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ORIGINAL RESEARCH

The Enduring Influence of a Dangerous Narrative: How Scientists Can Mitigate the Frankenstein Myth

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Abstract Reflecting the dangers of irresponsible science and technology, Mary Shelley's *Frankenstein* quickly became a mythic story that still feels fresh and relevant in the twenty-first century. The unique framework of the Frankenstein myth has permeated the public discourse about science and knowledge, creating various misconceptions around and negative expectations for scientists and for scientific enterprises more generally. Using the Frankenstein myth as an imaginative tool, we interviewed twelve scientists to explore how this science narrative shapes their views and perceptions of science. Our results yielded two main conclusions. First, the Frankenstein myth may help scientists identify popular concerns about their work and offer a framework for constructing a more positive narrative. Second, finding optimistic science narratives may allow scientists to build a better relationship with the public. We argue that by showing the ethical principles and social dimensions of their work, scientists could replace a negative Frankenstein narrative with a more optimistic one.

Keywords Frankenstein myth · Science narratives · Science ethics · Responsibility · Identity

Introduction

> I had been the author of unalterable evils, and I lived in daily fear lest the monster whom I had created should perpetrate some new wickedness. (Victor Frankenstein, in Mary Shelley's *Frankenstein; or, the Modern Prometheus*)

In 1976, Alfred Velucci, the mayor of Cambridge, Massachusetts, called a city council hearing on the potential dangers of genetic research, leading to the increased scrutiny of scholars who studied and modified human DNA, especially at Harvard University. Vellucci was driven not only by his passion to get revenge on the institution for political reasons but also by mistrust and fear of emerging bioscience practices. So, when the university decided to build a new laboratory for genetic research, a relatively new field at that time, Vellucci was ready to deploy the ultimate weapon to turn the public against science: Mary Shelley's *Frankenstein*. Leveraging the Frankenstein image and its nightmarish connotations about science, hubris, and disastrous consequences, he successfully convinced the city council to issue a

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three-month moratorium on DNA experiments (Culliton 1976). Vellucci even penned a letter to the National Academies of Science over the alleged appearance of weird and hairy mutant monsters in New England:

> I would hope as well that you might check to see whether or not these "strange creatures" (should they in fact exist) are in any way connected to recombinant DNA experiments taking place in the New England area. (Crotty 2001, 122)

The case of Alfred Vellucci and his vendetta against Harvard illustrates the ways the Frankenstein story shapes the perception of the moral authority of the scientist. From genetically modified food to mechanical creatures, *Frankenstein* has evoked strong reactions to new scientific advances ever since Mary Shelley published the first version of her novel in 1818. The Frankenstein story quickly became the symbol of irresponsible science, encapsulating people's ambivalent attitudes towards science and towards scientists in particular (Skal 1998). People often have positive expectations for science, but they also fear that science might harm them. These beliefs reflect one of the fundamental dystopian fantasies about science—its supposed capacity to transform human beings into unnatural creatures (Mulkay 1996) or even produce monsters (Swart 2014). From the Greek myth of chimera and the demonic multiheaded Cerberus to the Japanese Godzilla, the fear of monsters and monstrosity has perennially served as an underlying theme for myths and stories. With the advent of new sciences and technologies, however, the differences between humans and monsters has become increasingly problematic and distorted (Shattuck 1996). For instance, scientists are now capable of creating "monstrous" chimeras by adding human cells to animal embryos (Hyun 2016) and by producing sophisticated artificially-intelligent "monsters" that can act on their own and possibly even cause harm to human beings (Fell 2016).

Capitalizing on the widespread destabilizing impacts of science and technology throughout the nineteenth century, *Frankenstein* quickly became a mythic story, extending energetically into the twenty-first century through a variety of booming mass media industries. With the passing of time, *Frankenstein* is still fresh and even more relevant in the twenty-first century due to its perspicacity about the ethical quandaries swirling around scientific and technological change. Skal (1998) argues that Frankenstein "has become the dominant, if despairing, creation myth of modern times" (57). Similarly, biologist Leonard Isaacs (1987) argues that "Mary Shelley may in fact have created the first future myth—one whose structure was to correspond even more closely with the developments of a later century than with the author's own, and thus lay waiting for human activity to catch up with it" (62). In both its own century and the next, *Frankenstein* was seen as a potent and overridingly negative symbol of science and the figure of the scientist. As a result, the Frankenstein story has become a common, easily recognizable metaphor for the distrust surrounding the scientific community (Huxford 2000). More specifically, as Hirsch (1958) notes, the most common representation of the scientist in popular culture revolves around this Frankenstein image: the scientist as the victim of his own hubris, "blasphemously attempting to attack natural or divine law" (510). That is, while scientists are likely to be pictured as gifted individuals unlocking new knowledge and creating novel technology, they are also seen as controversial characters who may be blinded by their own scientific curiosity and commit transgressions (Rutjens and Heine 2016).

Through its various incarnations and media representations, the Frankenstein myth[1] has become a powerful and pervasive tool for imagining and understanding the potential dangers of scientific practices—especially those that are thought to have the capacity to create life, like artificial intelligence or cloning (Mazlish 1995), or to modify life, like genetic engineering or gene therapy (Hammond 2004). For instance, while some people are concerned about what viruses or bacteria bioscientists may unleash from their laboratories (Wade 1973), others are more anxious about the way scientists' advancements in artificial intelligence and robotics may change their lives (Jotterand 2008). Phrases like "Frankenscience" and "Frankenfood" create cultural frames for understanding scientific enterprises and procedures in very specific and visceral ways: they imply that scientists' work involves gruesome actions such as tinkering, sewing, and stitching (Hellsten and Nerlich 2011).

In this paper, we argue that the Frankenstein myth provides a template for science narratives—a social construction that helps people make sense of science

[1] We use the concept of Frankenstein myth to refer to people's general interpretation of the Frankenstein narrative. That is, combining various literary and cinematic adaptations of the original story, the Frankenstein myth represents how popular culture imagines *Frankenstein*.

and conceptualize its social and technical implications. On the other hand, the Frankenstein myth may also influence how scientists think and feel about their identities as professionals and about their relationship with the public. The narrative approach advocates the idea that humans are natural storytellers, constructing and sharing personally meaningful and significant stories about themselves as a way to find unity, purpose, and meaning for their lives and identities (McAdams and McLean 2013). Since narratives are natural sources for identity construction, mapping the different ways that the Frankenstein myth affects scientists can be beneficial for two reasons. First, it may help the scientific community recognize certain narrative frameworks that imbue their professional lives with structure and meaning (Csicsery-Ronay 2008). Second, narratives, especially science narratives, may allow scientists to reflect upon a wide range of moral and ethical issues around science and technology (Burnam-Fink 2015). In order to change the lens through which people perceive and approach science, we need to gain a better understanding of how the "victims," the scientists, think and feel about the Frankenstein myth.

For the current paper, we view the Frankenstein myth as an imaginative tool— a technoscientific reference that captures people's attention and facilitates their thinking and talking about scientific and technological issues. We attempt to explore scientists' interpretations and perceptions of the Frankenstein story to identify its most salient underlying themes. By using these notions to conceptualize the Frankenstein narrative, we argue that scientists can take a fresh look at their work, professional identities, and roles in society.

After introducing the Frankenstein myth and its impacts on science and the scientists, we present our findings from interviews with scientists who work within particularly "Frankensteinian" scientific fields, ranging from synthetic biology to robotics. In these interviews, we aimed to learn how the Frankenstein myth influences scientists' views and perceptions of science and to understand how this narrative affects the way they think and feel about their work.

The Frankenstein Myth

Myths are stories we use to make sense of the world, allowing people to conceptualize, understand, and interpret a wide range of natural phenomena (e.g., birth, death, weather) (Peters 2003). Myths teach people how to deal with the unknown and paradoxical and dissolve the conflicts of human existence (Isaacs 1987). Myths in this sense combine facts with fantastic concepts and narratives, enabling people to make speculations and models regarding the world (Csicsery-Ronay 2008). As an enduring modern myth of science, *Frankenstein* has become a readily accessible tool for understanding and interpreting the work of the scientist.

At the centre of the Frankenstein myth, we find Victor, who seeks fame and throws himself into a grandiose attempt to create life, an act that is traditionally limited to a god figure (Shattuck 1996). In fact, the central narrative of the Frankenstein myth reinvents one of the oldest stories from mythology: a man who cannot experience lasting satisfaction, who becomes blind to the consequences of his work, who becomes overconfident, and who commits a transgression and acquires forbidden knowledge. These myths have a simple message for people: "do not play God!" (Weasel and Jensen 2005). For instance, Daedalus fabricated wings for himself and his son Icarus so they could fly like the gods and escape from the island of Crete. Despite Daedalus' warnings, Icarus soared too close to the sun, fell into the sea, and drowned. The death of Icarus can be seen as a punishment for Daedalus, who outstrips human limitations by inventing a way to fly—something that only gods were meant to do. The legend of Prometheus, on the other hand, tells the story of Titan who rebelled against the natural order by creating life with his own hands from clay and water. Similarly, through secretive and dangerous scientific experiments, Victor Frankenstein overreaches by artificially producing life in his laboratory. As a result, he causes suffering to not only his creation but also to innocent people.

In contrast to these older myths, however, the Frankenstein story emerged contemporaneously with modern conceptions of science and created a unique fabric of beliefs around the scientist specifically (Isaacs 1987): First, the secrets of nature can only be unravelled through intense scientific inquiry. Second, science reflects scientists' personal interests and professional ambitions. Third, science allows people to transcend their human frailties through the acquisition of secret knowledge. Fourth, science is capable of producing lifelike entities that may turn against their creators. Finally, science can be used for good or ill, and it is the obligation of society to regulate scientific creativity and channel its potential into constructive and positive outcomes.

Without effective control and regulation, the Frankenstein myth warns, scientists may easily become overly ambitious and use their "secret" knowledge to create modern monsters (e.g., viruses, clones, robots) that turn against them and against innocent people.

The Frankenstein myth suggests that scientists should not learn divine secrets, overreach themselves, and tinker with the fundamentals of human life (Peters 2003). Presenting Victor as a scientist who works alone and hides from other people, the Frankenstein myth provides us with a horrifying narrative about the consequences of the separation of scientist from society (Davis 2004). As such, Frankenstein's story is a cautionary tale, but within this warning there is a nuanced presentation of the dangers of scientific experimentation and the seductive nature of scientific discovery that may push scientists into madness and isolation (Shattuck 1996). For instance, Shelley's novel depicts Victor Frankenstein as an initially compassionate and educated character who gradually becomes an isolated and obsessed man who has lost sight of his ethical principles and is either unwilling or unable to take responsibility for the destructive forces he has unleashed (Halpern et al. 2016).

Although distrust and fear of science can be seen in a great number of science fiction stories, the Frankenstein myth is still one of the world's most widely known and popular science fiction narratives (Haynes 1995; Turney 1998; Segal 2001). Science fiction stories share a common feature that is particularly relevant for the Frankenstein myth: They reflect people's views about the dangers of science and technology and their potential to cause radical societal and environmental changes (Ryan and Kellner 1990). As such, science fiction stories have become important rhetorical tools for understanding and imagining scientific practices (Huxford 2000).

The Frankenstein myth provides a narrative template for the character traits and motivations of the scientist working within various scientific fields, shaping how people think about scientists' work, ethical standards, and personal values. In the present paper, we view the Frankenstein myth as a science narrative, allowing us to investigate how it influences social and cultural imagination around the figure of the scientist.

Frankenstein Myth as a Science Narrative

Narrative theory (e.g., Sarbin 1986; Bruner 1986; Gergen and Gergen 1988) holds that we are born into a storied world and we live our lives through creating and exchanging narratives. Narratives are social constructions that help people make sense of the world they live in and communicate that understanding to others (Avraamidou and Osborne 2009). Recently, narrative theory has been applied increasingly often to the field of science communication. Previous research found that narratives are effective and persuasive communication devices because they have a specific and easy-to-follow structure to disseminate information (Murray 2003; Glaser et al. 2009; Dahlstrom 2014). Because they describe a particular experience rather than general truths, narratives are intrinsically persuasive: they do not need to justify the accuracy of their claims, because the story itself demonstrates the claim. They create a cause-and-effect relationship between events, altering and manipulating people's perception (Green and Brock 2000) and presenting conclusions as inevitable facts (Dahlstrom 2014). No wonder that it is a daunting task to counter their claims with scientific facts. Scientists typically engage in "logical-scientific" communication that provides abstract truths that only remain valid across a limited range of situations. In contrast, narratives use specific cases to convey general or universal truths, which are easier to understand and often more exciting to think about than those expressed through science discourse.

Viewing the Frankenstein myth as a science narrative opens up new ways to investigate its effects on people's perceptions of and attitudes towards science and the scientists. Science narratives exhibit two common themes: discovery and creation (Hoffmann 2014). When making a discovery in stories, scientists usually go through the classic stages of epic journeys: a quest, obstacles to overcome, and, in the end, success. At the end of their epic journeys, scientists are able to make a groundbreaking discovery and create something extraordinary, like a new cure for a deadly virus (e.g., *The Andromeda Strain* by Michael Crichton) or the first member of a new species (e.g. Mary Shelley's *Frankenstein*). Given that people struggle to distinguish between true and imaginary science and between science and science fiction (Petersen, Anderson, and Allan 2005), science narratives can easily be used to portray a negative image of science and scientists (Dahlstrom and Ho 2012). For example, a recent large-scale study found that negative narratives of science often use conspiracy theories to disseminate false claims and confusion (Bessi et al. 2015). As a result, these negative narratives create disengagement from the mainstream

scientific community and spread dangerous misconceptions about science. For instance, negative narratives may suggest that scientists want to produce horrific abominations through genetic engineering (Holmberg and Ideland 2016) or infect people with disease under the guise of vaccination (Kata 2010). In contrast to narratives conveying false information, the Frankenstein myth represents an overly simplistic and mistaken understanding of Mary Shelley's original *Frankenstein* story, which presents a more ethically complex picture of creation and its consequences. Although people might know some elements of Mary Shelley's novel, they tend to confuse the creator, Victor Frankenstein, with his nameless creation and the original story with its multifarious adaptations, such as TV shows or movies. Given that people often have difficulties separating fiction from reality (Marsh and Fazio 2006), it is no wonder that the simplified, distorted Frankenstein myth has become cultural template to conceptualize science and imagine the scientist.

The Frankenstein myth presents scientists as irresponsible authorities who are ready to open Pandora's box without thinking about the potential consequences (Larsen 2011). People have these ideas part because of the fundamentally experimental nature of science. Scientists seek to modify nature for their own theoretical and technological purposes. As early as 1924, the British scientist Haldane argued that:

> … the chemical or physical inventor is always a Prometheus. There is no great invention, from fire to flying, which has not been hailed as an insult to some god. But if every physical and chemical invention is a blasphemy, every biological invention is a perversion. (Haldane 1924, 40)

This idea reflects one of the most important messages of the Frankenstein narrative: that scientists constantly reinforce the notion that nature and even people should be manipulated and perfected through the practice of science (Passmore 1978). Imagined as secretive authority figures who like to interfere with the natural order of things, scientists are therefore considered dangerous and inconstant experts (Mulkay 1993). For instance, a recent large-scale study found that U.S. adults have mixed feelings about scientists: while they are trusted and often liked, they are also seen as immoral and unpredictable figures who can easily become dangerous when they engage in acts of misconduct (Rutjens and Heine 2016). Or as the philosopher and biologist Ludwig Fleck (1979) puts it, there are two types of scientists: "the 'bad guys' who miss the truth, and the 'good guys' who find it" (116).

The Frankenstein myth revolves around a "bad guy" who not only misses the truth, but who often overreaches and commits dire transgressions (van den Belt 2009). By engaging in dangerous scientific practices, the "bad guys" acquire forbidden knowledge and disrupt the natural order of life and death, human and nonhuman (Grinbaum 2010). The only thing that can prevent science from producing dangerous technological artefacts, according to this narrative, is the strict ethical standards and strong moral character of the scientist. In order to avoid becoming the next Victor Frankenstein, scientists should reflect on the ethical and social aspects of their work and take responsibility for their creations (Jotterand 2008). With their growing number and influence, scientists have increasingly been perceived as authority figures with great power in their hands (Frazzetto 2004). This is why people have ambiguous attitudes towards the scientist: while science as a whole tends to be viewed as a generally positive force by the public, scientists have increasingly become targets of suspicion and hostility (Holton 1992).

The Frankenstein myth has given rise to a negative image of science and scientists, preventing people from gaining a more nuanced understanding of what they are capable of doing. To change and dismantle counterproductive stereotypes of science, scientists should reflect upon science narratives such as the Frankenstein myth and use them to foster and disseminate respect for imagination and intellect. When it comes to understanding how these stories shape our thinking, we have to begin with the structure of the Frankenstein narrative. For instance, the critical theorist Andy Mousley (2016) argues that:

> Frankenstein's continual meta-fictional emphasis upon the situation of listeners listening to stories in different ways, and with different outcomes, might cause us to reflect upon our own reception of the stories, as well as upon the meditations of the characters on being human. (171)

Through all of its various adaptations, the Frankenstein myth reflects not just on science but on its popular reception. Therefore, it may serve as a ubiquitous sociocultural artefact for exploring the social and ethical figure of the scientist. More specifically, the ubiquity

and potency of the Frankenstein myth allow us to conceptualize the romance and potential hazards of science and use them as apt lenses for exploring these issues.

Methods for Exploring Scientists' Interpretations of the Frankenstein Myth

We used the Frankenstein myth to explore how scientists think and feel about their work, their portrayals, and the public image of their research. Focusing on these implications of the Frankenstein story, we interviewed scientists whose work reflects Victor Frankenstein's scientific enterprise in some way: creating and modifying biological or artificial life. Accordingly, we chose experts working on applied scientific projects with special focus on biosciences, robotics, nanotechnology, and artificial intelligence (AI).[2] Researchers using biotechnology are often labelled as "dangerous scientists" who create "monster genes" and thus disrupt the natural order. As Peters (2003) puts it, "there is something special—something almost sacred—about the genes" (7). Similarly, scientists' work within the fields of robotics, nanotechnology, and AI is also conceptualized and imagined as overreaching and transgressive (Gunkel 2012).

As an initial step, we identified a large network of scientists across various related fields of applied science and invited eighty-one of them via email to participate in our research; twelve of them (~15 per cent) volunteered to take part in our study (see Appendix 1 in online supplementary materials for further details). We selected our potential participants based on their research experience and research areas. All of our potential interviewees have been working as researchers at science institutions in the United States for more than ten years and have had extensive professional experience with the latest bioscience and/or computer science methods and applications. Given their general understanding of the Frankenstein story and cutting-edge scientific and technological advancements, our participants were able to reflect upon various social, ethical, and professional aspects of their scientific work.

[2] This interview data is part of a larger research project on how scientists relate to the Frankenstein myth. We will also be using this data in another stream of research focused on how scientists think about the influence of the Frankenstein myth on their professional identity. An article based on this second avenue of research is currently under review in another academic journal.

Our questions targeted the participants' scientific interests, motivations, and goals, along with their perceptions of the scientific and ethical values around the Frankenstein myth. After introducing their scientific work and discussing their professional background, we asked our interviewees to think about their responsibilities as scientists and public perceptions of their research (e.g., "What do you think most people don't understand about your research?" "What does it mean to be a responsible researcher in your field?"). Later, we discussed interviewees' perceptions of the Frankenstein myth and the role this myth plays in shaping people's values around and expectations for science (e.g., "What does Frankenstein tell us about science?" "What does Frankenstein tell us about our society?"). We also targeted the different ways scientists imagine Victor Frankenstein as a scientist and the ethical and moral implications of his scientific enterprise. Finally, we explored how our participants' interests, motivations, and scientific goals show resemblance to Victor's character. By allowing our participants to elaborate on their own scientific practices and reflect upon the Frankenstein myth, we encouraged them to consider and recognize potential similarities and differences between how people imagine their work based on the Frankenstein myth and what their actual work is. Each interview lasted for approximately one hour and was conducted by the same interviewer with expertise in qualitative methodology.

We analysed the interviews using the phenomenological research approach (Groenewald 2004). Enabling scholars to generate new ideas and theories, the phenomenological methodology concerns the qualities of human experience, "examining entities from many sides, angles, and perspectives" (Moustakas 1994, 58). Following the phenomenological interview protocol (Kvale 1983; Hycner 1985), one of the research team members transcribed, analysed, and drew interpretations from the interviews to find underlying themes and core narratives. In order to ensure validity, the researcher shared his personal observations and initial findings with other team members. Also, they participated in a joint discussion to identify the similarities and differences between how scientists talked about the Frankenstein myth and their professional life and values. This allowed the team to explore the key themes and narratives of the interviews, focusing on the scientists' motivations, perceptions, and aspirations. By sharing their own thoughts and interpretations of the interviews, the team members validated the analyst's assessments. As a result, we were able to

identify various narratives and themes around the Frankenstein myth, concerning the misconceptions of and false expectations for science, scientists' interpretations of the Frankenstein myth, and the controversies surrounding Victor Frankenstein's character and work.

Misconceptions of and False Expectations for Science

In general, our participants had no problem talking about the research they do and reflecting on their responsibilities as scientists. However, they also recognized that the public tends to have various misconceptions about and false expectations for their research. A researcher working within the field of neural engineering [P1] noted that:

> I think people are always a bit cautious or fearful whenever we start talking about "cyber things." I mean it is always very scary for them to imagine when a medical device is connected to the human nervous system. There is some good reason to be cautious, but people usually do not know anything about the whole ethical system that guides our work.

That is, scientists working at universities or companies have to follow a wide range of strict ethical and legal guidelines. Or as a researcher [P12] put it, "laypeople often lack knowledge about the complex institutional ethical regulations that govern scientific research." And, as a result, people tend to have misconceptions about research concerning creating and modifying artificial or biological life. Reflecting on these misconceptions and false expectations, our interviewees agreed that people would react negatively to research mixing human with nonhuman and organic with artificial. Scientific applications and technologies that are categorized as "nonhuman" or "cyber things" tend to evoke more concern about potential negative effects. These effects are centred on losing control over one's bodily and/or agentic functions. For instance, a robotics scientist [P3] noted that "the cyborg root has a really bad connotation. You know, the device that turns against its user is a very strong image for people." Another scientist focusing on rehabilitative technology and human–machine interaction [P4] stressed that:

> It is amazing how quickly prosthetics and exoskeletons blur the boundary between human and nonhuman. With these technologies, humans and robots work together, and it is often quite hard for people, including scientists, to see who is in control.

On the other hand, molecular or nanoscale applications are often hard for the public to imagine, so they produce slightly different attitudes, especially when they revolve around GMOs or vaccination. According to our interviewees, although the public is aware of the potential benefits of these artefacts, people also implicitly assume that scientists using molecular or nanoscale science to modify biological systems may accidentally poison or contaminate living entities. A researcher working on nanotechnology projects [P5] argued that:

> People have a conception of what nanotechnology and genetic engineering are. They often think that although they can be good, they can cause a lot of harm. None of them think that nanotechnology or genetic engineering are just dangerous. They are not like nuclear bombs

That is, the public has, according to our interviewees, quite mixed feelings about these scientific applications: although people know that genetic engineering or nanotechnology are not necessarily dangerous, they do believe that these technologies have the potential to cause some form of damage or harm. By harm, laypeople mean that scientists may infect people with diseases or viruses. The majority of our participants (ten out of twelve) argued that there are two topics that are particularly problematic for the public: vaccination and genetically modified foods. They evoke strong and vivid negative images among people; or, as a genetic scientist [P7] noted, "genetic research is polarizing because people think that it messes with humans and the natural order." As such, genetic engineering and vaccination in particular are considered suspicious and dangerous scientific practices. An immunologist whose work involves genetic engineering [P6] said:

> If I tell people that I am working on making vaccines better, they ask me, "why do you need to make them better?" And that's when anti-vaccination comes into the picture. Can vaccines be dangerous? Why do we use them? The problem is that the general public does not know anything about how vaccination works.

This suspicion tends to stem from people's misconception of what science and technology can and cannot do. Laypeople know what biology

and computer science are in a general sense, but they may lack knowledge of accurate science and technology knowledge on a more detailed level, limiting their ability to accurately interpret new discoveries and applications. Our participants agreed that although people have a general understanding of what science is, they do not know what is scientifically or technologically possible. For instance, one of them [P5] argued that "People are good at taking a broad understanding of science. They don't understand the technical. However, people are not stupid. If they have time to ask questions about science, they can make good decisions." Another scientist [P8] noted that "lots of people don't understand how scientific research happens. They don't have many representations to imagine scientific concepts." Given that science is changing at a rapid pace and that even scientists find it difficult to keep up with the latest trends, it is not surprising that the public has quite limited understanding of cutting-edge sciences and technologies. As one interviewee noted [P12], "the world we live in is technologically complex, and the public does not know how technologies work." Because scientific and technological changes happen so frequently, some people may find these changes offputting, stressful, and frightening. According to a researcher [P2], "we live in an era when everything is changing so quickly. Technology is moving so fast, and some people are scared of these changes because they don't want to move."

Our participants argued that because of these dizzying changes, people may easily fall into a distorted, overly negative view about science and technology. A scientist [P7] noted that "people are worried about unintended consequences of scientific research. What if we [scientists] create something that causes problems?" People get the negative ideas from different sources (e.g., news, movies, books) that, according to our interviewees, are likely to present a polarized image about certain scientific fields such as genetic engineering or AI. As such, popular culture often reinforces people's negative stereotypes by creating an easily accessible and misleading narrative around these scientific practices. A scientist who works on an AI project argued [P12] that "movies or sci-fi books quite often portray human–machine interfaces as tools for reading other people's minds or hijacking other people's bodies. But in reality, these technologies are not capable of these things." Similarly, bioscientists blamed the pervasiveness of scientific and technological misconceptions and the impact of media for people's negative attitudes towards science. One way to turn these negative attitudes into more positive ones is, obviously, to talk directly to the public. A bioscientist [P9], for example, noted that "we need to tell the public how the immune system works. Otherwise, people get together, form anti-vaccination groups and decide not to use vaccination." Talking to the public, however, is often challenging because people tend to be selective in what arguments they accept or reject. In fact, the public and the media have a tendency to talk about what one of our participants called "science horror stories." A genetic engineer [P2] noted that:

> Even one event can have a long-term impact on how we think about science. Like the fragile study about the correlation between vaccination and autism. It still haunts us. A lot of people do not trust in vaccinations because of that study.

The study mentioned by our interviewee linking autism to vaccination was a fraud written by a former British medical professional, Andrew Wakefield, in 1998. Despite the fact that Wakefield fabricated the results and had undisclosed financial conflicts of interest, our interviewee argued that people still see Wakefield's study as a proof of the potential dangers that not only vaccination, but science and technology more broadly, pose to society. This story also demonstrates that certain events, news, and stories—even if they are found to be fraudulent—might have a lasting impact on how people think about science and technology. Among these stories, our participants agreed that Frankenstein is one of the most well-known and influential modern myths shaping people's attitudes about science.

Scientists' Interpretations of the Frankenstein Myth

According to our interviewees, the Frankenstein myth has had a remarkable impact on how people think about science and technology. One of the researchers [P10] argued that:

> *Frankenstein* is an icon, it captures so well scientific and moral themes. The story is about what happens to scientists when they lose focus and become myopic. There is no technology that does not cause harm or problems, so you always have to take into consideration the potential side effects. This book had an enormous impact on society.

The Frankenstein myth has concrete and universal messages for scientists. As one of our bioscientists framed it [P8], "the thing is, Frankenstein is such a unique story. The story is timeless, and it transcends generations." For our participants, the Frankenstein myth clarifies three main dangers inherent in the practice of science: First, science can produce unexpected outcomes. An AI researcher noted [P11] that "for me, the message of the story is that science can always have unintended consequences that people need to consider." Second, the Frankenstein myth is also about creating incomplete or unstable scientific artefacts. According to a nanotechnology scientist [P5], "*Frankenstein* tells us how we think about science. Science is taking things apart and trying to put them together again, but you lose something valuable in the process." Finally, the Frankenstein narrative shows us the consequences of tinkering with dangerous components. As a cancer researcher put it [P6], "*Frankenstein* is about combining categories of the things of the world that always should be separated. When you combine them, unexpected things can happen. I guess it is a really powerful metaphor." These dangers may help the scientist think more elaborately about potential problems during research, allowing them to reflect on the ethical dimensions of their work. Our participants were all concerned about the potential dangers or problems their research may cause, and the Frankenstein story helped them articulate their views even more concretely. More importantly, the Frankenstein myth allows them to better imagine how people think and feel about their professional character and the work they do, often in a negative way. A scientist argued [P11] that "*Frankenstein* represents the fear about the scientist and what they are capable of. This image is so powerful that it becomes the first impression for a lot of people."

Following the contours of these three potential dangers, the Frankenstein myth has permeated the public's imagination of science, and as a researcher focusing on synthetic biology noted [P2], "it often creates overreactions." Our participants agreed that the main danger of the Frankenstein myth is that it has been retold and reimagined so many times through the decades that it can be easily applied to a wide variety of disparate scientific fields and communities. As a researcher [P1] noted:

> There are so many people who raise money to attack science or scientists they do not like. They are really successful in creating negative marketing buzzwords around technologies, like the "Frankenfood" or "Frankenscience." The beauty is that you do not need to use facts to support your claims, all you need is to do is come up with a good idea and it will result in a snowball effect.

Buzzwords like "Frankenfood" or "Frankenscience" imply that scientists engage in suspicious and ethically questionable practices to manipulate the world around them. Or as a participant [P9] put it:

> Frankenstein exemplifies whole genre of stories where the bad guy, the nemesis, the problem is generated by the scientist. I think Frankenstein is expressing a general or reasonable, sometimes extreme, cultural fear of potential dangers or devastating consequences of science.

The Paradoxical Character of Victor Frankenstein

The majority of our participants (nine out of twelve) also agreed that the Frankenstein myth introduced a very specific and mostly negative image of the scientist: Victor Frankenstein. According to our interviewees, the character of Victor Frankenstein has a lot to do with the fact that people instinctively use this myth to imagine and interpret the work of the scientist. More specifically, Victor is important because his character is used by laypeople as a template for thinking about scientists. One of the robotics researchers [P10] argued that:

> The story of Victor Frankenstein can be applied to every scientific field. Don't be arrogant! Be humble! It is easy to be arrogant. You often think that your work is so great. You start to forget about the suffering your work can cause to other people. You can easily become myopic.

A majority of interviewees (eight out of twelve) agreed that "Victor Frankenstein has always been depicted as an overly ambitious scientist, someone who does not care about the consequences." Others also emphasized that Victor exemplifies the arrogance of the scientist (the dark underside of "brave" and "pioneering" behaviour). For instance, a scientist [P9] argued that "Frankenstein is a careless scientist who goes against the ethical principles of science and unleashes a dangerous monster to the world." Another researcher working within the field of human–machine interaction [P11] also noted that "Frankenstein worked on topics that the rest of the

society was too afraid to explore." Seven researchers noted that Victor should be viewed as primarily a negative character, while others developed a more complex understanding of him. One of the interviewees [P3], for example, even found inspiration in the story:

> Scientists, when they read the Frankenstein novel or watch the movies, they find inspiration in Victor's passion to advance science. When I read the book, I thought "look at this passion, wow!" When I worked on my dissertation, I had an actual journal just like Victor had his own. I took this inspiration from the Frankenstein story. Everybody can take small inspirations from his story. But at the end of the day, you will see him as someone who broke the rules and did something really really bad.

These interpretations show that Victor is viewed as a paradoxical character—while he is brave, creative, and ambitious, he is also irresponsible, arrogant, and dangerous. As one our participants [P4] noted, "he exemplifies a combination of desirable and undesirable qualities." Several participants (seven out of twelve) agreed that one way to preserve Victor Frankenstein's passion and creativity while avoiding his mistakes is to take responsibility for their scientific creations and produce a transparent and ethically rigorous research agenda. Understandably, scientists need to be aware of the fact that their scientific practices might lead to dangerous outcomes. A researcher [P7] noted that:

> A scientist should study whatever they want to, but they also need to be ethically sensitive. You have to play according to the rules. Because otherwise things can go out of control. This is what Frankenstein is about. Frankenstein goes too far, though. He broke the ethics, so there was a price to pay. It is also about the implications of breaking down the well-accepted ethics and laws of society.

Contrary to the popular belief that scientists follow Victor Frankenstein's footsteps and work in secrecy, the scientific community is deeply embedded in society. However, scientists often find it hard to communicate with the public. Some interviewees argued that scientists lack the proper communication skills. For instance, a researcher [P3] argued that "the real problem is that we [scientists] lecture the public." Or as a scientist [P8] put it, "science has done a terrible job in developing good communication skills." Others also added that there are not too many opportunities for the scientific community to interact with the public. For instance, a researcher [P4] argued that "it is very hard to meet the public because you have to spend a lot of time in your lab." Although science is part of the social system, scientists often feel that they do not have enough time to talk about their work, especially when it comes to the ethical and social aspects of their profession. A scientist working within the field of robotics and nanotechnology [P10] noted that:

> Scientists have a responsibility in what they create. We share this responsibility with the society. How science is used should be shared, but we don't do a good job in this. It is really hard to do it well. We talk to people about the science we do, but there are not a lot of opportunities for input.

In fact, ethical sensitivity and responsibility may actually help the scientist create a better relationship with the public. As one of our participants [P1] put it, "ethics, safety, privacy—those are important factors for me, they are always in the back of my mind." By emphasizing the strong ethical principles and social nature of science, the scientific community could replace the Victor Frankenstein image with a more positive one. Since the Frankenstein myth creates overreaction and distrust, scientists should focus on values around ethics, responsibility, and honesty and use them as the foundations of a more effective rhetorical tool to reach out to the public. Most of our interviewees (ten out of twelve) agreed that the Frankenstein myth can be considered a useful framework to reflect upon the ethical principles that guide the scientist and create a better image of the scientific community in general. In this sense, "doing" science has a lot in common with "talking" science because they are both governed by similar ethical principles. As a cancer researcher [P6] put it:

> Being a responsible researcher means that you strictly follow the ethical guidelines. These principles and guidelines are well defined within science. When it comes to communicating with the

public, it is also about responsibility, honesty, and ethical standards.

Mitigating the Frankenstein Myth

The Frankenstein narrative is a unique sociocultural artefact that helps people interpret, organize, rationalize, and make sense of sciences, especially those that are engaged in creating and modifying biological or artificial life. This science narrative is deeply embedded in Western culture and influences how laypeople and professionals think of and feel about science. Our participants were quite familiar with the Frankenstein story, and, perhaps due to their high-level skills and competencies, had a quite detailed understanding of it. Therefore, they were able to reflect on the social, cultural, and ethical influence of the Frankenstein myth.

Our interviews suggest that scientists have concerns about the public image of their work as a result of negative science narratives, including the Frankenstein myth. According to our robotics and AI researchers, people often falsely assume that technologies are capable of hijacking and taking control over one's brain or body. Life scientists, on the other hand, may be accused of accidentally infecting people with dangerous substances such as viruses or diseases. The reason why the public has these misconceptions, our interviewees argue, is the lack of up-to-date knowledge on the latest science and technology trends, hampering people's ability to understand how new scientific methods and discoveries exactly work. And that is why the Frankenstein narrative is compelling to people: it helps them understand a wide range of complex or controversial science issues and imagine their potential implications for their lives, often in an unfavourable way. For our participants, this narrative dramatizes the outcomes of dangerous scientific practices—unstable and unnatural artefacts with horrifying consequences. Building on these interpretations, perceptions, and beliefs, our results have two important takeaways for scientists wishing to shape how science is perceived by the public.

First, reflecting on their own understanding of the Frankenstein myth may help scientists find other narratives to show the optimistic aspects of science. In this sense, scientists may use a wide range of science fiction stories to capture attention and imagination. For instance, a recent collection of short stories, *Hieroglyph: Stories and Visions for a Better Future* (2014), offers a plethora of "techno-optimistic" narratives for scientists to illustrate the different ways science can have beneficial effects on society. As editors Ed Finn and Kathryn Cramer noted, "a good science fiction story can share an iconic vision with millions of people. Isaac Asimov's robots, Robert Heinlein's rocket ships, and William Gibson's cyberspace shaped not just real technologies but the whole cultural frame around them" (xxiv-xxv). By capitalizing on imaginative stories, scientists could frame science as a constructive human endeavour, one that can help people solve problems and improve life conditions. Because positive science narratives leverage a good story as well as a technical premise, they are able to portray the messy and unpredictable nature of real-life science in a favourable and exciting way (Vint 2014). More importantly, while science stories often provoke our deepest concerns and anxieties about science, they also remind us that science is always produced by, and in turn shapes, the social world. Similarly, these stories illustrate that science is not a cold, deterministic force which has nothing to do with social or cultural life.

By showing the strong ethical principles and social nature of their work, scientists can replace the simplistic, mythicized Frankenstein narrative with more realistic and positive alternatives. Scientists should use science narratives focusing on values of ethics, responsibility, and honesty to mitigate the potential negative effects of the Frankenstein myth. Through discussion around these narratives, people could move beyond the simplistic terms of the Frankenstein myth and develop a more nuanced and accurate understanding of the capacities and limitations of science (van Dijck 1999). This could help counterbalance misrepresentations which hurt the public image of science and scientists (Evans 2010).

Second, by capitalizing on constructive and optimistic science narratives, scientists can build a better relationship with the public. Previous research highlighted that scientists tend to prioritize defending science against anti-scientific arguments, and consequently, they do not have enough time to build trust and tailor their messages to different audiences (Dudo and Besley 2016). Since scientists invest a lot of effort into defending science, they may not be able to focus on promoting science and developing new and effective approaches for interacting with the public. In this sense, communication scholars have long advocated the idea of using a strategic approach for creating a better

and more likeable public image for science (e.g., Bauer, Allum, and Miller 2007). This particular stream of research argues that people have a dual nature. While they acquire knowledge and create hypotheses about the world, they are also social beings actively seeking approval from their families, friends, and the collectives they belong to, altering how they perceive and react to science and to controversial science issues in particular (Kahan 2015). Both to avoid confusion and to secure their group affiliations, people automatically seek out and evaluate science information based on the values and beliefs surrounding their social and cultural identities (Kahan et al. 2012). In this sense, the Frankenstein myth can be seen as an easily accessible cognitive shorthand or heuristic that allows people to organize and interpret information about science in a way that justifies their suspicion and negative attitudes.

The results from our interviews can address these issues. For scientists, understanding their own perceptions of science narratives, such as the Frankenstein myth, can help them gain insights into common values and beliefs around science. As a sociocultural artefact, *Frankenstein* serves as a lens for identifying popular conceptions (and misconceptions) about science, which in turn may allow scientists to identify counter-narratives that have the potential to mitigate people's negative feelings and perceptions. Using optimistic science narratives that strategically target specific values and beliefs may enable scientists to build trust and create constructive sites for engagement with the public. For instance, previous research suggests that, when it comes to building trust, well-focused arguments should specify what people can expect from scientists, how these expectations can be met, and why it is important to meet these expectations (Resnik 2011). Consequently, scientists should focus on narratives showing ways that scientists and the broader public can cooperate to address important issues (e.g., diseases, injuries, or problems with AI and robotics applications). Science fiction provides an especially fertile ground for public engagement, because it translates abstract concepts about the risks and opportunities created by science into emotional, moral, and relational terms. From *Star Trek* to *Westworld,* popular TV shows offer a range of compelling examples and themes for scientists wishing to capture attention and imagination to turn people's negative reactions into constructive engagement and ultimately to build trust. One of the most important takeaways from our study is that scientists should use the horrific and monstrous narrative of the Frankenstein myth to prepare for public engagement—particularly because it helps them identify how popular culture imagines science—and construct more optimistic narratives to counteract the negative effects of these images.

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