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The Cognitive Foundations of Fictional Stories

An integrative and comprehensive framework

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Abstract: We hypothesize that fictional stories are highly successful in human cultures partly because they activate evolved cognitive mechanisms, for instance for finding mates (e.g., in romance fiction), exploring the world (e.g., in adventure and speculative fiction), or avoiding predators (e.g., in horror fiction). In this paper, we put forward a comprehensive framework to study fiction through this evolutionary lens. The primary goal of this framework is to carve fictional stories at their cognitive joints using an evolutionary framework. Reviewing a wide range of adaptive variations in human psychology – in personality and developmental psychology, behavioral ecology, and evolutionary biology, among other disciplines –, this framework also addresses the question of interindividual differences in preferences for different features in fictional stories. It generates a wide range of predictions about the patterns of combinations of such features, according to the pattenrs of variations in the mechanisms triggered by fictional stories. As a result of a highly collaborative effort, we present a comprehensive review of evolved cognitive mechanisms that fictional stories activate. To generate this review, we (1) listed more than 70 adaptive challenges humans faced in the course of their evolution, (2) identified the adaptive psychological mechanisms that evolved in response to such challenges, (3) specified four sources of adaptive variability for the sensitivity of each mechanism (i.e., personality traits, sex, age, and ecological conditions), and (4) linked these mechanisms to the story features that trigger them. This comprehensive framework lays the ground for a theory-driven research program for the study of fictional stories, their content, distribution, structure, and cultural evolution.

1. Introduction: Fiction as a puzzle about human psychology

Across all societies, humans enjoy engaging with fictional stories, whether transmitted orally or experienced through novels, movies, TV series, video games, or other media (D. E. Brown, 1991; Scalise Sugiyama, 2005; Wiessner, 2014). Data from the OECD Time Use database suggests that today people in various countries, such as the United States, China, Mexico, and France, devote more time to these activities than to socializing or shopping (Ortiz-Ospina et al., 2020). The growing investment of time, money, and energy in these activities is mirrored by the expansion of cultural industries, such as the movie or video game industries, which have evolved into multi-billion-dollar global markets. What makes such fictional stories so appealing? And what drives their evolution?

The space of possible fictional stories might seem infinite, as suggested by some philosophers and scholars in the study of fiction (Doležel, 1988, 1998; Ryan, 1991). We do observe a huge diversity of stories transmitted, in the form of tales, movies, novels, comic books, manga, poetry, or video games. The recent accumulation of genres (e.g., Thriller, Fantasy) and subgenres (e.g., Crime thriller, Sword and sorcery) to categorize such stories is a case in point. Yet, we argue that this space is *not* infinite and is in fact highly constrained—not so much by a lack of computational power, as the human mind is capable of simulating innumerable narrative scenarios, but rather by human *preferences*. Creators of fiction are primarily driven by the goal of crafting stories that catch attention and resonate with their audience. Consequently, human psychological preferences constrain the possibility space of viable fictional stories (Dubourg & Baumard, 2022a).

If this premise is correct, understanding the origins and workings of these preferences is essential for deciphering the content, structure, distribution, and evolution of fictional stories. Our framework is derived from recent developments in evolutionary psychology, evolutionary anthropology, behavioral ecology, cognitive neuroscience, and related fields, all of which emphasize the need for a nuanced understanding of the human mind to fully grasp the appeal of fiction (Bloom, 2010; Boyer, 2018; Pinker, 1997). For example, explaining the allure of love stories requires understanding the intrinsic human motivation to fall in love in real life. The same principle applies to science fiction, war fiction, or horror stories, which demand explanations of human interests in innovative technology, coalitional conflicts, or real-life dangers.

This evolutionary cognitive perspective on culture (André et al., 2020; Boyer, 2023; Claidière & Sperber, 2007; Singh, 2020; Sperber, 1996) has encouraged, and grown in line with, interdisciplinary works at the intersection between the humanities and the natural sciences (Barash & Barash, 2006; B. Boyd, 2018; J. Carroll, 2012, 2018; Durante & Griskevicius, 2018; M. Fisher & Salmon, 2012; Gottschall, 2012; Nettle, 2005b; Saad, 2012; Salmon, 2016; Scalise Sugiyama, 2005; Singh, 2021). Within this tradition, fictional stories gain cultural traction and success by aligning with human preferences (Acerbi, 2023; Berl et al., 2021; Stubbersfield, 2022; Stubbersfield, Flynn, et al., 2017). Over time, such stories are cumulatively refined to fit even more such preferences, by getting closer to sweetpots called "attractors" (Claidière & Sperber, 2007; Scott-Phillips et al., 2018). These preferences determine which story features thrive or fade in the realm of storytelling.

Researchers have applied this rationale to a number of cognitive domains (e.g., love, cooperation, competition, threat), to explain the cultural success of specific attractive features in fictional stories (e.g., love stories, likable protagonists, monstrous antagonists, horror scenes; Alberti, 2013; Clasen, 2017; Cox & Fisher, 2009; Jobling, 2001; Kjeldgaard-Christiansen, 2017; Nettle, 2005; van Monsjou & Mar, 2019; Wylie & Gantman, 2023). In this paper, our aim is to provide a comprehensive review of the cognitive mechanisms that impact fictional stories and identify corresponding story features that activate these mechanisms. We present a list of more than 70 mechanisms and associated features in fictional stories. This list is by no means a definitive map of human psychology, and it is obvious that this number is subject to change. A more exact and exhaustive list of cognitive mechanisms could surely be generated, for instance by showing how one purported mechanism is actually a special case of another. We only seek to create one that comprehensively and adequately reflects the current state of knowledge in evolutionary cognitive sciences and related fields, and that would be useful to study human symbolic culture at large. We also focus only on the cognitive mechanisms that can explain the type of stories people consume, not those thare are indispensable for the consumption of any story (e.g., vision, language)

Our systematic literature review aims to address the fundamental question, "What makes fictional stories attractive and pleasurable to human minds?" We do not attempt to resolve two other critical questions related to fiction: "What is fiction?" and "Why fiction?". Although debates surrounding the nature of fiction and the arts (Pignocchi, 2009; Searle, 1975; Walton, 1993) as well as the emerging consensus on the role of communicative intents and pragmatics in fiction (McCallum et al., 2020; Pignocchi, 2012; Schaeffer, 1999; Heintz & Scott-Phillips, 2023), are important issues, they are not central to our framework. Despite our focus on fiction,

we believe that our paper could be relevant beyond fiction studies, to understand the appeal of other cultural productions and phenomena, such as short clips, news, and non-fictional narratives more broadly.

Likewise, we do not address the debate surrounding the function of fiction (Mellmann, 2012). Some have argued that the disposition to tell or to enjoy stories is a biological adaptation, while still disagreeing on a specific adaptive function (Mar & Oatley, 2008; Dutton, 2010; G. Miller, 2001; Morin et al., 2019; Nettle, 2009b; B. Boyd, 2018; Scalise Sugiyama, 2005; Tooby & Cosmides, 2001; van Mulukom & Clasen, 2021; see D. Smith et al., 2017; K. M. Smith et al., 2022, for empirical evidence in small-scale societies). Others have proposed that fiction is a non-adaptive by-product because, as Tooby and Cosmides (2001) put it: "many well-known features of the visual arts, music, and literature take advantage of design features of the mind that were targets of selection not because they caused enjoyment of the arts, but because they solved other adaptive problems such as interpreting visual arrays, understanding language, or negotiating the social world" (see also: Pinker, 1997; Bloom, 2012).

Two authors of this paper proposed yet another alternative: fictional narratives would be technologies that people crafted because the attention they got through their stories provided them with opportunities to flexibly fulfill other adaptive goals, such as enhancing one's reputation or transmitting knowledge to one's kin (Dubourg & Baumard, 2022). In this case, the benefits for the consumers would be less clear (André et al., 2023; Dubourg et al., 2021; for an argument in the framework of signalling theory, see: Verpooten, 2023; De Tiège et al., 2021). In any case, to be able to share fictional stories, humans seem to recycle preexisting cognitive mechanisms that have evolved for other purposes, such as mechanisms related to simulation and communication (e.g., detection of communicative intents; e.g., Heintz & Scott-Phillips, 2023; Cave & Wilson, 2018; Nielsen et al., 2015). We believe that we do not need to settle this debate here: we can study why fiction is attractive, even if we do not have a straightforward answer as to the adaptive function it might, or might not, serve.

Our proposed framework involves indentifying all features that attract attention and bring pleasure in the domain of fictional stories. It offers a comprehensive approach to understanding the cognitive processes that contribute to the human enjoyment of fiction, providing a scientific foundation for analyzing the form, content, structure, and evolution of fictional stories. By advancing a framework that could account for the diverse range of individual psychological preferences, we offer a way to explain both the wide diversity of fictional stories and the recurring associations between specific features in fiction. We also argue that this framework can help address long-standing mysteries in literary studies and related fields, such as the paradox of tragedy and horror or the question of character identification, as briefly tackled in the Discussion. Furthermore, our framework can help navigate the complexities of fiction beyond rigid genre classifications, by acknowledging the possibility of more subtle mixes of finer-grained story features. Overall, we believe this framework provides a straightforward way to ground the analysis of fiction in empirical research.

Finally, all authors of this paper believe that fiction provides us with a unique lens through which we can better understand the human mind. We posit that fiction activates and amplifies aspects of human cognition. Thus, fiction serves as an ideal domain for investigating human psychological preferences, that is, what our cognition values more or less and therefore prioritizes. In line with others, we propose that by studying the fictional stories that people create and consume, we can gain valuable insight into human cognition at large (Baumard et al., 2023, 2022; Du et al., 2023; Gottschall, 2008b).

2. An integrative framework: From evolution to cognition to culture

2.1. Cognitive mechanisms evolved to solve recurrent adaptive challenges

Our framework is based on the idea that the human mind is a complex biological system composed of many cognitive mechanisms that have evolved to help individuals navigate their environment in adaptive ways (Pinker, 1997; Sperber, 1994; Tooby, 2020; Tooby & Cosmides, 1992; Pietraszewski & Wertz, 2022). These mechanisms are domain-specific, meaning that they are specialized to handle and deal with specific and recurrent adaptive challenges in human environments, such as (1) detecting predators, (2) detecting psychological phenomena, (3) or physical phenomena, (4) finding romantic partners, (5) collect resources, and (6) managing one's social standing. One of the key benefits of the evolutionary framework is that it allows us to carve the human mind into distinct, manageable parts, according to the specific function each part evolved to fulfill (Barkow, 1995; H. C. Barrett, 2015; Buss, 2015). These evolved mechanisms are identified through the convergence of multiple types of evidence, including the conceptual specification of input conditions and expected outputs or evidence for design-function fit from cross-cultural or developmental data (Scott-Phillips, 2022; Tooby & Cosmides, 1992). Let's review six examples of such evolved psychological mechanisms. Please note that in the rest of the article, all such cognitive mechanisms are identified in bold font and they are all listed in the table presented in **Section 3**.

The **predator detector** evolved to help individuals learn from and predict the presence of predators, which was a recurrent adaptive challenge in ancestral environments (Clinchy et al., 2013; Gross & Canteras, 2012; Öhman, 2009). This mechanism takes as input information about potential predators in the environment and outputs the concept of a predator, which can then be used to respond adaptively to such cues (**Figure 1.A**).

Intuitive psychology evolved to help individuals learn from and predict the mental states of others, including their beliefs, desires, and intentions, which is essential for successful social interaction and cooperation (Baron-Cohen, 1995; Call & Tomasello, 2008; D. C. Geary & Huffman, 2002; Mahr & Csibra, 2021a; Milligan et al., 2007; Saxe et al., 2004; Sperber & Wilson, 1987; Wang & Feigenson, 2019). This mechanism takes as input new perceptual information about the behavior of others and outputs a set of concepts that allow individuals to infer their mental states (**Figure 1.B**).

Intuitive physics evolved to help individuals learn from and predict the behavior of physical entities in their environment, which is arguably a very ancient and crucial adaptive challenge (Baillargeon et al., 1985; Baillargeon & Carey, 2012; Caramazza & Shelton, 1998; Carey, 2009; Fischer & Mahon, 2022; D. C. Geary & Huffman, 2002; Kubricht et al., 2017a; Mahr & Csibra, 2021a; Spelke, 1990; Ullman et al., 2017). This mechanism takes as input new information about the properties of objects and outputs an understanding of their behavior (**Figure 1.C**).

Romantic attraction evolved to motivate individuals to form pair bonds with partners who are able and willing to invest in their offspring, which was another recurrent adaptive challenge in ancestral environments (Campbell & Ellis, 2005; H. E. Fisher et al., 2006; Fletcher et al., 2015; Kenrick, 2006; G. Miller, 2001). This mechanism takes as input information about potential mates and outputs feelings of attraction and attachment, which can help individuals form long-lasting relationships (**Figure 1.D**).

Curiosity evolved to motivate individuals to find new information, which was another recurrent adaptive challenge in ancestral environments (Bunzeck & Düzel, 2006; Dubey & Griffiths, 2020; Gottlieb et al., 2013; Kaplan, 1992; Poli et al., 2022). This mechanism takes as input new information about the surrounding environment and outputs a set of cognitive and behavioral strategies for investigation (**Figure 1.E**).

Finally, **shame** evolved to motivate individuals to avoid appearing as a bad cooperative partner that others would devaluate (P. Gilbert, 2022; Sznycer et al., 2018; Thomas et al., 2018). This mechanism takes as input information about one's characteristic that could lead to social devaluation and outputs feelings of shame, which functions to limit such devaluation (**Figure 1.F**).

It has been hypothesized that these mechanisms evolved through natural selection because the functional outputs they prompted brought about more fitness benefits than costs in ancestral environments (H. C. Barrett, 2015; Darwin, 1859; Nettle & Scott-Phillips, 2021). By understanding the functions and adaptations of these mechanisms, we can gain a deeper insight into how the human mind works, how it has evolved, and how it continues to shape our behavior and preferences today (Boyer, 2018).

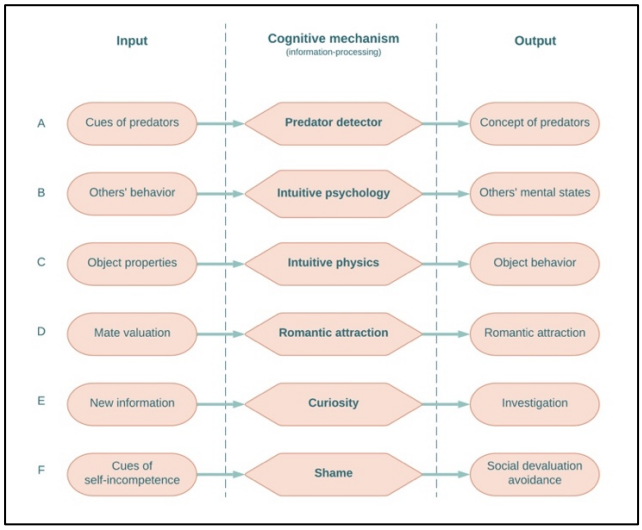

Figure 1. Examples of information-processing mechanisms.

2.2. Cognition is hierarchically structured from percepts to concepts to motivations

In addition to organizing such mechanisms by adaptive challenges, we can further differentiate them based on the levels of processing involved in their operation. The various cognitive mechanisms that guide human behavior can be differentiated into three levels of processing: *perceptual* mechanisms (i.e., mechanisms that aim at detecting external cues), *conceptual* mechanisms (i.e., mechanisms that aim at integrating perceptual cues into concepts), and *motivational* mechanisms (i.e., mechanisms that prompt behaviors based on cues and concepts). Additionally, this hierarchical structure allows modeling cognitive and behavioral flexibility as interactions between lower and higher-level cognitive mechanisms. It should be thought as a continuum from lower-level to higher-level cognition. For this reason, some mechanisms are hard to categorize. However, this strict partition will prove very useful by making clearer the different reasons why we enjoy fictional stories, in the next section. Let us also note that some mechanisms are not triggered by a specific class of percepts, but by some other higher-level mechanisms.

2.2.1. Perceptual mechanisms

Perceptual mechanisms are specialized detectors. They take as inputs sensory information and deliver as an output a perceptual representation of the world. For example, the snake-form detection mechanism is a low-level perceptual mechanism that evolved to visually detect snake-like shapes, which were recurrent adaptive challenges for our ancestors (Isbell, 2006; Van Strien et al., 2014). It is different from the **predator detector** example mentioned above because it is more perceptual and less conceptual. Another example is pitch discrimination: the human auditory system is highly specialized for detecting and discriminating between different pitches or frequencies of sound (McDermott & Oxenham, 2008). This ability is important for perceiving and distinguishing between different speech sounds in human communication, and its evolutionary origin could be even deeper, entrenched in the detection of body size in our non-human ancestors (Aung & Puts, 2020). The evolution of such low-level perceptual mechanisms is likely to be very ancient in the evolutionary history of perceptual systems. Scholars in aesthetics-related fields have explored the influence of such perceptual mechanisms on cultural productions such as movies or artworks (J. E. Cutting, 2005; J. E. Cutting et al., 2011; Kiianlinna, 2022; Prum, 2017; see Renoult, 2016, for a review of the different models in evolutionary aesthetics).

For instance, our preference for symmetry is likely due to the symmetrical features (e.g., faces) that humans have recurrently been exposed to in their evolutionary history (Thornhill & Gangestad, 1993), or to even more basic and general features of our vision system (Enquist & Johnstone, 1997; Reber, 2002). It makes us prefer symmetry in artistic or technological artifacts (Cárdenas & Harris, 2006; Enquist & Arak, 1994; but see: Gartus et al., 2020; Leder et al., 2019, for evidence that expertise modulates this preference). To take another example, a recent study provided the first evidence that the general preference for S-shape lines (i.e., the so-called 'Line of Beauty') is rooted in the universal low-level mechanism designed to detect fitness-relevant morphological features in people (Hübner et al., 2023). B. Boyd's exploration of patterns in Shakespeare's Sonnets is another example of how humans are drawn to patterns in a variety of forms, such as rhythms in language (B. Boyd, 2012). We do not explore further the origins and role of such low-level mechanisms in human psychology in this section, nor their impact on cultural preferences for fiction in the following sections. In the Discussion section, we will explain why we set them apart, even though we acknowledge their central role in the cultural success of fiction.

2.2.2. Conceptual mechanisms

Conceptual mechanisms evaluate and detect stimuli in their environment by taking as inputs the outputs of perceptual mechanisms. They have an internal structure that allows them to make specialized inferences about relevant stimuli (Delton & Robertson, 2016; Tooby et al., 2014). For instance, the **predator detector** is a conceptual mechanism that integrates perceptual cues, such as the shape, sound, or movement of a predator (e.g., the snake-form detector that we tackled in the previous subsection), to make many specialized inferences about the stimulus (Cook & Mineka, 1989; Öhman & Mineka, 2001). Another example is the evaluation of conceptual traits in other potential cooperative partners (Delton & Robertson, 2016): for instance, we evaluate the extent to which people are trustworthy (Everett et al., 2016; Goodwin, 2015; Uhlmann et al., 2015), warm (Eisenbruch & Krasnow, 2019; Fiske et al., 2007), and competent (Barclay, 2013; Bor, 2017; Fiske et al., 2007), with our **trustworthiness evaluator**, our **warmth evaluator** and our **competence evaluator**, respectively. The positing of three specialized mechanisms is consistent with the partner choice theory (Barclay, 2016; Baumard et al., 2013). In this perspective, human evolution favored the development of mechanisms for partner selection based on warmth, trustworthiness and competence, as these traits were crucial to prioritize those potential partners who would be *willing to initiate* a cooperative relationship (warmth), and who would be *willing* and *able* to *reciprocate* (trustworthiness and competence, respectively). Experimental evidence supports this division, demonstrating that individuals evaluate these dimensions independently, and that distinct behaviors and responses are associated with each of these evaluative dimensions (Abele et al., 2016; Everett et al., 2016; Fiske et al., 2007). In the examples from the previous subsection, **intuitive psychology** and **intuitive physics** are other instances of such conceptual mechanisms.

2.2.3. Motivational mechanisms

Motivational mechanisms function on the basis of appraisals or evaluations, which are the outcomes of other lower-level mechanisms, mainly conceptual mechanisms (Scherer & Moors, 2019; Bonard, 2021, chapter 9; Wharton et al., 2021; Moors, 2022, chapiter 6-7). They integrate information from such cognitive mechanisms and deliver output in the form of a behavioral or physiological response (Al-Shawaf et al., 2016; Cosmides & Tooby, 2013; Del Giudice, 2020, 2023; Sznycer, 2019). For instance, **fear of predator** is a high-level *motivational* mechanism that takes as input the output of the **predator detector** *conceptual* mechanism and prompts the organism to act in a way that maximizes survival chances in the presence of predators, such as fleeing or hiding (Öhman & Mineka, 2001). Another example is **romantic attraction**, which is a high-level motivational mechanism that takes as inputs the output of partner valuation mechanisms, such as the trustworthiness evaluator or the formidability evaluator, and prompts the organism to act in a way that maximizes mating opportunities

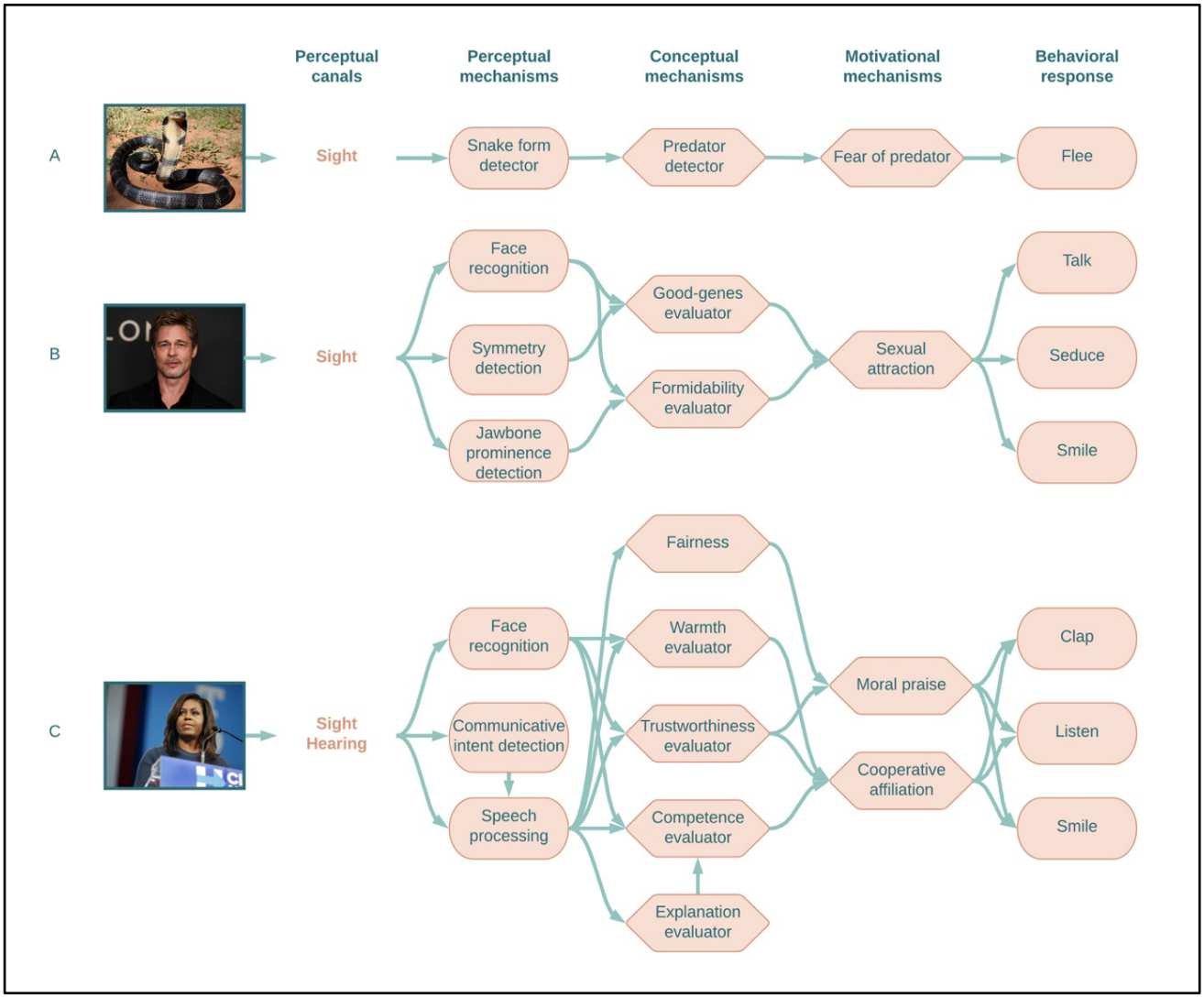

Figure 2. A. Simplified schema of the cognitive mechanisms activated by a snake. B. and C. Simplified schemas of the cognitive mechanisms activated by a attractive actor or a politician making a speech.

with a preferred partner, such as pursuing a relationship (Fletcher et al., 2015). **Curiosity** and **shame** are other motivational mechanisms.

2.2.4. Summary

In summary, cognitive mechanisms can be differentiated into different levels of processing, which perform different functions in guiding adaptive behavior. Perceptual mechanisms detect the presence of sensory cues in the environment, conceptual mechanisms make specialized inferences about relevant stimuli, and motivational mechanisms integrate information from other mechanisms, prompting adaptive behavior based on such appraisals. For instance, if you encounter a snake during a walk: first, your perceptual mechanisms will detect the form and movement of the snake, because of the detector of snake shape (**Figure 2.A.**). This will inform your **predator detector**, which is a conceptual mechanism designed to make specialized inferences about predators. Then, your **fear of predator** will motivate you to act in a way that enhances survival. This path from perceptual to conceptual to motivational mechanisms is not unidirectional. In fiction, for instance, you can elicit a certain *emotion* to make the consumers *perceive* a situation differently (i.e., a motivational mechanism has an impact on a perceptual mechanism). For example, research has demonstrated that when exposed to music designed to evoke fear, individuals are more prone to perceive a rope as a snake (Prinz & Seidel, 2012): the music makes our **predator detector** more sensitive (see also M. Smith, 2023).

Of course, many other mechanisms are activated by the sight of a snake. For instance, our **intuitive biology**, which detects cues that violate our core beliefs about intuitively categorized species (Atran, 1998), can make us be even more attentive to the sighted specimen if, for instance, it moves weirdly. Low-level mechanisms rooted in our perceptual systems evaluate how safe one is, notably according to one's distance from the snake. Let's imagine that the snake is behind glass in a terrarium: we will then deduce, thanks to our

intuitive physics, that the snake will not go through the glass, which will give us the right impression of being even safer. This partition between three levels of cognitive processing allows us to model flexibility as the many-to-many possible mappings between different cognitive mechanisms at different levels of the hierarchy. For instance, the vision of a beautiful face and the processing of a political speech activate many perceptual mechanisms and might activate several conceptual mechanisms and motivational ones (see examples in **Figure 2.B and 2.C.**).

2.3. Fictional stories belong to actual domains of such cognitive mechanisms

An evolved cognitive mechanism (e.g., **predator detector**, **competence evaluator**, **curiosity**) is an adaptation to a range of phenomena that presented recurrent problems or opportunities in the ancestral environments of a species (Barkow, 1995; Pinker, 1997; Tooby & Cosmides, 1992). Its function is to process a given type of stimulus or input (e.g., snakes, others' skills, new information). These inputs, that a given mechanism has *evolved* to react to, constitute the *proper* domain of this mechanism (Sperber & Hirschfeld, 2004). To function, all cognitive mechanisms have evolved such type of input criteria that decide whether a given phenomenon satisfies the input condition of the mechanisms and triggers a response from them. However, some items that do not belong to the proper domain of a mechanism might satisfy its input conditions (e.g., a piece of wood in the shape of a snake).

The phenomena that meet the input conditions of an evolved cognitive mechanism, but were not the evolutionary target of this mechanism, are said to belong to the *actual* domain of the psychological mechanism (Sperber & Hirschfeld, 2004). For instance, the proper domain of our **predator detector** encompasses *predators* (the stimuli that it evolved to detect), while its actual domain includes *monsters* that resemble such predators (**Figure 3**). While this mechanism obviously didn't evolve to detect fictional monsters, it reacts to monsters because (1) the **predator detector** evolved to be oversensitive and react to predator-like cues, and (2) monsters and predators share features, such as big and sharp teeth or claws. Therefore both predators and monsters in fiction activate our **predator detector** mechanism; and, arguably, monsters are actually *designed* to do so (Clasen, 2012b; Morin & Sobchuk, 2022a). In this framework, we posit that such features in fictional stories (e.g., predators, competent characters, new environments) that mimic real-life stimuli explain the attraction and pleasure we derive from the consumption of these stories.

We call these features 'ingredients'. Strictly defined, ingredients are *story features that, by activating evolved specialized cognitive mechanisms, hold cognitive appeal to human minds*. A variety of different ingredients can activate the same cognitive mechanism, as long as the ingredient in question complies with the condition(s) of activation of said mechanism (see the different ingredients in the 'Actual domain' spaces in **Figure 3**).

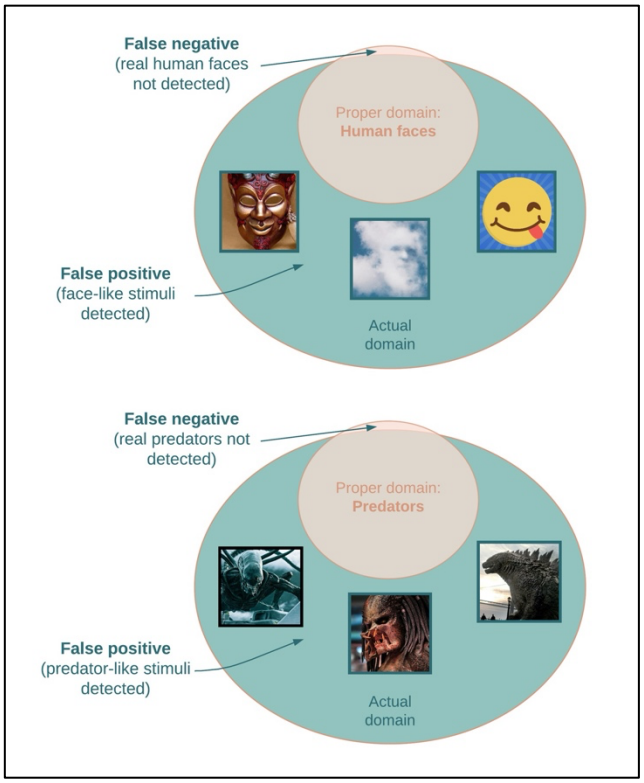

Figure 3. Proper and actual domains of the face-recognition perceptual mechanism (adapted from Sperber & Hirschfeld, 2004) and of the predator-detection conceptual mechanism.

Producers of fiction can exaggerate some features of a stimulus and invent what has been called a 'superstimulus' (D. Barrett, 2010; Dubourg & Baumard, 2022a; Nettle, 2005b, 2005a). Superstimuli are very powerful ingredients because they amplify the mechanism's response to them. This effect of superstimuli has been first evidenced in non-human animals. For instance, in herring gulls, artificial eggs bigger than natural eggs elicit enhanced nesting behavior in female adults. In chicks, dummy models of parents with more contrasted colors on their bills elicit enhanced pecking behavior (Tinbergen, 1953b). In stickleback fish, male adults prefer to fight dummy models with brighter red than real male adults and prefer to escort dummy round-bellied models rather than real egg-bearing females (Tinbergen, 1953a). In humans, an experimentally exaggerated baby schema (i.e., a baby-like figure with disproportionately enlarged head and eyes and other paedomorphic features) elicits enhanced cuteness reactions and caring behaviors (Glocker, Langleben, Ruparel, Loughead, Gur, et al., 2009; Glocker, Langleben, Ruparel, Loughead, Valdez, et al., 2009; Lorenz, 1943; see D. Barrett, 2010; see Kringelbach et al., 2016, for a review). This

perceptual mechanism explains, for instance, the form of Mickey Mouse, with his big eyes and rounded head (Gould, 2008)—although we would need more explanation as to why it *changed* to be cuter and cuter over time (see section **2.5.** on the sources of variability of cognitive preferences for potential explanations).

In principle, any stimulus can be artificially exaggerated in fiction to elicit a stronger pull than the normal stimulus (e.g., physical features of superheroes that make them appear more formidable and more competent for our **formidability evaluator** and **competence evaluator**; see: Burch & Johnsen, 2020; Burch & Widman, 2023). To use some of the examples used in **Section 2.1.**, fiction may include monsters, with exaggerated predatory features such as height, teeth, or claws (Clasen, 2012b; Morin & Sobchuk, 2022b). In some romance fiction, the capacity of mates to bring in resources or to serve as a protector is exaggerated (Cox & Fisher, 2009; Salmon, 2012; Salmon & Symons, 2003), tapping into our **resource evaluator** and **formidability evaluator**. And in plots with vilains who are eventually foiled, our formidability and competence detectors are triggered (Wylie & Gantman, 2023). Because the attractive properties of such ingredients are enhanced, the responses of the cognitive mechanisms are enhanced too (e.g., the rewarding feeling triggered by **curiosity** due to enhanced novelty properties of imaginary worlds; see: Dubourg et al., 2022; Dubourg & Baumard, 2022b).

2.4. Different kinds of ingredients activate different mechanisms along the hierarchy

We believe that the structural architecture of human cognition that we proposed (see **2.2.**) can shed new light on the question of the appeal of fictional stories. Importantly, the existence of different levels of processing makes it apparent that there are different kinds of ingredients. While this theoretical proposition deserves a research project in itself, we draw here the main lines of the partition between two kinds of ingredients: first-party ingredients and third-party ingredients.

2.4.1. First-party ingredients

First-party ingredients in fictional stories are elements that activate *perceptual and conceptual mechanisms*, capturing our attention as *first parties*, as if we were observing reality through an invisible window, in the cover of an impenetrable shelter (Menninghaus et al., 2017; G. M. Wilson, 2011). These ingredients comprise elements that would naturally pique our interest in the real world if we were watching from this absolutely safe and secret space. For instance, predators lurking in the environment (Scalise Sugiyama, 2006), competent individuals who could be potential allies or antagonists who seek to harm us (Singh, 2021, Wylie & Gantman, 2023), unexplored paths opening up new environments (Dubourg & Baumard, 2022b), peculiar physical situations that defy our understanding (Nyhof & Barrett, 2001), highly attractive people who might be suitable mates (Cox & Fisher, 2009; Salmon, 2012) or endearing babies who elicit our protective instincts (Gould, 2008). These features activate, respectively, our **predator detector**, our **competence evaluator**, our **landscape evaluator**, our **intuitive physics**, our **fertility detector**, and our **cuteness evaluator**. By incorporating these first-party ingredients in fiction, storytellers successfully engage our conceptual cognitive mechanisms, holding our attention much like they hold our attention in real life. Such story features mostly belong to the actual domains of stimuli that our conceptual mechanisms target. Note that we will tackle the question of the activation of perceptual mechanisms in the Discussion section.

2.4.2. Third-party ingredients

But what about motivational mechanisms? It is not self-evident whether and how they are activated by a movie or by a novel, as one cannot interact with the story. Consuming such non-interactive fiction, we should not feel motivated to seduce anyone (i.e., our **romantic attraction** shouldn't be activated) or to display our competence (i.e., our **pride** should not be activated). We call 'third-party ingredients' ingredients that relate to characters' actions or mental states that we observe, as third parties. Scholars in neuroaesthetics and embodied cognition have shown that characters' actions and emotions do activate brain areas corresponding to the performance or experience of such actions and emotions *in consumers* (Gallese & Wojciehowski, 2011; Keen, 2006). Why is that the case? Past research has already provided a hypothesis to explain why motivational mechanisms are activated: we would simulate the activation of motivational mechanisms to learn what to do in specific situations (Mar & Oatley, 2008; Morin et al., 2019; C. Scrivner et al., 2021a; van Mulukom & Clasen, 2021).

Concerning first-party ingredients, we described how conceptual mechanisms are activated by such ingredients in the same way as by real-life input. Through the same metaphorical window, we become interested in witnessing *people* dealing with adaptive challenges and pursuing goals that align with our own, according to our *motivational mechanisms*. This process, also known as observational learning (Bandura, 2008; Burke et al., 2010; Szczepanik et al., 2020), allows us to indirectly gather information and insights from the experiences of fictional characters (see: Vermeule, 2006; see De Backer & Fisher, 2012, for the same argument about gossip). Examples of third-party ingredients include *characters* engaging in mating rituals, becoming friends, escaping predators, forming alliances, dealing with immoral characters, and discovering novel ways to traverse their environments.

Such story elements *vicariously* activate our **romantic attraction**, our **cooperative attraction**, our **fear of predator**, our **coalitional affiliation**, our **moral indignation**, and our **resource foraging** mechanisms. We therefore hypothesize that these ingredients maintain our interest in the story because they provide us with events intuitively perceived as vicarious opportunities to learn about potential solutions to our relevant problems (see **Figure 4**).

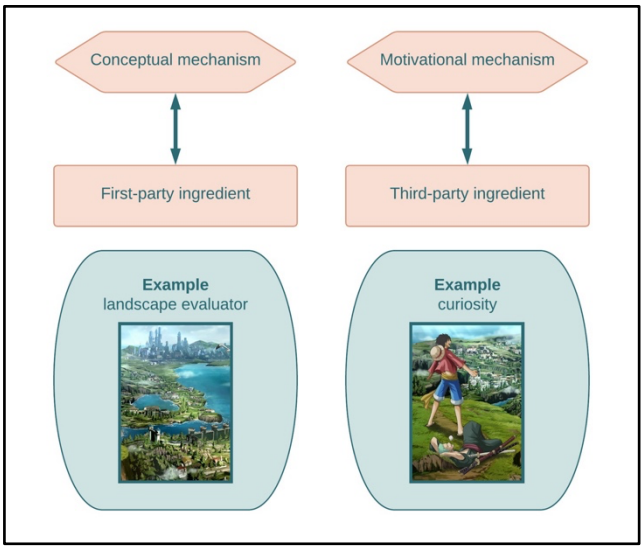

Figure 4. The distinction between a first-party and a third-party ingredient. When we look at an imaginary landscape, we evaluate it based on the opportunities to discover new resources or information, just like any landscape in real life: it is a first-party ingredient activating the landscape evaluator conceptual mechanism. When we watch a fictional character exploring an imaginary world, we (pseudo-) learn relevant ways to fulfill our own motivation to discover new information: it is a third-party ingredient activating our curiosity, which is a motivational mechanism.

However, it is important to note that the learning experience facilitated by third-party ingredients does not necessarily need to be based on genuine insights or useful knowledge (Currie, 2020). Instead, this phenomenon can also involve what we call 'pseudo-learning', where we feel *as though* we are acquiring relevant information even if it does not apply to our own lives (i.e., activating the actual domain of our mechanisms aiming at detecting novel information and learning from them). For example, a person with a strong desire to fall in love may become engrossed in romance novels (van Monsjou & Mar, 2019), feeling as though they are gaining valuable insights into relationship management when, in reality, the situations presented in the stories may not be directly applicable to their own experiences (and might even be counter-productive to the goals in mind, here, finding an appropriate romantic partner). This pseudo-learning experience still provides a sense of gratification and satisfaction (Oliver & Raney, 2011; Wirth et al., 2012), even if it does not result in actual, actionable knowledge (Mercier, 2022). In this way, third-party ingredients contribute to the overall appeal and enjoyment of fictional narratives, regardless of whether they provide genuine learning opportunities or satisfy our curiosity. In general, stories may, or may not, lead to adaptive knowledge and behaviors: this distinction does not change anything to our framework.

2.4.3. Summary

In any given fictional narrative, as we peer through the invisible window into the world of the story, both first-party and third-party ingredients are intricately intertwined. For instance, consider a protagonist who displays exceptional competence. Our interest in this character may be twofold. As a first-party ingredient, we perceive the character as a potential cooperative partner and assess their competence (Singh, 2021). The more skilled and proficient the character appears, the more captivating they become. And all the more so if we are interested in having competent partners in real life (i.e., if our **competence evaluator** mechanism and our **cooperative affiliation** mechanisms are very sensitive). Simultaneously, as a third-party ingredient, we can be drawn to observe and learn from their strategies and actions (Brody & Stoneman, 1985; Vázquez et al., 2013), all the more so if we are motivated to appear competent ourselves (i.e., if our **pride** mechanism is sensitive). For instance, as we follow Harry Potter's journey, different mechanisms perceive him both as a potential friend because of his competence and as a potential role model to (pseudo-)learn how to appear competent (**Figure 5**). For fictional characters, this distinction is close to the one between parasocial relationship and identification (e.g., Hall, 2019). Likewise, in the realm of horror stories, our engagement with the narrative can take on dual roles. As a first-party ingredient, when our **predator detector** conceptual mechanism detects a threat within the story, we may experience fear ourselves, as if the danger were here. Simultaneously, as a third-party ingredient, we might find ourselves vicariously interested in the observation of the character's **fear of predator**. The same ingredient (e.g., a competent protagonist, a monster) can be interesting for different reasons.

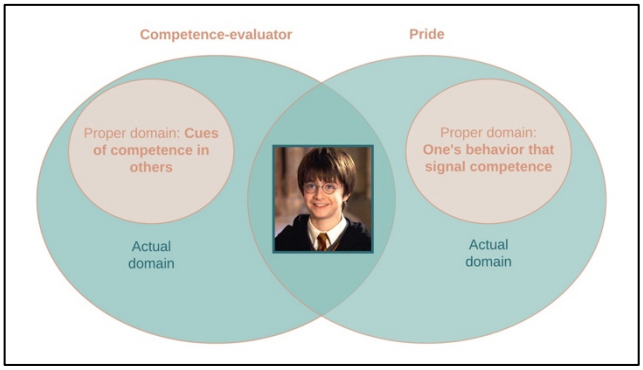

Figure 5. Example of two different mechanisms, one conceptual, one motivational, activated by the fictional character Harry Potter.

We further believe that this distinction between first-party ingredients—that co-opt conceptual mechanisms—and third-party ingredients—that vicariously trigger motivational mechanisms for learning or pseudo-learning purposes—overlaps with the distinction between hedonic and eudaimonic entertainment (Oliver & Raney, 2011; see also: D. Wilson, 2018 for a distinction between internal and external relevance). People seem to separate the motivation to seek sheer pleasure (from the exposure to first-party ingredients that activate our reward system) and the motivation to seek useful knowledge (from the exposure to third-party ingredients that activate our learning system). Put another way, our conceptual partition is supported by a seemingly shared intuition that humans seek enjoyment and meaningfulness in entertainment (Pinker, 2007).

Our distinction between first-party and third-party ingredients, which aligns with the partition between conceptual and motivational mechanisms, helps us understand our enjoyment of non-interactive fiction such as novels or movies. However, while non-interactive fiction mainly engages our motivational mechanisms through third-party ingredients, video games and other interactive forms of storytelling offer a different kind of experience. In video games, players have actual agency and can make decisions that affect the story's outcome, which leads to other kinds of fictional experiences (Dubourg & Chambon, 2023; Grodal, 2000; Robson & Meskin, 2016). This allows motivational mechanisms to be activated, not vicariously by third-party ingredients, but by first-party ingredients, as players can feel **pride**, **shame**, or other self-conscious emotions based on their own actions in the game. This is not normally possible in non-interactive fiction, where we can only *vicariously* experience such emotions. Thus, video games represent a medium that allows for a specific experience, where both conceptual and motivational mechanisms can be activated as first-party. This insight highlights the specificity of interactive media and suggests avenues for further research exploring the interaction between different kinds of ingredients and cognitive mechanisms in different forms of media.

2.5. The sensitivity of cognitive mechanisms varies in adaptive ways

Now that we have established that universal cognitive mechanisms are triggerred by fictional story features, we can ask the question: why do people enjoy such a wide variety of fictional stories with differing features? This question can be rephrased as: why do people have diverse specific cognitive preferences? These preferences arise from the varying sensitivities of cognitive mechanisms, causing individuals to feel varying levels of reward or captivation in response to different stimuli. This premise leads us to the central question: why do humans vary in the sensitivity of their cognitive mechanisms?

2.5.1. Developmental stage

Humans of different ages faced different adaptive challenges, so they evolved cognitive traits that are not fixed but rather change with age (Del Giudice et al., 2009; Gangestad & Kaplan, 2015). In doing so, they adjust to each age-specific adaptive challenge. The field of evolutionary developmental psychology is grounded in studies on the genetic determinants that drive the emergence of cognitive mechanisms and calibrate their sensitivity (Bjorklund & Ellis, 2014; West-Eberhard, 2003). The idea is that there is such a thing as a life history of cognition: just like human bodies, human cognitive mechanisms undergo adaptive recalibration throughout ontogeny. This approach predicts that *humans of different ages should enjoy on average different ingredients in fiction.*

For instance, in ancestral environments, children and adolescents have been more frequently faced with the adaptive challenge of understanding new tools or technologies: Their **technical efficiency evaluator** (sometimes called technical reasoning) is, therefore, more sensitive than that of adults (Defeyter & German, 2003). This leads to the prediction that younger individuals should typically prefer stories with tools and gadgets. Conversely, some cognitive mechanisms, such as **romantic attraction**, develop only after 'adrenal' puberty (Del Giudice et al., 2009), suggesting that younger people should not enjoy fiction with related fictional ingredients. Many findings in cultural studies focusing on the use of available technology to entertain audiences of different age categories (e.g., Elza, 2014; Jenkins, 1998) could be read in the light of this broad framework. Further collaborations between scholars in the humanities and in developmental psychology could lead to novel predictions about the specific features in fiction targeted at different age groups and new results pointing to unexplored age-specific cognitive preferences (e.g., Lesnik-Oberstein & Cocks, 2018).

2.5.2. Biological sex

Humans of different sexes also faced some different adaptive challenges. Evolutionary biology studies how natural and sexual selection, constrained by the gamete sizes of each sex and the different levels of unconditional parental investments, led males and females to be endowed with different sensitivities of their cognitive mechanisms, prompting different behaviors efficient in solving the specific adaptive problems they each faced (Del Giudice et al., 2016; Buss, 1995; Darwin, 1871; R. A. Fisher, 1915; Geary, 2000). In other words, human cognition is in part subject to sexual dimorphism, but only in contexts where humans of each sex faced different recurrent adaptive problems. It explains why people of different sexes can have, on average, different sensitivity levels in the same cognitive mechanisms (Baron-Cohen, 2003). It leads to the prediction that *there might be*

differencees in the way humans of different sexes enjoy some ingredients in fiction.

For instance, finding mates that are able and willing to invest in one's offspring was a recurrent adaptive challenge that was more important for females (because of their higher minimum initial investment in offspring). Their interest in **romantic attraction** should thus be heightened as compared to males (Brase, 2006; Buss et al., 2001). It is therefore predicted that females should overall prefer fictional stories about long-term romantic relationships and long-term committed partners (see Salmon, 2012). This is precisely what Cox and Fisher (2009) found, for instance, through the study of the most frequent words used in Harlequin romance, which are mostly bought by women: titles very often included words describing a long-term commitment or words describing the male protagonist through his high-income occupation. They conclude that—consistent with predictions informed by evolutionary psychological research—women are more prone to purchase romance novels that trigger their **romantic attraction**, which encompasses our **resource evaluator** mechanism (Buss et al., 2001; Buss & Schmitt, 1993; Jankowiak & Fischer, 1992; La Cerra, 1995).

It is important to note that, although biological sex is a binary category in biology, preferences cannot be simply categorized as 'male' or 'female'. The distribution of the sensitivity of cognitive mechanisms according to sex follows a Gaussian curve, with large overlap between the two groups. For instance, while it is generally true that females have a higher sensitivity Theory of Mind (Baron-Cohen, 2003; Greenberg et al., 2018; Nettle, 2007; Stiller & Dunbar, 2007), it is not true for every female, and there are some males who have a higher sensitivity than most females. Therefore, we should expect significant overlap in male and female preferences for most ingredients.

2.5.3. Personality traits

Human personality traits have evolved because some adaptive challenges were dependent upon highly local environments, characterized either by the prevalence of others' personality traits (i.e., frequency-dependent selection) or by the specific features of the said environment (i.e., niche specialization; de Vries et al., 2016). This led the sensitivity of some cognitive mechanisms to be genetically fixed at different levels according to each individual, as a specialization to a social or ecological niche (Buss, 2009; Penke & Jokela, 2016; see van den Berg et al., 2016, for an example for extraversion). A complementary hypothesis posits that personality traits are behavioral calibration to other enduring individual traits (Lewis, 2015; Lukaszewski et al., 2020). For instance, people who are more physically formidable derive more benefits from being more extraverted. Evidence suggests that they are indeed more extraverted (Lukaszewski & Roney, 2011). In this framework, each personality trait is interpreted as a cluster of cognitive mechanisms the sensitivity of which normally varies together at the individual level (Nettle, 2006; Schiralli et al., 2019). This predicts that *humans with different personalities should on average enjoy different ingredients in fiction.*

For instance, our **familial love** mechanism varies with the personality trait Agreeableness: people higher in this trait are more motivated to help their kin (Ashton et al., 1998; Ben-Ner & Kramer, 2011; Oda et al., 2014; Quinlan, 2007). They should therefore be more interested in stories in which there are family-related ingredients. This type of prediction has already been tested with a dataset of 3.5 million Facebook users who answered a Big Five personality questionnaire: people who 'like' family movies on Facebook are overall higher in Agreeableness (Nave et al., 2020). Nevertheless, the association between personality traits and preferences for ingredients is largely understudied (but see: Kjeldgaard-Christiansen et al., 2021; Fong et al., 2013; Cantador et al., 2013; Manolika, 2023; Golbeck & Norris, 2013; Chausson, 2010; see Michelson, 2014, for an introduction to the associations between the Big Five and story-related preferences). Meanwhile, the Big Five framework has been used to study paintings (e.g., Feist & Brady, 2004; Furnham & Bunyan, 1988; Mastandrea et al., 2009; Rawlings, 2003; Rawlings et al., 2000; Twomey et al., 1998; Zuckerman et al., 1993) and music (e.g., Dollinger & Kilman LaMartina, 1998; Schäfer & Mehlhorn, 2017; Vella & Mills, 2017). Our framework leads to concrete and fine-grained predictions about interindividual differences in cultural consumption behavior (see Ingredient table). It can also lead to an increase in the usefulness of the Big Five framework by extending the range of cultural behavior it can predict (Cantador et al., 2013; Chausson, 2010; Feist & Brady, 2004; Furnham & Bunyan, 1988; Rawlings, 2003; Rawlings et al., 2000; Roberts et al., 2007; Roose et al., 2012; Vella & Mills, 2017).

In the remainder of the paper, we discuss personality traits only with references to the Big Five framework (McCrae et al., 2012; McCrae & John, 1992; Rammstedt & John, 2007). The five dimensions that compose it (i.e., Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) have been empirically derived from the variability of human observed and self-reported behaviors or preferences, with lexical and experimental approaches, respectively. Humans differ in the personality "scores" associated with each of these dimensions. The Big Five is considered the most widely accepted model of human personality today (see Bainbridge et al., 2022 for a study showing that among 1,039 psychometric scales, between 71 and 83% are in fact associated with the Big Five; see Durkee et al., 2022 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 Wright & Jackson, 2022 for a study of the individual stability of Big Five traits with 21,616 participants;

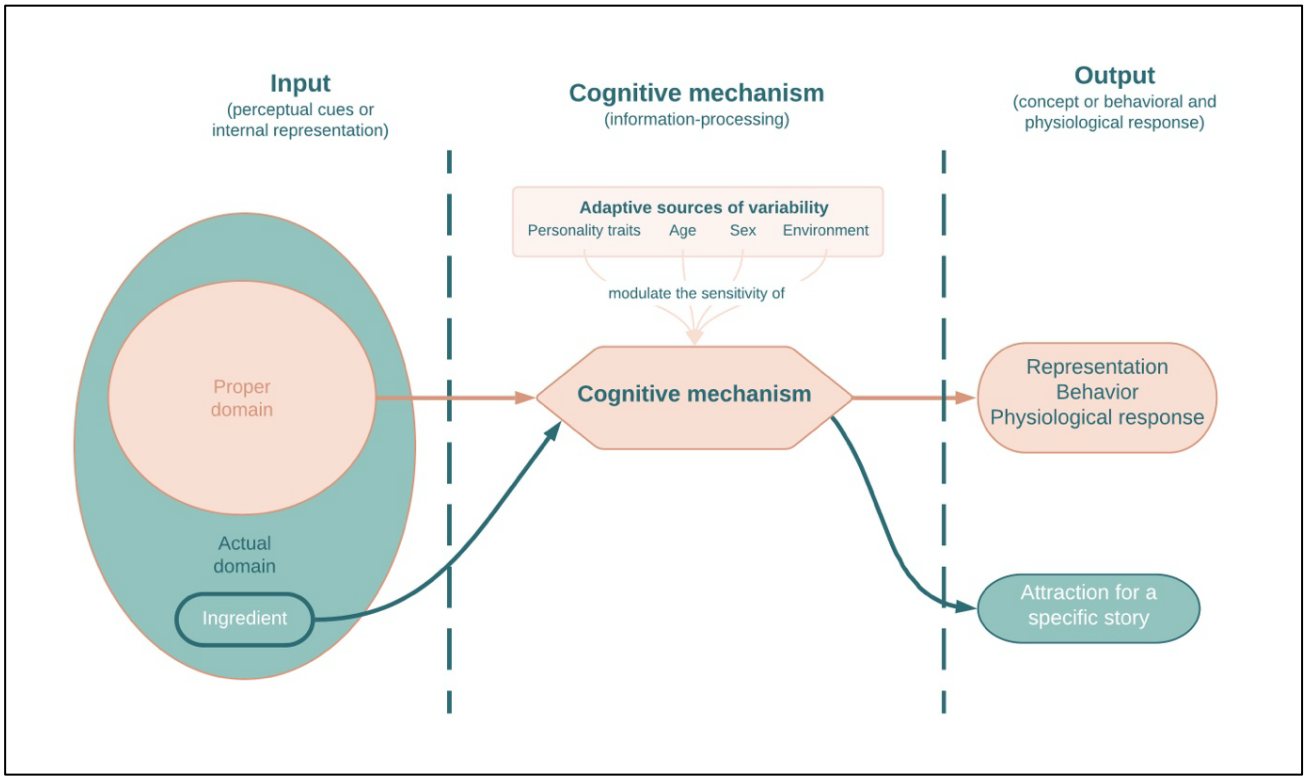

Figure 6. General schematic representation of a cognitive mechanism. The input conditions for the activation of the cognitive mechanism is the "proper domain", in orange. The sensitivity of this cognitive mechanism varies as a function of different individual and environmental characteristics. And it leads to an output in the form of a mental representation or a behavior. In green, the effect of the existence of a proper domain of activation: some stimuli that fall outside of the proper domain still activate the mechanism and can therefore be used for entertainment or other purposes.

but see Gurven et al., 2013, for some limitations when testing forager-horticulturalist societies).

2.5.4. Ecological conditions

Humans evolved in changing environments, and the defining characteristics of each local environment shaped in different ways the adaptive challenges humans faced. This process led some cognitive mechanisms to be highly plastic, so as to enable behavioral flexibility in response to different environments, and more precisely to changing characteristics of such environments. In other words, the mechanisms in the human mind are subject to adaptive phenotypic plasticity: recent developments in evolutionary human sciences show that the sensitivity of some mechanisms changes according to environmental cues (Baumard, 2019; Frankenhuis et al., 2016; Pepper & Nettle, 2017; Sng et al., 2018). We therefore predict that *humans living in different environments should on average enjoy different ingredients in fiction.*

For example, **curiosity** is less risky, therefore less evolutionary costly and more adaptive, in affluent ecologies (Baumard, 2019; Dubourg & Baumard, 2022b). Thus, when navigating such ecologies, there should be a heightened sensitivity in the **landscape evaluator** and **curiosity** mechanisms in such ecologies. This is because evolution should have crafted this mechanism to be highly plastic to such ecological characteristics, to be able to adapt to different ecologies. It thus leads to the prediction that people living in affluent ecologies should prefer stories with foreign worlds or imaginary worlds (Dubourg et al., 2023). This rationale is a brand new research direction in the study of fiction which has the potential to explain not only crucial interindividual differences in preferences for fictional ingredients, but also the cultural evolution of fiction over large periods of time: the fluctuations of resource availability over history should account for fluctuations of the sensitivity of some mechanisms, and this should, in turn, translate to the cultural domain because the producers selectively retain ingredients that become more attractive in such environments (Dubourg & Baumard, 2022a). Our framework could therefore explain and predict very broad cultural trends, such as the rise and fall of imaginary worlds in literary texts across time and space, by looking at changes in ecological conditions.

2.5.5. Other sources of variability

Our choice to focus on age, sex, personality, and resource availability as sources of variability is primarily due to their extensive study in evolutionary sciences and their potential to explain a significant portion of the variance in cognitive preferences (see **Figure 6** for a summary and **Figure 7** for examples). However, other factors, both individual and contextual, could be further explored to enhance our understanding of

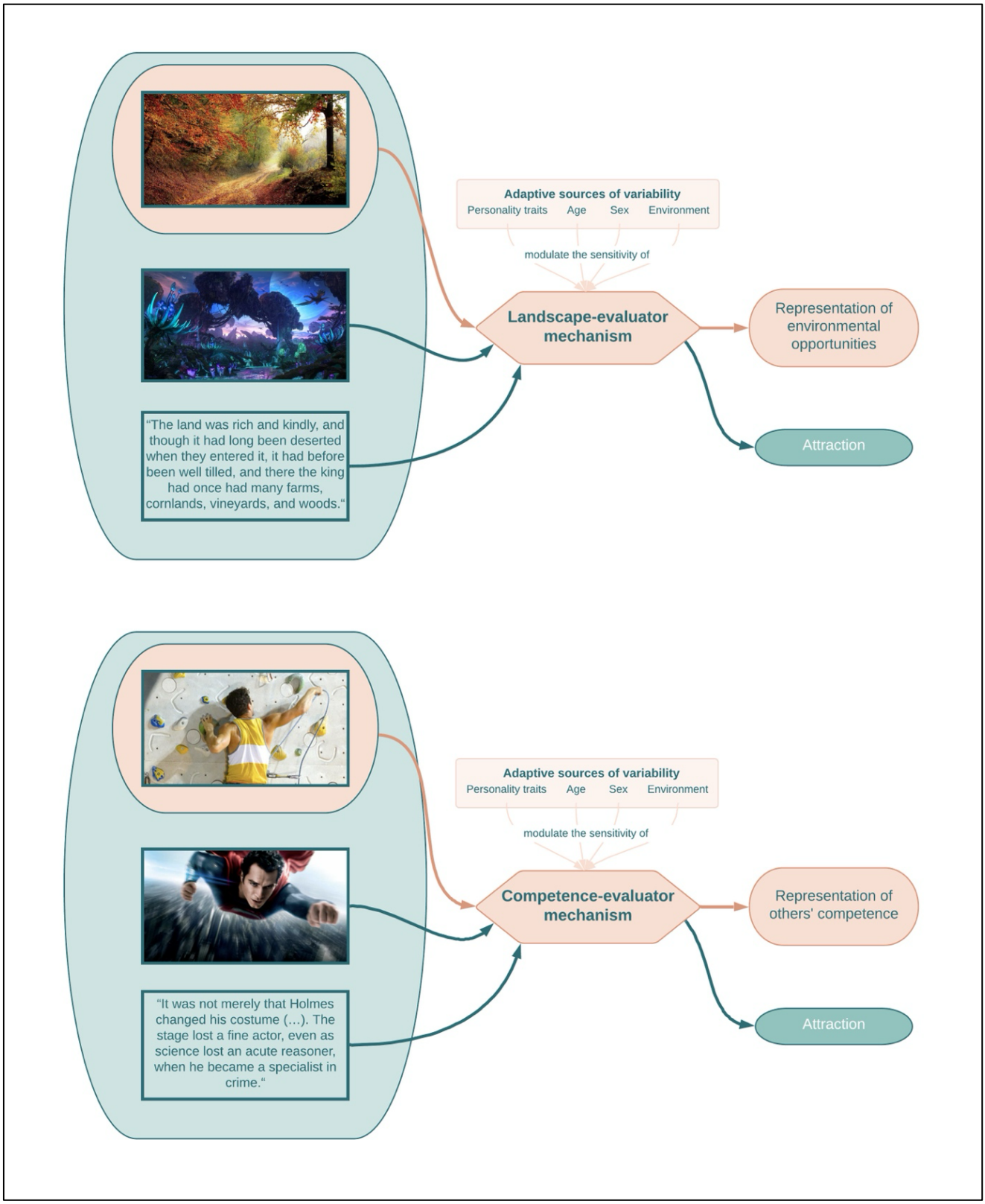

Figure 7. Examples of the landscape-evaluator mechanism and competence-evaluator mechanism. The landscape evaluator is triggered by real-life cues of explorable environments (e.g., an open landscape with a path in the distance) but also by imaginary worlds in movies (e.g., The Hobbit, Peter Jackson, ©Warner Bros. Discovery), and by descriptions of such environments in novels (e.g., Lord of the Ring, The Fellowship of the Ring, Tolkien, 1954). The competence evaluator is triggered by real-life cues of competency in potential cooperative partners (e.g., a person able to climb) but also by super-powers in fictional heroes that make them ideal cooperative partners (e.g., Man of Steel, Zack Snyder, 2013, ©Warner Bros. Discovery) or descriptions of high skills (e.g., The Adventures of Sherlock Holmes, Conan Doyle, 1892).

these differences. Individual characteristics other than personality, sex and age, affect the sensitivity of specific cognitive mechanisms (see Götz et al., 2022, for a review of small effect size of interest). For instance, as people become expert in some artistic domains, their preferences shift in predictable ways (Verpooten, 2018; Verpooten & Dewitte, 2017). Another example is pregnancy, which has an effect on the sensitivity of the disgust mechanism (Fessler et al., 2005; Kaňková et al., 2023). Among ecological factors, we focused on the level of resources, but other factors (e.g., population density, pathogen levels, climate) have been shown to explain a significant part of the variance of inter-individual differences in the sensitivity of some mechanisms (Wormley et al., 2023). For instance, the sex ratio could be another interesting source of variability, as it might affect the sensitivity of many cognitive mechanisms, particularly through its influence on inter- and intrasexual competition (e.g., Barber, 2000). Economic inequality might also have an impact on morality-related preferences: a recent empirical study shows that more inequality leads to harsher moral judgments (Kirkland et al., 2023). Finally, more local contextual factors can also shift preferences, such as a pandemic increasing the appeal of fiction with pandemic themes (C. Scrivner, 2021a) or a real-life murder increasing the appeal of crime fiction (Boyanowsky et al., 1974).

Why don't we speak of culture as a source of variability? Because culture is, in fact, our explanatory target here. To be clear, we seek to understand why and how our entertainment devices vary across time and space, with the premise that individuals' preferences are the primary driving forces behind this variation. While we acknowledge that past artifacts or ideas or traditions can influence contemporary storytelling, we believe that this influence operates mainly as a resource for creators, not as a direct determinant of individual preferences. Culture, as a repository of past narratives, serves as a reference point and tool for refinement, with each generation inheriting, modifying, and building upon such cultural legacies. Our framework thus centers on cognitive mechanisms as the primary drivers of preferences, with culture emerging as an *outcome* of these cognitive mechanisms—as such cognitive mechanisms have constrained what we inherit, and now constrain what we choose to build upon and how we modify it.

Let's finally note that, so far, we have focused on age, sex, personality, and ecological conditions, without considering potential interactions between these factors. For example, a study on cuteness perception in infants' faces revealed that premenopausal women were more sensitive to variations in cuteness compared to men *and* postmenopausal women (Sprengelmeyer et al., 2009). This research suggests that the sensitivity of the **cuteness detector** varies as a function of an interaction between age and sex. By examining potential interactions between factors in future empirical research, we can gain a more nuanced understanding of how these variables collectively shape preferences for different fictional ingredients. Statistical models can be employed to test the significance of such interactions, allowing us to better account for the complex relationships between various sources of variability. It is also worth noting that the effects of age, sex, personality, and ecological conditions on preferences for different ingredients may be mediated by other factors.

3. Methodology and construction of the Ingredient table

So far, we have mainly used examples of particular adaptive challenges, specialized cognitive mechanisms that evolved in response to such challenges, and specific domains of stimuli to which they react. Here, we present the elaboration of the Ingredient table, which lists more than seventy of them in a systematic way.

In the previous section, we have referred to many scientific papers that theoretically ground or empirically test associations between specialized cognitive mechanisms and such ingredients (e.g., predator-detection mechanism and monsters). In the Ingredient table, we also list the result of an extensive review of the literature about such associations, in a separate column. Some of the boxes in this column are empty because research in fiction study has not yet explored the influence of all cognitive mechanisms identified by evolutionary cognitive scientists. We therefore see empty boxes from this column as potentially fruitful directions for future research on fiction.

The construction of the Ingredient table was a collaborative process that involved a team of experts from various disciplines. Our aim was to provide a comprehensive representation of the conceptual and motivational mechanisms that are activated by the ingredients in fictional stories. Our approach began with a thorough investigation of the general adaptive challenges faced by humans, which we organized according to the global types of referents of human cognitive life (**Figure 8**). This initial step allowed us to identify the main domains of the scientific literature that should be further investigated. It was inspired and supported by previous attempts to organize adaptive challenges in broad categories, including handbooks in evolutionary psychology (Buss, 2005; Dunbar & Barrett, 2007; Nettle, 2009a), broad theoretical frameworks aimed at making apparent a structure in cognitive systems (H. C. Barrett, 2015; Del Giudice, 2020, 2022, 2023; Kenrick et al., 2010; Neel et al., 2016; Pick et al., 2022), and applications of such findings to fictional stories (J. Carroll, 2012; Nettle, 2005b, 2005a).

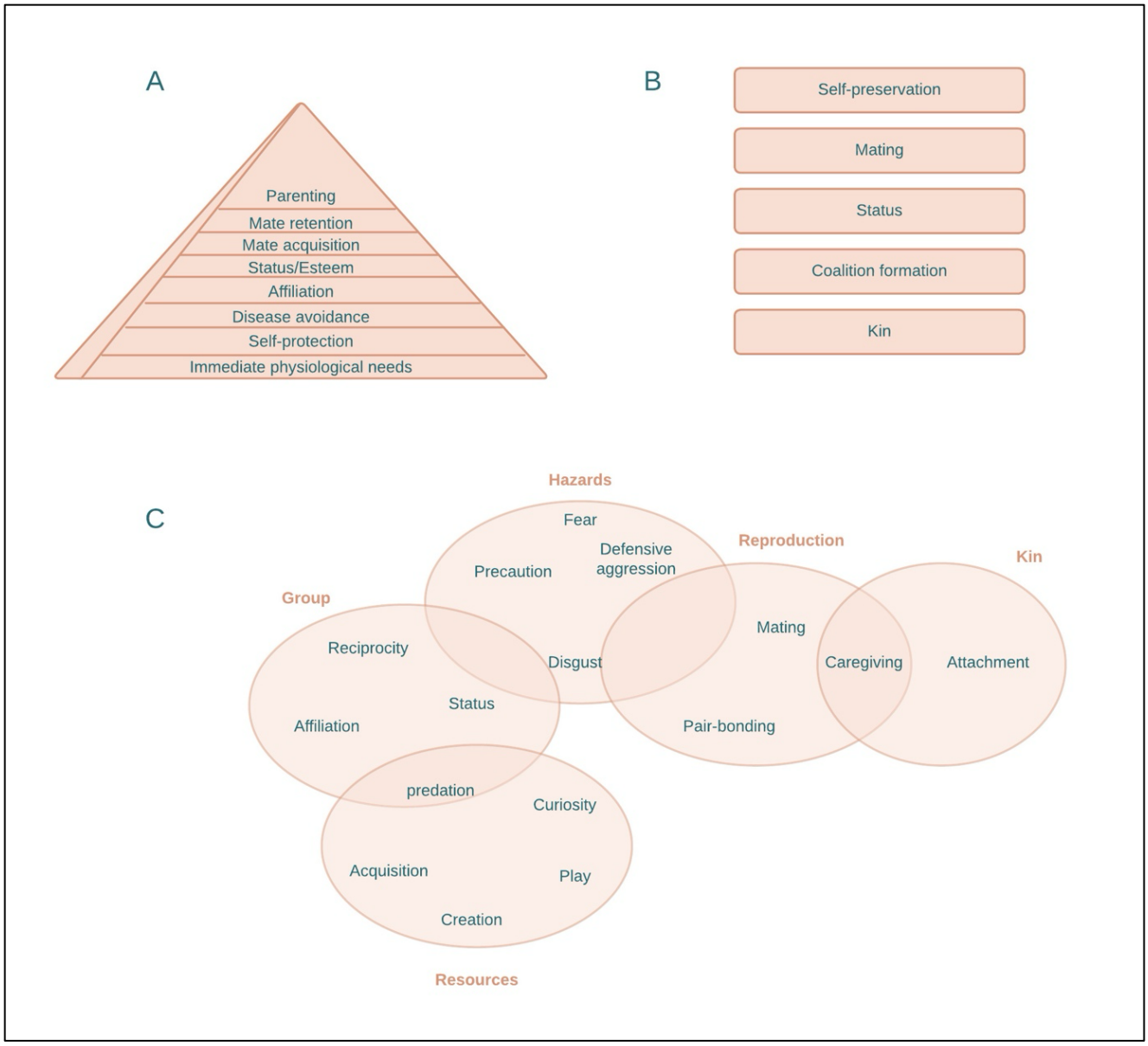

Figure 8. A. Proposed hierarchical organization of general adaptive challenges by Kenrick and colleagues (2010) and then refined (Neel et al., 2016; Pick et al., 2022). B. Proposed domains of adaptive challenges adapted to fiction study by Nettle (2005a). C. Proposed organization of specific motivational cognitive mechanisms grouped in general domains by Del Giudice (2022, 2023).

We then dove into specific adaptive challenges. We identified separate cognitive mechanisms that evolved to solve those specific challenges and documented how their sensitivity varies. This process required an extensive review of the psychological and evolutionary research literature. When available, we prioritized meta-analyses, replicated empirical papers, or systematic reviews of the empirical literature. For the sources of variability, we identified different kinds of relevant empirical papers.

For conceptual mechanisms (e.g., the agressor-detector mechanism), we selected papers testing the associations between personality or socio-demographic variables and either (1) the capacity to rapidly detect a stimulus and turn it into a concept (e.g., measuring the rapidity at which participants identify an hostile face) or (2) the self-reported level of interest in a specific concept (e.g., asking participants how much they are interested in aggressors).

For motivational mechanisms (e.g., the curiosity mechanism), we selected papers testing the associations between personality or socio-demographic variables and either (1) physiological or behavioral measures indicating the presence of motivational drive (e.g., measuring participants' number of visits in unknown locations) or the self-reported sensitivity of their own emotions after an event (e.g., asking participants how much they feel motivated to explore). It is important to note that the sources of variability we have identified here are derived from studies outside the realm of fiction reception. In future research, it will be valuable to investigate whether these sources of variability align with the

preferences of the anticipated audiences in the context of entertainment and fiction.

Let's note that some boxes in the Ingredient table that specify the sources of variability are empty. It can mean that research has not identified a given source of variation for a given mechanism yet, or that we did not find it in our literature review. Each intersection of a row (i.e., a cognitive mechanism) and a column (i.e., a source of variability) in the Ingredient table represents a vast body of literature, and we cannot claim to have exhausted all the potentially relevant sources. It is highly likely that there are many more studies and findings to discover. Our intention in presenting this framework and table is to provide a starting point and a structured way of organizing existing knowledge on specialized cognitive mechanisms. To facilitate ongoing updates and refinements, we have created an open archive where this table can be amended and expanded in the future. Our goal is to motivate scholars to contribute to this evolving framework, making it a more accurate reflection of the extensive literature on the topic.

However, we want to emphasize that the sensitivity of the listed mechanisms does not always vary with any given source of variation, for reasons that owe to our evolutionary history. For instance, the sensitivity of many mechanisms does not vary with biological sex, reflecting the fact that the ancestral problems they evolved to solve were relevant for humans *independently of sex*. For instance, although Buss (1989) identified several sex differences in mate preferences (e.g., women's preference for resource and men's preference for beauty), he stressed that "species-typical mate preferences may be more potent than sex-linked preferences" (p. 13).

The final step was to gather reviews from researchers who specialize in the study of some specific mechanisms or sources of variation, but who were not part of the original team (**Figure 9**). These external reviews helped us to reconsider the whole picture iteratively and refine the table. For instance, during this iterative process of creating the Ingredient table, and thanks to relevant feedback from scholars who would become collaborators on this project, we realized the need to differentiate between conceptual and motivational mechanisms, mirroring the partition between first-party and third-party ingredients.

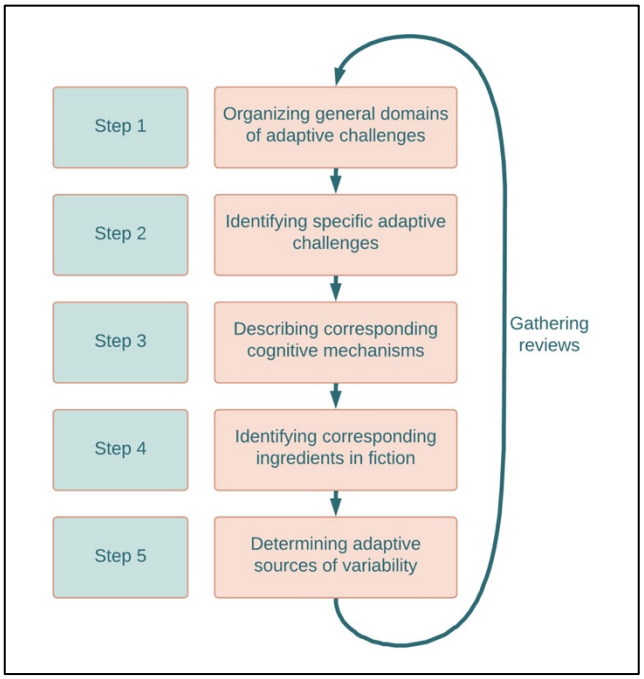

Figure 9. Steps describing the methodology of the construction of the table.

4. Theory-driven predictions and how to test them

4.1. Predictions about the audience of fiction

We contend the predominant of fictional stories can be broadly predicted by their recipes (i.e., the quantity of each ingredient that is present). Because ingredients are associated with cognitive mechanisms the sensitivity of which can adaptively vary with age, sex, personality traits, or ecological conditions, the identification of such ingredients in fictional stories leads to testable predictions about who will enjoy them more, on average.

First, this framework provides evolutionary rationales to explain what we observe—leading to verifying so-called 'retrodictions'. Let's think of a fictional story in which one of the main ingredients is the improvement of the protagonist training hard to acquire new skills or knowledge (e.g., *Attack on Titans*, *Mulan*, *Dragon Ball*, *One Piece*, *Spider-Man*, *Harry Potter*, *Karate Kid*). Our framework explains why such fictional stories are apparently preferred by younger people, all over the world: because this prominent third-party ingredient triggers the **skill acquisition** mechanism. People who are younger are naturally more motivated to develop skills and are therefore more interested in fictional characters developing skills.

This framework also leads to new testable predictions. For instance, let's now think of fictional stories in which one of the main ingredients is related to **friendship** (e.g., *Friends*, *How I Met Your Mother*, *Five*, *The Perks of Being a Wallflower*, *Toy Story*). Engagement in interdependent relationships is associated with a cognitive mechanism whose sensitivity varies with personality traits: people higher in agreeableness, higher in extraversion, and lower in neuroticism are more motivated to form friendships in real life (Ashton et al., 1998; Oda et al., 2014). We therefore predict that such variations in personality are associated with the consumption of and preference for fictional stories in which one of the main ingredients is friendship.

Every row of the Ingredient table makes testable predictions such as these each time the sources and directions

of the variations in the sensitivity of the associated mechanisms are specified.

4.2. Recipes in fictional stories

The fact that preferences vary in human populations—reflecting evolved variations in the sensitivity of cognitive mechanisms—has consequences on the structure of fictional stories. We hypothesize that people's variable preferences shape what stories creators produce (Dubourg & Baumard, 2022a). Let's note that we do not claim that producers always add attractive ingredients to their narratives intentionally. They can do so unconsciously, with the intention to create something beautiful, pleasurable, or interesting, to themeselves only or to other people.

Just like a meal, fictional stories are composed of various ingredients in differing proportions, which contribute to their success in specific audiences. For instance, the manga and anime *Attack on Titan* features monsters (activating, notably, the **formidability detector**, **predator detector**, **fear of predator**, and **fear of agressor**), and innovative technologies (engaging the **technical efficiency evaluator**), but only a hint of romance and kin-related ingredients. In contrast, a romantic drama like *The Notebook* places greater emphasis on love-related and kin-related ingredients, vicariously activating **long-term love** and **familial love** (see **Figure 10** for another example).

Each fictional story represents a unique and carefully balanced combination of ingredients designed to captivate its audience. To put it another way, we consider each ingredient as a dimension and each fictional story as a unique combination of all dimensions (ranging from total absence of being the main driver of the story). This combinatorial mixture of *dimensional* aspects explains the great variety of fictional stories that genres or other *categorial* approaches had attempted to capture. Ingredients, however, do not seem to be randomly distributed in fictional stories. We posit that the account of psychological variability that we proposed in subsection **2.5.** sheds light on the somewhat stable compositions of fiction, that is, on the recurrent associations of the same ingredients in different fictional stories. We argue that the patterns we observe in fiction—and the reasons why genres seem to be an intuitive categorization—are due to the fact that *variations in the sensitivity of cognitive mechanisms are systematically structured by selection pressures*. This is what we call *recipes*: groups of ingredients that tend to appear together more than chance would predict. The existence of those recipes is due to the fact that the mechanisms the ingredients tap into vary in the same directions, according to the same sources of variability.

For example, a story that appeals to a young audience might combine ingredients that target mechanisms that are more sensitive during youth, such as imaginary worlds (activating both our **landscape evaluator** and **curiosity**), gadgets (engaging our **technical efficiency evaluator**), and groups of friends (activating our **group affiliation** mechanism). By catering to particular psychological profiles, these recipes maximize their impact on the intended audience, by prioritizing some ingredients over others. This approach of putting together ingredients that appeal to the same audience is also evident in the organization of publishing houses, with separate collections for different cognitive profiles. For instance, in Western literature, specific terms emerged to directly specify a targeted audience, such as 'chick-lit', which describes a type of fiction targeted at younger women, or 'young-adult', which is a category of fiction targeted at 12-18 year-olds. We observe the same kind of partitions in Japan, where the structure of manga genres is explicitly categorized based on their intended demographics (e.g., *Shonen* for teen boys and *Shojo* for teen girls). Finally, this framework is consistent with long-standing findings in literary theory that some themes or tropes seem to recur and co-occur in fictional stories (Cawelti, 1977; Propp, 1968; Fowler, 1971; Hogan, 2003; Pavel, 2017; Schaeffer, 1999; see Moretti, 2007, for a data-driven approach).

This notion of recipes is central to our understanding of why some ingredients often appear together in successful fiction. When ingredients appeal to similar psychological

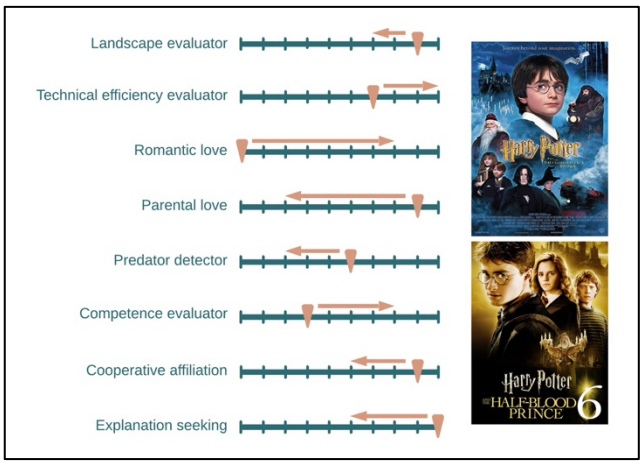

Figure 10. Examples of recipes. We take 8 examples of cognitive mechanisms. The orange sliders represent how a hypothetical participant might rate the 'amount' of ingredients activating each mechanism in Harry Potter and the Philosopher's Stone. The orange arrows represent where the cursors would move if we annotated Harry Potter and the Half-Blood Prince, in which there seems to be less exploration of the environments, more magical technologies to evaluate, more long-term love, etc. This gives an example of manual annotation that should be performed by multiple coders to ensure internal validity. Let's imagine that such annotations were provided by impartial annotators, who would be unaware of the theory, and who would converge on such annotations. Then, such annotations would align with the notion of recipes: different Harry Potter books are tailored to entertain specific groups of people, varying in age, and, therefore, in preferences. See Appendix A for a list of short intuitive descriptions of all ingredients that can be used to annotate stories by participants or algorithms.

profiles, they tend to complement each other, much like ingredients in a meal. Furthermore, just as in cooking, consumers are unlikely to enjoy a fictional story containing ingredients they find bland or repulsive. To overcome this challenge, creators strategically design fiction to cater to the preferences of specific target audiences. This phenomenon is amplified by technical constraints. For instance, given the constraint of the length of novels, films, or video games, each fictional ingredient comes at the cost of another. For example, the inclusion of Peter Parker and Mary Jane Watson's love story in *Spider-Man* comics and movies may occur at the expense of action-packed fight scenes or family-related scenes. This refines what we call 'preferences' in this article, which refer to the sensitivity of cognitive mechanisms that are activated by certain story elements *at the expense of others*. When we have a preference for a particular ingredient, it means that we find it more cognitively attractive than other alternatives and that we are willing to forgo the benefits of those alternatives in order to experience that particular ingredient.

Precise recipes intended for specific audiences are complemented by what we may term 'generalist recipes'. These recipes are akin to a lavish buffet, offering an array of ingredients designed to cater to a wide range of tastes and preferences within a single narrative. In contrast to niche recipes that meticulously tailor their ingredients to a specific audience, generalist recipes take a more inclusive approach. They incorporate features that tap into various sensibilities, which do not consistently align with the same sources of variability. Their objective here is to create a cinematic or literary feast where there's something for (almost) everyone, albeit at the risk of some viewers or readers finding certain ingredients less to their liking. A prime exemplar of the generalist recipe phenomenon can be found in the world of blockbuster cinema, such as the Marvel Cinematic Universe (MCU) standing as a shining illustration. In these films, we witness an orchestration of diverse ingredients, ranging from high-octane action sequences that engage the **fear of agressor** to intricate interpersonal relationships that tap into, for instance, **long-term love** and **familial love**. These movies, often characterized by their extended durations and substantial budgets, have the luxury of accommodating multiple ingredients without sacrificing coherence. As a result, viewers can fulfil their own preferences within these expansive narratives, each drawn in by different elements that resonate with their individual preferences.

It is also important to clarify that our framework does not suggest that there is a finite set of recipes that can guarantee success in fiction. The combinatorial explosion of ingredients, each of which operates as a dimension within storytelling, contributes to the endless possibilities for crafting captivating fictional experiences. And, in fact, **curiosity** also plays a significant role in shaping fictional stories (Luan & Kim, 2022; J. Cutting, 2022; Dubourg & Baumard, 2022b; Wylie & Gantman, 2023). People tend to enjoy novel elements, even if the degree of novelty preferred can vary widely. This implies that new ingredients and new recipes can continually emerge to captivate audiences: they have an advantage all else being equal *because* they are novel. However, it is also worth noting that the number of completely new ingredients is not infinite because of the limited number of cognitive mechanisms (that, in our framework, emerge only by natural selection). This perspective opens up exciting avenues for research, encouraging exploration of what has been done in the past and what can still be achieved to maintain innovation in storytelling.

4.3. Predictions about the clustering of ingredients

The Ingredient table leads to both explanations for and testable predictions about the clustering of ingredients into so-called recipes, because of the structured variability of the sensitivity of cognitive mechanisms. We hypothesized that some ingredients would be more likely to be found together in stories, because the sensitivities of the associated cognitive mechanisms vary in the same directions, according to the same sources of variability in the target audience.

This framework leads to consistent explanations for the emergence of genres and subgenres. For instance, the heroic fantasy sub-genre, which is successful in both Western and non-Western countries (Rehling, 2012), is a bundle of multiple prominent ingredients: an imaginary world (triggering the **landscape evaluator**) and a humble hero (triggering **moral praise**), who is learning new skills (vicariously triggering **skill acquisition**) and is successful in overcoming the monster (triggering the **competence evaluator**). Such ingredients trigger mechanisms that are all more sensitive during youth and adolescence, according to the evolutionary literature tackling adaptive developmental variability.

To take another example, the romantic comedy genre seems to systematically include attractive protagonists (triggering the conceptual mechanisms related to partner valuation such as the **status evaluator**), who have trouble either finding a suitable mate able and willing to start a family (vicariously triggering **romantic attraction**) or keeping their mates (vicariously triggering **romantic jealousy**). Protagonists almost always associate with warm friends that help them overcome such difficulties (triggering the **warmth evaluator**). All the cognitive mechanisms associated with such ingredients are more sensitive in women of all ages and young adults of both sexes, because of the specific adaptive challenges female individuals and young adults repeatedly faced in ancestral environments. We can therefore explain why some ingredients seem to cluster together, and why we may have the intuition that they 'go along well together'.

This framework also leads to new testable predictions about the clustering of ingredients. As we have argued, some

cognitive mechanisms (e.g., **curiosity**, **romantic attraction**, **familial love**, and **fairness**) vary according to ecological conditions: the more secure and affluent the environment is, the more sensitive these mechanisms are (Baumard, 2019; Baumard et al., 2022; Dubourg & Baumard, 2022b). The sensitivity of some other mechanisms decreases with the same ecological factor (e.g., **resource exploitation**, **moral blame**, **sexual jealousy**), for related evolutionary reasons. We therefore predict that fictional stories will include more and more of ingredients triggering the former kind of mechanisms, and less and less the latter, because of increasingly favorable ecological conditions in modern societies. That is, we predict the emergence of new recipes that would include ingredients better fitting the changing preferences of their audience, which follow changes in ecological conditions. We also predict that recipes will differ between regions of the world according to the general level of affluence of each region.

In all, this framework generates predictions about the recurring associations of ingredients in fictional stories. It is also important to note that, symetrically, this framework makes predictions about *incompatible* ingredients, each time the predicted sources of variability of the cognitive mechanisms are not consistent in the Ingredient table. For instance, consider **fear of predator** and **romantic attraction**. The sensitivity of the former is predicted to be higher in younger individuals and in males. Conversely, the sensitivity of the latter is predicted to be higher in older individuals and in females. Due to these opposing sensitivities based on age and sex, the corresponding ingredients that activate these mechanisms are expected to co-occur less frequently than what would be expected by chance (except in some highly generalist recipes). This means that the presence of predators and monsters, common in horror narratives, might be less frequently combined with long-term romantic relationships. Horror fans might intuitively grasp this, as many horror movies rarely feature enduring love relationships. This example highlights just one instance of how our framework generates predictions for ingredient incompatibilities. This aspect should be further tested in the future.

5. Discussion

We hope to have provided theoretical evidence for the relevance of evolutionary theory and adaptive sources variability to study fiction. This framework lays the groundwork for a broad theory-driven empirical research program on ingredients and recipes that could be relevant beyond the study of fiction, to understand the dynamics of human entertainment at large. In this Discussion, we suggest future directions that could build on this broad framework.

5.1. The proportion of ingredients

In previous sections, we emphasized the importance of the presence and absence of ingredients in fictional works but also the need to carefully consider the proportion of these ingredients. Each narrative fiction contains a unique combination of ingredients, but they are not present in equal relative amounts. For example, the proportion of ingredients triggering **romantic attraction** in *Spider-Man* is still much lower than in *Notting Hill*. We believe that this explains why genres seem so intuitive: because they capture ingredients that are in greater proportions. Because *Spider-Man* contains less love-related ingredients than typical romance movies like *Notting Hill*, it is not a 'Romance'. Yet, tagging this movie as a 'Science fiction' or 'Super-Hero' movie gives no clue as to whether it contains ingredients related to love or not, and in what proportion. Another example: Harry Potter novels all include a central investigation (the first book is even a kind of Whodunit) but they are never categorized as detective fiction, because this ingredient is present in smaller *proportion* in comparison to detective stories (not because it is not central, as it is in all seven volumes, but because many more ingredients are central in *Harry Potter* versus, for instance, *Sherlock Holmes*).

The categorization of fiction by genre is quite recent and still evolving. This makes it hard to compare fictional stories coming from different periods, though they may share similar ingredients. For example, can *Hamlet* be tagged as a Thriller? And is *The Illiad* Fantasy fiction? We run into similar issues due to language: stories may share similar ingredients in similar proportions but this would not necessarily be reflected in the different tagging systems used in different countries. For instance, American Western and Japanese *Jidaigeki*, which are rarely studied together, might be quite similar when we consider their ingredients. The emergence of a myriad of sub-genres in folk theories of fiction and the use of keywords instead of genres in marketing research are symptomatic of the limitation of genres. (Netflix uses 76,897 micro-genres; Madrigal, 2014). We argue that our framework enables us to move above and beyond genre categorization, which can be overly simplistic, as well as keyword tagging, which can be excessively detailed: it makes it possible to characterize each fiction not with a single tag such as 'Thriller' or 'Science fiction', nor with hundreds or thousands of keywords, but with approximately 70 ingredients in different proportions.

This framework could also offer new ways to approch fiction in marketing studies. With the tremendous increase in entertainment products, marketing and other recommendation systems can be thought of as cultural compasses: without it, we would be flooded with new content, with no clue as to where we could find individually relevant products (Waldfogel, 2018). But to effectively fill this role, any tool needs to be well calibrated. In marketing, it is standard to contrast *collaborative approaches* (i.e., models trying to predict

consumers' preferences based on similar consumers' past preferences) with *content-based approaches* (i.e., models trying to predict consumers' preferences with content features). In order to increase the predictive power of marketing studies, scholars have been moving away from *collaborative approaches* toward developing more *content-based approaches* (Toubia et al., 2019). However, such approaches suffer from the fact that defining the key features of fiction is not as straightforward as for other products (e.g., memory, size, or shutter speed for a digital camera; Toubia et al., 2019). Categorization by genres has been used as a feature set by empirical approaches to narrative fictions (e.g., Eliashberg & Sawhney, 1994; Nave et al., 2020). We believe the consideration of fictional recipes composed of different ingredients, in different amounts, could increase the predictive power of such content-based or hybrid models, much like the inclusion of personality dimensions can improve recommendation systems (Chen et al., 2016; Tkalcic & Chen, 2015).

5.2. The content and form of ingredients

In **Section 2.2.**, we categorized cognitive mechanisms based on their level of processing, initially separating low-level perceptual mechanisms because of their apparent distance from the study of fictional content. However, it is crucial to recognize that, in the context of storytelling, ingredients encompass both *form* and *content*, aligning with the perspective of some literary theorists who argue that form and content are inseparable facets of narrative. This perspective arises from the fact that the output of perceptual mechanisms feeds into and shapes the operation of conceptual mechanisms. In fact, ingredients represent the output of perceptual mechanisms that influence the activation of conceptual mechanisms, which subsequently drive motivational responses. Thus, an ingredient in a fictional narrative does not merely depend on content; it equally involves how that content is presented, encapsulating both form, style, and media characteristics (e.g., for the impact of shot length, see: J. E. Cutting, 2016; for the impact of music in horror film, see: Lerner, 2010; Prinz & Seidel, 2012; for example of low-level cues feeding our fear-related mechanisms, see: Watier, 2022, 2023; for the correspondence between length of line in verse across cultures and the capacity of human working memory, see: Fabb, 2015).

For instance, consider the characters within a narrative. Their formal presentation, including visual appearance, behavior, and interactions, significantly impacts how audiences recognize and interpret them. Formal features play a pivotal role in determining whether a character is perceived as high status, a villain, or someone demonstrating manifest incompetence. For instance, style elements, such as low-angle shots that portray characters from below, further enhance our perception of their dominance or formidability, influencing the activation of our status-evaluator and formidability-evaluator mechanisms. Such visual effects seem close to real-life experiences: here, the low-angle shot creates the sensation of looking up at a character as if we were very small in comparison.

To further illustrate this point, let's revisit the adaptations of *Alice in Wonderland* from Disney (1951) and from Tim Burton (2010). While both versions might initially appear to share similar ingredients due to their common source material, a closer examination reveals important distinctions. Tim Burton's adaptation, for example, accentuates elements that activate fear-related mechanisms to a greater extent, altering the audience's perception of certain characters as more threatening. Thus, the inclusion of form, such as character design and visual style, modulates the cognitive mechanisms activated by the ingredients themselves. Another compelling example arises from the films *Dr. Strangelove* (Kubrick, 1964) and *Fail Safe* (Lumet, 1965). These two films, released in the same year and featuring nearly identical storylines (to the extent that legal action ensued), diverge dramatically in their reception. By depicting a nuclear holocaust, *Dr. Strangelove* invokes humor, while *Fail Safe* elicits vicarious fear and grief. The crucial distinction here lies in the films' styles—their respective approaches to conveying a shared narrative content—underscoring how style significantly influences the cognitive mechanisms engaged by the audience (see: Hye-Knudsen, 2022).

While our framework primarily operates at the conceptual and motivational levels, focusing on what audiences infer from fictional narratives, it is important to acknowledge that perceptual features feed into these inferences by presenting the revelant ingredients in ways that enhance or diminish their effects. This specification makes our framework close to the one governing the whole field of evolutionary aesthetics, that focuses on which cognitive adaptations are being tapped into by artistic representations (S. Brown et al., 2011; Dutton, 2009; Hogh-Olesen, 2019; Prum, 2017; V. Ramachandran & Hirstein, 1999; Reber et al., 2004; Renoult, 2016; Thornhill, 2003; Van de Cruys et al., 2021; Van de Cruys & Wagemans, 2011; Voland & Grammer, 2003).

However, we emphasize the conceptual and motivational aspects in our paper, for one main reason: focusing on higher-level domains of cognition, such as concepts and motivations, allows us to delve into the question of preference. For example, when it comes to evaluating cuteness in characters, nearly everyone can do so and generally agrees on which character is cuter (with little variation). However, some people may find cute characters highly enjoyable while others may not. We hypothesize that this is, to a large extent, influenced by the different sensitivities of the *motivational* mechanisms, in a functional manner that should still be unpacked. For instance, people whose **parental love** motivational mechanism is more sensitive should enjoy cuter stimuli more.

This approach allows us to delve into the cognitive mechanisms underlying preferences and reactions to fiction while recognizing the rich interplay between form and content in shaping the audience's experience.

5.3. The sequentiality of ingredients

While we focused on the presence and quantity of ingredients, we did not take into account their place along the storyline. However, the sequentiality of ingredients is an important aspect that can greatly influence the appeal of a fictional story.

Just like when preparing a complex meal, you cannot add the ingredients in any random order and expect a good outcome, so too with fiction: there needs to be some sequence that allows the ingredients to consistently blend successfully. This idea lays the ground for a crucial future direction for our framework, which can benefit from incorporating insights from cognitive narratology, but also other empirical projects that have already proved useful in identifying patterns in narrative sequentiality, using text analysis on thousands of novels and movie scripts (R. L. Boyd et al., 2020; Del Vecchio et al., 2021; Reagan et al., 2016). By considering the order in which ingredients are presented, we can better understand how stories are constructed and how they impact the cognitive mechanisms of their audience. Overall, the sequentiality of ingredients is an important consideration for future research in this field. Let's note that some typical sequences of events are themeselves individual ingredients (e.g., when a character faces a challenge and then succeeds is an ingredient that activates our **competence-evaluation** mechanism; see Singh, 2021).

5.4. The blending of ingredients

Storytellers have a unique creative freedom to craft fictional stimuli that blend concepts and motivations that rarely co-occur in real life. They can create superstimuli that activate multiple cognitive mechanisms simultaneously, thereby capturing people's attention for different reasons. Titans in *Attack on Titan* are a good example of this phenomenon. They act like predators, devouring humans, which activates our **fear of predator**. But, they also look like aggressors, with their human shape, activating our **fear of agressor**. They are disgusting because of their torn skin, activating **disgust**, and they walk in groups, activating our **fear of coalition**. The Titans' ability to activate multiple cognitive mechanisms simultaneously makes them an appealing ingredient. We use the term 'composite ingredients' for such fictional superstimuli that activate several mechanisms at once.

Another example: the case of the Beast in the story of *Beauty and the Beast*. The Beast looks like a dangerous predator, with sharp claws and teeth, a large frame, and a menacing growl. He is initially hostile to Beauty but later becomes protective and caring. He is also competent—being able to read, write, and play musical instruments. The Beast is a composite ingredient because he activates both our **trustworthiness evaluator**, **competence evaluator**, and **formidability evaluator**, all of which evaluate him as a valuable mate or cooperative partner. However, because of his appearance, he also triggers our **predator detector**, making him initially fearsome. This blend of predator and mate features makes him a unique and intriguing character.

Looking forward, the study of such composite ingredients is a promising area for future research. Some short stories that are orally transmitted, such as urban legends, are highly constrained by memory encoding and retrieval, which makes them a good test case to study how many and which ingredients can be successfully blended together. Content analysis of urban legends has shown that they most frequently activate two or three cognitive mechanisms in combination, suggesting an optimal number of mechanisms being activated by composite ingredients under memorial constraints (Stubbersfield, Flynn, et al., 2017; Heath et al., 2001a). Research using recall-based transmission chain experiments can help in understanding which ingredients are more successful than others under specified constraints (Eriksson & Coultas, 2014a; Upal, 2011; Jiménez & Mesoudi, 2020; Stubbersfield, Tehrani, et al., 2017; see Stubbersfield et al., 2015, for a study relaxing memorial constraints). Such methods are also successfully used in the study of online misinformation (Berger & Milkman, 2012; Berriche & Altay, 2020)

5.5. Conclusion: The non-specificity of fictional ingredients

Some fictional ingredients may seem special at first glance, because humans seem to react differently to them in fiction versus in real life. For instance, we obviously do not react the same way when we encounter a fictional predator and a real predator. However, we believe that this difference is primarily due to the evaluation of the safeness of the fictional situation, which we argue is processed as if the stimuli were located really far in the distance (Clasen, 2021; Menninghaus et al., 2017; C. W. Scrivner, 2022; see also: Yang & Zhang, 2022). This is the direct consequence of such stimuli being unreal and in our control (Kerr et al., 2019; Yang & Zhang, 2022), much like behaviors during play (Andersen et al., 2020, 2022; Deterding, 2009; Spinka et al., 2001).

We can better understand this by revisiting the window metaphor, which represents the idea that we are not physically present in the story world but observing it from a secure distance. This sense of safety enables us to engage with potentially threatening stimuli, much like we would in real life if we were completely safe (Oosterwijk, 2017; Powell et al., 2022; Scrivner, 2021b). This positive association between the

evaluation of safety and interest in threats has been consistently found in the animal literature (FitzGibbon, 1994; Lönnstedt et al., 2012; Pitcher et al., 1986; Scrivner, 2022). For example, Thomson's gazelles approach and inspect cheetahs, despite their predatory nature (FitzGibbon, 1994). This behavior increased when the Gazelles were in a safer situation (e.g., in low vegetation). This behavior also increased for adolescents and when in groups, very much like recreational horror consumption in humans. This perspective could help future research defuse the paradoxes of horror and tragedy: they would not be true paradoxes, as our enjoyment of these stories would arise for the same reasons why we would feel captivated by predators in real life and similar circumstances. We feel morbidly curious in cases where the threat is observable but not capable of hurting us (Scrivner, 2022; see **Figure 11**), just like for the minds and motives of villains (Wylie & Gantman, 2023).

This approach to fictional ingredients also applies to character identification (as conceptualized first by literary theorists; see Jauss et al., 1974; see also: M. Smith, 1994, 2023; Cohen, 2006). We do not identify or empathize with fictional characters in a unique, special way. Rather, we employ the same socio-cognitive mechanisms that we use in real-life (Vermeule, 2011; Zunshine, 2006). We may appreciate a character because they would be a good cooperative partner, because we enjoy understanding their motivations, or because we become emotionally invested in them, much like our connections with real people (Singh, 2021). For instance, our attachment to a fictional character might stem from the length of our exposure to them, as our kin-detection mechanism takes as a cue of kin-relatedness the time spent with an individual, especially during childhood. Consequently, we should become emotionally attached to fictional character that we repeatedly encounter in our preferred fictional stories (Ott & Slater, 2022; Schmid & Klimmt, 2011; Stever, 2017). Finally, we can learn from fictional characters and their experiences, just as we do in real life. Again, the puzzle of character identification is not a puzzle if we adopt this evolutionary cognitive lens. As a matter of fact, this framework has even been proven useful to explain our appeal for antipathetic characters (Kjeldgaard-Christiansen et al., 2021).

In conclusion, our response to fictional ingredients is not fundamentally distinct from our reaction to real-world stimuli. Fictional stimuli, or what we called 'ingredients', activate evolved cognitive mechanisms, explaining their appeal. Because the sensitivity of such mechanisms varies at the interindividual level, people vary in their preferences for different fictional stories. And because different sources of variability impact the sensitivity of some cognitive mechanisms in similar ways, recipes emerge. A number of predictions derived from this broad framework need to be tested in the future, including (1) the match between cognitive preferences and ingredients (e.g., testing that people who have a more sensitive **trustworthiness detector** in real life enjoy more stories in which the trustworthiness of the characters is questioned), (2) the predicted sources of variability for the preferences for ingredients (e.g., testing that people who are higher in Openness enjoy more movies that activate our **curiosity**, such as 'whodunnits'), (3) the tendency for ingredients to cluster together as a function of how human cognitive preferences vary together (e.g., testing that ingredients that trigger the **explanation evaluator** and the **landscape evaluator** tend to co-occur because their sensitivities vary accordingly), and (4) the effect of ecological conditions on the rise and fall of ingredients, according to how responsive to such conditions the mechanisms activated are (e.g., testing whether the success of ingredients that activate our **parenting love** increases when resource availability increases).

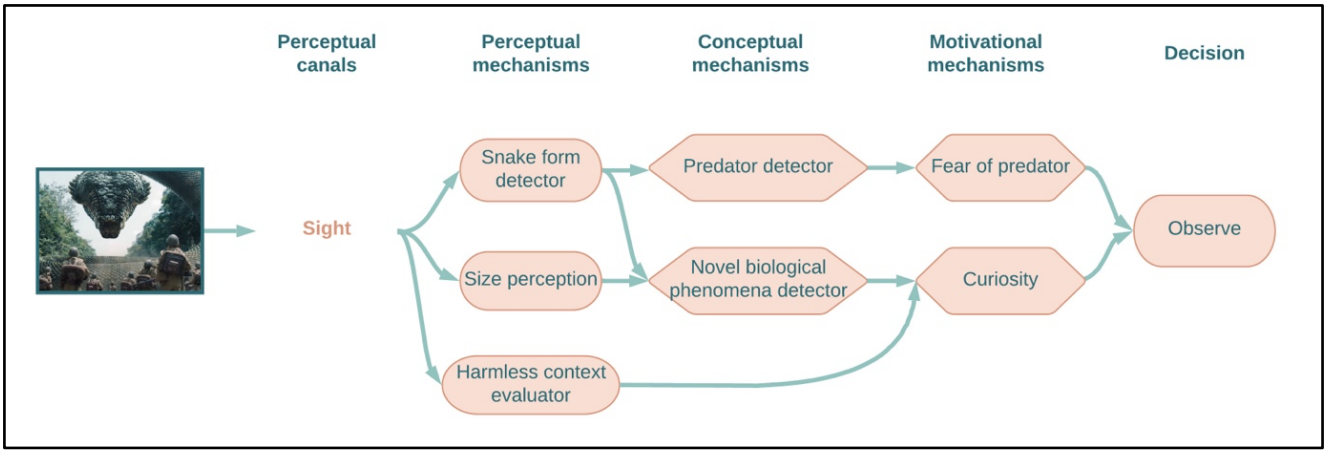

Figure 11. Simplified schema of the cognitive mechanisms activated by a fictional snake. Similar to Figure 2 but adapted to fiction consumption.

Figure 23. The Ingredient table 1. For the Big Five: 'O'=Openness, 'C'=Conscientiousness, 'E'=Extraversion, 'A'=Agreeableness, 'N'=Neuroticism, and 'B'=All Big Five traits moving in the same direction (with inverted direction for Neuroticism). '+' means a positive correlation (i.e., the higher the personality trait, the more sensitive the cognitive mechanism) and '-' means a negative correlation (i.e., the higher the personality trait, the less sensitive the cognitive mechanism). For Age, 'C'=Childhood, 'O'=Adolescence and 'U'=Adulthood. '+' means that people of this life stage have a more sensitive cognitive mechanism than people of other life stages, on average. For Ecology, 'F'=Favorable and 'H'=Harsh. '+' means that people in this kind of ecology have a more sensitive cognitive mechanism than people in other kinds of ecology, on average. For Sex, 'M'=Male and 'F'=Female. '+' means that people of this biological sex have on average a more sensitive cognitive mechanism than people of the other biological sex. In the 'Cognitive mechanism' column, '/' separates names for same mechanisms while terms between parentheses refer to conceptually close notion in the scientific literature. References for sources of variability are numbered and listed in a separate bibliography below.

Conceptual mechanisms										
Ultimate level			**Proximate level**		**Cultural domain**		**Variability**			
Domain	Identifier	Adaptive challenge	Cognitive mechanism	References for the cognitive mechanism	Examples of ingredient	References for the cognitive ingredient	Big Five	Age	Ecology	Sex
Conceptual mechanism	1	Detect potential predators	**Predator detector**	(Fishman, 1999; Gutiérrez-García & Contreras, 2013; So et al., 2016)	Predators, Monsters, Kaiju	(Clasen, 2012b, 2021; Morin & Sobchuk, 2022b; Scalise Sugiyama, 2006; C. Scrivner, 2021b)				+M[1]
	2	Detect potential aggressors	**Aggressor detector**	(Gutiérrez-García & Contreras, 2013; So et al., 2016)	Aggressors, Villains, Murderers	(Black et al., 2019; Gantman & Wylie, 2023)			+H[2]	+M[1,3]
	3	Evaluate pathogens presence	**Pathogen detector**	(Hlay et al., 2021; Tybur & Lieberman, 2016)	Parasites, Skin disease, Deformity, Human fluids	(Clasen, 2012a, 2012b; C. Scrivner et al., 2021b)	+E - C[4]			+M[3]
	4	Detect injuries	**Physical pain**	(Gross & Canteras, 2012; Khera & Rangasamy, 2021)	Painful injury, Torture	(Clasen, 2021)	+A +C[5]			+F[6]
	5	Understand physical laws	**Intuitive physics**	(Baillargeon et al., 1985; Kubricht et al., 2017b; Mahr & Csibra, 2021b, 2021a; Spelke, 1990; Ullman et al., 2017)	Immaterial objects, Teleportation, Flying	(McCoy & Ullman, 2019; Norenzayan et al., 2006; Purzycki & Willard, 2016)	+O[7]	+C[8-11]		+M[12]
	6	Understand biological beings	**Intuitive biology**	(Atran, 1998; Mahr & Csibra, 2021a)	Creature classification, Undead, Hybrid	(Clasen, 2012a; Norenzayan et al., 2006; Nyhof & Barrett, 2001; Purzycki & Willard, 2016)				
	7	Understand human psychology	**Intuitive psychology (Theory of mind)**	(Mahr & Csibra, 2021a; Milligan et al., 2007; Saxe et al., 2004)	Strange thoughts of the protagonists	(Black & Barnes, 2015; Carroll, 2018; Kidd et al., 2016; Saunders, 2012; Zunshine, 2006)	+A[13-15]		+F[16]	+F[17]
	8	Understand causal factors	**Explanation evaluator**	(Gopnik & Glymour, 2002; Lombrozo, 2006; Lombrozo & Vasilyeva, 2017)	Strange events, Mysterious disappearance	(Grodal, 2010)	+O[18-22]	+C[23,24]	+F[25,26]	
	9	Understand technologies	**Technical efficiency evaluator (Technical reasoning)**	(Mangalam et al., 2021; Osiurak & Reynaud, 2019; Stout, 2021; Vaesen, 2012)	Gadgets, Magical wands, Futuristic objects		+O[27-29]	+C[30-32]		+M[33]
	10	Detect nutritional value of food	**Nutritional resources detector**	(Piech et al., 2010; Teichroeb & Chapman, 2014)	Delicious food, Banquet	(Scalise Sugiyama, 2001a)			+H[34]	
	11	Evaluate resource potential in the environment	**Landscape evaluator**		Fantasy worlds, Futuristic worlds, Foreign worlds	(Dubourg et al., 2023; Dubourg & Baumard, 2022b)	+O[35-37]	+C[38-40]		+M[41-44]

Conceptual mechanisms										
Ultimate level			**Proximate level**		**Cultural domain**		**Variability**			
Domain	Identifier	Adaptive challenge	Cognitive mechanism	References for the cognitive mechanism	Examples of ingredient	References for the cognitive ingredient	Big Five	Age	Ecology	Sex
	12	Detect situation with risk of social devaluation	**Social devaluation evaluator**	(Landers & Sznycer, 2022)	Situation of manifest incompetence	(Clasen, 2017)				
	13	Detect begnign violation	**Humor appreciation**	(Warren et al., 2022)	Harmless social devaluation	(Eitzen, 2012; Hye-Knudsen, 2022)	+E - N[45,46]			
	14	Identify the effect of one's actions	**Agency / Sense of control, Locus of control**	(Pacherie, 2014; Wuepper & Lybbert, 2017; Chambon et al., 2018)	Overcoming challenges, Life-changing decisions	(Dubourg & Chambon, 2023; Kjeldgaard-Christiansen, 2020)	+B[47-49]	+O[50]	+F[51-53]	+M[54,55]
	15	Evaluate competence	**Competence evaluator**	(Fiske et al., 2007)	Geniuses, Superheroes, Superstars	(Johnson et al., 2011; McCrae et al., 2012; Rapaport et al., 2016)				
	16	Evaluate trustworthiness	**Trustworthiness evaluator**	(Brambilla et al., 2021; Everett et al., 2016; Goodwin, 2015; Taylor, 2006; Uhlmann et al., 2015)	Superheroes, Honest characters	(B. Boyd, 1998; Corbey & Mol, 2011; Eden et al., 2011; Johnson et al., 2011; Luttrell, 2013; Martins & Baumard, 2020; McCrae et al., 2012; Rapaport et al., 2016; J. Saunders, 2005 ; Wylie & Gantman, 2023)				
	17	Evaluate willingness to initiate cooperation	**Warmth evaluator**	(Fiske et al., 2007)	Warm character	(Johnson et al., 2011; Schmid & Klimmt, 2011)				+F[208]
	18	Evaluate level of material ressources	**Resources evaluator**	(La Cerra, 1995)	Character with high status, Billionaire				+H[56,57]	+F[58,59]
	19	Evaluate capacity to inflict damage	**Formidability evaluator**	(Sell, 2011; Sell et al., 2009; Snyder et al., 2011)	Muscular character, Deadly character	(M. Gilbert et al., 2023; Kjeldgaard-Christiansen, 2020; Wylie & Gantman, 2023)				
	20	Evaluate position in social hierarchy	**Status evaluator**	(Zeng et al., 2022)	Dominant character, Hierarchy	(Corbey & Mol, 2011; Luttrell, 2013; Nettle, 2005b, 2005a)				
	21	Compute interpersonal obligations	**Fairness, Free-rider detector**	(André et al., 2022; Price et al., 2002)	Ambiguous characters, Cheaters	(Flesch, 2007; Kjeldgaard-Christiansen, 2016a, 2017, 2021; Krakowiak & Tsay-Vogel, 2015; R. J. Lewis et al., 2014; D. Smith et al., 2017; Sugiyama, 2008; Vaage, 2013; Wylie & Gantman, 2023)	+O[60]	+U[61]		/[62]
	22	Attribute coalition to people	**Group member detector**	(Cosmides et al., 2003; Hammond & Axelrod, 2006; Pietraszewski et al., 2014)	Distinguishing mark, Similar clothes	(Proudfoot et al., 2019)				
	23	Evaluate coalitional formidability	**Coalitions evaluator**	(Raihani & Bell, 2019; Schlueter & Scheepers, 2010)	Angry crowd, Conspiracy, Synchronized fighters					
	24	Evaluate sexual qualities of females	**Fertility detector**	(Bryant & Haselton, 2008; S. L. Miller & Maner, 2011)	Beautiful and sexy women	(M. L. Fisher, 2012; Gottschall, 2008a; Gottschall et al., 2004; Grant, 2020; J. Saunders, 2009; Scalise Sugiyama, 1999)				+M[63]
	25	Evaluate sexual qualities of males	**Good genes evaluator**	(Gangestad & Thornhill, 1997; Greiling & Buss, 2000; Thornhill & Gangestad, 2008)	Beautiful and sexy men	(Grant, 2020; Grant & Kruger, 2023b; Kruger et al., 2003, 2013; Nettle, 2005b; Salmon, 2012)				+F[64]

Conceptual mechanisms										
Ultimate level			**Proximate level**		**Cultural domain**		**Variability**			
Domain	Identifier	Adaptive challenge	Cognitive mechanism	References for the cognitive mechanism	Examples of ingredient	References for the cognitive ingredient	Big Five	Age	Ecology	Sex
	26	Evaluate fidelity	**Fidelity detector**	(Apicella & Marlowe, 2004; Buss, 1989)	Character faithful in love	(M. L. Fisher, 2012; Nettle, 2005b; J. Saunders, 2009; J. P. Saunders, 2015)				+M[58,63]
	27	Detect babies	**Cuteness detector**	(Daly & Wilson, 1998; Glocker, Langleben, Ruparel, Loughead, Gur, et al., 2009; Glocker, Langleben, Ruparel, Loughead, Valdez, et al., 2009)	Parental protection, Parental rescue	(Gould, 2008; Hinde & Barden, 1985; Saunders, 2009, 2012, 2020)				+F[65,66]
	28	Evaluate children relatedness	**Relatedness evaluator**	(Apicella & Marlowe, 2004; Burch & Gallup, 2000)	Paternity testing, Illegitimate child	(Saunders, 2005, 2009, 2020)				
	29	Detect kin	**Kin detector**	(Bressan & Kramer, 2015; Lieberman et al., 2007)	Very familiar character					

Motivational mechanisms										
Ultimate level			**Proximate level**		**Cultural domain**		**Variability**			
Domain	Identifier	Adaptive challenge	Cognitive mechanism	References for the cognitive mechanism	Examples of ingredient	References for the cognitive ingredient	Big Five	Age	Ecology	Sex
Self	30	Find and consume nutrient-rich food	**Hunger**	(Al-Shawaf, 2016)	Extremely starving character				+H[67,68]	+F[69,70]
	31	Allow the body to hydroregulate	**Thirst**	(Aarts et al., 2001)	Extremely thirsty character					
	32	Allow the body to thermoregulate	**Feeling cold / hot**	(IJzerman et al., 2015)	Character freezing to death	(J. Carroll, 2019)				
	33	Allows the body to repair and maintain itself	**Sleepiness / Fatigue**	(Dishakjian et al., 2021; Nunn et al., 2016)	Insomniac character					
	34	Discover new information	**Curiosity**	(Dubey & Griffiths, 2020; Gottlieb et al., 2013)	Character investigating paranormal phenomena	(Dubourg et al., 2023; Dubourg & Baumard, 2022b)	+O - E[18,18,71-73]	+C[23,74-78]	+F[79-84]	
	35	Develop relevant competence in a given environment	**Skill acquisition**	(Bjorklund, 2022; D. Geary & Berch, 2016)	Character who trains hard		+O[85,86]	+C +O[77,87,88]	+F[89]	

Motivational mechanisms										
Ultimate level			**Proximate level**		**Cultural domain**		**Variability**			
Domain	Identifier	Adaptive challenge	Cognitive mechanism	References for the cognitive mechanism	Examples of ingredient	References for the cognitive ingredient	Big Five	Age	Ecology	Sex
	36	Accumulate and preserve material ressources	**Resource accumulation**	(Krekels & Pandelaere, 2015; Mehlhorn et al., 2015)	Character developing a successful business	(Jonsson & Kruger, 2019)	+C -O[29,90]	+U[76,91]	+H[92]	
	37	Collect resources	**Resource foraging**	(Hills, 2006; Stephens et al., 2014)	Character exploring wonderful lands		+O[93-97]	+C +O[38,76,98,99]	+F[25,100,101]	+M[41-43,102-104]
	38	Identify the best strategy given the context	**Simulation, Mental Time Travel**	(Addis, 2020; Boyer, 2008; Suddendorf & Corballis, 2007; Gaesser et al., 2018)	Character building a meticulous plan		-N +C +O[105,106]			+F[107]
Threats	38	Avoid predation	**Fear of predators**	(Clinchy et al., 2013; Gross & Canteras, 2012; Öhman, 2009)	Character running away from a monster	(Andersen et al., 2020; N. Carroll, 1990; Clasen, 2017, 2021)	+N[108,109]		+H[110]	+F[1,111]
	39	Avoid aggression	**Fear of aggressors**	(Duntley & Shackelford, 2012)	Character running away from an attacker	(N. Carroll, 1990; Clasen, 2017, 2021; Clasen & Platts, 2019; Kjeldgaard-Christiansen, 2016b; Stubbersfield et al., 2015; Vicary & Fraley, 2010; Wylie & Gantman, 2023; Black et al., 2019)	+N[108,109]		+H[110]	+F[1,111]
	40	Avoid falling	**Fear of the height**	(Huppert et al., 2020; Shang et al., 2023)	Character suffering a spectacular fall					
	41	Avoid contact with pathogens	**Disgust**	(Oaten et al., 2009; Royzman et al., 2009; Thielscher & Pessoa, 2007; Tybur et al., 2013)	Character avoiding zombie contamination	(Clasen, 2010; Eriksson & Coultas, 2014b; Heath et al., 2001b)	+N[108,112]		+F[113]	+F[114]
	42	Avoid injuries	**Pain aversion**	(Clinchy et al., 2013; Gross & Canteras, 2012; Öhman, 2009)	Character hurting themselves	(Andersen et al., 2020; N. Carroll, 1990; Clasen, 2017, 2021)	+N -E[115-117]			+F[118]
Cooperators	44	Appear competent	**Pride**	(Cheng et al., 2010; Durkee et al., 2019; Sznycer, 2019; Sznycer et al., 2017)	Character accomplishing the impossible		+C[119,120]			/[121]
	45	Avoid appearing incompetent	**Shame**	(Brosnan et al., 2017; Durkee et al., 2019; P. Gilbert, 2022; Sznycer et al., 2018; Thomas et al., 2018)	Deeply anxious character	(Rapaport et al., 2016)	-A[122]			+F[121,123,124]
	46	Appear trustworthy	**Moral pride**	(Barclay, 2013; Baumard et al., 2013; McLatchie & Piazza, 2017; Tomasello, 2020)	Character respecting a strict moral code		+C -N[125]		+F[126,127]	
	47	Avoid to appear untrustworthy	**Guilt**	(Fitouchi et al., 2021; Stanford, 2018; Tomasello, 2020)	Well-meaning character causing a catastrophe	(J. Carroll, 2005)	+A[128]			+F[121,129]
	48	Appear willing to initiate cooperation	**Warmth**	(Eisenbruch & Krasnow, 2019; Fiske et al., 2007; Goetz et al., 2010)	Character with a pronounced warmth	(Grant, 2020)	+A +E[130,131]			+F[132,133]
	49	Limit immoral behaviors in others	**Moral blame, indignation**	(Fitouchi et al., 2021, 2022; Malle et al., 2022)	Character inflicting a curse on a culprit	(Eden et al., 2011)	+A +C[125,134]		+H[135]	
	50	Encourage moral	**Moral praise**	(R. A. Anderson et al., 2020; Carnes et al., 2022; Monroe, 2020)	Character sacrificing herself heorically	(Eden et al., 2011; Wylie & Gantman, 2023)	+A +C[125,136]			

Motivational mechanisms										
Ultimate level			**Proximate level**		**Cultural domain**		**Variability**			
Domain	Identifier	Adaptive challenge	Cognitive mechanism	References for the cognitive mechanism	Examples of ingredient	References for the cognitive ingredient	Big Five	Age	Ecology	Sex
		behaviors in others								
	51	Punish cheaters or aggressors	**Revenge**	(McCullough et al., 2013)	Character who takes revenge at any cost	(Andrews, 2012; Flesch, 2007)	-A[137,138]			+M[139,140]
	52	Limit escalation of violence and favor cooperation	**Forgiveness**	(McCauley et al., 2021; McCullough et al., 2013)	Character who forgives a horrible act she has suffered		+A[137,138]			+F[139,140]
	53	Provide benefits to others in need	**Compassion**	(Decety & Wheatley, 2015; Fitouchi et al., 2021; Goetz & Simon-Thomas, 2017; Tomasello, 2015)	Character helping someone fragile	(Saunders, 2005; Schmid & Klimmt, 2011; Singh, 2021)	+A +O[141,142]		+H[143]	+F[143]
	54	Attract cooperation partner	**Cooperative attraction**	(Barclay, 2013)	Character forming a new friendship	(J. Carroll et al., 2015)				
	55	Keep interdependent relationships	**Friendship**		Character helping a friend	(Fox, 2005)	+A +E[144,145]			
	56	Limit devaluation of cooperators	**Cringe, Embarassment**	(Krach et al., 2011)	Character violating a social norm	(Hye-Knudsen, 2018)	+N[146,147]			/[121]
	57	Exchange reasons to convince	**Reasoning**	(Mercier, 2016; Mercier & Sperber, 2011)	Character arguing in a heated debate		+O[22]			
	58	Form coalitions	**Coalitional affiliation / recruitment**	(Boyer, 2018; Boyer et al., 2015; Lopez, 2017; Tooby & Cosmides, 2010)	Character becomes part of a close-knit team	(J. Carroll et al., 2011)	+E[148-151]	+C +O[152]		+M[153]
Competitors	59	Capture or secure resources	**Aggressiveness**	(Albouza & Chazaud, 2019; Buss & Shackelford, 1997; DeWall et al., 2011)	Character acting violently with premeditation	(Jobling, 2001)	-A[27,154]	/[155]	+H[126,156,157]	+M[158,159]
	60	Gain higher placement in social hierarchy	**Status-seeking**	(von Rueden et al., 2011; von Rueden, 2014; Zeng et al., 2022)	Character obtaining a disproportionate inheritance		+C +E[119,160]			+M[161]
	61	Gain or capture what competitors have	**Envy, Jealousy**	(D. Geary et al., 2014, 2014; Hill & Buss, 2008; V. S. Ramachandran & Jalal, 2017)	Envious, gossiping character	(B. Boyd, 2010; Dunbar et al., 1995; M. L. Fisher, 2012; Saunders, 2009)	+N -C[162]			
	62	Defend against exploitation and bargain for better treatment	**Anger**	(Sell, 2011; Sell et al., 2009, 2014)	Character in a rage	(Kjeldgaard-Christiansen, 2016b)	+E -A +N[163]			+M[123]
	63	Compete in adversarial relationships	**Hate / Schadenfreude, Malicious joy**	(Cecconi et al., 2020; R. H. Smith et al., 2009)	Deeply detestable character	(Fitzgerald et al., 2020; Grant, 2020; Kjeldgaard-Christiansen, 2016b, 2018; Kjeldgaard-Christiansen & Schmidt, 2019; Wylie & Gantman, 2023)				

Motivational mechanisms										
Ultimate level			**Proximate level**		**Cultural domain**		**Variability**			
Domain	Identifier	Adaptive challenge	Cognitive mechanism	References for the cognitive mechanism	Examples of ingredient	References for the cognitive ingredient	Big Five	Age	Ecology	Sex
Mates	64	Attract mate	**Romantic attraction**	(Finkel & Baumeister, 2010; Greiling & Buss, 2000; Jankowiak & Fischer, 1992)	Character trying to seduce another	(Cawelti, 1977; Cox & Fisher, 2009; M. L. Fisher, 2012; Kruger et al., 2013; J. Saunders, 2009)	+E[164, 165]	+O +U[166]	+F[167-169]	
	65	Reproduce	**Sexual attraction**	(Diamond, 2004)	Character with a burning sexual desire	(Salmon & Symons, 2003; J. P. Saunders, 2015)		+O +U[166]		+M[170-172]
	66	Pair-bond	**Long-term love**	(Fletcher et al., 2015; Kenrick, 2006)	Character who loves another eternally	(Baumard et al., 2022; Gottschall & Nordlund, 2006; Grant & Kruger, 2023b; Keener, 2010; Lucchi Basili & Sacco, 2018; Nettle, 2005b; Nordlund, 2007; Salmon & Burch, 2020; Vanderbeke, 2019)	+B[167, 173-178]	+O +U[166]	+F[167-169]	+F[179]
	67	Mate with various and numerous partners	**Desire for sexual variety and frequency**	(Ellis & Symons, 1990; Schmitt & International Sexuality Description Project, 2003; Surbey & Conohan, 2000)	Character engaged in one-night stands	(Salmon & Symons, 2003; J. P. Saunders, 2015)	+E +C[27, 165,180]	+O +U[166]	+H[181]	+M[179]
	68	Keep mate	**Romantic jealousy (Mate retention)**	(Daly et al., 1982; Symons, 1979)	Character undergoing deception in love	(M. L. Fisher, 2012; Nettle, 2005b; Salmon, 2012; J. Saunders, 2009; J. P. Saunders, 2015)	+N[182, 183]	+O +U[166]	+H[184]	+F[185-187]
	69	Control mate	**Sexual jealousy (Mate guarding)**	(Buss et al., 1992)	Character subjected to sexual deception	(M. L. Fisher, 2012; J. Saunders, 2009, 2012a; J. P. Saunders, 2015)	+N[182, 183]	+O +U[166]		+M[185,188]
	70	Avoid bad reproduction mate	**Sexual disgust**	(Al-Shawaf et al., 2015)	Character subjected to rape		+A +C[189-191]	+O +U[166]		+F[192, 193]
Kin	71	Avoid inbreeding	**Kin sexual disgust (Inbreeding avoidance)**	(Antfolk et al., 2012; Lieberman & Smith, 2012)	Character in an incestuous relationship	(Scalise Sugiyama, 2001b)	-O +A +C[190,191,194]			+F[195-197]
	72	Protect and raise children	**Parental love**	(K. G. Anderson et al., 2007; Hagen & Barrett, 2007; Keller & Reeve, 1994)	Character protecting a child	(Nordlund, 2007; J. Saunders, 2009, 2020; Xu, 2013)	+B[167, 176-178]		+F[198, 199]	+F[200, 201]
	73	Provide benefits to kin	**Familial love (Kin altruism)**	(Gurven et al., 2001; Hamilton, 1964; Tanskanen et al., 2021)	Character helping a family member	(M. L. Fisher, 2012; Palmstierna et al., 2017)	+C +A[144,145,202,203]		+F[204-206]	+F[207]

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6. Appendix A

List of short intuitive descriptions of all ingredients that can be used to annotate stories by participants or algorithms. In surveys, it could be preceded with the following instruction:

We are going to present you with a list of elements that may or may not be present in a movie. For each of these elements, you will need to determine if it is negligible, secondary, or central to the film you have selected.

- *Negligible elements are those that are absent, or present but whose removal would leave the film virtually unchanged.*
- *Secondary elements are those that are present and whose removal would change the film but not drastically alter it.*
- *Central elements are those that are present and whose removal would completely change the film.*

For example: In Titanic, *'A physical threat posed by a creature with dangerous animal behavior' is a negligible element. In* Harry Potter *and the Sorcerer's Stone, a 'A situation or event with comic intent' is a secondary element. In* Star Wars IV*, a 'A sophisticated technological tool, gadget, or magical object used to achieve a goal' is a central element.*

Domain	Identifier	Adaptive challenge	Cognitive mechanism	Examples of ingredient	Description of the ingredient
Conceptual mechanism	1	Detect potential predators	Predator detector	Predators, Monsters, Kaiju	**A creature with dangerous animal behavior.**
	2	Detect potential aggressors	Aggressor detector	Aggressors, Villains, Murderers	**An aggressive, physically threatening character.**
	3	Evaluate pathogens presence	Pathogen detector	Parasites, Skin disease, Deformity, Human fluids	**Physically repulsive character, context, or element.**
	4	Detect injuries	Physical pain	Painful injury, Torture	**Physical pain.**
	5	Understand physical laws	Intuitive physics	Immaterial objects, Teleportation, Flying	**Intriguing phenomena related to space, time, sound, gravity and/or light.**
	6	Understand biological beings	Intuitive biology	Creature classification, Undead, Hybrid	**Form of organism or intriguing behavior of supernatural or animal creatures.**
	7	Understand human psychology	Intuitive psychology (Theory of mind)	Strange thoughts of the protagonists	**Complexity or ambivalence of a character's thoughts, feelings, or psychology.**
	8	Understand causal factors	Explanation evaluator	Strange events, Mysterious disappearance	**Explanation or revelation that allows us to understand a situation or phenomenon.**
	9	Understand technologies	Technical efficiency evaluator (Technical reasoning)	Gadgets, Magical wands, Futuristic objects	**Sophisticated technological tool, gadget or magical object used to achieve a goal.**
	10	Detect nutritional value of food	Nutritional resources detector	Delicious food, Banquet	**Tasty food.**
	11	Evaluate resource potential in the environment	Landscape evaluator	Fantasy worlds, Futuristic worlds, Foreign worlds	**Information about the region, time or world in which the story takes place.**
	12	Detect situation with risk of social devaluation	Social devaluation evaluator	Situation of manifest incompetence	**Situations of manifest incompetence.**

Domain	Identifier	Adaptive challenge	Cognitive mechanism	Examples of ingredient	Description of the ingredient
	13	Detect begnign violation	Humor appreciation	Harmless social devaluation	**A situation or event with comic intent.**
	14	Identify the effect of one's actions	Agency / Sense of control, Locus of control	Overcoming challenges, Life-changing decisions	**A character's willingness to perform an action with the aim of profoundly influencing the situation in which he finds himself.**
	15	Evaluate competence	Competence evaluator	Geniuses, Superheroes, Superstars	**A character's advanced skill, in-depth knowledge or exceptional or supernatural ability.**
	16	Evaluate trustworthiness	Trustworthiness evaluator	Superheroes, Honest characters	**A character's honesty, loyalty or reliability.**
	17	Evaluate willingness to initiate cooperation	Warmth evaluator	Warm character	**A character's warmth or sympathy.**
	18	Evaluate level of material ressources	Resources evaluator	Character with high status, Billionaire	**A character's substantial material resources.**
	19	Evaluate capacity to inflict damage	Formidability evaluator	Muscular character, Deadly character	**A characters' ability to cause significant damage.**
	20	Evaluate position in social hierarchy	Status evaluator	Dominant character, Hierarchy	**A character's elevated status recognized by the members of a group.**
	21	Compute interpersonal obligations	Fairness, Free-rider detector	Ambiguous characters, Cheaters	**Action with a moral value (positive or negative) that can be questioned.**
	22	Attribute coalition to people	Group member detector	Distinguishing mark, Similar clothes	**A group united around a shared identity, with a sign of recognition, distinctive sign or symbol shared by a group.**
	23	Evaluate coalitional formidability	Coalitions evaluator	Angry crowd, Conspiracy, Synchronized fighters	**Physical threat posed by a group.**
	24	Evaluate sexual qualities of females	Fertility detector	Beautiful and sexy women	**A feminine characters's physical beauty that is remarkable to one or more other characters.**
	25	Evaluate sexual qualities of males	Good genes evaluator	Beautiful and sexy men	**A masculine character's physical beauty that is remarkable to one or more other characters.**
	26	Evaluate fidelity	Fidelity detector	Character faithful in love	**A character's manifest fidelity in a love relationship.**
	27	Detect babies	Cuteness detector	Parental protection, Parental rescue	**A character's cuteness.**
	28	Evaluate children relatedness	Relatedness evaluator	Paternity testing, Illegitimate child	**A character who seems to be a child of the viewer.**
	29	Detect kin	Kin detector	Very familiar character	**A character's familiarity to viewers.**
Self	30	Find and consume nutrient-rich food	Hunger	Extremely starving character	**A character's extreme hunger.**
	31	Allow the body to hydroregulate	Thirst	Extremely thirsty character	**A character's extreme thirst.**
	32	Allow the body to thermoregulate	Feeling cold / hot	Character freezing to death	**A character's suffering from extreme temperatures.**
	33	Allows the body to repair and maintain itself	Sleepiness / Fatigue	Insomniac character	**A character's extreme fatigue.**
	34	Discover new information	Curiosity	Character investigating paranormal phenomena	**A character's search for new information to investigate.**
	35	Develop relevant competence in a given environment	Skill acquisition	Character who trains hard	**A character's search for skills.**

Domain	Identifier	Adaptive challenge	Cognitive mechanism	Examples of ingredient	Description of the ingredient
	36	Accumulate and preserve material ressources	Resource accumulation	Character developing a successful business	**A character's desire to accumulate resources.**
	37	Collect resources	Resource foraging	Character exploring wonderful lands	**A character's desire to explore a new place.**
	38	Identify the best strategy given the context	Simulation, Mental Time Travel	Character building a meticulous plan	**A character's reflection to determine the best tactics to adopt.**
Threats	38	Avoid predation	Fear of predators	Character running away from a monster	**A character's fear of another aggressive, physically threatening character.**
	39	Avoid aggression	Fear of aggressors	Character running away from an attacker	**A character's fear of a creature with dangerous animal behavior.**
	40	Avoid falling	Fear of the height	Character suffering a spectacular fall	**A character's fear of the danger of falling from a great height.**
	41	Avoid contact with pathogens	Disgust	Character avoiding zombie contamination	**A character's disgust with a physically repugnant character, context or element.**
	42	Avoid injuries	Pain aversion	Characters hurting themselves	**A character's physical suffering.**
Cooperators	44	Appear competent	Pride	Character accomplishing the impossible	**A character's desire to demonstrate his skills.**
	45	Avoid appearing incompetent	Shame	Deeply anxious character	**A character's feeling of shame.**
	46	Appear trustworthy	Moral pride	Character respecting a strict moral code	**A character's desire to demonstrate honesty, loyalty or reliability.**
	47	Avoid to appear untrustworthy	Guilt	Well-meaning character causing a catastrophe	**A character's feeling of guilt.**
	48	Appear willing to initiate cooperation	Warmth	Character with a pronounced warmth	**A character's desire to show warmth.**
	49	Limit immoral behaviors in others	Moral blame, indignation	Character inflicting a curse on a culprit	**A character's moral indignation.**
	50	Encourage moral behaviors in others	Moral praise	Character sacrificing herself heorically	**A character's moral praise**
	51	Punish cheaters or aggressors	Revenge	Character who takes revenge at any cost	**A character's desire for revenge.**
	52	Limit escalation of violence and favor cooperation	Forgiveness	Character who forgives a horrible act she has suffered	**A character's forgiveness of another.**
	53	Provide benefits to others in need	Compassion	Character helping someone fragile	**A character's compassion for a weak character, victim of injustice, or losing something or someone very important to him/her.**
	54	Attract cooperation partner	Cooperative attraction	Character forming a new friendship	**A character's desire to cooperate with another character.**
	55	Keep interdependent relationships	Friendship	Character helping a friend	**A character's friendship for another.**
	56	Limit devaluation of cooperators	Cringe, Embarassment	Character violating a social norm	**A characters' embarrassment or awkwardness in a situation.**
	57	Exchange reasons to convince	Reasoning	Character arguing in a heated debate	**A character's argumentation or reasoning to justify or convince.**
	58	Form coalitions	Coalitional affiliation / recruitment	Character becomes part of a close-knit team	**A character's desire to join a group or recruit members for a group.**
Competi-	59	Capture or secure resources	Aggressiveness	Character acting violently with premeditation	**A character's deliberate use of physical violence to achieve an end.**
	60	Gain higher placement in social hierarchy	Status-seeking	Character obtaining a disproportionate inheritance	**A character's desire to achieve or maintain a high status.**

Domain	Identifier	Adaptive challenge	Cognitive mechanism	Examples of ingredient	Description of the ingredient
	61	Gain or capture what competitors have	Envy, Jealousy	Envious, gossiping character	**A character's desire to obtain what another character possesses.**
	62	Defend against exploitation and bargain for better treatment	Anger	Character in a rage	**A character's anger at another character.**
	63	Compete in adversarial relationships	Hate / Schadenfreude, Malicious joy	Deeply detestable character	**A character's hatred of another.**
Mates	64	Attract mate	Romantic attraction	Character trying to seduce another	**A character's budding feeling of love.**
	65	Reproduce	Sexual attraction	Character with a burning sexual desire	**A character's sexual attraction to another.**
	66	Pair-bond	Long-term love	Character who loves another eternally	**A character's love for another character over a long period of time.**
	67	Mate with various and numerous partners	Desire for sexual variety and frequency	Character engaged in one-night stands	**A character's desire for diversity and frequency in sexual relations with different partners.**
	68	Keep mate	Romantic jealousy (Mate retention)	Character undergoing deception in love	**A character's jealousy caused by an extra-marital romantic relationship.**
	69	Control mate	Sexual jealousy (Mate guarding)	Character subjected to sexual deception	**A character's jealousy caused by an extra-marital sexual relationship.**
	70	Avoid bad reproduction mate	Sexual disgust	Character subjected to rape	**A character's risk of undesired sexual relationship.**
Kin	71	Avoid inbreeding	Kin sexual disgust (Inbreeding avoidance)	Character in an incestuous relationship	**A character's revulsion at an incestuous sexual relationship with a family member.**
	72	Protect and raise children	Parental love	Character protecting a child	**A character's help or protection of a weaker character.**
	73	Provide benefits to kin	Familial love (Kin altruism)	Character helping a family member	**A character's support for a family member.**

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