# Psychology and Neurobiology of Horror Movies

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***Abstract:*** This article covers the neurobiological and psychological aspects of horror movies. Cinema audiences are not exposed to real threats, thus the movie should pass the brain's "reality check" systems and emotion regulation to engage the fear responses. This is achieved through vicarious simulation, proximity of threats, and unpredictability of the fearful events, and using universal sources of fear such as illness or isolation. Paradoxical appeal of horror movies stems from universal curiosity toward morbid and threatening subjects, mixing of emotions of fear and excitement in the brain, and the capability to learn about dangerous situations safely in the context of movies. These findings are summarized in a conceptual model for eliciting fear through cinema.

***Keywords:*** cinema, embodiment, emotion, fear, horror, simulation

Fear is a protective mechanism that acts as "survival intelligence" in the brain, mind, and body. It has a strong and distinct evolutionary function as a response to acute threats to physical and psychological well-being. Although our species instinctively avoids dangers and threats in the natural environment, the human nature is also instilled with curiosity and desire for excitement. Suspenseful and downright scary stories have been a staple of human entertainment despite this almost paradoxical desire to experience something awful for recreational purposes. The human brain does not operate in isolation or purely on learned associations. Instead, evolution has carved the human mind for optimizing survival. Our joys, sorrows and traditions all reflect the pressures that the evolution has exerted on the brain and mind. Thus, to understand how our ancestral fears can be turned into exciting entertainment, we need to approach the issue from a multidisciplinary scientific viewpoint while appreciating the evolutionary basis of human mental and brain functions.

This article addresses the neural and psychological determinants of fear in cinema from a practical viewpoint, describing the scientific principles underlying successful recreational horror experiences. After a brief overview of the brain basis of fear, five major themes are discussed: (1) simulationist mechanisms for evoking emotions and (2) their dependence on the vicarious affective experience. Next, the general biological principles of (3) fearful events and (4) their timing are reviewed, and finally (5) the nature of enjoyment in horror is discussed. These themes are then summarized in a general framework for engaging the human fear circuit in a pleasurable yet exciting way through cinema.



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### Psychological and Neurobiological Basis of Fear

Fear is a complex phenomenon that prepares the individual to meet the survival challenges by automatically adjusting cardiovascular, skeletomuscular and endocrine functions alongside actual behavior and psychological processes including attention and memory (Adolphs 2013; Mobbs et al. 2015). This complex cascade aims at recruiting physical and psychological resources for avoiding the danger by freezing and remaining hidden when the predator is still far away or initiating fight-or-flight response when the threat is already imminent (LeDoux 2000). Fear is a biological universal, and most people will respond with a broadly similar fashion in a life-threatening situation. The neural cascade leading to the fear response takes less than half a second to be completed in the brain (Zheng et al. 2017). Because fear response optimizes survival changes, it can almost completely take over the control of both humans' and other animals' immediate actions no matter how pleasant or important their current activity would be. This happens because fear and other negative emotions signal potential injuries, discomfort or even death, thus they must be able to override positive emotions to ensure survival (Baumeister et al. 2001). Accordingly, humans and other animals avoid getting into fearful situations unless they might lead to significant gains—for example, prey might enter territory routinely patrolled by predators if it knows that it can scavenge resources such as food or nesting material in the area.

***Fear is a powerful emotion because it alters what we hear and see.***

Fear is a powerful emotion because it alters what we hear and see. Fear potentiates attention and we automatically orient ourselves toward potential threats while our perceptual awareness and learning/memory mechanisms are enhanced (Vuilleumier 2005). Fear is also a corporal emotion, altering the state of numerous physiological systems. These lead to strongly felt subjective experiences in the body, making fear, panic, and related states some of the most powerful experiences humans may have (Nummenmaa et al. 2018; Nummenmaa, Glerean et al. 2014). Fear feels subjectively unpleasant because it tries to motivate us for survival—the psychological experience signals presence of severe danger. Conversely, when the threat is gone the feeling of dread disappears, and this relief feels rewarding because it signals safety. Although our brains and minds instinctively know how to filter the fearful and dangerous information from the environment and respond to it, this knowledge cannot be necessarily readily conceptualized. If we want to tailor the scariest possible events and scenes for the purposes of entertainment, we need to rely on controlled experiments and careful measurements of neural, physiological, and psychological components of the fear response to distill the core determinants of human fears.

### Brain Basis of Fear

The fear response consists of a complex neurobiological and physiological cascade that ultimately leads to change in the behavior and psychological

state of the individual (Figure 1). The brain's fear circuit operates at multiple timescales and it constantly evaluates distance and severity of different threats. The midbrain circuits operate at the immediate fight-or-flight situations where direct contact with the threat can no longer be avoided. The higher-level systems in the frontal cortex are involved in prevention and planning of avoidance when the threat is not yet imminent (Fanselow and Lester 1988; McNaughton and Corr 2004). This dynamic interplay between higher-level volitional planning of escape strategies and automated fight-or-flight provides effective means for optimizing survival strategies at multiple time scales (Mobbs et al. 2010). This explains why approaching a fearful situation feels so unnerving—when we get closer and closer to the snake that we dread but must nevertheless get out from our lawn, the midbrain defense circuits try to push us away while our higher-level

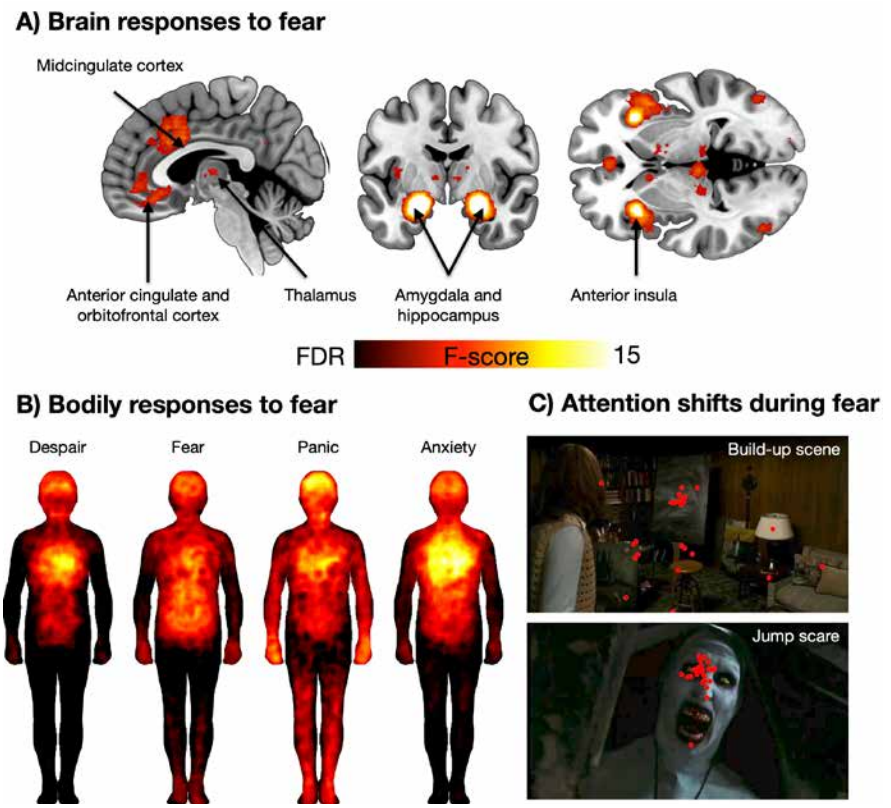


*Figure 1. (A) Brain basis of fear. The figure summarizes brain regions responding consistently to fear across 363 functional magnetic resonance imaging studies. The analysis is based on the NeuroSynth database (Yarkoni et al. 2011) per August 4, 2020. (B) Bodily experiences during fear and related states. The coloring shows the relative intensity of net bodily sensations during each feeling state, modified from (Nummenmaa et al. 2018). (C) Illustration of narrowing of attentional focus during fear while watching a horror movie; each dot represents gaze position of a single individual. During neutral or less fearful situations viewers' eye movements are widely distributed, while intense shocks capture everyone's attention to the location of the threat (unpublished data from the author's laboratory).*

executive system tries to fight back to get us to remove the snake from the lawn. Many horror video games exploit this dissonance to create almost unbearable levels of suspense. To destroy the supernatural threats that lurk around the dark corners in this type of games, the player must muster up their courage and get terrifyingly close to the villains. Such constant push-pull activity between the approach and avoidance circuits in the brain can generate truly unnerving experiences.

Neuroimaging studies show that the amygdala is consistently activated during fearful situations (see the statistical summary in Figure 1a). In line with this, neurological patients with amygdala damage are unable to recognize fearful facial expressions or sounds (Adolphs et al. 1994; Calder et al. 2001). The amygdala is also critical for the subjective experience of fear, as patients whose amygdala has been damaged are unable to feel that they are afraid in dangerous situations, such as when handling snakes or spiders (Feinstein et al. 2011). Frontal cortical systems support the amygdala in generating the conscious experience of fear ("I am afraid") (Saarimäki et al. 2016) and coordinating complex, strategic escape and avoidance responses when the threats are still far away (Fanselow and Lester 1988; McNaughton and Corr 2004). These systems also support regulation of emotional responses by inhibiting amygdala activation (Ochsner et al. 2002). This control is, however, far from perfect. When the threat becomes imminent, an automatic fight-or-flight response is triggered by midbrain structures (Mobbs et al. 2007), and frontocortical emotion regulation breaks down. The goal of the fear response is to prepare the body for action—either freezing, flight, or fight, depending on the proximity of fear. These changes induce prominent corporal sensations (Nummenmaa et al. 2018; Nummenmaa, Glerean et al. 2014; Volynets et al. 2019) that are mediated by the insula and somatosensory cortices (Figure 1a–b). Finally, fear and anxiety also increase attentional preparedness and vigilance promoting detection of threats (Figure 1c), and acute threats in the environment capture and hold attention effectively to ensure efficient detection and processing of survival-salient information (Bishop et al. 2004; Vuilleumier 2005).

### How Horror Movies Affect the Human Brain

The fear response is often automatic and uncontrollable. A visitor in a zoo might be shocked by a snake jumping against the glass of its terrarium, or an individual may tremble in the heights of a tower crane before making a bungee jump. In both examples, the individuals *feel* fear despite *knowing* that they are safe. The snake is housed safely in the terrarium, and the bungee rope will eventually prevent the jumper from hitting the ground. Because automatic fear response precedes and often overrides the processing of contextual safety information, we may be startled even when we know that we are not threatened at all. Direct recordings from the amygdala show that this structure responds to fearful information, such

as movies showing fearful facial expressions, in less than 120 milliseconds (Zheng et al. 2017). This is much faster than the prefrontal cortex can evaluate the contextual information. The "enjoyable fear" we experience during horror movies results from the interaction of the survival circuits that automatically respond to the threat cues such as sudden noises or predators, and the executive systems and long-term memory evaluating the contextual information and confirming us that we are safe. We would never go to see movies if we knew the killers would come after us or would never try a bungee jump if we knew the bungee rope would fail.

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Amygdala activation recorded while viewing a horror movie is proportional to the subjectively felt fear (Kinreich et al. 2011). Functional, whole-brain imaging studies (Figure 2) have shown that while viewing movies or listening to narratives, brain activity of the viewers becomes time-locked not just in the sensory cortices that process the incoming information in same timescale but also in the key nodes of the emotion and fear circuits (Nummenmaa et al. 2012; Nummenmaa, Saarimäki, et al. 2014; Santavirta et al. 2023; Smirnov et al. 2019). Such synchronization is prominent during the most aversive episodes, suggesting that fear and other negative emotions tune brains into intrinsic fight-or-flight survival mode that is consistent across viewers. In other words, horror movies thus make the viewers at least temporarily more similar to each other.

## Principles of Translating the Science of Fear to Cinema

### *Simulated Fears*

Fear systems have evolved to protect humans and other animals in situations where we may get hurt. It is thus perplexing why we may feel in-

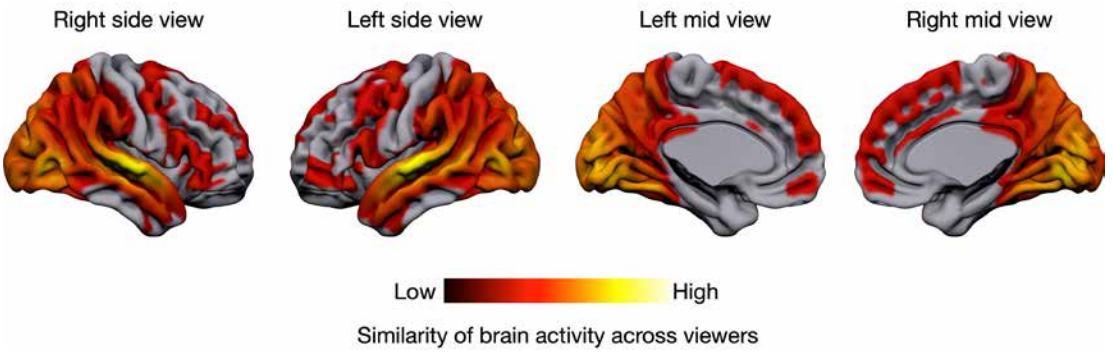


*Figure 2. While viewing a horror movie (*The Conjuring 2*), brain activity becomes synchronized across viewers. This synchronization is particularly strong during the "jump-scare" episodes of the movies. Adapted from (Hudson et al. 2020).*

tense fear during artificial situations where we are perfectly safe, such as reading a thriller or watching a horror movie. The reason for this is that humans are predisposed to think that whatever we see or hear is real. For the majority of human history, this was practically always true; there were very few instances when our sensations and perceptions did not reflect the external reality, which explains why arts such as theatre and movies are so effective—by default, we take our surroundings as real. Artists can thus fool the brain by making copies of our reality that are good enough to pass through to the brain's reality checking systems. Corresponding "simulation" principles apply to nearly all human perception. We make copies of the real physical environment, and enjoy these copies such as paintings, photographs, or video games when the real experience cannot be achieved. Additionally, our imagination allows us to generate improved copies of the reality (such as enhanced photographs) or even completely unrealistic copies (such as science fiction movies) that allow the audiences to experience something that would be impossible in the real world. This greatly expands the experience horizon we have, as long as the simulated reality will pass as the real thing (Adolphs et al. 2016).

Because the human mind is capable of conscious, internal thought, we must constantly distinguish the external world from the internal world and perform numerous reality checks to assess whether our experiences and perceptions stem from the external environment. Extreme break-down of this may lead to hallucinations, that is, experiencing internal thoughts as stemming from the environment (Raij et al. 2009). However, bypassing this reality filter is routinely exploited by books, photographs, movies, and other media. Place illusion refers to the experience that an audience is situated in the virtual experience, whereas plausibility illusion refers to the experience that the events are happening. Research has shown that particularly the plausibility illusion is a major determinant of fears evoked by digital media such as games (Lin 2017). When fully engaged, these illusions give the audience the experience of "being there" or living and experiencing the events seen in the movie or described in a book.

While most powerful place and plausibility illusions can be generated by virtual reality, several factors can strengthen them significantly in other display formats such as in two-dimensional movies. A large body of research shows that the more life-like the reproductions of reality are, the stronger the brain responds to them (Hasson et al. 2010) and immersion into the film is a major determinant of the intensity of the emotions the audience experiences (Visch et al. 2010). Big high-quality screens in theaters and television sets in homes help the audience to immerse in the world of the movie: when the movie literally fills the whole field of view, external environments (such as living-room furniture) do not interfere with the illusion of being in the virtual world of the movie. The 3D surround sound—as the name suggests—surrounds the audience in the soundscape, giving a strong feeling of being in the middle of the action.

***Inducing Fear with Vicarious Experience***

Movies do not cause emotions only via their aesthetic qualities leading to "artifact emotions" but also via empathetic engagement with the characters (Gaut 2010; Plantinga 2009). Because horror movies often portray graphically violent and disturbing scenes involving humans in major distress, it could be argued that lack of empathy would be necessary for enjoying the brutalities in horror films. Empirical evidence, however, speaks against this claim. Enjoyment of horror is not associated with (lack of) affective empathy, cold-heartedness, or real-life indices of empathy (Scrivner 2024). Quite the opposite, it is more likely that capacity for empathy is an essential prerequisite for enjoying horror in the first place: if we cannot empathize with the distress of the protagonists in the movies, there would be very little to be afraid of in horror.

Fear has evolved to protect first-hand survival (Adolphs 2013; Feinstein et al. 2011), thus our most potent fears emerge when our own well-being is at stake. In digital media, such first-hand experiences can readily be simulated with first-perspective 3D games and particularly in virtual reality, where players are literally experiencing the events happening to themselves. However, most conventional movies portray events that are occurring to the movie characters, while spectators merely watch the events unfolding. But why do we experience the dangers occurring to the actors as scary? Because humans are an inherently social species, we have the tendency to automatically share emotions with each other—even with the characters in a movie. Our bodies thus freeze, and our hearts begin to race, when we see Danny Torrance riding around the corridors of the Overlook Hotel in *The Shining*, ultimately bumping into the ghastly twins.

Observation of others in a particular emotional state may trigger a behavioral and physiological "copy" of emotional state in the observer (Dimberg and Thunberg 1998; Hietanen et al. 1998; Wild et al. 2001). Neuroimaging studies have revealed common neural activation for perception and experience of states such as pain (Jackson et al. 2005; Saarela et al. 2007; Singer et al. 2004), disgust (Wicker et al. 2003), and pleasure (Jabbi et al. 2007). Such vicarious experiences of others' emotional states in one's own body and brain support social interaction via contextual understanding. Sharing others' emotional states provides the observers a bodily reference that helps in understanding their intentions and actions and allows to tune in or "sync" with other individuals (Hatfield et al. 1994; Keysers et al. 2010; Niedenthal 2007). Emotion transfer is often automatic. We know how difficult it is to resist yawning when seeing someone else yawn, or that it may be impossible not to burst into a laughter when hearing everyone else around us cracking up (Platek et al. 2003; Scott et al. 2015).

This kind of vicarious simulation or emotional contagion is a powerful means for emotion transfer because we literally feel the same thing as someone else. Emotional contagion is also

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engaged while viewing movies (Karjalainen et al. 2017). Via means of vicarious simulation, we can literally feel the tarantula on our hand when it's crawling over Indiana Jones on the screen or experience the terror of Wendy Torrance escaping her husband through the Overlook Hotel in *The Shining*. To elicit powerful emotions via movies, it is thus imperative to engage the vicarious experience in the audience. Vicarious experience of the emotions in the body is a powerful mediator of aesthetic experience (Nummenmaa and Hari 2023; Putkinen et al. 2024) and is also at the core of the cognitive and film theoretical models on how cinema affects humans and their emotions (Grodal 2009). Although vicarious simulation is often automatic (Decety et al. 2012; Saarela et al. 2007), there are well-known factors that bolster the contagion of others' emotions. We are more prone to engage in the emotions of people who are close to us, such as our friends and relatives (Singer et al. 2004; Preston and de Waal 2002). Conversely, we are less likely to mirror others' emotions when they are considered not to belong to our own group (Avenanti et al. 2010). Others' behavior influences whether we mirror their feelings—one study found that the perceived fairness of another person determines the degree of empathy toward them, with significantly greater emotional empathy toward fair individuals—most likely because we intuitively consider fair people to be on our side (Singer et al. 2006). For the same reason, we automatically tend to side with the protagonist in the movie and feel their fortunes and misfortunes, whereas we do not experience similar attachment toward the antagonist.

## General Determinants of Fear

### *Uncertainty and Unknowns: The Terrible Twos*

Anxiety is a state that promotes active vigilance and prepares the mind and body for survival in uncertain situations. Unlike fear, it does not have a clear target (Rosen and Schulkin 1998), and uncertainty is stressful, which fuels our fears and anxiety (Grupe and Nitschke 2013). One of the major functions of the brain and learning is to reduce uncertainties about the environment and allow the individual to better predict what will happen next. When these predictions are difficult to make, we experience the situation as unnerving. Fear of the unknown might actually be the most fundamental fear in humans (Carleton 2016), and it explains a multitude of other fears: We are afraid of darkness because we never know what is hiding there, we are wary of strangers because we do not know how they will behave, and we find abandoned places creepy because we do not know why they have been deserted. This is why learning about the uncertainties feel so good—it signals that we are getting the situation under control. Brain imaging studies have accordingly found that learning to anticipate fearful situations that have not yet occurred engages the brain regions associated with pleasure and reward processing. However, this does not happen for unpredictable threats (Klucken et al. 2009). This means that when fear is

used for entertainment, it has to be *somewhat* predictable to be enjoyable. We do not enjoy going into our home in the night and finding a masked, bloody man creeping around with a knife because we never wanted that to happen and did not expect to see that in the first place. However, seeing the same, horrifying scene in a movie can translate into an exciting experience because we deliberately went to see a movie we knew would contain such scenes.

***Fear of the unknown might actually be the most fundamental fear in humans.***

Fear of uncertainty is also closely related to fear of loneliness: Social contacts are so critical to humans that lack of social support is actually one of the most important determinants of premature death (Holt-Lunstad et al. 2010; Holt-Lunstad et al. 2015). When we are alone, we know that we are more exposed to our surroundings, making our life significantly less predictable. We automatically evaluate how competent the people surrounding us are in protecting us, and these evaluations reduce our anxiety toward threats when we think we are in safe company (Tedeschi et al. 2015). Breaking this safety net by isolation and loneliness is thus a very powerful way of increasing anxiety and threat. The feeling of loneliness is easy to manipulate as it can stem from multiple factors, ranging from direct physical distance to others to perceived isolation and availability of support in, for example, a remote and desolate location.

***Fear of Strangers***

Familiarity feels safe to humans, and both adults and children seek companionship from people they experience as similar to themselves (Brewer 1979; Kinzler et al. 2010; Sherif et al. 1961). We are naturally wary of strangers and people who seem different because we do not know what to expect from them. Consequently, we often consider in-group members as good and out-group members as bad or evil (Baumeister 1997), which unfortunately leads to numerous conflicts. For the same reason, we are afraid of creatures and creations that somehow resemble humans but are still different from us, such as zombies or corpses. Numerous horror movie villains and antagonists are humans or human-like creatures that are somehow different than the rest of us—either psychologically (e.g., Norman Bates in *Psycho*) or physically (e.g., Samara Morgan in *The Ring* or Freddy Krueger in *A Nightmare on Elm Street*). These characters play with our primordial fear of strangers and abnormalities. Such aversion for deviations from the prototypical human form does not follow a linear pattern (Figure 3). For example, humanoid-like robots are experienced as relatively neutral because they are not considered as humans at all. Cartoon characters or plush toys are more human-like, and they feel pleasant to us. However, when the human-likeness gets close—but not close enough. to a real human—there is a clear drop in the pleasantness of the objects: creatures and creations that are almost but not enough human-like elicit aversion, and they are said to fall into the uncanny valley (Mori 1970). This applies to most current "realistic" androids and imper-

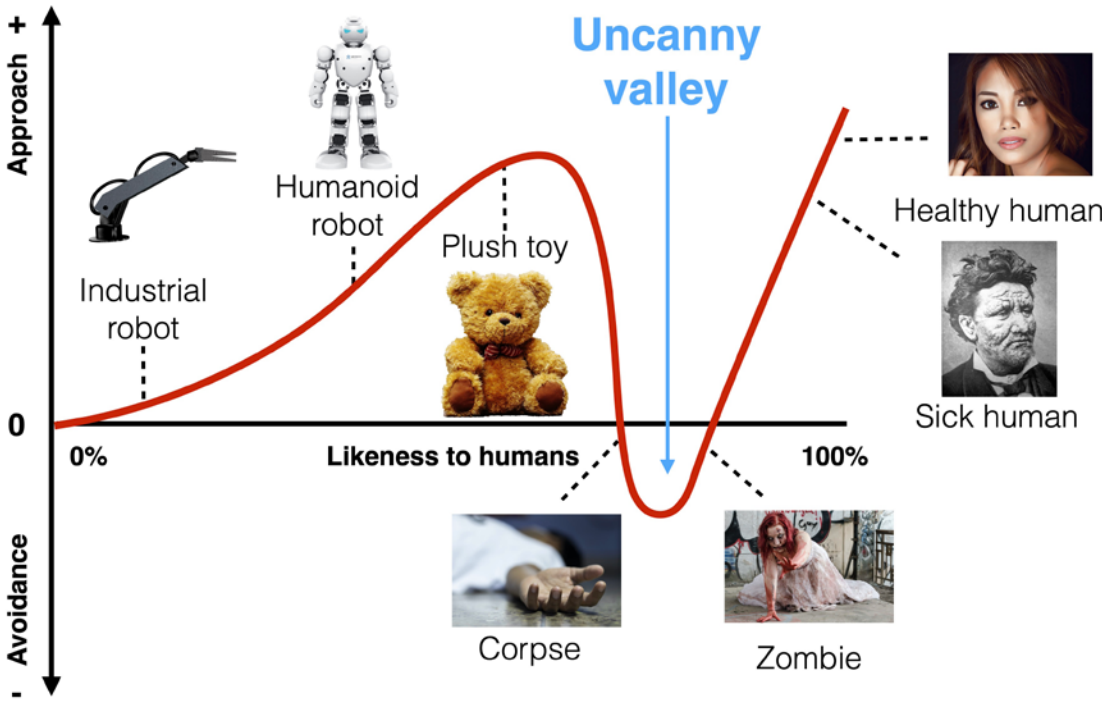



*Figure 3. Illustration of the uncanny valley*

fect early 2000s 3D characters but also to deformed humans or corpses that are humans but still somehow different from what we expect humans to be like.

Uncanny valley is consistently observed in both humans and non-human primates, suggesting that it is automatic and genetically determined rather than learned (Mathur and Reichling 2016; Steckenfinger and Ghazanfar 2009). It likely stems from the natural aversion toward corpses or humans whose appearance is markedly altered by diseases and which may transmit various pathogens, thus it is not surprising that classical villains both in horror films and folktales such as living dead and uncanny monsters usually have the capacity to transmit physical diseases or conditions to their victims. Landing the villains and antagonists in the middle of the uncanny valley is thus a powerful way for creating memorable and frightening characters, but it requires a great deal of care. If the characters are unnatural enough (such as animated villains in Disney cartoons), they do not engage in any aversion because they are too definitely non-human. Conversely, too human-like characters may end up being likable and elicit empathy.

***Fear of the Dark***

Twilight of a peaceful summer night in the countryside might be experienced as soothing, but we become increasingly alert when our surroundings are occluded. Simply blindfolding humans makes them feel anxious when they need to traverse a novel environment (Ponchillia et al. 1984),

and mere darkness potentiates a startle response—the most rudimentary reaction to surprising and potentially dangerous events (Grillon et al. 1997). Darkness causes fear and anxiety because brains are hard-wired to expect sensory stimulation and will do their best to work out a coherent representation even from imperfect input by filling in the missing details based on experience and memory. This explains why we perceive crooked trees in a dark forest as monsters or mistake a piece of an old garment in the attic to a supernatural being (Riekki et al. 2013). These misperceptions are based on our experiences and memory, and the brain uses various top-down mechanisms for filling in the gap. Thus, we perceive the tree as a monster *only* if we have a strong enough belief for existence of such beings and a pre-existing memory template for filling in the details of the monster.

***Darkness causes fear and anxiety because brains are hard-wired to expect sensory stimulation.***

This filling-in phenomenon is so ubiquitous that it also occurs in near absence of sensory inputs. For example, all over the world children play the conjuring game where, with appropriate rituals, they stare at a mirror in a dimly lit room and expect ghost or apparition such as Bloody Mary or Hanako-San to show up. Unlike many folk legends, this trick works, but it does not involve any supernatural beings. When deprived of detailed visual input while staring at the darkened mirror, the visual system starts guesswork to fill in the missing details, and the person staring at the mirror may perceive dead relatives or demons in the place of their own poorly lit face. In an empirical study almost seventy percent of subjects staring at a mirror in a dimly lit room saw their own face deforming, and almost half saw something that resembled a supernatural being (Caputo 2010). These experiments show that darkness is a potent fear factor in movies, as it literally makes our imagination run wild, and if appropriate contextual information is provided (for example, the horror movie strongly hints that a killer or monster will appear from the darkness), the audience will automatically conjure threats and dreads to their mind's eye.

### *Getting the Timing Right*

Fear system operates at multiple timescales. Distance from the threat is a major determinant for the intensity of fear and the corresponding protective response. When the potential threats are far away, humans rely on thinking, reasoning, and other cognitive strategies for planning escape. However, when the threat becomes so close that it seems unavoidable, there is a sudden shift toward automatic fight-or-flight circuitry in the midbrain structures (Mobbs et al. 2007; Mobbs et al. 2010). This means that, in movies, fear can be manipulated in two major ways: by inducing a slow phasic suspense that leads to anxiety-like state, as well as sudden, immediate shocks such as canonical "jump-scares" when the fears may realize almost literally in the front of the viewers' eyes.

The startle response is the most rudimentary reaction to dangers. It is a largely unconscious defensive reaction to threats such as sharp noises,

rapid movements, or other sudden changes in the environment. This brainstem refractory reflex consists of quick descending muscular contractions that begin from the head and that extend through the trunk and the knees (Lang 1995; Vrana et al. 1988). Being startled feels unpleasant, and simple loud noises or flashes are enough to make most peoples' heart race, especially when they are already anxious. Startle responses are much stronger in negative rather than in positive context. Accordingly, tuning the brain to expect forthcoming threats makes the actual protective responses stronger, because the emotion system "knows" that something bad will happen (Vrana et al. 1988). This startle phenomenon is famously implemented in the fast cuts in the shower scene in Alfred Hitchcock's *Psycho*, where the swift cuts in the edit lead to repeated startle responses potentiating the overall scariness of the scene.

Forewarnings of an upcoming danger may trigger emotional arousal, and the concomitant build-up of suspense would amplify the upcoming emotion-inducing scene. Indeed, studies have found that this kind of forewarning signals, such as exposures to the frightening environment or hints about the dangerous nature of a locale, significantly amplify the experiences of dread during the actual scary episode (Cantor et al. 1984). Proper build-up of the forthcoming shocks in movies is thus imperative for maximizing the scariness. This is highlighted in Figure 4 that shows continuous fear ratings from a test audience viewing two feature horror films. Although the specific timing of the fearful episodes varies between the movies, there is also a consistent pattern seen in both films. To achieve powerful shocks, the intense scenes of dread are slowly built up and intermixed with calm and less intense episodes. Such variable suspense is necessary for achieving effective scares. For example, viewing an isolated five-second jump-scare event from a movie is not particularly scary, as it lacks the build-up, and the viewer knows that they will be scared constantly during the next five seconds. For the same reason, viewing a medley consisting *only* of the jump-scares in horror movies feels lame after a while; the predictability is too high, and the build-up period is missing. This is because the brain quickly accommodates or adapts to repeatedly occurring events (Grill-Spector et al. 2006), thus both pleasant and unpleasant experiences lose their power if repeated constantly. The elements of surprise and immediate shock must thus be delivered cautiously—if every build-up of suspense leads to a major shocking scene, the predictability becomes too high, diluting the scariness. Positive, serene, and humorous scenes can also be considered important for an effective horror movie. They generate the much-needed breaks from the tensions, and the pleasure and laughter evoked by these scenes may act as a "safety signal" and the concomitant neurohormonal stress relief response will temporarily reset the fear and anxiety (Manninen et al. 2017), preparing the viewer to meet the next threat.

Keeping viewers' minds preoccupied is also an important means for increasing the fear levels in audience, as increased working memory load

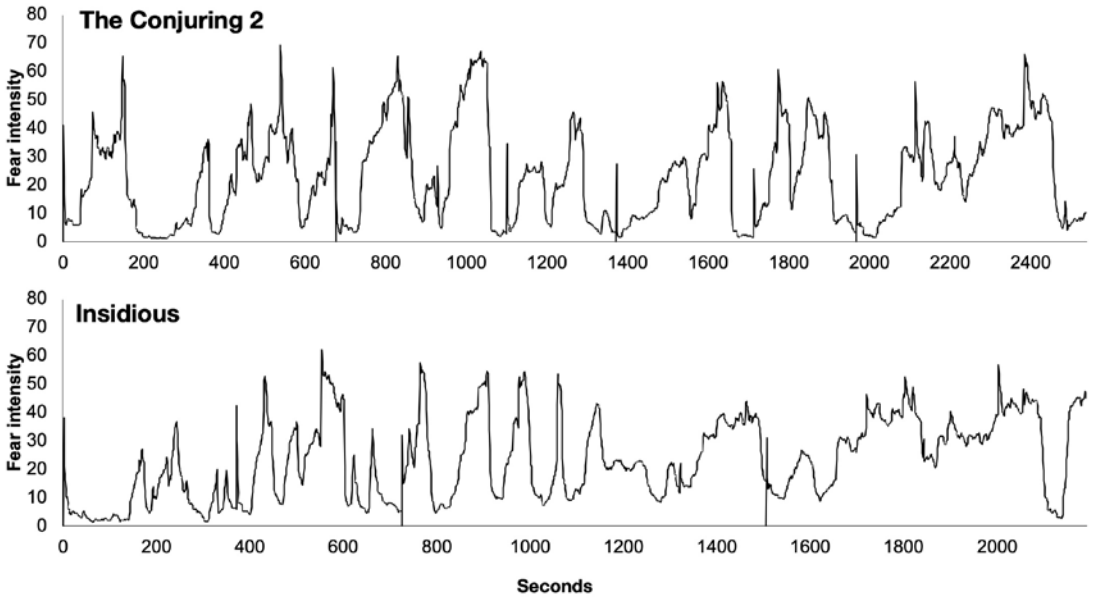



*Figure 4. Mean time course of fear ratings from the experimental audience viewing two horror films (*The Conjuring 2 *and* Insidious*). Modified from (Hudson et al. 2020).*

leads to amplified physiological responses to jump-scares (Terkildsen et al. 2023). Because the limited-capacity working memory is also involved in emotion regulation (Gyurak et al. 2012; Schmeichel et al. 2008), these findings show that the temporal dynamics of the fear response are also intertwined with the temporal profile of the cognitive engagement. Elicitation of strong fear in movies also depends on effective depletion of the executive resources so that cognitive control of the fear becomes more difficult. Increasing the working memory load is also important because it makes viewers more suspectable to supernatural beliefs which may then pass through the brain's reality filters. Belief in supernatural beings is strongest in early childhood, where the distinction between real and imaginary has not yet been established (Harris et al. 1991), yet many adults hold paranormal and supernatural beliefs. For example, in late adolescence and early adulthood, almost one third of people believe in horoscopes and ghosts, about half believe in paranormal phenomena such as UFOs and telepathy, and almost eighty percent believe in premonitory signs. Psychological studies show that under stressful and demanding situations, people become increasingly superstitious and begin to believe in impossible or supernatural things (Dudley 1999; Keinan 2002). Overall suspense and stressful events in movies make this kind of phenomena more readily believable for adults in general too, increasing the audience's immersion in the virtual world of the movie.

### Biological Universals in Fears

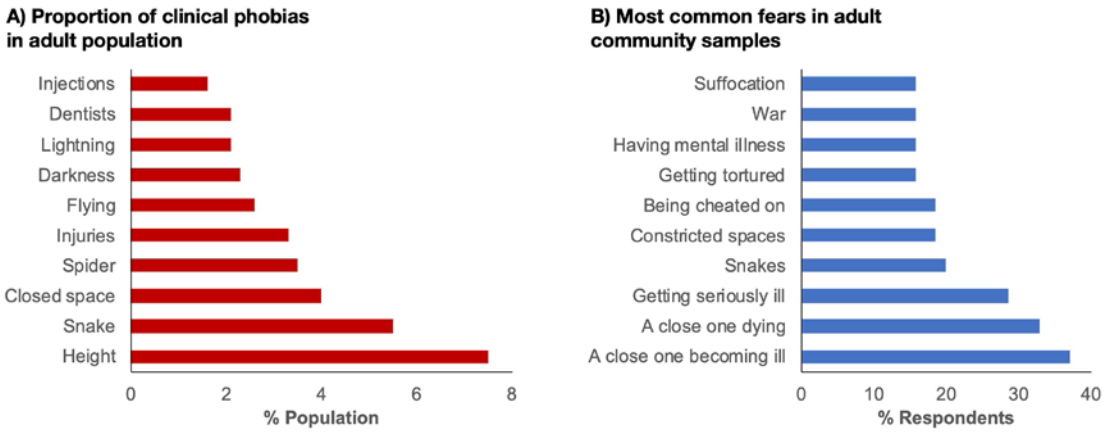
Some events and environments are so consistently threatening that fear toward them does not seemingly require any learning and is considered innate. For example, rat pups are afraid of the smell of cat even when they have never been exposed to cats, suggesting innate basis for such protec-

***The brain has an innate tendency for prioritizing protection from factors and situations that the evolution has flagged as most threatening.***

tive response (Panksepp 1998). Similarly, human infants almost invariably express stranger anxiety—fear toward unknown individuals—between six and twelve months of age despite never having any negative experiences with them (Brooker et al. 2013). Research in human adults also confirms that we may be pre-wired to be afraid of specific threats. This is evidenced by the prevalence of phobias—that is, severely disturbing and irrational fears, such as toward specific objects. Phobias can be associated with a wide range of targets ranging from animals to specific locales, but they are most commonly associated with situations and events that are evolutionarily significant and actually dangerous, such as snakes, spiders, heights, and other humans (Figure 5a) (Fredrikson et al. 1996). This suggests that the brain has an innate tendency for prioritizing protection from certain elements that the evolution has flagged as most threatening (Ohman and Mineka 2001), and this sensitivity makes phobias toward survival-salient events more common.

Such innate preparedness toward specific fears is also mirrored in population-based studies on healthy adults (Figure 5b). Most common fears pertain to the social domain and losing of close ones. Because humans are strongly social species and dependent on the closely knit social networks, these kinds of losses are obviously detrimental to our well-being (Dunbar 2008; R.I.M. Dunbar and Shultz 2010). After the social losses, the next most frightening events comprise direct physical threats such as ending up in constricted spaces with lack of an escape route and becoming injured or under extreme stress, such as being tortured or living in wartime. The only specific animal reaching the top ten list was snake. Many common horror and thriller movie tropes ended up also reasonably high on the list of the top 130 frightening events, such as accidents (24.), murderers (34.), terrorist attacks (37.). However, in real life, supernatural phenomena were not common causes of fear (92.) even though they are common theme in horror movies (see Figure 6).

*Figure 5. (A) Most common targets of clinical phobias and (B) most common non-clinical fears. The clinical data are reproduced from (Fredrikson et al. 1996) and those pertaining to the healthy population from a previously unpublished dataset from our laboratory.*



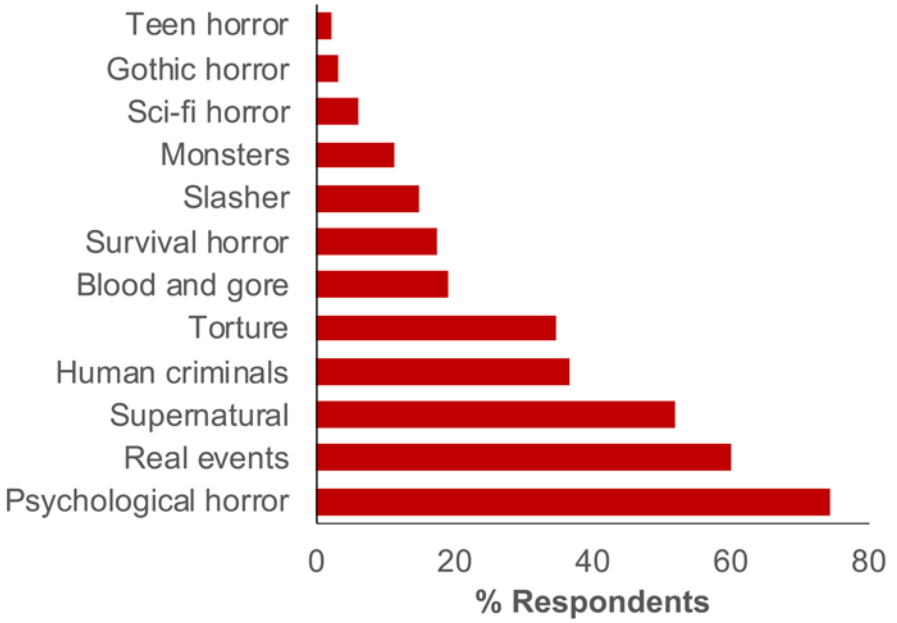



*Figure 6. Scariest types of horror movies. The data show the proportion of respondents considering each horror movie genre as scary. Modified from (Hudson et al. 2020)*

### Most Fearful Content in Horror Movies

The data on the biological universals in fear are also paralleled with ratings of horror movies. Some studies have also addressed the general contents of the horror movies that are considered as scariest (Hudson et al. 2020). In line with the data on prevalence of clinical phobias and prevalence of fears in healthy populations, these data suggest that movies that are based on plausible settings and events (such as psychological horror and movies based on real events; Figure 6) are in general considered the scariest, while more clearly implausible sci-fi horror movies or those based on monsters were evaluated as less scary. The only exception to this is movies with supernatural content, possibly because these movies are close enough to real life that they pass the brain's reality filter as believable. This might, however, be explained by personality level factors. Individuals with strong beliefs in the paranormal enjoy particularly supernatural horror films, whereas those with weaker paranormal beliefs prefer movies with more realistic content. Thus, people in general seem to enjoy horror movies depicting events that they believe to be plausible from their own viewpoint (Clasen et al. 2020).

### Low-Level Visual Features

Some studies have tested whether specific low-level visual features such as spatial frequency composition and color are associated with specific emotions. Most consistent effects are found for saturation and bright-

ness: Scenes with both dark and desaturated colors are systematically experienced as unpleasant (Valdez and Mehrabian 1994), likely reflecting the general disliking and fear for darkness (Grillon et al. 1997; Ponchillia et al. 1984). The evidence for spectral composition effects is limited with no clear effects on emotional response (Delplanque et al. 2007). The evidence for color–emotion pairing is mixed. Some cross-cultural studies have found that fear is universally associated with the color black. This could arise from findings suggesting that cross-modal associations could originate from both universal human experiences and cultural factors, such as language, mythology, and literature (Hupka et al. 1997). However, similar color–emotion parings are not observed in all studies (Fugate and Franco 2019).

**Learned Fears**

Humans can have a striking array of fears, including strangers, heights, illnesses, cemeteries, and different animals. This brevity is partially explained by learning; repeated exposure to fear and anxiety can easily lead to association between the fear and the originally non-threatening event or context in which the fear was associated, thus leading to learning of novel fears (LeDoux 2000). Fear system is powerful because it provides flexible and effective means for learning new threats (Ohman et al. 1975). Such sensitivity in fear learning is important, as it allows humans and other animals to adapt to novel threats in their environment. Learning can be also exploited to manipulate fears in movies. Fear can be built upon the cultural conventions and shared knowledge on what constitutes dangerous. This may range from general long-standing beliefs (e.g., afterlife, spirits), generalized beliefs (e.g., fear of mental wards or prisons) to regional mythology and urban myths (e.g., folk stories of haunted houses, myth of the Slender Man). Using such belief-based threat signals, however, is difficult for regional audiences if the beliefs are not held widely enough.

A cemetery is a classic staple in Western horror movies and ghost stories. Although in purely empirical terms they are perfectly safe places, the clichéd scene of a thunderstorm in a dark, ruining cemetery leads the audience to expect a forthcoming supernatural thriller or horror movie. Appreciating the terror of the scene requires that we know that the place is a cemetery, and that we have learned to believe that the dead people might continue to exist in some supernatural form. Without such knowledge and experience, the cemetery might feel just like another unusual location. Finally, movies themselves are an effective means for generating expectations of fear and horror. Within a single movie, repeated pairings between shocking events and jump-scares and specific environments, objects and characters may generate movie-specific fears. Some of these may be so effective that they become recurring tropes in horror movies, such as masked killers (Hannibal Lecter, Ghostface, Jason Vorhees) or creepy dolls (Annabelle). Sometimes

these are even overused to such an extent that they become humorous: The classical horror trope of Indian burial grounds has been extrapolated and repeated so many times that it has become a source of parody and is no longer experienced as particularly threatening.

**Soundscape of Dread**

Sound is an effective indicator of dangers, as we can hear a nearly 360-degree soundscape around us in contrast with about a 200-degrees field of view. Although humans primarily use vision for guiding their exploration of the environment, acoustic information is important because it helps us localize and identify targets out of eyesight, such as those behind us or those obstructed by scenery or objects. Sound design is central to cinema and particularly horror movies; practically no horror movie feels particularly scary if watched with sound turned down. Research suggests that sounds associated with direct threat such as fearful or aggressive human vocalizations are recognized universally, thus suggesting biological basis of their communication (Sauter et al. 2010). Accordingly, the brain rapidly and automatically differentiates between safe and threatening sounds; for example, fearful vocalizations (screams) result in a differential brain signature already 150 milliseconds after the sound onset, suggesting highly automated processing of emotional sounds (Sauter and Eimer 2010). Sound is thus a convenient way of inducing thrills, as it is constantly processed in the background and in parallel and independently of other sensory information such as vision and touch.

The fear-inducing effects of sounds are significantly stronger when the sounds are louder versus softer, and when they match with the visual events, that is, when they occur due to a clearly distinguishable visual event (Toprac and Abdel-Megiud 2010). Sometimes it has also been argued that low-frequency sounds below the typical audible range in humans (i.e., beneath 20 Hz) could trigger unpleasant sensations, nausea, and anxiety. The evidence for this, however, is mixed. Although high levels (~150 dB) of naturally occurring low-frequency sounds may have physiological effects in humans that lead to discomfort, they are difficult to use in theaters and concert venues due to the need for special sound systems to reproduce low-frequency sounds (Leventhall et al. 2003). Humans produce harsh, unpredictable, nonlinear sounds (screams) when they are afraid or alarmed. This kind of distress or alert signals sound harsh possibly because the vocal cords and syrinxes are overblown when used in stressful, dangerous situations. Studies have consistently found that these kinds of rough and dissonant sounds are perceived as alarming, particularly when generated with modulation rates of 30–160 Hz. The brain's fear circuit is also attuned to this frequency (Arnal et al. 2015). The alerting, fearful screams occupy a specific location in the acoustic space, and humans automatically assess this type of sound as alerting and fearful. These kinds of sounds are also difficult to ignore, and they push easily to our awareness, making them

powerful startling signals (Fitch et al. 2002). These principles can be applied to practically any sound effect. Additionally, synthetic sound effects can be used for mood manipulation. Although not scary per se, unusual, looming sounds can provoke anxiety and vigilance because listeners simply cannot identify them.

**Musical Thrills**

Music can be used for communicating a multitude of emotions (Eerola and Vuoskoski 2013; Zentner et al. 2008) and evoking strong bodily sensations (Putkinen et al. 2024), even though musical conventions vary across cultures (Cowen et al. 2020). Brain imaging studies have found that fearful music engages the brain's fear circuit similarly as "natural" affective sounds such as vocalizations (Aubé et al. 2014), thus providing an unobtrusive means for manipulating emotions outside audience's awareness. This can be done by either presenting music that is directly related to the film's narrative structure, or as background music that does not directly arise from the visual scene in the film but which is instead used for altering the emotional impact of the scene (Smith 2009). For example, different nonlinearities can be induced into music and soundtracks with technological manipulations, and adding noise and abrupt frequency modulations makes the music sound more arousing. Indeed, scary scenes from horror films contain this kind of noisy elements for amplifying the experience of horror, while dramatic films suppress this kind of noise (Blumstein et al. 2010). Music can also significantly influence visual perception during cinema viewing. Low-level acoustic features of the soundtrack such as loudness already influence the interpretation of cinematic scenes, even more than the actual musical qualities of the soundtrack (Tan et al. 2017), and anxiety-evoking music reliably increases alertness and arousal in the viewers, likely via increased attentional engagement (Ansani et al. 2020).

***Low-level acoustic features of the soundtrack such as loudness already influence the interpretation of cinematic scenes, even more than the actual musical qualities of the soundtrack.***

Music may, however, be a less consistent elicitor of emotions across individuals than sounds directly mimicking threats or threat signals. Research has shown that a great portion of the emotion-evoking power of music is learned, and musical emotions stem often from autobiographical events associated with the music as well as nostalgia (Barrett et al. 2010; Janata 2009; Janata et al. 2007). This makes tailoring of one-size-fits all music more difficult, warranting careful pre-testing with test audiences. Nevertheless, recent large-scale cross-cultural work has revealed surprisingly consistent emotional responses to music across cultures. This study also measured bodily responses to various types of emotional music and found that particularly scary music was a powerful elicitor of fear (Putkinen et al. 2024). Because music activates the sensory-motor regions of the brain even in the absence of visible movement (Putkinen et al. 2021), scary

music is an important pathway for implicit induction of the bodily experience of fear in horror films as operates independently of the natural soundscape of the cinema.

**Why Do We Enjoy Horror Movies?**

Pleasures of the cinema are not only restricted to positive emotions, as evidenced by the popularity of horror movies, even though their goal is to shock and scare the audience (Martin 2019). This kind of irrational enjoyment of negatively valenced recreational events is commonplace and it extends beyond horror films. People enjoy artworks with negative themes such as sadness (Menninghaus et al. 2019; Nummenmaa and Hari 2023). Similarly, sad music is often experienced as pleasing and can lead to positive emotions, thus making it an effective means for emotional regulation (Sachs et al. 2015). Finally, sexual preferences involving domination and sadomasochism are common in humans, despite involving actual first-hand physical distress (Joyal et al. 2014). Philosophically, the tendency to avoid of negative affect in real life but seek it recreationally in the context of horror movies seems paradoxical (Carrol 1990; Smuts 2009). Empirical work, however, highlights four factors explaining this effect in cinema and horror movies in particular: suffering of the characters, perceived danger, excitement, and happy versus unhappy endings (Hoffner 2009). Of these, suffering and danger are particularly associated with the enjoyment of horror. Another study compared audience responses to a graphically violent film and its edited version where the violent scenes were toned down or completely removed. The nonviolent version was significantly more enjoyable than the two violent versions, confirming that violence per se does not increase enjoyment of movies (Weaver and Wilson 2009). However, when administered skillfully, it can increase the startle responses during jump-scares or temporarily ramp up the fearfulness of the scenes. Field studies with "haunted house" experiences have shown that optimal intensity of fear follows an inverted-U-shaped relationship, with moderate levels of fear leading to the highest enjoyment. Moreover, results from physiological studies demonstrate that the experience of being frightened is a linear function of large-scale heart rate fluctuations, whereas there is an inverted-U-shaped relationship between participant enjoyment and small-scale heart rate fluctuations (Andersen et al. 2020).

Also, despite being wary of the unknown, humans have a strong curiosity and fascination with the unusual (Oosterwijk 2017). This kind of *morbid curiosity* is a stable individual difference and people scoring high on trait-levelo morbid curiosity prefer entertainment such as horror films where threats are a central theme (Scrivner 2021). Negative emotions experienced while viewing horror movies also consistently predict how much viewers will enjoy the movie (Hoffner and Levine 2005). We seek out coverage of violence in the news and on the internet and are similarly drawn toward thrillers and horror movies. This is driven by sensation-seeking

motivation, as the scares and morbidities give rise to arousing sensations, which might be experienced as pleasant when experienced in otherwise safe environment (Zuckerman 1990). Indeed, fear and excitement have, in many parts, overlapping neurobiological basis, the most salient parallels being the hypothalamus-driven control of the physiological stress response, which may lead to "mixing" of these two emotions, and fear may be experienced as exciting.

Alternatively, we may be curious about the unusual and negative events because they allow us to learn new things about the world (Berlyne 1966). According to this view, horror movies may act as a "mental gym" or training ground for the mind. During the safe, simulated environment such as oral story, novel, or film, we may be psychologically and somatically exposed to events that would be life-threatening if encountered for real. This way, the mind can learn to prepare scripts for action during real emergencies cope with the difficult emotions (anxiety, fear, sadness) so that we are better prepared for dealing with them whenever they happen in real life. Because death has been a central point to humans through the evolution, it is possible that the stories about supernatural threats have evolved (in the cultural sense) as an additional means for protection against toxins, virus vectors and predators, as antagonists in the folktales such as animated dead, werewolves, and vampires are essentially imaginary extensions of the biologically transmitted threats (Grodal 2009).

This could also explain why people have so strong preference for horror movies that are both plausible and based on realistic settings (Figure 6). This is supported by data acquired during the COVID-19 pandemic revealing that fans of horror films were psychologically less distressed during the pandemic, and that individuals scoring high on morbid curiosity (who also enjoy horror movies) were more resilient during the COVID-19 pandemic (Scrivner et al. 2021). However, field studies indicate that this kind of mental exercise must be administered cautiously, as moderate (rather than extreme) levels of recreational horror lead to the highest levels of enjoyment (Clasen et al. 2020). Finally, it must be noted that there are large individual differences in the enjoyment of horror. Particularly in male viewers, individuals lower in empathy, and those higher in sensation-seeking, aggressiveness, and intellect- and imagination-related personality traits report more enjoyment of fright and violence (Clasen et al. 2020; Hoffner and Levine 2005), thus the enjoyment of horror is highly subjective rather than a stable population-level phenomenon.

## Conclusions

A healthy dose of scares in a horror movie or tears in a heart-breaking drama can be psychologically beneficial. Learning how different emotions feel and being exposed to them in a safe, controllable environment builds up psychological resilience and helps in dealing with difficult emotions in real life. Because the enjoyment of recreational horror depends on indi-

vidual differences and is contingent on sufficiently but not overly strong fear levels (Clasen et al. 2020), there is no one-size-fits-all solution for effective horror scenes of movies. This is highlighted by the fact that emotional experiences become progressively weaker after early adulthood (Volynets et al. 2019), and it is well known that emotion regulation ability increases during aging (Urry and Gross 2010). Consequently, younger audiences are easier to scare with movies, which is also reflected in the restrictions prohibiting showing of potentially traumatic or overly graphic movies to younger audiences. Appropriate levels of excitement need to be tailored for each audience, as even mildly scary movies aimed at adults can cause downright dread in young children.

***Learning how different emotions feel and being exposed to them in a safe, controllable environment builds up psychological resilience, which helps in dealing with difficult emotions in real life.***

The conceptual model for the psychological and cinematic mechanisms of eliciting fear through horror movies are summarized in Figure 7. The cinematic and structural factors are designed to deliver a psychologically engaging yet believable fearful input. This is based on universal human fears ranging from sensory features and startles to unknowns, strangers, and direct threats to physical and psychological well-being. By keeping the targeted fear level within the maximal "recreational fear" levels, the experiences can remain pleasurable rather than aversive. These threats are delivered in manner that combines both suspense-dependent predictability (leading to amplified anxiety) as well as fully unpredictable events (leading to pure startle responses). When passing the viewer's reality check, the cinema can trigger the fear responses via the sensory and biological fearful features, while vicarious simulation and empathetic alignment with the protagonists may further increase the experience of fear, also depending on the current executive system load. This concept thus provides a workable guideline for writing and directing effective horror films, as well as

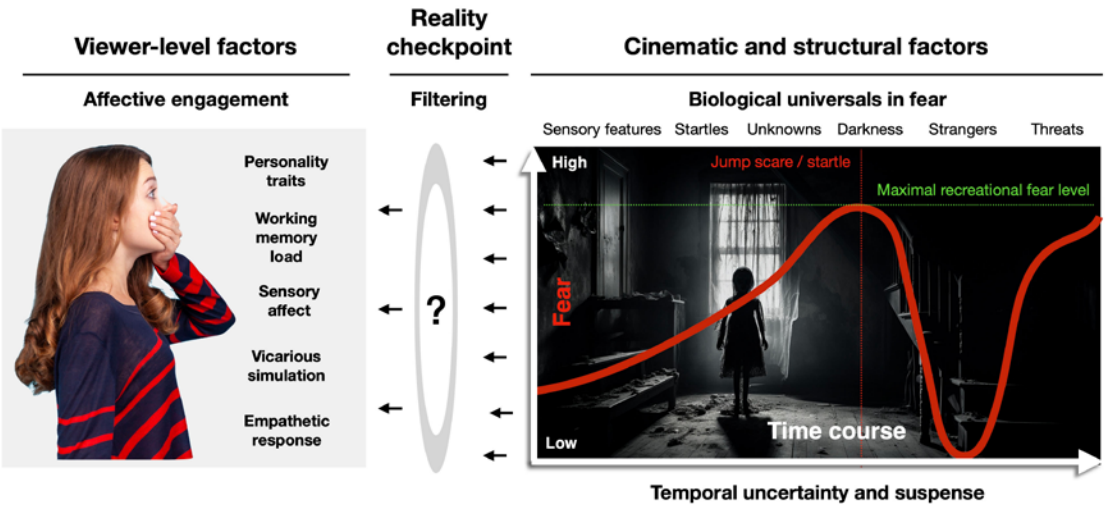



*Figure 7. Conceptual model of the psychological and cinematic effects of horror movies*

a framework for psychological, neuroscientific, and theoretical studies on fear and horror in films.

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