



Modifying the Environment or Human Nature? What is the Right Choice for Space Travel and Mars Colonisation?

Maurizio Balistreri · Steven Umbrello

Received: 31 March 2022 / Accepted: 19 February 2023
© The Author(s) 2023

Abstract As space travel and intentions to colonise other planets are becoming the norm in public debate and scholarship, we must also confront the technical and survival challenges that emerge from these hostile environments. This paper aims to evaluate the various arguments proposed to meet the challenges of human space travel and extraterrestrial planetary colonisation. In particular, two primary solutions have been present in the literature as the most straightforward solutions to the rigours of extraterrestrial survival and flourishing: (1) geoengineering, where the environment is modified to become hospitable to its inhabitants, and (2) human (bio)enhancement where the genetic heritage of humans is modified to make them more resilient to the difficulties they may encounter as well as to permit them to thrive in non-terrestrial environments. Both positions have strong arguments supporting them but also severe philosophical and practical drawbacks when exposed to different circumstances. This paper aims to show that a principled

stance where one position is accepted wholesale necessarily comes at the opportunity cost of the other where the other might be better suited, practically and morally. This paper concludes that case-by-case evaluations of the solutions to space travel and extraterrestrial colonisation are necessary to ensure moral congruency and the survival and flourishing of astronauts now and into the future.

Keywords Space travel · Bioethics · Human enhancement · Terraforming · Geoengineering

Introduction

Many of the challenges concerning space exploration and the potential colonisation of Mars will most probably be connected to the harsh and very different environments we will have to deal with compared to those we are used to on Earth. Many of these challenges can be confronted with the help of technological solutions; others pose a significant, if not impossible, obstacle to overcome for any extraterrestrial settlement mission. Despite questionable or limited feasibility, two primary solutions have been proposed in the last several years to meet these challenges. The first is radically changing the environmental conditions in space. For example, Elon Musk, someone who openly aims to create a settlement on Mars and thinks that in subsequent centuries millions of human beings could inhabit the Red Planet, has argued that

M. Balistreri (✉) · S. Umbrello
Department of Philosophy and Educational Science,
University of Turin, Turin, Italy
e-mail: maurizio.balistreri@unito.it

S. Umbrello
Department of Values, Technology & Innovation, Delft
University of Technology, Delft, Netherlands

S. Umbrello
Center for Advanced Studies, Eurac Research, Bolzano,
Italy

we need to detonate 3000 nuclear bombs per day and for an indefinite period to render the planet habitable [1]. This approach to radically changing the environment is often called geoengineering or terraforming [2, 3]. This approach, however, is not possible at the moment and perhaps even for the coming decades. Others have proposed another vector: that the only solution is to modify human beings (terrestrials) to enhance them in ways that permit them to survive in extraterrestrial environments [4–6]. Extreme genetic adaptations like these, however, are likewise quite futuristic. Here, we do not aim to speak on the current feasibility of these approaches but rather on their philosophical implications in terms of their moral acceptability if/when they are possible.¹ Hence, this paper aims to outline and evaluate, all things being equal, the best solution to invest in from a moral perspective concerning Mars colonisation. In doing so, this paper distinguishes between two positions: (1) geoengineering (terraforming) is morally preferable to that of modifying human beings and (2) that interventions in modifying human beings to make them better capable of surviving space explorations and extraterrestrial settlement are morally preferable. This paper concludes that we do not always have reasons to support one position in all cases exclusively. Instead, all things being equal, one solution (e.g., geoengineering) is not superior to the other (e.g., human modification). To determine which is morally appropriate, the solutions must be evaluated on a case-by-case basis concerning the objectives at hand.

Geoengineering is Morally Preferable to Human Transformation (or Modification)

Those who take a principled stance against any form of human enhancement likewise hold that geoengineering is always preferable to redesigning human

beings. In the recent bioethics debate, this position has been defended by a broad spectrum of thinkers. For example, Habermas argued that (re)designing human beings means reducing them to objects since we are fundamentally evaluating the conformity of the object (or means) to an end. This line of reasoning can also be applied to missions into space or those to Mars. Doing so means we should not consider and calculate the advantages we can obtain from the enhancement, given that any (bio)enhancement project is incompatible with human dignity. According to Habermas, moreover, and confirming the problematic nature of enhancement interventions, any genetic (re)programming project of human beings would represent an unacceptable violation of the principles on which liberal-democratic societies are grounded, as it would not be possible to practice human enhancement within a society that purports symmetrical relations amongst its members.² People who resort to, for example, the (bio)enhancement of their children would be granted the possibility to choose the genetic heritage and, therefore, the life of those children (e.g., [7]). Consequently, those born would feel like puppets in the hands of others, given that they were born with a genetic heritage based on the personal preferences of their progenitors. The result—says Habermas—would bring into question the notion of a pluralistic and democratic society, as the life of some people would directly depend on the choices of others:

In the context of a democratically constituted pluralistic society where every citizen has an equal right to an autonomous conduct of life, practices of enhancing eugenics cannot be ‘normalized’ in a legitimate way, because the selection of desirable dispositions cannot be *a priori* dissociated from the prejudgment of specific life projects ([8], p. 66).

According to Sandel [9], on the other hand, the problem of the (bio)genetic enhancement project is not so much political but rather moral, as any project of redesign (of human beings) would have negative

¹ There is a potential third, more probable and feasible strategy: to fight the consequences of low gravity and other harsh conditions with classical medical and technical interventions and to live permanently in habitats. However, this paper eschews the feasibility claims of the approaches (they could be better categorised as near, medium, and long-term strategies) and instead aims to show that neither option, technically feasible or not, can be dismissed or assumed *a priori* but need to be evaluated on their own case-by-case merits.

² For Habermas, the interventions of genetic modification of embryos are always morally questionable (both for therapeutic purposes and for purposes of strengthening). On the somatic level, however, interventions with therapeutic purposes are acceptable, while those with the sole purpose of enhancing are not.

consequences for the moral character (and sensitivity) of those enhanced people. In other words, we can also go beyond therapeutic uses and use new (bio)technologies to endow future generations with dispositions and abilities that humans do not yet possess. However, the more we enhance human nature, the more we should expect morally corrupt people ([9], p. 86). Imagine an individual who no longer depends on others thanks to their improvements. Consequently, we can see how that person will no longer have humility and thus find it difficult to feel compassion for others. Sandel's conclusions are troubling when applying this reasoning to missions in space and on other planets. Dispositions (or qualities) such as humility and compassion have value in any context. It is evident, however, that the ability to cooperate with other people and, when necessary, to help them will be a very precious virtue on missions in space and the establishment and sustainability of new settlements on Mars, as those undertaking such endeavours will deal with demanding and unpredictable living conditions. It will not be enough to have the ability to survive in different environments beyond Earth; it will also be necessary to have the ability to work and collaborate with other people with ease and, ideally, with pleasure. Furthermore, at least in the beginning, one can imagine that the colonisers will not only have to share very small spaces but will probably have infrequent opportunities to isolate themselves (from each other). If, therefore, Sandel is correct and any human (bio) enhancement project fuels pride and impoverishes our natural disposition to empathise with other people (and feel compassion for them), resulting in the impediment of cooperation, we will undoubtedly be confronted with severe challenges for long-term settlement.

Nonetheless, we can still look with hope to missions in space or other (extraterrestrial) planets. Still, we should put aside the idea of improving or (re)designing human nature and thinking about the changes we can produce in the environment to make it more survivable (or habitable). By doing so, we can continue cultivating that capacity to be open to the unexpected, which, according to Sandel, is another fundamental human virtue that can be jeopardised by the development of those technologies that make it possible to plan the life of those to be born.

According to Fukuyama [10], the (bio)enhancement project would have two other problems: first, an

intervention that radically changes human nature can never be an enhancement, as it does not improve our essential characteristics but produces a new species. Therefore, it would be naive to think that a program of (bio)enhancement or redesign of human nature could be the solution for space travel or, possibly, allow our species to emigrate to other planets in the event of existential risk. The more life conditions on Earth become ever more complex, for example, due to reckless innovation programs or natural disasters, migration to other planets may be our only chance of survival [11–13].³ However, says Fukuyama, enhancement is never a morally acceptable solution, as it would lose (perhaps irreversibly) those essential characteristics that support the “sense of who we are and where we are going, despite all of the evident changes that have taken place in the human condition through the course of history” ([10], p. 101). This means that we could also think about enhancing and then transferring an entire population to another planet, but this would not save the human species from the risk of extinction, as the people who would leave the earth would no longer belong to our species. Furthermore, according to Fukuyama, the enhancement would represent a threat to the survival not only of the human species but also of our culture and our fundamental values, as our moral concepts would be deeply rooted in human nature and would depend on the possibility of referring to characteristics that we share.

People born enhanced could receive essential benefits or advantages; for example, a much longer life or the ability to carry out their work more efficiently. This, according to Fukuyama, is not in question, although the long-term consequences could be less favourable than we currently want or can imagine. For example, in line with the aspirations of any “transhumanist” project or manifesto, we may also achieve longer life. Still, our quality of life may deteriorate

³ We need to keep in mind that these potential reasons for colonisation are not sufficient conditions. However, the reasons mentioned require the precondition that such events or developments would devastate Earth to such an extent that it would become more hostile to life than Mars. This means, however, that if you can colonise a harsh planet like Mars, then one can similarly take similar measures to live on a severely damaged Earth. However, sudden disasters could make such impossible, whereas an extant colony on Mars would avoid having all eggs in one basket.

because a more extended life typically involves more disease and (years of) suffering. The problem is that once we radically change the characteristics of human nature, we also lose our ‘moral sense’ and the natural ability to distinguish good from evil:

It may be the case that, as Nietzsche predicted, we are fated to move beyond this moral sense. But if so, we need to accept the consequences of the abandonment of natural standards for right and wrong forthrightly and recognise, as Nietzsche did, that this may lead us into territory that many of us don’t want to visit. To survey this terra incognita, however, we need to understand modern theories of rights and what role human nature plays in our political order ([10], p. 102).

Finally, according to Kass [14], we would not even need to resort to so many (rational) arguments, as the feeling of ‘repugnance’ that we would feel towards any project of human (bio)enhancement would sufficiently prove its moral unacceptability. After all, we think that moral issues should only be addressed rationally. Still, our feelings have more profound wisdom than any rational argument, so it is not always necessary to rationalise things or look for rational justifications:

In some crucial cases, however, repugnance is the emotional expression of deep wisdom, beyond reason’s power completely to articulate it. Can anyone really give an argument fully adequate to the horror that is father-daughter incest (even with consent), or bestiality, or the mutilation of a corpse, or the eating of human flesh, or the rape or murder of another human being? Would anybody’s failure to give full rational justification for his revulsion at those practices make that revulsion ethically suspect? Not at all. On the contrary, we find suspect those who think they can easily rationalize away our horror, say, by trying to explain the enormity of incest with arguments about the genetic risks of inbreeding ([14], p. 150).

However, the attempt to show the immoral character of any form of enhancement is unsuccessful [15–19]. First, it is not true that enhancement always involves some form of exploitation or that it can only be practised by reducing a person to an object or

product. The interventions of (bio)enhancement could be practised on the genetic patrimony of embryos at the parents’ request or the genetic code of the cells of an adult person. In the first case, we are talking about genetic modification interventions on the germline (because the genetic modification can be performed on the embryo or gametes, which will then be used in fertilisation). In the other case, however, in genetic modification interventions on the somatic line, the modification only concerns the subject involved and cannot be transmitted to future generations [20–24]. A parent could choose to ask for a genetic modification or embryo enhancement intervention only to assure the child that they will have greater access to more abundant opportunities without having the slightest intention (or desire) to plan what their life will turn out to be. Habermas, that is, thinks that a parent can resort to enhancement only because they intend to have a child who can conform to their narcissistic desires and ambitions. For this reason, from his perspective, the enhancement would always be exploitative and incompatible with the principles (or values) of a liberal democratic society. On the other hand, it can be argued that (bio)enhancement does not limit opportunities; on the contrary, it can put people in the condition of being (much) freer to choose their own life, as it would allow them to have a better endowment than what otherwise they would.

In space travel or colonising other planets, describing (bio)enhancement interventions as a form of exploitation would make even less sense, as they would only serve to allow people to survive in hostile environments [25, 26]. It is true that, in this case, the intervention could seem much more ‘therapeutic’ than ameliorative [27]. Still, at least for the astronauts, it would be a form of (bio)enhancement, as they could survive well even without this. More clearly, they would only be enhanced to travel into space and explore other planets, not because of the survival risk of continuing to live on our planet. Furthermore, we have no reason to think that (bio)enhancement interventions can negatively affect the character or sensitivity of the people yet to be born. Sandel [9] is concerned that people with improved (enhanced) skills or dispositions may no longer have any reason to care for or worry about other people’s lives, as they will be self-sufficient (i.e., they will no longer get sick or otherwise live in good health, and perhaps, they will not even get old) and will no longer

need others. Furthermore, Sandel says that once any enhancement intervention can be chosen, it will become more challenging to think that we owe some debt to one's community, as talents will no longer seem the result of chance but something that we can attribute to ourselves. Sandel says that those who are

successful would be even more likely than now to imagine themselves as self-made and self-sufficient, and hence wholly responsible for their success. Those at the bottom of society would be viewed not as disadvantaged, and so worthy of a measure of compensation, but as simply unfit, and so worthy of eugenic repair. The meritocracy, less chastened by chance, would become harder, less forgiving ([9], p. 92).

However, Sandel's mistake is to idealise the enhancement program because it is discussed independently of any implementation problems. No matter what (bio)enhancement intervention we think about, it is unthinkable to give birth to individuals who will not need the assistance and love of other people, as—this can easily be imagined—even people who will be born with enhanced dispositions will fall ill or have problems or accidents like any other person. Furthermore, the fact of being born with (or developing) improved dispositions and abilities is obviously not incompatible with the possibility of developing character traits and moral sensitivity, as it does not compromise the ability to feel the suffering and/or pleasure of other people or to consider what is the right thing to do from a firm and general point of view [28]. On the contrary, as Persson and Savulescu [29] explain, some forms of enhancement could precisely improve human beings' moral abilities—for example, sympathy. We should not worry that the use of human (bio)enhancement interventions reduces our presumed ability to be open to the unexpected and accept life as a gift, as an attitude of openness to the unexpected and a disposition to humility and respect for the mystery of life are profoundly compatible with any ethics of responsibility. Especially in the choices concerning the birth of other people, we should not rely on chance but evaluate the behaviour that promotes the well-being of the people involved. This means acting (behaving) responsibly towards our neighbours. Sandel's concern is that the desire to control our contexts and master the mystery of life may compromise a parent's ability to love their children

unconditionally.⁴ However, one can love one's children unconditionally and still have the desire to protect them from disease (and suffering) and give them a good life. The latter seems directly in line with what is generally accepted to be the mores of good parenthood.

Finally, concerning Fukuyama's concerns, it is not true that any enhancement program would have the necessary (even if perhaps involuntary) result of the end of the human species [30]. First of all, not only could we have different ideas about the alleged essential characteristics of the human species, but the upgrading interventions could modify secondary characteristics and dispositions and instead preserve the essential elements [31–33]. Furthermore, the end of the human species and, following Fukuyama's argument, its replacement by a different living species could be a 'morally' irrelevant question, in the sense that what—from a moral point of view—matters is not the survival of the human species, but rather the well-being of the people who belong to the human species. If, as we are trying to argue, (bio)enhancement interventions have positive consequences and improve the lives of the people concerned, why should we consider them immoral? According to Fukuyama, the risk is that changing human nature will not only replace one species (the human species) with another but also that we lose our values and ideals. However, this seems more like a bias than a minimally justified conclusion or position. There seem to be no reasons why enhanced people cannot claim (or attribute) the same dignity or rights that we rightly claim today.

On the contrary, one can also think that empowered humans—possibly even morally (for example, more capable of empathising with other people or simply more rational)—could be much more sensitive to questions of justice [29, 34–38]. Furthermore, belonging to the human species is not a necessary (in the case of embryos) condition for dignity. We can attribute dignity not only to non-human animals but also to enhanced human beings. Finally, we can

⁴ Sandel's argument does contain further nuance that merits presenting. He does not rule out that unconditional love is still possible; it is only made more difficult. The crux of Sandel's argument is that there is no principled difference between genetic readjustment and other exaggerated forms of readjustment.

agree with Kass that feelings also matter in morality, but this does not mean that we cannot distinguish between more or less justified feelings. That is, we should retain the ability to critically confront the emotions we feel in order to accept or recognise the authority only of those feelings that seem justifiable. A feeling of repugnance towards (bio)enhancement does not seem justified.

The Transformation (or Modification) of Human Beings is Morally Preferable to Geoen지니어ing

So far, we have shown that environmental interventions are not always morally preferable to modifying human nature, as the improvement (or bioenhancement) of human beings is morally acceptable, that is, practising interventions of this type does not seem morally wrong.

In this second part of our article, we will explore whether—concerning travel and missions in space and the colonisation of other planets—the transformation of human beings, in addition to being morally acceptable, can also be morally preferable to that of geoen지니어ing. First, we intend to present a list of the most significant reasons or arguments that could be advanced in favour of the preferability of interventions on human beings (that is, in favour of the moral preferability of human interventions over environmental engineering). Then, in the next section, we will explore whether these reasons are sufficiently convincing and should guide our policies (or choices) regarding space travel.

Travelling in space and to other planets will test any crew. We will have to deal with very different scenarios and environments than those we are used to on Earth; even surviving for an extended period within these contexts could be impossible [39]. To face these journeys, therefore, we have no other choice: either we modify the environment to make it compatible with human life or alter human beings to adapt them to conditions that would otherwise be incompatible with even mere survival. The first reason for preferring the redesign of human beings to the redesign (and modification) of an extraterrestrial environment can be found in those positions in the environmental ethics debate that emphasise the moral value of any form of life [40]. In the environmental ethics debate, we can distinguish between positions that attribute

moral relevance to individual living organisms and positions that instead hold that even superorganic entities—such as species, ecosystems, and planets—deserve full moral relevance [41–49].

Apart from these differences regarding the entities that deserve full moral relevance, these positions broadly converge on the idea that we should go beyond the anthropocentric paradigm and recognise moral value applied even to ‘non-human’ entities and forms of life [50]. It seems correct to assume, therefore, that according to these perspectives, space missions should give priority to interventions on human beings over interventions in the environment, as in this way, there is no risk of damaging or endangering the survival of other living beings, who, for the sole reason of being alive, deserve our respect and moral attention [51]. It is true that even positions—such as biocentrism, earth ethics, and holism—strongly question the anthropocentric paradigm and hope for it to be overcome do not affirm that we should always avoid causing damage to other living forms. On the contrary, they argue that the right to use or destroy other life forms only applies when we cannot survive or achieve a certain level of well-being. For example, it is not only permitted to kill a lethal virus but also to destroy a forest or natural area because otherwise, we would not have space and material to build libraries, schools, universities, and infrastructures that favour mobility and economic exchange.

The important thing is that any development policy tries to fit

human construction and ‘developments’ into natural surroundings in a way that preserves the ecological integrity of a region as a whole. Office buildings and stores, factories and warehouses, hotels and motels, houses and apartment complexes, airports and highways, schools and libraries, bridges and tunnels, and other large-scale human artefacts are designed and located with a view to avoiding serious ecological disturbances and environmental degradation. Natural areas in the region that are essential for ecological stability are left unmodified. Thus certain habitats used by wild species populations are not destroyed, and some wildlife is given a chance to survive alongside the works of human culture ([42], p. 299).

However, we are considering a scenario in which it is possible to face the difficulties associated with space travel and living on other planets through two equally effective solutions: (1) we can choose to modify humans or (2) the environment; the result would be the same.

Therefore, there is no situation of necessity to which we can appeal (or refer to) to justify the need to carry out essential modification interventions on the environment. Of course, survival is always at stake, but the problem can be faced and therefore solved without the need to damage the environment, but “simply” by modifying human beings. To be clear, we do not mean to say that when considering the colonisation of other planets, we will not have to consider the need and importance of carrying out essential interventions on the environment to create the conditions for making the planet fully habitable (and self-sufficient). The fact, however, that practising specific geoengineering interventions may be necessary does not mean, or permits us to conclude, that then we can carry out any environmental engineering projects or, in any case, this is only the point of view that a strongly anti-anthropocentric position (which extends full moral relevance to non-human entities as well) could consistently argue [51, 52].

However, it can be argued that interventions on human beings should have priority over interventions on the environment without the need to take an “anti-anthropocentric” position and affirm that any living organism (or superorganism) deserves moral relevance. For example, it could be argued that it is better to modify (or enhance) human beings because, in this way, we can preserve the beauty—even natural—of the ecosystems we explore [53, 54]. This argument can obtain independent of the moral relevance that can be recognised or attributed to them. For example, Robert Sparrow states that starting from an agent-based virtue ethics, it is possible to conclude that “terraforming reveals in us two serious defects of character. First, it demonstrates that we suffer from ethically significant aesthetic insensitivity. We would become cosmic vandals. Second, it involves us in the sin of hubris. We show ourselves to be suffering from an excessive pride which blinds us to our own place in the world” ([55], pp. 232–233).

On the other hand, any genetic modification of human beings engaged in space missions would

not destroy the aesthetic value of human beings (of human biology), as an unenhanced population would continue to live on Earth. On the other hand, the radical transformation of a planet (one in which we aim to live) would forever deprive humanity of the beauty (or aesthetic value) of that particular natural ecosystem and landscape. Other planets that are aesthetically similar to those we aim to transform may also exist in the universe, but their history and geological uniqueness will probably be unrepeatably. Add to this that any modification (genetic improvement) of human beings would confer even more significant beauty and aesthetic value to the planet, allowing these new colonisers to appreciate its characteristics even more. Some believe that aesthetic value is subjective (and therefore, it simply depends on the viewer’s reaction towards the object they observe). Others, however, believe that aesthetic value is “intrinsic” to the object and, consequently, independent of the spectator and their ability to experience pleasure in its presence. If the aesthetic value were intrinsic to the object, any enhancement of the sensitivity of human beings could not contribute to increasing the aesthetic value of the planet. However, it could encourage human beings to continue to preserve or exacerbate it, given that they would have less difficulty recognising its beauty at any moment. In any case, affirming that the natural beauty of planets can be a moral reason for preferring the modification of human beings to the modification of the environment does not mean establishing that beauty (or aesthetic value) must always be preserved. A position of this type would be difficult to accept because it is somewhat counterintuitive: it is easy to imagine situations in which destroying something beautiful can be a necessary act to have the possibility of satisfying the basic needs of a large number of people. In our case, however, preserving natural ecosystems seems like a ‘luxury’ that we can afford since the same results can be had by intervening on human beings.

Still, even if they produce the same results and permit the survival of extraterrestrial missions, the modification of human beings could still seem preferable to interventions on the environment based on reasons concerning the appropriate use of resources. For example, human modification interventions may have lower costs than any other program or long-term benefits for galaxy exploration or planetary colonisation and settlement construction that

other programs do not have. Additionally, a human-enhanced space program could contribute more to the success of any space mission, as it could encourage people to participate in space missions and even engage in colonising new planets or star systems. Although some changes (such as greater resistance to disease, a longer life and orientation skills) will be much more therapeutic than ameliorative, in the sense that they will allow people to survive in very unwelcoming environments, others will improve and enable people to experience conditions and have advantages they otherwise would not have. It is not unreasonable to posit that a large number of people may believe that these advantages can amply compensate for the risks and difficulties that can be connected, especially at the beginning, to space travel. The possibility of passing on these enhancements to their children could make the idea of space travel or a period of work on another planet even more attractive. Lastly, we should also consider the fact that, whatever we choose to do to make a planet or colony (more) liveable, bioenhancement may still be inevitable, as people may still decide to genetically enhance their children to bestow them with new abilities and resiliencies to allow them to act better within their environment. This will have costs that will add to geoengineering interventions (i.e., first, there will be the costs of transforming the environment and then those of enhancements). Therefore, it is more reasonable to immediately opt for the space program based on (bio)enhancement. By doing so, the results will be the same, but the costs will be lower, as we will not need to consume resources to redesign extraterrestrial environments. For what reason, moreover, should we give up practising an enhancement program (or redesign of human beings) that could have immediate benefits for any program of space exploration or study and colonisation of other planets in the universe? The only reason for preferring interventions in the environment (to those on human beings) can be the desire to preserve human nature's biological (or genetic) integrity. However, we have already seen extensively that this is not an argument we can accept.

Finally, for missions in space and the exploration of new planets, human enhancement interventions could be 'morally' preferable to interventions on the environment. Why? It is because using these interventions for missions in space could encourage

greater moral acceptability of human enhancement interventions on people living on Earth. Even if enhancement interventions do not confer more significant advantages to people participating in space missions or the colonisation of the planets than interventions on the environment, they could have, however, better consequences for the people living on Earth, given that they can reduce their difficulty in accepting enhancement interventions. This would be an advantage because we have seen that human enhancement can be both good and desirable despite the objections we considered earlier. Of course, we cannot establish a priori whether the enhancement of astronauts will make the intervention morally more acceptable on Earth; this is an empirical question that we can only verify a posteriori after we have put such an enhancement into practice.

However, some reflections are possible and allow us to frame the question better. First of all, it cannot be said that (bio)enhancement interventions for space missions cannot represent a model of interventions that can be appropriated for our own planet, given that people living on Earth would not need upgrades to survive. It is not true that (bio)enhancement interventions are morally justifiable only in situations where people could not otherwise survive. Suppose (bio)enhancement interventions are safe and can improve people's quality of life. In that case, we have an important reason for practising them, even if they are not undertaken for the purposes of mere survival. Furthermore, we cannot exclude that even on Earth, situations may arise in the future that put our survival at risk, and that Make (bio)enhancements necessary (which would de facto make some (bio)enhancement interventions essential for our survival). For example, Persson and Savulescu [29] argue that without some form of moral (bio)enhancement, we may not be able to worry too much about environmental problems, depriving future generations of the possibility of still having a life worth living.

According to them, moral (bio-)enhancement could therefore be the only solution to avoid or at least limit the risk of terrorists or psychopaths using their cognitive abilities to cause deadly harm to the whole of humanity. Furthermore, we cannot agree with those who argue that (bio)enhancement interventions practised in space would be more natural than those we could practice on Earth [27], as an action does not

change its nature only because it is practised in a different space. Even if the enhancements on earth were unnatural, this would not represent a problem, as it is an established point of philosophical reflection that what is (or appears) natural cannot be a point of reference for our moral reasoning. Not only what is unnatural can be 'good' and morally approachable, but something can be natural (think, for example, of death) and, at the same time, be bad. Secondly, we may have reason to believe that practising (bio) enhancement interventions on human crews leaving for space missions and journeys to Mars could make it easier to accept these (same) interventions on people living on Earth. David Hume argued that we could not evaluate new things correctly, as novelty arouses a "natural" wonder that confuses the mind and judgement [56]. We think that these considerations can also be applied to the case of (bio)enhancement and that some of our difficulties in considering human (bio) enhancement morally acceptable depend solely on the fact that we are not yet used to this intervention. For this reason, space missions could help us change our perspective and enable us, for the first time, to use these biotechnologies and experience what it means to be an enhanced person.

First, before becoming a routine intervention for people participating in space missions, enhancement interventions will probably be practised on people suffering from diseases that are not curable by traditional means [5]. If, then, the people who leave for space missions must be first (bio)enhanced, over time, the chances of meeting them, both before and after their journey, will increase. While we may prevent them from returning, it would not be fair to deprive people who grew up on Earth and have spent a long time in space from moving freely. Also, if they stay on Earth and start a family (even with non-enhanced people), their children could inherit at least some of their genetic modifications and (enhancements). In this way, our concern for human (bio) enhancement interventions could gradually fade away through the knowledge of enhanced people. After a certain period of time, we may not only perceive people with enhanced abilities as something natural or as a simple variation in human biology, but we may also have the desire to ensure these same characteristics for our children.

Considerations of the Arguments According to Which Human (Bio)Enhancement is Morally Preferable to Geoen지니어ing

Above, we presented a series of considerations to show the weakness of the arguments that defend a principled position against any human (bio)enhancement intervention. What we aim to do now is to consider the positions that instead affirm that human (bio)enhancement interventions can be morally preferable to environmental interventions. First, we will start with the justifications that can be presented from an anti-anthropocentric perspective, and then we will move on to analyse and discuss the other positions we have already encountered.

The anti-anthropocentric positions present important reasons for allowing humans to survive in extra-terrestrial environments without the need to transform the environment and by practising modification interventions exclusively on humans. The problem is that these conceptions (i.e., biocentrism, earth ethics, and holism) extend relevance beyond boundaries that seem morally acceptable and compatible with human survival. From a moral standpoint, it does not seem wrong to acknowledge full moral relevance or some form of moral relevance to non-human animals, as non-human animals are sentient beings whose well-being can be affected by what we do. However, with plant-based life or superorganisms such as ecosystems, species, or the planet, things are different, as whatever we do, we cannot cause them any harm or suffering. According to the supporters of anti-anthropocentric positions, what we do towards plant organisms or superorganisms would still have moral relevance as they would have a condition of well-being that would coincide with the natural capacity for development. In these terms, we deserve moral approval or disapproval, depending on whether our actions favour or hinder (or prevent) their (spontaneous) growth. Apart from the fact that in the case of some organisms or superorganisms, it could be challenging to ascertain which is their most natural or ('spontaneous') development (or growth) condition. For example, considering our planet, what is its condition of 'natural' development? Would a planet not inhabited by living organisms be less natural than the current condition in which a wide variety of living

beings inhabit it? It does not make sense to attribute any condition of well-being to organisms (or superorganisms) that do not have the slightest ability to perceive the surrounding world and their condition. Suppose we attribute a condition of well-being to a non-sentient organism or superorganism. In that case, we could also attribute a condition of well-being to any car and identify it with the ability to function at its best in relation to its potential. Even if, however, we could attribute to plant organisms or superorganisms a condition of well-being and identify it with the ability to develop in their own environment, it is questionable that this condition of well-being could have any relevance for us, as we cannot (or it would at least be difficult) to empathise with a vegetable or an ecosystem.

Finally, any moral perspective that defends the importance (or the need) of extending moral relevance to non-sentient beings (individuals and superorganisms) is asking too much, as we cannot live or survive without using or destroying other living beings. According to supporters of anti-anthropocentric ethics, there would be no contradiction in affirming the full relevance of ('natural') plant organisms or superorganisms and simultaneously recognising that in conditions of necessity, we have the right to 'destroy' them. However, the appeal to necessity conditions does not make the theory more morally acceptable. If we had, in fact, the right to use or destroy other (non-sentient) living beings only in cases of necessity (when, in other words, our survival is at stake), we could also survive, but we could not have a good life. Why? An example of such a life would be where we should live in caves and have a diet reduced to what is strictly necessary, hardly a 'good' life. This problem cannot be solved with a broader definition of 'conditions of necessity', as doing so risks slipping into an extreme form of anthropocentrism. Suppose by conditions of necessity, we mean any situation in which our well-being or quality of life is at stake (consequently, even beyond mere survival). In that case, there is no longer any limit to what we can do to living organisms or superorganisms, given that we can always appeal to a situation or condition of necessity. If our travels into space and exploration of other planets were to be marked by the need to protect and respect any "living form", our possibilities of intervening in the surrounding environment and transforming it would be considerably reduced. In addition to having

the duty to respect any living organism (or superorganism), we should act with caution and be aware that in an extraterrestrial environment, we may have difficulty or not be able to recognise the presence of other living forms immediately. In this way, the very value of these explorations would be called into question, as any of our intervention or interference could seem morally questionable.

A position that defends the not moral but aesthetic value of nature might seem more acceptable, as there is a very long tradition of thought that draws attention to the need to preserve our relationship with uncontaminated and spontaneous nature. However, it is legitimate to ask why we should think that the natural is (or must always be) superior to what is artificial and the result of human creativity and resourcefulness. Furthermore, on Earth, nature in its pristine state and not contaminated by human interventions that reduce biological variety (i.e., wild nature or *wilderness*) can arouse unique emotions, but the 'natural' landscape of other planets could be more monotonous and much less charming. It is legitimate to ask, then, whether the landscape of Mars we observe is genuinely natural. According to posthumanists, the Anthropocene would show that nature is already an artificial product because, through our actions, we can influence—even indirectly, for example, through actions that produce warming and climate change—any living thing. It is unthinkable that our behaviours could affect the 'life' of the planet Mars: however, the condition of Mars could be the product of uncontrollable geological and astronomical phenomena that, over time, have transformed the original condition of the planet.

In recent years, transhumanists have affirmed that the "human" should be overcome. Only through hybridisation with technology will we be able to get out of an innate condition of vulnerability and reach an "evolutionary stage" that allows for a better condition of well-being. One might think that overcoming the natural condition is desirable not only for humans but for all living beings (i.e., non-humans, including nature/environment). According to posthumanists, nature, at least on Earth, is already an artificial product. Through our actions, we indirectly influence any living thing (e.g., through activities that produce global warming and climate change).

Furthermore, it is difficult to think that the colonisation of Mars can take place simply by changing human nature and, therefore, without making

radical changes to the planet. Even if we would initially choose to privilege interventions on human nature (and on the first astronauts and the first group of colonisers) over interventions on the environment, we could later be forced to practice increasingly radical interventions on the environment. With a small settlement, there is no need to completely transform the environment. However, if we want Mars to be inhabited by an ever-increasing human population, more homes, hospitals, schools, universities, infrastructures, and sports centres, then such geoengineering efforts will be needed. The change could take place more slowly than the change that could be implemented with a 'space colonisation' program that aims at the transformation of the environment (terraforming), but in the end, however, it would be no less radical. Add to this that any transformation of the 'natural' condition of the planet would not result in a significant reduction in the natural beauty of the world, as the number of planets not touched by humans in the universe would be immense.

It is also true that the economic costs of genetic modification (or enhancement) interventions for astronauts could be much lower than those for the transformation of the environment, but other considerations could tip the balance in favour of environmental interventions. One might think, for example, that, despite the costs, it is still preferable to intervene in the environment because, in this way, the danger that, over time, a different 'human species' will form on Mars than that which continues to live on Earth can be avoided. The fact that human beings who will live on the Red Planet tomorrow can become a new human species compared to the one that continues to live on Earth is not in itself morally relevant; however, the more 'human' species become different, the more the risk increases that they will not be able to mutually understand each other. Of course, in nature, the process of the formation of new species occurs very gradually. If, however, one opts to change human nature through genetic modification, the process of speciation could be much faster (and perhaps even uncontrollable). In this case, we should also consider that genetically modified people could have difficulty leaving Mars or returning to Earth, as they would now have very different genetic characteristics compared to those who departed originally. In other words, as Norman and Reiss argue, we should consider that we may have a responsibility, perhaps even a moral

obligation, to ensure that our species does not divide into different human species:

Perhaps the most significant challenge raised by a long-term mission to Mars is the challenge to remain a unified species. This in itself addresses the problems of allegiance to Earth, raised in the context of conservation of our home planet, and presumes that, even if we are able to engineer our genes to make life on Mars and deep space travel possible, we have a responsibility, even a moral obligation, to ensure that we remain one species. ([57], p. 161).

Furthermore, it is true that the costs of a radical transformation of a planet would be much higher than those of any genome editing intervention on the crew of a space mission. However, such costs could be amply compensated by the possibility of developing a technique for modifying the planet's environment that we could then easily use for the colonisation of other planets.

Finally, to convince people that enhancement interventions are morally acceptable, perhaps there is no need to send genetically engineered astronauts to another planet. We could promote greater discussion of ethical and bioethical issues in schools, or we could provide training programs that foster greater confidence in scientific practices and new procedures made possible by scientific and technological development. It is also possible that genome editing interventions on the germline practised for therapeutic purposes can encourage or make more acceptable the use of enhancement interventions. Furthermore, linking enhancement programs to space missions could somehow encourage the idea that human (bio) enhancement interventions are still something exceptional and that they are not morally acceptable under more normal or ordinary conditions.

Conclusion

This paper aimed to evaluate the various arguments proposed as solutions to meeting the challenges of human space travel and extraterrestrial planetary colonisation. In particular, two primary solutions have been present in the literature as the most straightforward solutions to the rigours of extraterrestrial

survival and flourishing: (1) geoengineering, where the environment is modified to become hospitable to its inhabitants, and (2) human (bio)enhancement where the genetic heritage of humans is modified to make them more resilient to the difficulties they may encounter as well as to permit them to thrive in non-terrestrial environments. Both positions were shown to have strong arguments supporting them, but they also had some severe philosophical and practical drawbacks when exposed to different circumstances. This paper aimed to show that a principled stance where one position is accepted wholesale necessarily comes at the opportunity cost of the other where the other might be better suited, both practically and morally. In sum, case-by-case evaluations of the solutions to space travel and extraterrestrial colonisation are necessary to ensure moral congruency and the survival and flourishing of astronauts now and into the future.

Funding Open access funding provided by Università degli Studi di Torino within the CRUI-CARE Agreement.

Declarations

Ethical approval N/A

Informed consent N/A

Competing interests The authors declare no competing interests.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Walker R (2019) Nukes can never terraform Mars - a million 100 megaton nukes can't do it - Elon Musk's Sci. Fi Teeshirts. Science 2.0. Retrieved 30 March 2022, from https://www.science20.com/robert_walker/nukes_can_never_terraform_mars_a_million_100_megaton_nukes_cant_do_it_elon_musks_sci_fi_teeshirts-240782
- McKay CP (1982) On terraforming Mars. *Extrapolation* 23(4):309
- McKay CP (2009) Planetary ecosynthesis on Mars: restoration ecology and environmental ethics. In: Bertka CM (ed) *Exploring the origin, extent, and future of life: philosophical, ethical and theological perspectives*, Cambridge astrobiology. Cambridge University Press, Cambridge, pp 245–260
- Szocik K, Braddock M (2019) Why human enhancement is necessary for successful human deepspace missions. *New Bioeth* 25(4):295–317
- Szocik K, Shelhamer M, Braddock M, Cucinotta FA, Impey C, Worden P, Peters T et al (2021) Future space missions and human enhancement: medical and ethical challenges. *Futures* 133:102819. <https://doi.org/10.1016/j.futures.2021.102819>
- Szocik K, Tachibana K (2019) Research viewpoint: Human enhancement and artificial intelligence for space missions. *Astropolitics* 17(3):208–219
- Balistreri M, Umbrello S (2022) Should the colonisation of space be based on reproduction? Critical considerations on the choice of having a child in space. *J Responsible Technol* 11:100040. <https://doi.org/10.1016/j.jrt.2022.100040>
- Habermas J (2003) *The future of human nature*. Polity Press, Cambridge
- Sandel M (2007) *The case against perfection. Ethics in the age of genetic engineering*. Harvard University Press, Cambridge, MA
- Fukuyama F (2002) *Our posthuman future. Consequences of the biotechnology revolution*. Farrar, Straus and Giroux, New York
- Cooper GF (2017) Stephen Hawking: Earth could be 'ball of fire' in 600 year. <https://www.cnet.com/news/steph-enhawking-earth-ball-of-fire-600-yearstencent-we-summit-beijing/>
- Szocik K, Norman Z, Reiss MJ (2020) Ethical challenges in human space missions: A space refuge, scientific value, and human gene editing for space. *Science and Engineering Ethics*. pp 1209–1227
- Szocik K (2021) Humanity should colonize space in order to survive but not with embryo space colonization. *Int J Astrobiol* 20(4):319–322. <https://doi.org/10.1017/S1473550421000148>
- Kass L (2002) *Life, liberty and the defense of dignity*. Encounter Books, San Francisco
- Buchanan A (2011) *Beyond humanity? The ethics of biomedical enhancement*. Oxford University Press, Oxford
- Buchanan A (2017) *Better than human: The promise and perils of biomedical*. Oxford University Press, Oxford
- Harris J (2010) *Enhancing evolution: The ethical case for making better people*. Princeton University Press, Princeton
- Savulescu J, Bostron N (2009) *Human enhancement*. Oxford University Press, Oxford
- Sorgner SL (2021) *We have always been cyborgs: Digital data, gene technologies, and an ethics of transhumanism*. Bristol University Press, Bristol, UK

20. Baylis F (2019) *Altered inheritance. CRISPR and the Ethics of Human Genome Editing*. Harvard University Press, Cambridge, MA
21. Davies K (2021) *Editing humanity. The CRISPR revolution and the new era of genome editing*. Pegasus Books, Berkeley
22. Musunuru K (2019) *The CRISPR generation. The story of the world's first gene-edited babies*. Bookbaby, Pennsauken
23. Musunuru K (2021) *Genome editing: A practical guide to research and clinical applications*. Academic Press, Cambridge, MA
24. Greely H (2021) *CRISPR people. The science and ethics of editing humans*. MIT Press, Cambridge
25. Szocik K (ed) (2020) *Human enhancements for space missions*. Springer, Cham, Switzerland
26. Szocik K (2020) Is human enhancement in space a moral duty? *Missions to Mars, advanced AI and genome editing in space*. *Camb Q Healthc Ethics* 29(1):122–130
27. Garasic M (2021) The war of ethical worlds: Why an acceptance of post-humanism on Mars does not imply a follow-up on Earth. *Medicina e Morale* 70(3):317–327. <https://doi.org/10.4081/mem.2021.944>
28. Balistreri M, Umbrello S (2022) Space travel does not constitute a condition of moral exceptionality. That which obtains in space obtains also on Earth! *Medicina E Morale* 71(3):311–321. <https://doi.org/10.4081/mem.2022.1213>
29. Persson I, Savulescu J (2012) Unfit for the future. *The need of moral enhancement*. Oxford University Press, Oxford
30. Abood S (2020) Crossing the posthuman Rubicon: When do enhancements change our definition of human? In: Szocik K (ed) *Human enhancements for space missions*. Springer, Cham. <https://doi.org/10.1007/978-3-030-42036-9>
31. Agar N (2004) *Liberal eugenics*. Blackwell, Oxford, UK
32. Agar N (2010) *Humanity's end*. MIT Press, Cambridge, MA
33. Glover J (2006) *Choosing children. Genes, disability, and design*. Oxford University Press, Oxford
34. Danaher J (2018) Moral enhancement and moral freedom: A critique of the little Alex problem. *R Inst Philos Suppl* 83:233–250. <https://doi.org/10.1017/S1358246118000371>
35. DeGrazia D (2014) Moral enhancement, freedom, and what we (should) value in moral behaviour. *J Med Ethics* 40(6):361–368
36. Douglas T (2008) Moral enhancement. *J Appl Philos* 25(3):228–245. <https://doi.org/10.1111/j.1468-5930.2008.00412.x>
37. Rakic V (2021) *How to enhance morality*. Springer, Springer, Cham, Switzerland
38. Rakic V (2021) *The ultimate enhancement of morality*. Springer, Cham, Switzerland
39. Umbrello S, Balistreri M (2023) Human enhancement and reproductive ethics on generation ships. *Argumenta*
40. Dworkin R (1994) *Life's dominion: An argument about abortion, euthanasia, and individual freedom*. Vintage, New York
41. Taylor P (1981) The ethics of respect for nature. *Environmental Ethics* 3:197–218
42. Taylor P (2011) *Respect for nature*. Princeton University Press, Princeton
43. Rolston III H (1975) Is there an ecological ethic? *Ethics* 85:93–109. <https://doi.org/10.1086/291944>
44. Rolston III H (1988) *Environmental ethics: Duties to and values in the natural world*. Temple University Press, Indiana
45. Rolston III H (1989) *Philosophy gone wild*. Prometheus Books, New York City: NY
46. Callicott JB (1989) *In defense of the land ethic: Essays in environmental philosophy*. SUNY Press, Albany, NY
47. Callicott JB (1999) *Beyond the land ethic: more essays in environmental philosophy*. SUNY Press, Albany
48. Callicott JB (2013) *Thinking like a planet: The land ethic and earth ethic*. Oxford University Press, Oxford
49. Stone CD (1972) Should trees have standing? *Southern California Law Review* 45:450–501
50. Agar N (2001) *Life's intrinsic value*. Columbia University Press, New York
51. Di Paola M, Garasic MD (2023) *Philosophy and Mars colonization*. Routledge, Milton Park (under contract)
52. Schwartz JSJ, Milligan T (eds) (2016) *The ethics of space exploration*. Springer, Cham
53. McMahon S (2016) The aesthetic objection to terraforming Mars. In: Schwartz J, Milligan T (eds) *The ethics of space exploration. Space and society*. Springer, Cham. https://doi.org/10.1007/978-3-319-39827-3_15
54. Rolston III H (1986) The preservation of natural value in the solar system. In: Hargrove EC (ed) *Beyond spaceship earth: Environmental ethics and the solar system*. Sierra Club Books, San Francisco, pp 140–182
55. Sparrow R (1999) The ethics of terraforming. *Environmental Ethics* 21:227–245. <https://doi.org/10.5840/enviroethics199921315>
56. Hume D (2000) *A treatise of human nature* (ed. by David F. Notyion and Mary J. Norton). Oxford University Press, Oxford
57. Norman Z, Reiss MJ (2020) Two planets, one species: Does a mission to mars alter the balance in favour of human enhancement? In: Szocik K (ed) *Human enhancements for space missions*. Springer, Cham, p 151–167

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.