothesize that there is any specific value in the information included in *The Lord of the Rings* or in *Harry Potter*. Imaginary worlds, we propose, are appealing because they meet the 'input conditions' of our cognitive dispositions geared toward exploration (Sperber & Hirschfeld, 2004), just as romances and tragedies meet the input conditions of our preferences for love and social

competition (Nettle, 2005a, 2005b). Because fiction makers can intensify such attention-grabbing stimuli in the fictions, they grab our attention, even if the information is totally useless in real life.

Obviously, fictions tap into many kinds of human interests and our paper is about just one of them. Thus, our paper does not suggest that everybody should prefer fictions with imaginary worlds. A parallel can be made with cuisine: sugar is clearly an important cultural attractor in the cultural evolution of recipes, but not all recipes include sugar and not everybody likes candies and pastries. In other words, while some people prefer consuming fictions about familiar places and comforting stories, other would preferably consume fictions with imaginary worlds and adventurous journeys. In the next section, we will argue that this variability in cultural preferences is evoked by the variability in the strength of exploratory preferences at the individual level.

4. The evolution and psychology of exploratory preferences

Our hypothesis is that the cultural preference for imaginary worlds relies on our exploratory preferences, driving our motivation to explore novel environments. As Tolkien put it himself, "part of the attraction of *The Lord of the Rings*", and other fictions with imaginary worlds, relies on the "intrinsic feeling of reward" we experience when "viewing far off an unvisited island or the towers of a distant city" (letter to Colonel Worskett, 20 September 1963). This statement is very close to the one of Shigeru Miyamoto, the creator of *Zelda*, who reported that he "wanted to create a game world that conveyed the same feeling you get when you are exploring a new city for the first time" (1989). Such fictions would thus "tap into that deeply-seated human desire to travel, seek out new experiences, and absorb new knowledge about the world" (Etchells, 2019). In this section, we explain further the ultimate and proximate mechanisms behind exploratory preferences.

4.1. The evolution of exploratory preferences and capacities: the fitness benefits of exploration

From an evolutionary point of view, there is a broad consensus to say that exploring the environment is especially adaptive for mobile species, as it leads to discovering new vital resources such as food, finding mates and habitats, avoiding predators and learning new action-outcome associations (Cashdan & Gaulin, 2016; Chambon et al., 2018; Gottlieb & Oudeyer, 2018; Hayden & Niv, 2020; Hewlett et al., 1982; T. T. Hills, 2006; MacDonald & Hewlett, 1999; Miner et al., 2014; Panksepp, 2005). For many species in many ecologies, such benefits outweigh to a certain point the costs of

exploration (e.g., energetic loss, economic costs, risks of injury, opportunity costs). Humans were particularly shaped by this selection pressure. Long-distance dispersal have been an important component of human migrations, allowing fast colonization of new territories all over the planet (Alves et al., 2016). Moreover, during the majority of its evolutionary history, *Homo Sapiens* led a nomadic way of life (Lee, 1966), like many other species who are known to travel across space (Chapman et al., 2014).

In line with the idea that there are fitness benefits derived from spatial exploration, studies have shown that non-human animals are endowed with specific capacities to explore their environment, recall the location of resources, determine the best navigation route between resources, and reorient when approaching locations from new perspectives (Rosati & Hare, 2012). Importantly, these capacities vary according to the ecology of the species (Healy et al., 2005; Platt & Brannon, 1996; Rosati et al., 2014). For instance, chimpanzees exhibited more accurate spatial memory than bonobos across contexts, supporting predictions from these species' different feeding ecologies: wild chimpanzees depend more on patchily distributed fruit, whereas bonobos depend more on homogeneously distributed resources such as terrestrial herbaceous vegetation (Rosati & Hare, 2012). Fishes' spatial behavior too is very flexible, and this plasticity would rely on homologous cognitive mechanisms as those identified in mammals and birds (Broglio et al., 2003). Importantly, these adaptations are not limited to purely cognitive capacities, they also extend to reward orientation. For instance, tamarins who feed on an ephemeral, dispersed food source (e.g., insects) and travel through large territories are much more likely to travel to a smaller, closer reward or a larger, more distant reward than marmosets who feed on a localized, immobile food (gum and sap exuding from trees) and, consequently, face little pressure to travel long distances for food (Stevens et al., 2005).

Finally, it is important to note that such cognitive capacities are hypothesized to be the evolutionary precursor to goal-directed cognition: many disciplines ranging from behavioral ecology to molecular genetics provide evidence that, for instance, problem-solving is a cognitive system born out ancient space foraging behaviors (T. T. Hills, 2006; T. T. Hills et al., 2010; T. T. Hills & Stroup, 2004). Such capacities are shared across all mobile organisms. Fishes' spatial behavior, for instance, is as elaborate as the ones of land vertebrates (Broglio et al., 2003). Even further away from humans in the phylogenetic tree, bacteria's attempts to go back to resourceful environments through turns after removal from food is a strategic foraging behavior (Korobkova et al., 2004; Neidhardt & Curtiss, 1996). In humans, cognitive maps are applied to non-spatial domains such as conceptual thinking (Behrens, 2018; Epstein et al., 2017; Jacobs, 2003), and exploratory preferences are rallied

to domain-general decision-making processes (Daw et al., 2006; T. T. Hills et al., 2010; Le Heron et al., 2019). Crucially, there is empirical evidence that preferences for spatial exploration in foraging tasks are correlated with preferences for cognitive exploration in problem-solving tasks (T. T. Hills & Stroup, 2004).

4.2 The behavioral manifestations of exploratory preferences: animal exploration, wayfinding, and environmental aesthetics

Such preferences for spatial exploration are blatant when studying animal behavior. Many experimental studies revealed how curious about novel environments animals can be. In a famous study, rats were found to spend more time exploring novel environments than exploiting familiar ones (Berlyne, 1950). Since then, the novelty-based theory of exploration and curiosity has been supported by many studies in the non-human animal literature, with various empirical tests, from the 'open-field arena' test for mice (Berlyne, 1970; Peeler & Nowakowski, 1987) to the 'visual novelty preference' test for monkeys (e.g., Fagan, 1970; Gunderson & Sackett, 1984). Rats can learn to find their way around a maze in the absence of rewards (Byrne, 2013; Reed & Adams, 1996), suggesting that the opportunity to explore is intrinsically rewarding (Polizzi di Sorrentino et al., 2014). Rats and pigeons prefer multiple-choices paths over no-choice, shorter paths leading to the same reward (Bown et al., 2003; Catania, 1980; Catania & Sagvolden, 1980; McDevitt et al., 2018). More recent studies with two-choice tests showed that animals are more interested by unfamiliar objects compared to familiar ones. At this stage, it has been proved to be the case for bottlenose dolphins, Pacific white-sided dolphins, beluga whales (Guarino et al., 2017), rhesus macaques (Englerova et al., 2019; Wang & Hayden, 2019) and orangutans (Borel et al., 2016). Also, it is worth noting that exploration is still preferred when the payoff is removed: in so-called non-instrumental tasks, animals observe novel stimuli even if they cannot act on them (Gottlieb & Oudeyer, 2018). More surprisingly, exploration is attractive to the point that animals are willing to pay a supplementary cost to keep exploring (FitzGibbon et al., 2020; Hughes, 2007; Oudeyer et al., 2016).

In humans, one obvious place to look for exploratory preferences are studies of wayfinding. Wayfinding is generally defined as the ability to move around efficiently and find the way from a starting point to a destination (Montello, 2005). It is different from pure locomotion. Locomotion depends on sensory-motor systems interacting with an immediate surrounding, while wayfinding invokes higher-level cognitive systems to maintain orientation relative to the distal environment. Experimental work has shown that performance in wayfinding is predicted by both cognitive capacities

(e.g., visuospatial memory, mental rotation ability) and individual preferences. For instance, individuals who take pleasure in exploring places tend to have a good sense of direction (Muffato et al., 2017) and perform better in spatial tasks (Carbone et al., 2020; Muffato et al., 2016, 2017). In particular, Pazzaglia et al. (2018) showed that a significant part of the variability in the performance was explained by an aggregate measure of pleasure in exploring. Interestingly, the strength of the relationship between preferences and wayfinding tasks seems to depend on how difficult the task is: the tougher the task, the stronger the relationship (Pazzaglia et al., 2018; Weisberg et al., 2014).

Another area of research is known as 'environmental aesthetics', a domain of empirical psychological research which investigates the elements of settings to which people are attracted the most (Balling & Falk, 1982; Falk & Balling, 2010; T. R. Herzog, 1984, 1985; T. R. Herzog & Bryce, 2007; T. Herzog & Smith, 1988; Ikemi, 2005; R. Kaplan & Kaplan, 1989; S. Kaplan, 1988; Ruso et al., 2003; Ulrich, 1979). Scholars working in environmental aesthetics have conducted a great number of experimental studies to investigate the existence and the nature of universal preferences regarding environments. One of the key findings of this research program is that environments and landscapes are typically better rated and thus preferred when the settings signal an opportunity to gather information through exploration (e.g., the picture shows a trail that disappeared around a corner). Therefore, what makes an environmental setting appealing is the promise of further novel information, causally inferred from cues indicating that an enrichment in knowledge is a possibility. It is important to note here that these preferences are said to be automatic, unconscious and intuitive. More often than not, participants were unable to explain their choices when rating the landscapes (S. Kaplan, 1987), sustaining the hypothesis that sometimes "preferences need no inferences" nor explicit judgments (Zajonc, 1980).

4.3. The cognitive and neural mechanisms underpinning exploratory preferences: plasticity, the exploitation-exploration trade-off, and the dopamine system

The study of wayfinding abilities and environmental preferences demonstrates the existence of specific preferences for spatial exploration. Exploratory preferences are part of a broader set of personality traits related to the meta-trait 'Plasticity'. The trait Plasticity reflects the degree to which an organism is prone "to generating new goals, new interpretations of the present state, and new strategies to pursue existing goals" (DeYoung, 2013, 2015). Behavioral plasticity and exploratory preferences are inseparable notions because spatial exploration requires to be able to flexibly adapt to changing environments, otherwise exploration is too costly (Rojas-Ferrer et al., 2020; Sol et al.,

2016). From an empirical perspective, exploratory preferences are best studied through two important constructs that are highly correlated (DeYoung, 2015; George & Zhou, 2001; Gocłowska et al., 2019; Gottlieb et al., 2013; Li et al., 2014; McCrae, 1993): 1) the Big Five trait Openness to experience in personality psychology (e.g., Carbone et al., 2019, 2020; Meneghetti et al., 2020; Pazzaglia et al., 2018) and 2) novelty-seeking in the neuroscience of decision-making (e.g., Costa et al., 2014; Krebs et al., 2009). It is worth noting that wayfinding inclinations have been shown to be positively associated with Openness to experience (Carbone et al., 2020; Meneghetti et al., 2020).

To further understand how exploratory preferences work at the proximate level, researchers designed the 'bandit' task and its variants (Schulz & Gershman, 2019): in its most basic design, the learner must choose between pulling a lever with known but degressive reward (i.e., to exploit) or a lever with unknown payoff, which is the exploratory choice (Cohen et al., 2007; Daw et al., 2006; Gershman, 2018; Le Heron et al., 2019). It has been found that humans use a combination of both directed and random exploration strategies, with novelty cues as informative "bonuses" (Chakroun et al., 2020; Gershman, 2018; Gottlieb & Oudeyer, 2018; Schulz & Gershman, 2019; Wilson et al., 2014). The exploitation-exploration trade-off is a classic problem in reinforcement learning. It corresponds to an evolutionary dilemma all mobile organisms face: they constantly need to arbitrate between exploiting a well-known (but maybe decreasing) source of resources or explore to find unknown (but maybe better) opportunities (Mehlhorn et al., 2015). The computational theory of reinforcement learning claims that the high-level goal of any learning agent is to obtain as much reward as possible, even if it is delayed (Dubey & Griffiths, 2020; Gozli, 2018) and it supports the idea from behavioral ecology that knowledge acquisition, prompted by novelty-based exploration, aims at optimizing future rewards (Brändle et al., 2020; Dubey & Griffiths, 2020; Oudeyer et al., 2016).

The study of animal exploration in the previous sub-section suggested that rewards associated with exploratory behavior are different from and independent of external rewards present in the environment. Thus, across species, it is generally accepted that there is an intrinsic motivation to explore novel environments (Gottlieb et al., 2013; Gottlieb & Oudeyer, 2018; Liquin & Lombrozo, 2020a, 2020b). What are the neural bases for this intrinsic motivation to explore? There is persistent evidence that the dopamine system, known to be at the basis of rewards across many species (e.g., Baumann et al., 2002; T. Hills, 2004; Schultz, 1998, 2015), reacts specifically to novel stimuli which do not involve any primary reward (Düzel et al., 2010; Horvitz et al., 1997; Kakade & Dayan, 2002; Reed et al., 1996). Data from experiments with injections of a selective dopamine transporter

inhibitor show that dopamine crucially enhances novelty-related value (Costa et al., 2014). A pivotal event-related fMRI study has demonstrated that novel pictures activated the mid-brain Substantia Nigra and Ventral Tegmental Area (SN/TVA) more than rare, arousing and behaviorally relevant pictures (Bunzeck & Düzel, 2006). That is, in the absence of reward, the dopamine system is activated by novel stimuli rather than interesting but more familiar ones. This finding supports the idea that "novelty can serve as its own reward" (Knutson & Cooper, 2006) and is very much in line with the novelty-based theory of exploration (Bromberg-Martin et al., 2010; Gottlieb & Oudeyer, 2018; Kidd & Hayden, 2015). Interestingly, the reaction of the dopamine system to novel stimuli has been interestingly referred to as "novelty bonuses" (Frank et al., 2009; Kakade & Dayan, 2002; Koster et al., 2016; Krebs et al., 2009; Krueger et al., 2017; Sutton, 1990). Finally, empirical results from fMRI studies also show that, while the neuronal system coding for novel information-seeking behavior recruits the dopamine-based reward system, non-explorative choices (i.e., exploiting existing information) recruit different brain regions (Blanchard & Gershman, 2018; Chakroun et al., 2020; Costa et al., 2019; Daw et al., 2006). Exploration therefore accounts for a specific neuronal and cognitive domain (Blanchard & Gershman, 2018).

4.4. The variability of exploratory preferences: life stage and ecological conditions

Finally, we go back to the ultimate level, to explain why and how such exploratory preferences are flexible, and vary according to the local environment and the life stage of the individual (Baumard, 2019; Frankenhuis et al., 2016; Jacquet et al., 2019; Nettle, 2019). Indeed, behavioral sciences have shown that organisms flexibly allocate resources such as energy and time to spatial exploration in a way that maximizes biological fitness (Charnov, 1976; H. Kaplan & Gangestad, 2004; Stephens et al., 2014). More specifically, all foraging species face an exploration-exploitation trade-off, that is, the dilemma between choosing either an exploitative or an exploratory option, be it for spatial foraging, choice making or problem solving (T. T. Hills et al., 2015; Mehlhorn et al., 2015). Therefore, the strength of exploratory preferences should vary according to ecological conditions (because the costs and benefits of exploration depend on the resources of the environment) and the life stage (because the costs and benefits of exploration vary with one's life stage).

4.4.1. Exploratory preferences and life stages

In many animals, individuals' life stage impacts their exploratory strategy: typically, they go through an early period of exploration followed by a later period of exploitation (Cohen et al., 2007; Morgan

et al., 2020; Stansfield & Kirstein, 2006). This is the case because exploration is most adaptive when the individual knows little about the world, and juveniles from all species have less knowledge than adults (Blanco & Sloutsky, 2020, 2021). But juveniles from different species don't explore at the same rate or to the same extent. We argue that species with parental care explore more because the major costs associated with exploration (e.g., resource shortage risk) are outweighed by parental caregiving investments. Humans are a case in point here because human's juvenile period is longer than in any other species and allows for a long early protected period which can be devoted to cognitive and spatial exploration (Del Giudice, 2014; H. Kaplan & Gangestad, 2004). In fact, studies have shown that while chimpanzees start being autonomous around 3 years old, individuals in modern hunter-gatherers societies are still dependent on their parents and kin up until 25 years old for feeding and protection (Bogin, 1997; H. Kaplan et al., 2000). This suggests that, while primates need to stop exploring very early on, human children can continue to play, learn and explore their environment for a very long period of time before reaching puberty (Del Giudice, 2014). Researchers agree that human's prolonged childhood is central to our unique intelligence (e.g., Gopnik et al., 2017; Piantadosi & Kidd, 2016; Tomasello, 2019).

Many evolutionary anthropologists and developmental biologists argue that this extended childhood stage is in fact a pivotal human adaptation. This life stage would have evolved in humans so that juveniles could have had the opportunity to acquire new foraging skills (H. Kaplan et al., 2000; H. Kaplan & Robson, 2002), social skills (Flinn & Ward, 2005), spatial skills (Piccardi et al., 2014), and reasoning skills (Buchsbaum et al., 2012). Therefore, skill learning would be the primary function of this long-lasting life stage. It can only work because, in return, older individuals compensate for the low productivity of juveniles with huge investments of time and resources (H. Kaplan et al., 2000). It can be seen as an adaptive feedback loop or as an adaptive developmental division of labor (Buchsbaum et al., 2012; Gopnik, 2020; Gopnik et al., 2017; H. Kaplan et al., 2000; Sumner, Steyvers, et al., 2019). Such learning advantages of the extending childhood life stage explain why it evolved despite the heavy evolutionary costs associated with late reproduction.

In behavioral and cognitive sciences, much experimental evidence supports this idea. First, there is evidence that parental investments make early exploration possible: cues of parental support or even the mere presence of a parental figure enhance exploratory behavior in children (Belsky et al., 1980; Rubenstein, 1967; Snell-Rood & Snell-Rood, 2020; Tottenham et al., 2019). Second, in some circumstances, children are more motivated to explore or better skilled at exploration than adults. From early in development, children seek causal explanations by asking questions about their

environments (Liquin & Lombrozo, 2020a, 2020b). Younger children explore alternative uses of a tool more than older children (Defeyter & German, 2003) and explore more flexibly alternative hypothesis than older children and even adults in problem-solving tasks (Gopnik et al., 2017). Finally, children spend significantly longer time exploring their environments and explore at a higher rate than adults do (Blanco & Sloutsky, 2019, 2021; Gopnik et al., 2017; Schulz et al., 2019; Sumner, Li, et al., 2019; Sumner, Steyvers, et al., 2019).

To take one example, in an experiment with two sources of reward, children of age 5 to 12 collected fewer rewards than adults because they explored more (i.e., they switched more between the two sources of reward, even though one had higher payoffs), but, on the other hand, they were significantly more likely to detect an important change in reward opportunities, that a majority of adults missed because of their exploitative strategy (Sumner, Li, et al., 2019; on the costs of selective attention, see Blanco & Sloutsky, 2019; on learning traps, see Rich & Gureckis, 2018). The same kind of experimental design and the same results have been found with children doing a bandit task (Sumner, Steyvers, et al., 2019), a reinforcement learning task (Liquin & Gopnik, 2019) and a change-detection task (Plebanek & Sloutsky, 2017): children outperform adults because the latter missed information that children got through prolonged exploration. These results suggest that adults maximize payoffs at the cost of exploration and that, conversely, children invest more in exploration and thus miss fewer learning opportunities (Blanco & Sloutsky, 2019).

Finally, further experimental research showed that children learn more from exploration than adults (Bonawitz et al., 2012; Sim & Xu, 2017a). For instance, experimental research in cognitive developmental psychology showed that children learn new, unexpected or unusual causal relationships better (e.g., more rapidly, with fewer events) than adults do (Gopnik et al., 2015, 2017; Lucas et al., 2014; Sim & Xu, 2017b).

4.4.2. Exploratory preferences and ecological conditions

Adaptive plasticity is the idea that individuals can adaptively express a range of different phenotypes depending on the state of the local ecology (Baumard, 2017; Frankenhuis & Nettle, 2020). More specifically, natural selection has favored psychological preferences that can flexibly adapt to different environments, so that the behavioral 'programs' associated with such preferences maximize fitness in each of them. We argue that a substantial part of the variability in exploratory preferences, across time and populations, can be explained with adaptive plasticity. If exploration is more

beneficial and less costly in some environments than in others, natural selection should have favored the expression of stronger exploratory preferences in such environments.

This is what behavioral ecologists commonly observe. Across species, exploration is sensitive to the level and steadiness of resources in the local environment (English et al., 2016; Humphreys et al., 2015). For instance, studies with rats showed that exploratory behavior decreases with adversity in life (Spivey et al., 2008). The same results have been found in other species such as black-capped chickadees (Rojas-Ferrer et al., 2020), sixty-one different parrots species (Mettke-Hofmann et al., 2002), vampire bats (Carter et al., 2018), honeybees (Katz & Naug, 2015), wild spotted hyenas (Benson-Amram & Holekamp, 2012), and orangutans (Damerius et al., 2017; van Schaik et al., 2016). This is also true in humans, who innovate and are more creative and opened to new experiences in affluent and safe societies (Baumard, 2019; Inglehart, 2018). Empirical studies on human behavior have consistently supported this hypothesis: individuals with high and steady levels of resources are more ready to explore novel information and new rewards (Frankenhuis et al., 2016; Jacquet et al., 2019; Nettle, 2019). In sum, many species including humans become more exploratory under the condition of relative safety.

These findings are best explained by the level of risks raised by exploratory behavior in different ecologies. In unsafe and poor ecologies, exploration is very risky, notably because if exploration doesn't pay off, one is left with nothing. Relatedly, the opportunity costs of exploration are higher in scarcity because one is better off providing for more pressing needs. Conversely, in more affluent and safer ecologies, such risks are lower: when surrounded by more resources, individuals can afford to lose some of them in the short-term (Baumard, 2019). For instance, field observations suggest that wild orangutans avoid novelty while zoo orangutans are a lot more curious and explorative, with the very same tests. This contrast is best explained by the ecological differences between the two environments: captive apes are fed and protected, and the risks of exploration such as resource shortage or predation are removed (Damerius et al., 2017; van Schaik et al., 2016). In line with this idea, there is much evidence that animals adaptively reduce their exploration rate as predation risk increases (Verdolin, 2006).

The example of the risk of resource shortage is another good test case here. Spatial exploration for foraging involves many risks related to resource collection. More specifically, it involves crucial opportunity costs such as waiting costs, i.e., the costs associated with delayed (as opposed to immediate) collection of resources (Boon-Falleur et al., 2020; Mell et al., 2019). Multiple optimal

foraging models emphasize the discrepancy between the immediate risks of an exploratory strategy (e.g., the decrease of the resource levels during search time) and the positive value of the acquired information for future exploitation (e.g., Eliassen et al., 2007; Maspons et al., 2019). In fact, exploration is best seen as an investment which is costly in the short-term but beneficial in the long-term, that is, a risky investment that organisms should only 'prefer' to make in safe and affluent ecologies.

This line of argument suggests that it is only in an affluent environment that humans should afford to invest more in unpredictable exploratory activities (Baumard, 2019). It is also true if we consider the cultural evolution of human societies. It is well-established that, during the 20th century, economic development is associated with more tolerance, more optimism, more interest in science and less interest in religion (Inglehart, 2018; Norris & Inglehart, 2004). Similar observations can be done over the longer term: economic development in ancient societies is associated with more tolerance (Martins & Baumard, 2020; Safra et al., 2020) and more exploration (Baumard, 2019; de Courson & Baumard, 2019). To sum up, when resources are high, exploration is less risky and, thus, more likely to be advantageous. Therefore, in such conditions, phenotypic plasticity adaptively promotes and enhances exploratory preferences.

5. Exploratory preferences explain the cultural distribution of imaginary worlds

While preferences for exploration is a human universal, the strength of exploratory preferences varies greatly from one individual to another. In this section, we argue that the variability in exploratory preferences partly explain individual differences in the preference for fictions with imaginary worlds, and therefore the cultural distribution of imaginary worlds across time, space, and population. We derive three predictions from this idea: (1) fictions with imaginary worlds should be more attractive to people high in Openness to experience, a personality trait measure used as a proxy for exploratory preferences, (2) younger individuals, for which exploration is less costly and more advantageous, should be more drawn to imaginary worlds than older individuals, and (3) individuals living in more affluent environment, where exploration is less risky and more adaptive, should have higher preferences for imaginary worlds.

5.1 Imaginary worlds should be more attractive to people higher in Openness to experience

If imaginary worlds co-opt our exploratory preferences, the appeal for imaginary worlds should be associated with Openness to experience, a component of the 'Big Five' related to exploratory preferences (Carbone et al., 2020; Meneghetti et al., 2020). This is indeed the case. In a recent paper, Nave et al. (2020) studied the association between personality traits and the 'liking' of movies in Facebook users (N=3,5 million). Using the same dataset, we show that higher scores in Openness to experience are associated with a preference for imaginary worlds (Dubourg et al., 2021). It is worth noting that, by contrast, fictions with imaginary worlds are associated with lower levels of Extraversion, Conscientiousness, Agreeableness and Neuroticism (Dubourg et al., 2021).

Because Openness to experience is positively correlated with intellectual curiosity and higher academic achievement (Hakimi et al., 2011; Sorić et al., 2017), it can be further predicted that people with a preference for fictions with imaginary worlds should have higher academic achievement. This is also the case. Consumers of fictions with imaginary worlds seem to be highly educated, compared to the general population. For instance, 82,4% of the survey with science fiction and fantasy fans report being educated to university level or above (Menadue & Jacups, 2018). This compares to 46% of the United States population, 50% of Australians, and 46% of the United Kingdom population (Organization for Economic Co-Operation and Development, 2017). This reinforces previous audience data that found "astonishing" high levels of education among the science fiction readership (Berger, 1977, p. 236). Future research could notably test whether people who preferably consume fictions with imaginary worlds also preferably read informative non-fiction books, as well as other world-dominant fictions such as historical novels.

Openness to experience is also associated to more exploration in the social domain. People high in Openness to experience are indeed more likely to be tolerant of diversity, liberal, opened to new lifestyles and opposed to right-wing political orientations (Butler, 2000; Sibley & Duckitt, 2008). We thus predict that people who like imaginary worlds should be, overall, more politically tolerant, and socially liberal. This reasoning also predicts that people who enjoy imaginary worlds should prefer fictions exploring new social roles (Mar, 2018; Mar & Oatley, 2008). In line with such predictions, recent research has observed that fans of fictions with imaginary worlds are more politically progressive and committed against prejudice (Besson, 2021). Future empirical work could test this prediction.

In sum, we hypothesize that the preferences for imaginary worlds should be associated with a cluster of cultural preferences (e.g., more progressive political opinions, higher consumption of informative essays and historical novels) associated with Openness to experience.

5.2. Imaginary worlds should be more attractive to children, teenagers, and young adults

In **section 4.4.1.**, we reviewed research showing that children have stronger exploratory preferences than adults and, in some conditions, even explore more than adults. For instance, in multiple experiments, they explored longer and generalized information from fewer events. We showed that this extended life stage can in fact be seen an adaptation: major costs associated with exploration are outweighed by parental investments, so that children can 'afford' to be more exploratory. We thus hypothesize that children are more attracted to fictions with imaginary worlds.

In line with this hypothesis, we commonly observe that humans develop an early interest for imaginary worlds. Psychological research has shown that, very early on, children produce imaginary worlds in their heads (Silvey & MacKeith, 1988; Taylor et al., 2020). More importantly, consumers of fictions with imaginary worlds are typically (and, according to our hypothesis, accurately) stereotyped as young (Besson, 2015; Jenkins, 1998; Proctor & McCulloch, 2016). For instance, young readers are targeted by massively consumed novels in the fantasy genre, sometimes adapted for the screen with unparalleled successes. Let's think of Tolkien's *The Hobbit* (1937), Horowitz's *Groosham Grange* (1988), Riordan's *Percy Jackson* (2005-2009), Rowling's *Harry Potter* (1997-2007), Pullman's *His Dark Materials* (1995-2000), Saint-Exupéry's *The Little Prince* (1943) and Colin's *Hunger Games* (2008-2020). All these highly successful books with their famous imaginary worlds are edited in the children's collections from the publishing houses. We can further illustrate this point by mentioning the Walt Disney Studios, the single most productive and lucrative studios for children films. It is commonly observed that a majority of Disney films is based on the exploration of imaginary worlds (Elza, 2014). For instance, in *Alice in Wonderland* (1951), Alice decides to explore Wonderland (as in the children novel by Lewis Carroll) and in *Peter Pan* (1953), Wendy and his two brothers decide to explore the imaginary world of NeverLand.

Empirical research partly confirmed this prediction. In a study on the correlation between literary taste patterns and social differentiation in Finland, age was the only variable which significatively decreased the liking of speculative fictions (a proxy for fictions with imaginary worlds; see **section**

2), whereas age had no such effect on other fictional genres (Purhonen et al., 2009). In Dubourg, Thouzeau et al. (2021), we found a significative and negative correlation between age and a preference for movies with imaginary worlds: such movies tend to be liked by younger people. To our knowledge, our approach is the only one that consistently explains this strong association between the preference for imaginary worlds and the age of consumers.

5.3. Imaginary worlds should be more attractive to people living in more affluent environments

In **section 4.4.2.**, we have also shown that exploration is more adaptive in a predictable and affluent ecologies, because of the risk variable involved in the exploration-exploitation trade-off. If the level of resources in the local environment is high and steady enough, individuals can afford to delay potential benefits and to take risks: they become more motivated to explore the real world. We therefore predict that, both at the level of the individual and at the level of societies, affluence is a good predictor of the preference for imaginary worlds.

This prediction is in line with empirical findings. A recent empirical survey (N=909) provided insights about the socio-economic status of science fiction and fantasy fans (Menadue & Jacups, 2018). To the question about income satisfaction level, most respondents answered: "I do well enough" (54,1%), and 32% answered "I'm happy with what I have" or "I have more than I need". Such readers also have curious and open-minded psychological traits. For instance, 95,2% reported they found new and unfamiliar ideas easy to understand. Because this study is based on a selected sample, we lack data to compare these results with the socio-economic status of readers of other fictional genres, but it still confirms that consumers of fictions with imaginary worlds fit this general prediction. In another study, in Finland, speculative fictions were found to be significantly more read by people with higher income, whereas income as a variable had no such effect on the consumption of other genres (Purhonen et al., 2009).

At the global level, our hypothesis predicts that imaginary worlds should be more popular and therefore emerge in economically more developed countries. In line with this idea, the very first imaginary world comparable in size to the real world, Tolkien's world Arda, is extremely recent. Before 1914 (the first developments of Arda by Tolkien), humans had long begun to produce and consume literary fictions, and they didn't lack any cognitive abilities that would have prevented them to invent large imaginary worlds with much background information. However, only a few

stories had developed large imaginary worlds (e.g., Dante's Hell) and virtually none had been precisely described and mapped. We argue that the late appearance of imaginary worlds is explained by the evolution of the strength of exploratory preferences. For a long time, people's exploratory preferences were too weak to give rise to the production of imaginary worlds in fictions. Economic development made such preferences adaptive in some populations, and only then could imaginary worlds appear and be culturally successful.

In fact, modern imaginary worlds first appeared in the United Kingdom (Wolf, 2013), which was at the time the leading country in term of GDP per capita (Manning, 2017), and then mostly developed in the Euro-American sphere (e.g., France, the United-States, Germany) and in the 50's in Japan. By contrast, while Jules Verne was first translated in Chinese in the early 20th and inspired Chinese writers to write science fiction and fantasy stories during the late Qing dynasty and early Republican era, fictions based on imaginary worlds remained marginal in Chinese literature during the 20th century (Jiang, 2013). Imaginary worlds started to become popular first in Hong-Kong and Taiwan, which started to develop in the 1970', and really became mainstream in mainland China in the turn of the new millennium, that is, 20 years after the take-off of the Chinese economy (Song, 2013).

In a recent empirical work (Dubourg et al., 2021), we studied the evolution of the share of fictions with imaginary worlds in 11 countries, since the beginning of the 19th century, with data extracted from Wikidata (N=44,608). In most countries, when GDP per capita increases, the share of fictions with imaginary worlds rises too. We also studied another indicator of success, namely the box-office of films with imaginary worlds in the United States (Dubourg et al., 2021). An indicator of the success of films with imaginary worlds (IWS indicator) was computed by subtracting, for a given year, the mean box-office of films with imaginary worlds and the mean box-office of films with no imaginary worlds, in the United States. This indicator is highly and positively correlated to the GDP per capita in the United States. It even becomes positive: above a certain threshold of GDP, films with imaginary worlds generate more revenues than others do. It would be interesting to test whether the quantitative analysis of the success of films with imaginary worlds and its association with affluence indicators replicate in non-Western developed countries (e.g., Japan, Korea) and developing countries (e.g., India, Nigeria).

Finally, it is interesting to note that as societies become safer and more affluent, people seem to grow out of the fondness for imaginary worlds at a later and later age. We argue that this is the case

because, in such local environments, people should afford to remain explorative longer. This would explain why a new target audience has recently emerged, the 'young adults', with associated editorial collections (i.e., YA literature) often specialized in speculative fictions with imaginary worlds. Future empirical research could focus on this prediction that in more economically developed societies, across both time and space, the mean age of fans of imaginary worlds is higher. This hypothesis lay the ground for a more general research program in behavioral sciences on the longer hold of children cultural preferences in modern societies.

6. Exploratory preferences shape the content and form of fictions with imaginary worlds

We argued that human's exploratory preferences, determined by ecological conditions and the life stage of the individuals, explains the cultural distribution of imaginary worlds, that is, the individual differences in the preference for imaginary worlds, the timing of their appearance in cultural history, and the variability of their success across societies and across populations. In this section, we focus on modern and contemporary culture. We hypothesize that, as soon as fictions with imaginary worlds emerge as a competitive market, their form and content should be shaped by what best co-opt humans' exploratory preferences. The basic idea is that cultural items compete for the attention of audiences and, therefore, producers are likely to intensify appealing stimuli to increase the success of their works. For instance, Walt Disney's Mickey co-opts our visual preference for baby faces. It has been shown that the evolution of its design is driven by this preference: across the last decades, Mickey progressively became cuter, that is, more baby-like, with larger heads and more doting eyes (Gould, 2008; Hinde & Barden, 1985). Likewise, because films have competed for the attention of moviegoers since the beginning of cinema, they have undergone continual changes. For example, over time, films have gotten faster (shot lengths have decreased) and darker (luminance have decreased), to better grab the attention of the viewers and improve their engagement in the film (Cutting et al., 2011).

This 'superstimuli' hypothesis (or 'stimuli intensification' hypothesis) posits that, as soon as enough people were safe and rich enough that strong exploratory preferences emerged and made imaginary worlds culturally successful (i.e., after second WWII in Europe and North America), producers started to invent, selectively retain, and cumulatively refine features that best exploited exploratory preferences, to make their imaginary worlds more appealing than other ones. From this point,

several predictions follow, two of which we detail in this section: across time, (1) information background should increase in fictions with imaginary worlds, and (2) more particularly, fictions with imaginary worlds should generate more and more 'paratexts' (i.e., information devices that surround the fiction; Genette, 1997).

6.1. Fictions with imaginary worlds should generate more and more non-narrative background

At the ultimate level, the function of exploration is to accumulate new information and maximize the usefulness of knowledge for future rewards (see **section 4.1**). This means that any new information about the real world (e.g., the localization of a foraging site) and any device making such information easier to learn (e.g., navigation systems) should attract the human mind. If the appeal for imaginary worlds indeed exploits such exploratory preferences, fiction makers should target this evolutionary function by generating, in their fictions, more and more apparently useful background information leading to a better grasp of the imaginary environment.

This prediction appears to be validated by the cultural evolution of imaginary words. First, as time goes by, imaginary worlds are more and more precisely detailed in literary texts (Wolf, 2021). Tolkien's world is a case in point. It is remarkable that never before in the history of literature had there been such a comprehensive imaginary world. Imaginary worlds existed in ancient literature (see **Table 2**) but they were never thoroughly described and documented. Since Tolkien, though, many imaginary worlds have been extensively developed with much information about the settings (Wolf, 2013). This observation is perfectly in line with our prediction: now that humans' exploratory preferences are heightened, any piece of background information about the world becomes an even more interesting stimulus, that fiction makers can target. Why would consumers memorize so well so much information that yet only apply to the imaginary world? For instance, fans of *Harry Potter* know Quidditch rules, fans of *Star Wars* know the names of the planets, fans of *Game of Thrones* know the geography of Westeros, and fans of *Pokémon* know the evolution of each specimen (e.g., Delle, 2015). Such a list of useless (but effective-seeming) pieces of information about imaginary worlds that hundreds of millions of people learn, retain, and debate about, could go on and on (Besson, 2015). A case in point: such information is not only memorized but also organized and stored online by fans: there is a 'fandom' encyclopedia-like website for each famous imaginary world. To take one salient example, the online encyclopedia about *Star Wars* had 167,792 pages at the time of writing this paper.

Because background information has become an attention-grabbing stimulus, it should be intensified in fictions, that is, it should eventually become a 'superstimuli'. This is what fiction makers do: they expand the amount of information made available for a given imaginary world. Wolf (2018) defines the 'size' of an imaginary world as "the number of world data describing it". Importantly, this should not be mixed up with the 'scope' of an imaginary world, which is the extent of the space covered by the imaginary world (e.g., an imaginary village, an imaginary planet). An imaginary world can be large but poorly described and, conversely, small in scope but very dense in details. We can now refine our prediction by saying that, because of humans' exploratory preferences, imaginary worlds with more world data should be more successful at a given time and, therefore, world data should increase. In sum, the size of imaginary worlds should progressively be intensified, regardless of their scope. Therefore, our hypothesis posits that exploratory preferences explain why "we are drawn to master what can be known about a world which always expands beyond our grasp" (Jenkins, 2006).

This is a strategy largely observed in video games, which rapidly evolved to include open imaginary worlds that the players can freely explore with 'sandbox' gameplay: the player is given a great degree of freedom in the gradual discovery of the world. A case in point: in most open-world video games, the map of the imaginary worlds is not revealed right away, and one of the player's goal is to unveil it (Bartle, 2004). This is also the case in films and novels. Imaginary worlds are never precisely described at once, for instance at the beginning of the fiction. Rather, information about the otherworldly settings comes progressively as the narrative unfolds, keeping our curiosity alive. For instance, the *Star Wars* galaxy is composed of many environments that are revealed in the course of the story. Crucially, such planets, to which characters travel by high-speed spaceships, are highly different from one another (e.g., Tatooine is a desert planet, Dagobah is a jungle planet, Hoth is an ice planet). Another option for producers of fictions is to add more world data in other fictions set in the same imaginary world (Besson, 2015; Wolf, 2021), and sometimes from different media platforms. This gives rise to transmedial imaginary worlds (Konzack, 2018; Rebora, 2016) and to media franchises (Besson, 2015). For instance, Rebora (2016) argued that fantasy is "the best fitting literary ground for any transmedial expansion". Let's note that among the 20 highest-grossing media franchises, more than half are fictions set in an imaginary world (Wikipedia, 2021).

To further test this prediction that background information about imaginary worlds increases and makes fictions with imaginary worlds more successful, one could further operationalize the

quantity of world data about imaginary worlds and look at the evolution of this measure over time. To do that, one could use a semantic tool that encodes spatial structure of worlds from literary texts (Louwerse & Zwaan, 2009). It has already been done with Tolkien's Middle Earth (Louwerse & Benesh, 2012). If applied to enough literary fictions, this tool could measure the cultural evolution of the informational complexity of imaginary worlds.

6.2. Fictions with imaginary worlds should generate more and more paratexts

Information about imaginary worlds can be more or less organized. It can be transmitted in a natural way, as in everyday life, but it can also use artificial devices such as maps, lists or genealogies that greatly increase our ability to manipulate, store and organize vast amounts of information (Goody, 1986). We thus predict that information devices leading to a better grasp of the information embedded in fictions with imaginary worlds should be appealing and should therefore increase in number across recent time.

In line with this prediction, paratexts (Genette, 1997) such as maps, guidebooks, appendices, lists, family trees, footnotes or glossaries recently emerged in fictions with imaginary worlds, and became rapidly mainstream (Saler, 2012). In particular, maps attract our attention because they deliver spatial information about imaginary worlds. The fictional map in Stevenson's *Treasure Island* (1881-1882), one of the first imaginary map, is partly what drew consumers to this book (Wolf, 2013). This suggests that people at that time rapidly became curious with non-narrative fictional artefacts. Since then, a substantial and growing part of fantasy fictions is released with maps of the imaginary worlds (Ekman, 2013). Some maps, such as Thror's map in *The Hobbit* and the Marauder's Map in *Harry Potter*, are used by the characters in the fictions. Even if a map is not provided by the producers of the fiction, some fans always compile spatial information in the fiction, create their own maps and put them online. This suggests that virtually all imaginary worlds have been mapped, be it my fiction makers or by fans. Maps are even more useful in open-world video games, because gamers interact with the game world (Haggard & Chambon, 2012; Nguyen, 2019; Tanenbaum & Tanenbaum, 2009). Such video games always include an interactive map which allow the players to find their way around the world (Akchelov & Galanina, 2016; Nitsche, 2008; Wolf & Perron, 2014).

But maps are not the only kind of information device made available by fiction makers to increase the appeal of their fictions. Fictions with imaginary worlds can also include informational texts, either in the fictions (e.g., the Encyclopedia Galactica in *Foundations*) or published after the release of the fiction as real-world books (e.g., *Pandorapedia*, James Cameron's encyclopedia of Avatar's

imaginary world Pandora, and Harry Potter Schoolbooks). Such guidebooks can even be written by other people than the creator and still be successful (e.g., *Philip Pullman's His Dark Materials: The Definitive Guide* by Laurie Frost). They almost all contain, among other things, hierarchized information about creatures, locations, and plants, as well as family trees of the protagonists. This information is also widely available online, notably in the 'fandom' encyclopedias. 'Pottermore' is yet another illustration of this trend: Rowling herself created a website for the sole purpose of providing more background information about the 'Wizarding World' of Harry Potter. Finally, guidebooks for video games are highly successful worldwide. For instance, the guidebook to *Final Fantasy VIII* is an actual best-seller, with 2.2 million sold copies over the world. It is part of the Japanese guide series Square Enix companion books, which is by far the best-selling guide series about imaginary worlds, and largely outgrows any series of encyclopedia of the real world in terms of revenue.

6.3. Limitations of the 'superstimuli' hypothesis

Further research should investigate if this stimuli intensification has limits: not enough world data could be disappointing or even boring, but, conversely, too much world data could be bewildering, frustrating or too complex, exactly like the attraction to novelty (Andersen et al., 2020; Clark, 2018; Kidd et al., 2012; Kiverstein et al., 2019). This limitation has been mentioned in other studies about stimuli intensification in fictions. For instance, Gessey-Jones et al. (2021), studied the network of character interactions in George R. R. Martin's epic novels, *A Song of Ice and Fire* and found that the degrees of the most connected characters reflect a cognitive limit on the number of concurrent social connections that humans tend to maintain (see also Dunbar, 2017). It is likely that similar limits constrain the size of imaginary worlds.

The example of *No Man's Sky* (2016) is compelling: through procedural generation of worlds, this video game includes over 18 quintillion planets, with as many different imaginary environments which can be explored with complete autonomy from the players. Before its release, it was expected to be a major hit in the video game industry precisely because it was announced to be the biggest explorable game world (Morris & Hartas, 2004). Yet, it has been less successful than other exploration-based video games (only 68% of users' evaluations are positive on the popular ranking website for video games *Steam*). Further experimental research could assess whether people are reluctant about virtually infinite imaginary worlds and, if so, why. This is a burning issue for the video game industry because technological improvements make such developments technically feasible, while our cognitive constraints might not make them desirable.

7. Discussion

7.1. Remaining questions and alternative explanations

In research fields interested in fictions, there has long been a focus on "who" and "how" questions, about plots and protagonists, at the expense of "where" questions, about settings, probably because of our narrative-oriented understanding of fictions. As Ryan recently wrote, "narrative space remains a relatively unexplored territory" (Ryan, 2014). In this article, we have provided evidence that narrative spaces, and in particular imaginary worlds, are central in modern fictions partly because they tap into human's preferences for exploration, which have been co-opted by cultural evolution for entertainment. Obviously, more research is needed to further test this theory. For instance, we need to be able to quantify the size of imaginary worlds, that is, the amount of background information associated with a particular world. The existence of clusters of cultural preferences (e.g., imaginary worlds and historical novels) should also be tested rigorously. Besides, many questions remain unsolved: what exactly is the cultural advantage of fictions with imaginary worlds over non-fictions describing the real world (e.g., history books, travel books)? Why are medieval fantasy and space opera so attractive, compared to other imaginary worlds? Is there an ideal cognitive trade-off between too much imagination and too much similarity with the real world? To our knowledge, no empirical research has tested the limits of the processing of novelty in human culture.

On another note, other sets of cognitive mechanisms might play an important role in the appeal for imaginary worlds, and we do not rule out other complementary explanations. For example, systemizing seems central in the appreciation of world-dominant fictions, be it with an imaginary world (e.g., *Star Wars*), or not (e.g., *Sherlock Holmes*). Indeed, while humans are lured by new environments, there is much evidence that they also prefer rich and organized ones (S. Kaplan, 1987). This might come from our drive to systemize (Baron-Cohen, 2002) and from our cognitive mechanisms which make us intuitively think about plants and animals in highly structured ways (Atran, 1998). This hypothesis is consistent with recent cognitive frameworks stating that curiosity seeks both novelty and complexity to maximize knowledge acquisition (Brändle et al., 2020; Dubey & Griffiths, 2020). This echoes the 'encyclopedic impulse' scholars in cultural and literary studies targeted to explain the attractiveness of world-dominant fictions (Besson, 2015; Eco, 1997; Wolf,

2013). It leads to testable predictions about sex differences in cultural preferences for highly structured imaginary worlds.

7.2. Exploratory preferences and other cultural trends

On the other hand, our hypothesis could explain other trends in the cultural evolution of fictions. For instance, fanfictions (i.e., fictional writings written by fans and based on previous canonical fictional works) have become highly mainstream in many countries (e.g., *dōjinshi* in Japan, Star Trek fanzine in the United States) and are beginning to be taken very seriously by consumers and the publishing industry. Gamers too started to computationally create more content for their favorite video games, with the intention of sharing it with others. Such alterations of the games are called 'mods' (short for 'modifications'). More and more game studios create mod tools to ease this process on the fan's side. This massive cultural phenomenon, with fans reshaping and improving video games for the sole benefit of the mod community, and free of charge, has been overlooked in psychological and cognitive research fields (Poor, 2014; Sotamaa, 2010). It has never been put in parallel with literary fan fictions nor with the literature on exploration and curiosity. More generally, the motivation behind unpaid user-generated content (UGC) has mainly been explained with social benefits (Chavez et al., 2020; Crowston & Fagnot, 2018; Daugherty et al., 2008; Omar & Dequan, 2020; Sun et al., 2017) and economic incentives (Poch & Martin, 2015). We argue that our hypothesis could better explain this drive to create new cultural content without any direct return on investment. It relates to the examples we mentioned of many animals that explore even in presence of other primary rewards, and even with experimentally added costs. Humans seek so much for new information that this may well push fans to create new content, even at some costs. In other words, according to our hypothesis, modders, writers of fan fictions and other participants of UGC are best seen as curious explorers.

Our hypothesis could also contribute to clarify the cognitive bases of other types of fiction, such as interactive books, films and TV series (e.g., *Black Mirror: Bandersnatch*, 2018), or, to a lesser extent, crime, mystery, horror and detective fictions. These genres arguably tap into our exploratory preferences, but not into spatial exploration per se. Rather, they seem to exploit an uncertainty-based form of exploration. We therefore believe fictions in these genres target the related mechanisms designed to minimize uncertainty, seek for reason-based explanations (Gottlieb et al., 2013; Grodal, 2010; Liquin & Lombrozo, 2020a), and detect and evaluate arguments (Mercier, 2016).

7.3. Imaginary worlds and the cultural evolution of fictionality

Our theory about the cultural evolution imaginary worlds can be put in the wider perspective of the cultural evolution of fiction. We argue that fictionalization has been a gradual process. As it has long been noted by literary historians and literary theorists (Bakhtin & Emerson, 1984; Cave, 1999; Lavocat, 2016; Lévi, 1995; H. Lu, 1994; X. Lu, 2000; N. D. Paige, 2011; Postel, 2019), the most ancient fictions such as The Greek and Indian epics, the Greek and Latin tragedies, and the Arthurian romances, all tend to feature characters (e.g., gods, heroes, kings) already known to the audience, with plots that are themselves known (e.g., the Trojan War, the story of Tristan and Iseult), and in already familiar worlds (e.g., Troy, the court of King Arthur). As Bakhtin famously wrote: in the epics, "the special interest in the 'end' ('How will the war end?', 'Who will win?', 'What will happen to Achilles?' etc.) is totally excluded". In ancient fictions, creators mostly invent new versions of old stories, with new scenes or secondary characters. The other possibility is that they take the form of anecdotes, legends, *chuanqi* (i.e., 'tales of the strange' or 'records of the anomalies'), *novella* (i.e., news), which they relate as true, as having really happened to someone they know. It is only gradually that the stories will become fictionalized both by the inclusion of completely new characters and intrigues, and by the progressive abandonment of the claim to veracity.

Thus, we argue that the important question is not whether people in ancient societies 'believed' in their fictions (Veyne, 1988) but to which degree their narratives were truly fictional. We argue that in ancient time, such stories were not 'as fictional' as they can be in modern societies. This would explain why, for instance, Chinese people recognized fictions not before the Ming and Ch'ing dynasties, only when they 'dehistoricized' narratives (H. Lu, 1994). Consistently, data-driven studies show that it is only in the 17th century in England that fiction makers started to write fictions about 'nobodies', that is, characters that are completely unknown to the audience (N. D. Paige, 2020). It marked the beginning of the 'novel' (Bakhtin & Emerson, 1984; Cave, 1999; H. Lu, 1994; N. D. Paige, 2011). In this perspective, imaginary worlds can be thought as the ultimate step of this fictionalization process that started centuries ago: after having fictionalized the events and the protagonists, fiction makers started to fictionalize the settings, giving themselves even more freedom to intensify all stimuli in the fictions.

7.4. Broader concluding remarks

We now discuss some broader conclusions our paper brings about. First, our paper adds further support to the cultural attraction theory according to which human culture is influenced by our

cognitive biases (Boyer, 2018; Claidière et al., 2014; Claidière & Sperber, 2007; Morin, 2016; Scott-Phillips et al., 2018; Singh, 2019). Culture is neither faithfully nor randomly transmitted, but rather reconstructed in a way shaped by our cognition. The cultural evolution of imaginary worlds is one example of this cultural evolutionary process: a set of cognitive mechanisms which evolved to solve the adaptive trade-off between exploration and exploitation drives the evolution of fictions with imaginary worlds. Following this view, we disentangled two main paths through which imaginary worlds culturally evolved: imaginary worlds have emerged and changed over the course of history (1) because our exploratory preferences evolved to adapt to crucial ecological changes, through phenotypic plasticity (**section 5**), and (2) because producers of fictions target and exaggerate already preferred stimuli (**section 6**). Crucially, the combination of these two processes explain both the universality and the cultural variability of imaginary worlds.

Second, we expect that our findings could be relevant for literary theory, cultural history and fiction study. For instance, the existence of distinct genres such as horror, comedy and detective fictions has been said to derive from the involvement of distinct sets of cognitive mechanisms (Clasen, 2010; Clasen et al., 2018; Clasen & Platts, 2019; Fishelov, 1995; Grodal, 2010, 2017). Our work extends this on-going research program and could also support the cognitive studies of fictional media, such as cinema (Jullier, 2018; Tan, 2018). We believe our hypothesis, if supported by more empirical evidence, can also be used by scholars in evolutionary psychology and computational history. The consumption of fictions with imaginary worlds could be used as a behavioral proxy to measure the evolution of exploratory preferences, offering insights on their adaptive flexibility to the changing environments.

Finally, it is our belief that this paper could be relevant outside the research domain, for education and fiction production. The fact that children are intrinsically captivated by imaginary worlds suggests that such fictions should be brought into the classrooms. The links between curiosity and learning being increasingly understood (Gordon et al., 2015; Wade & Kidd, 2019), cultural attraction theory could be a relevant and useful framework to design curiosity-based learning interventions. More generally, exploring which types of fictions exploit which cognitive mechanisms brings about new predictions about the socio-psychological determinants of the attractiveness of specific cultural items. Further research in this domain could lead to more fine-grained and evidence-based individual suggestions of which fictions to read or watch. This would have direct implications for the fiction industry and their recommendation algorithms (Nave et al., 2020).

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