Technology in Society 74 (2023) 102278

Contents lists available at ScienceDirect

Technology in Society

journal homepage: www.elsevier.com/locate/techsoc

Moral adherence enhancement and the case of long-distance space missions

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A R T I C L E I N F O

Keywords:
Cognitive enhancement
Moral enhancement
Long-distance space missions
Human spaceflight
Space ethics
Bioethics

A B S T R A C T

The possibility of employing human enhancement interventions to aid in future space missions has been gaining attention lately. These possibilities have included one of the more controversial kinds of enhancements: biomedical moral enhancement. However, the discussion has thus far remained on a rather abstract level. In this paper we further this conversation by looking more closely at what type of interventions with what sort of effects we should expect when we are talking about biomedical moral enhancements. We suggest that a more grounded way to picture moral enhancement, at least in the near term, is to envision a form of cognitive enhancement that also provides some moral benefits by heightening the enhanced person's capability for acting according to their own subjective moral code. While this concept of moral adherence enhancement also has relevance for the moral enhancement discussion more widely, in this paper we apply it specifically in the context of space missions. We argue that there are weighty reasons to consider making biomedical enhancements of the proposed kind a mandatory feature of early-phase long-distance space travel because these missions are high-stakes in nature and take place in an environment where the enhancement could be seen as conferring important advantages while negating many of the traditional arguments weighed against it.

1. Introduction

In recent years, the futuristic-sounding concepts of biomedical enhancement and deep space missions have been discussed together in increasing frequency. Much of this is thanks to the efforts of Konrad Szocik, who has entertained various ideas on how and what kind of enhancements could be utilised to aid in coming space ventures [1–5]. These ideas include recommending one of the more controversial kinds of enhancement interventions often proposed – biomedical moral enhancement – at least in limited circumstances [,1,5,6]. Unfortunately, Szocik is rather silent on the nature of these proposed enhancements, leaving it an open question whether they would still be recommendable if we had a more detailed picture of them. We wish to further this conversation by taking a more in-depth look at what type of interventions with what sort of effects we should envision when we are talking about biomedical moral enhancements and to use this analysis to re-investigate should such enhancement interventions be applied in the context of human space missions.

We feel that this is a step that needs to be taken since while the end goal of biomedical moral enhancement – making humans more moral – is obviously laudable, often the feasibility of this goal is too easily supposed from the fact that moral reasoning seems to be at least somewhat responsive to biological factors.[1] Thus, setting realistic expectations on what kind of biomedical moral enhancement outcomes we could reasonably expect is imperative before applying them to specific cases, such as human activity in space. If the proposed enhancement interventions remain vague, we run the risk of not being able to effectively gauge the potential benefits and permissibility of biomedical moral enhancement, rendering the whole discussion indeterminate.[2]

This paper proceeds as follows. We will first provide a very brief overview of human enhancement in general, followed by a more in-depth look at biomedical moral enhancement and our view of what it could be in practice. We argue that moral enhancement interventions that would actually provide humans with better morals or motivations are, for the time being, hopelessly out of our reach, and end up recommending a more grounded conceptualisation on what could be done in the near-term to increase the capability for moral action. To this end, we end up recommending a type of enhancement we call *moral*

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[1] For an example of this responsiveness, the neurotransmitter serotonin has been suggested to alter human behavioural responses to unfairness [55].
[2] A similar need for a more focused debate and realism in the moral bioenhancement discussion has been argued at least by Ref. [56].

https://doi.org/10.1016/j.techsoc.2023.102278
Received 17 March 2023; Received in revised form 24 May 2023; Accepted 26 May 2023
Available online 29 May 2023

adherence enhancement, which is a type of cognitive enhancement that also offers moral benefits by heightening the enhanced person's capability of acting according to their own subjective moral code. Afterwards, we will proceed to analyse biomedical moral adherence enhancement in the context of space missions and lay out our case for considering making enhancements of the proposed kind a mandatory feature of long-distance space travel. Finally, we conclude by considering some possible objections.

2. Human enhancement

Human enhancement is the most widely used term for the still largely hypothetical project of heightening the existing capabilities of humans in one way or another.[3] Proposed enhancement interventions are many and varied, but some of the more commonly suggested are *neuroenhancements* such as enhancements to memory and concentration. One common way to define neuroenhancement is to say it means the use of interventions to modify brain processes in a way that heightens human capabilities in some way (memory, attention, mood, and so on) when no illness or other disorder is present [7]. We take cognitive enhancement, a category which will be important for this paper, to be interchangeable with neuroenhancement, as do many other authors (e.g., [8,9]).

Much like interplanetary travel, human enhancement might still sound like something out of science fiction in the year 2023. However, the first steps toward these technologies have already been taken. In the last twenty years, research has shown that concentration, awareness, memory, learning and general cognitive capabilities can all be positively influenced by pharmacological and neurotechnological means (e.g., [10, 11]). There is also a demand for these sorts of interventions: the use of nootropics or "smart drugs" has been on the rise globally [12]. All this is not to say human enhancement is already here. The effectiveness of nootropics is dubious at best, and it is likely that effective and safe enhancement interventions in general remain years in the future. However, these developments help us understand that human enhancement does not need to be a thing of the far future – indeed it could already be in the early testing phase.

In many cases the line between enhancement and therapy is vague [13]. Is drinking coffee or other caffeinated products an enhancement for heightening awareness? How about going to elementary school, does that count as a cognitive enhancer for children? We are bringing up these labelling difficulties as a matter of acknowledgement, but for the scope of this paper, we are not interested in engaging with them. Instead, we are going to be focusing our attention on a specific type of human enhancement, namely those that are biomedical in nature – in other words, mainly pharmacological or neurotechnological interventions.

When it comes to biomedical enhancements, there are still some important distinctions to make. It can be broadly asserted that there are several categories of biomedical enhancement: nonhereditary and hereditary, as well as impermanent and permanent. Nonhereditary biomedical enhancements only affect the person using them, and some forms of these can be envisioned to be impermanent. These could be pictured to be like most standard pharmaceuticals: stop taking the drugs and their effects will expire in time. Hereditary biomedical enhancements, on the other hand, are enhancements that can be passed onto offspring. These are usually envisioned to be genetic modification interventions aimed at affecting the germline, and their effects might be permanent. Out of these, nonhereditary enhancements are less controversial than hereditary enhancements, especially permanent hereditary enhancements. Voluntarily taking enhancement pharmaceuticals to enhance your capabilities permanently or impermanently is an action that is in line with many other things we commonly think autonomous agents have the right to do. Compared to this, deciding to enhance unborn children without their consent is a much more questionable endeavour [14–16].[4] In this paper, we will be considering only nonhereditary enhancement as it is sufficient for the arguments in this paper, and bringing hereditary enhancement to the equation would only serve to muddy the waters.

3. Moral adherence enhancement

Moral enhancement is a subcategory of human enhancement where the proposed enhancements are directed towards heightening human capability for moral action. The case for moral enhancement has perhaps most famously been championed by Ingmar Persson and Julian Savulescu [17,18], who paint a gloomy picture of our collective situation: human psychology, having been developed over tens of thousands of years in small tightly knit communities, is woefully undeveloped to deal with the ethical dilemmas of the global era. Further on, they claim that we are used to making decisions that have a relatively small impact mainly affecting our immediate surroundings, but with the exponential speed of our technological advancement, we suddenly find ourselves in a reality where our seemingly modest actions can have big consequences on the other side of the planet. At the same time, the technological level of our society has developed to the point where a sufficiently determined and resourceful but otherwise quite average evil individual can gain access to means of mass destruction and cause untold harm.[5] These two factors combined lead Persson and Savulescu to argue for the need to radically enhance our capability for moral action, bringing it in line with the needs of our current situation. *Everyone* must be biomedically morally enhanced, and this needs to be brought about as soon as possible since every day we delay brings about more technological advances and thus even greater risks.

Persson's and Savulescu's argument is compelling when it comes to analysing our global predicament in the face of collective action problems. However, it has also been criticised from multiple angles, including, for example, having a questionable historical view on moral progress [19], being self-defeating [20], and from the point of view that making enhancement mandatory for all curtails something that is arguably vital for humanity – freedom [21–23]. It should also be noted that their suggested solution to the *malevolent actor problem* can be critiqued for being overly heavy-handed. By the malevolent actor problem, we mean a scenario where a single individual (or a small group of individuals) with evil intentions can cause serious harm. Morally enhancing every human being on the planet for the sake of preventing terrorists from using weapons of mass destruction is an enormous undertaking with many caveats. The most serious of these is perhaps that we would be hard-pressed to accept that people willing to build or otherwise obtain and then use weapons of mass destruction are acting so primarily because of a defect in their moral reasoning. It seems likely that such an extreme action needs to be fuelled by some deep conviction or an utter disregard for human life, both of which are issues that biomedical moral enhancement is unlikely to ever resolve.

[3] The use of the less normatively charged term *body modification* instead of enhancement has been suggested as an attempt to sidestep the often-voiced issues of (at least most) 'enhancements' only counting as such in a limited number of scenarios [57]. As a simple example, increased muscle mass is only an asset in an environment that values such things and could be a hindrance in another where physical strength is of little use or undesirable.

[4] This conversation in human enhancement discourse resembles another discussion in space ethics concerning autonomy and reproduction. It has been proposed that an individual may well decide for themselves to embark on a long space voyage into the unknown, but that it may be unethical to have children being born during that voyage ([58]; 208–209).

[5] Persson and Savulescu [17]; 47–48) specifically discuss nuclear and biological weapons, citing evidence of attempts by terrorist organisations to acquire such things and pointing out that it is simple for even a single individual to fabricate lethal poisons like sarin gas.

This negative assessment stems from our view (which [18] share) that biomedical moral enhancement should not be taken as drugs that insert new and better moral ideas into human minds. Such technology is, at least for the foreseeable future, in all probability hopelessly beyond our reach. Even if this was not so, it would come with many serious problems pertaining to questions of autonomy and epistemology.[6] Instead, we argue that, at least in the near term, it is much more plausible to rather envision moral enhancement taking place through a type of cognitive enhancement that enables the recipient to better follow their already existing moral code and to avoid needless social conflict. Often these cognitive enhancements would be the very same enhancement interventions that could be applied to heighten cognitive performance, but they are just applied with the end goal of heightened capability for moral action. As previously stated, many facets of our cognitive capabilities can be positively affected by pharmacological and neurotechnological means. Given time for study and development, it is plausible that we could foster moral action with safe and effective[7] drugs that could be envisioned as something like selective serotonin reuptake inhibitors and other antidepressants. If we agree that many of our lapses in following our morals stem from compromised cognitive performance due to stress, anxiety, lack of focus and other similar very human issues, then using biomedical cognitive enhancement interventions to alleviate these factors would also count as a (subjective) moral enhancement. Simply put, in a situation where stress leads to compromised moral actions, heightening the ability to withstand stress acts as a form of cognitive enhancement *and* moral enhancement.

Related to this, it should perhaps be clarified again that when we talk about cognitive enhancement, we use the word cognitive in the wide sense. This means anything pertaining to brain processes and the senses, not just directed thoughts and rational reasoning, but executive functions, focus, memory, and impulse response as well [24]. Thus, when we talk about enhancing human ability to withstand factors that hamper these cognitive skills – such as stress – we take this to be a cognitive enhancement, since the benefits it provides are aimed towards cognitive capabilities.

Even though the potential link between cognitive enhancement and moral enhancement has already been discussed by multiple authors (e.g. [21,22,25,26–29]), this is still perhaps a controversial take on what being morally enhanced means. Perhaps doubly so because we are not only talking about enhancing cognition in the name of gifting people with heightened ability for moral reasoning, but rather about something akin to *anti-akrasia* when it comes to moral behaviour, that is, filtering out factors that undermine moral action. Many writers have suggested that for something to count as a moral enhancement, it should at the very least lead to the enhanced having better motivations [30,31]. If we only settle for enhancement leading to morally better outcomes, then this could lead to some unwanted conclusions. Robert Sparrow [31] has argued that if we disregard motives from the equation, we could say that causing a potential robber to fall asleep would count as morally enhancing them since the robber did not steal anything due to their condition. Because of this, it is good to make it clear that we are, in fact, advocating a different sort of moral enhancement, one which is not interested in consequences or motivations as much as about how closely our actions resemble our subjective moral codes.

This view of cognitive enhancement providing moral benefits is also in line with our everyday experiences. We often find ourselves in situations where we know what the morally right thing to do is but struggle to comply with our knowledge due to being tired, stressed out or simply in a hurry. Morally commendable actions are usually not the easiest or the most pleasant actions out of those available, and often require discipline, impulse control, and self-sacrifice.[8] Biomedical cognitive enhancement interventions could help us fight against our tendency to allow ourselves lapses in judgement when it is convenient for us or stop us from lashing out in anger at other people when we are stressed. However, since biomedical interventions cannot give us new morals altogether, they will not stop a person with bad morals from acting out on them. Therefore, we will still need traditional moral education like the one provided by schools, communities, and moral stories. Biomedical enhancement would just *enhance* the effects of those lessons, helping the enhanced adhere to their moral code to the letter. Viewed this way, it becomes clear that enhancement that provides moral benefits does not have to be seen as some far-off utopian invention that will turn people with questionable morals into paragons of justice with a visit to a doctor. Instead, it will likely be something much more boring and mundane.

Our view of the proposed kind of biomedical enhancement is thus as follows: it is a form of cognitive enhancement where the enhancement interventions in question are applied not solely for the purpose of heightening cognitive capabilities, but also with the end goal of producing heightened subjective moral action. We argue that this is a form of moral enhancement. Despite this view, we do not suggest that all biomedical moral enhancement interventions would have to be forms of cognitive enhancement. For example, should we learn how to directly make a person's moral motivations more noble, that could be an example of a 'true' moral enhancement. However, as we are sceptical that such interventions will be available any time soon, we think that the kind of enhancements we have envisioned here are our best bet for biomedically enhancing moral action for the foreseeable future. To emphasise that our view is not interested in granting people with superior morals, and to distinguish it from more traditional conceptions of both cognitive and moral enhancement, for the rest of this paper, we will be calling our view moral adherence enhancement. This conceptualisation is relevant to the biomedical moral enhancement discussion more widely, but next, we wish to apply it to the case of long-distance space travel and test how it fares in this special case.

4. Biomedical moral adherence enhancement and long-distance space travel

Human activity in space is accelerating and in recent years we have heard ambitious plans for humanity's future in space. For example, in 2016, the then NASA deputy administrator Dava Newman estimated that NASA would be prepared to make crewed missions to the Martian orbit in the 2030s [32], and the agency is also developing technology for mobile homes to be used on the Red Planet [33]. In addition, NASA is currently working on returning humans to the surface of the moon in

[6] As an example of questions pertaining to biomedically overwriting a person's existing moral code with a new one: what set out of all the possible sets of morals should we apply? In a world with moral pluralism, who is capable and justified in making this decision? And are people, who this sort of intervention is applied to, still autonomous agents, even if they gave their permission for the procedure?.

[7] While "safe and effective" is a term frequently used in the enhancement literature (e.g. [56,20,59,60]), we should perhaps clarify that we mean biomedical interventions that have undergone rigorous testing, proving within acceptable margins that they both have the intended effect and have no common serious side effects (see also [25]; 4–5). To put it simply, we expect them to follow the same strict guidelines that are used when evaluating pharmaceuticals meant for continuous, long-term use. We also would like to note that we do not imagine that there will ever be a one-pill-fits-all-solution to biomedical enhancement needs as human biology differs from one individual to another. More likely there will be various enhancers designed to work for different people – just like with many other common drugs such as pain medication and antidepressants.

[8] It is common that one's values may not correlate with their actions. This so-called *value-action gap* has been discussed, for example, in relation to ecological sustainability where it has been observed that many people would like to act in a pro-environmental manner but in practice often fail to do so [37]. Rakić [23,29], calls a similar phenomenon in the context of moral enhancement a *comprehension-motivation gap*.

2025 in preparation for a crewed mission to Mars [34].

Should humans ever wish to settle outer space permanently, there are many hurdles that must be overcome, one of the chief obstacles being the sheer vastness and inhospitality of space. With our current level of spacefaring technology, travelling just to Mars would take many months. To succeed in such a long and arduous journey in an environment where mistakes can be costly, space travellers would need every advantage they can get. This includes a strong commitment toward the whole group's well-being and the ability to hold on to that commitment through stress, anxiety, fatigue and other psychological as well as social hardships. As physician and astronaut Jay C. Buckey ([35]; 34) has said:

> Long-duration spaceflight can test any individual's psychological well-being. Factors such as confinement, under- or overwork, sleep loss, and monotony can combine to worsen interpersonal tensions or even lead to frank depression. Conflicts can arise with ground control, with a resulting loss of trust and teamwork. A chronic dispute between or among crew members can destroy team functioning. Suppressed anger or frustration can erupt unexpectedly and create potentially hazardous situations.

Therefore, in this section we focus on the possible challenges posed to long-distance space travel by human psychology and make a case for biomedically enhancing humans heading out far into space for extended periods of time. The reason we are discussing long-distance human space flights instead of long-term missions is that we already have prolonged missions on the International Space Station (ISS). Even though conditions on the ISS are certainly challenging, they arguably are not as onerous as the ones on future long-distance missions such as a crewed mission to Mars. One significant difference is that on the ISS astronauts can be evacuated to safety in the case of an emergency. Because of this, we narrow our argument to only cover long-distance space missions and we leave open the question of the need for biomedical enhancement on the ISS and other future long-term Earth orbit missions. We will also not be proposing that enhancing humans is a necessity space travel cannot succeed without. Instead, our argument will be along the lines of advocating for seat belts in cars. Not having them will not make much of a difference if the trip goes smoothly from start to finish, but since there are many scenarios where they might save lives, it is sensible to consider their use all the same. This need is compounded by the supreme hostility of space and the extremely high-stakes nature of the endeavour, which require mustering all the possible advantages to bear.[9]

As mentioned in the introduction, the idea of using biomedical moral enhancement on future deep space missions has been suggested by Szocik [1,6]; who argues that biomedical moral enhancement is an option worth considering if space missions remain an exclusivist activity, but that it should not be applied to the masses should space travel become more common. This is reasonable. Our view is that for long-distance space travel to become a common activity available for the masses, it would need to become a much cheaper, safer, and less high-stakes endeavour. In such a scenario, travelling to another planet would not be so different from travelling to another continent via aeroplane, and thus requiring everyone to enhance themselves simply to be a passenger on a vehicle would be harder to justify. However, such a situation will not be reached for quite some time, and that is why, in the meantime, enhancement interventions are a relevant option to consider.

While Szocik has written on multiple occasions about the subject of applying biomedical moral enhancement on space travel, they have thus far remained on quite an abstract level when it comes to how they think such interventions would work in practice. This may be understandable caution on their part, given the hypothetical nature of the endeavour. However, as they discuss the problem of selecting a suitable set of moral rules and beliefs that would best further mission goals ([1]; 260) and about programming astronauts to make certain kinds of moral decision ([6]; 5), we take these as a sign that they view biomedical moral enhancement as being capable of applying completely new sets of morals on enhanced persons. As we have discussed in the previous chapter, we do not find this proposal believable, at least in the foreseeable future. Thus, we wish to next analyse could our more grounded conception of moral adherence enhancement be recommended to be applied to long distance space missions.

One major obstacle to space travel is the extreme distances involved. On Earth, even the longest commercial passenger flights are completed in under 24 hours. By comparison, it took *The Perseverance* rover about seven months to travel to Mars. It is obvious that advancements in spacefaring technology can cut down this time, but it is also a fair estimate that for the foreseeable future, travelling to Mars or other celestial bodies will take a significant amount of time. On a trip of months or years, a traveller is not just a passenger in a ship's cabin: they are living their lives in their vessel, forming a small society.

NASA lists isolation and confinement, distance from Earth, and hostile environments as some of the hazards of human spaceflight to Mars [36]. They state that after extended periods of living in confined spaces in chronic isolation, behavioural problems are always going to surface among travellers no matter how hard they train and prepare. Travellers cannot be resupplied if problems arise, and their ability to stay in touch with Earth is at least limited. They must endure extreme isolation while at the same time having to constantly stay vigilant to protect their vessel or habitats from all threats. Labouring in such an environment day after day for months or years is bound to create tensions, conflicts, fatigue, anxiety, stress, and other psychosomatic and interpersonal problems (e.g.,[28–32,35,37–39]). In such a scenario, momentary lapses in judgement due to the aforementioned factors can cascade, leading to the group losing cohesion and with it, the ability to cooperate effectively (cf. [40]; 40–41). In an inhospitable environment such as space, this lost efficiency can endanger the whole mission, and with it, the lives of everyone on board. This threat is compounded by a variation of the malevolent actor problem. In space there is no need to painstakingly build or secretly obtain a weapon of mass destruction – the surrounding environment is so hostile that a simple lapse in judgement or base negligence can cause as much harm as a bomb.[10]

If we have safe and effective moral adherence enhancement interventions available in the future, we see no weighty reasons why they would not be made mandatory for long-distance space travel, at least in the early stages of space expansionism. Traditional concerns raised against biomedical enhancements, such as worries pertaining to autonomy [14] and authenticity [41], have very limited appeal in this scenario. It is not hard to argue that in special high-risk scenarios, safety (especially the safety of others) supersedes rights. Consider a scenario where you are to treat patients with a potentially contagious and deadly disease, and there are countermeasures available. Regardless of your feelings towards those countermeasures, they should be required to not risk spreading the disease further. In the same vein, biomedical moral adherence enhancement should be enforced for all long-distance space missions due to their high-risk nature which requires constant efficient

[9] As we are discussing moral enhancement and space exploration it is worth mentioning that there is a possibility that being in space and gazing at Earth from a distance helps people to gain a 'cosmic perspective' that can shift one's moral thinking arguably for the better. This cognitive shift that can result from viewing the Earth from space is often referred to as experiencing the 'Overview Effect' (see [61]). Interestingly, if this is the case, then space *itself* could be seen as providing a form of moral enhancement. Nevertheless, there is no necessary link between space exploration and moral progress even though imaginaries of space exploration often entail utopian hopes for the future. Also, it is still unclear how strong moral benefits experiencing space provides (if any).

[10] John Harris [27] has discussed Persson's and Savulescu's theory in relation to the danger of 'the village idiot', a name, brought up by Martin Rees [42]; that is commonly used for the idea that in a society with enough technological advancement someone could cause untold damage just by sheer incompetence.

cooperation between crew members.

This raises the question: if Persson's and Savulescu's argument of mandatorily enhancing the whole of humanity was problematic from the point of view of autonomy and freedom, why would not applying mandatory moral adherence enhancement in the context of long-distance space travel run afoul of the same problems? For example, Vojin Rakić [21–23] has championed voluntary biomedical moral enhancement, arguing that making the initial decision to enhance oneself voluntarily is the only way to implement biomedical moral enhancement interventions in society without curtailing human freedom. While we agree with Rakić that making biomedical moral enhancement mandatory for all is a problematic proposal, that does not mean that such measures might not be warranted in certain limited special circumstances. Participating in long-distance space missions is not a human right. As such, we think that our argument is compatible with Rakić's view, for as long as every potential candidate for such a mission is made aware that participating in the mission requires them to enhance themselves. In such a scenario, deciding to go ahead with their application can be constituted as voluntarily deciding to enhance themselves. This does not even mean that people who do not want to be enhanced are deprived of the possibility of becoming astronauts. They would just not be allowed on future deep space missions, at least until spacefaring technology develops further and such missions become less dangerous and demanding. Rakić [21] themself has pointed out that there could be possible exemptions from the requirement to have biomedical moral enhancement be voluntary, as they have noted that perhaps it could be made compulsory for some convicts. Interestingly, there are problems related to making enhancement mandatory for felonies that are not present in our case. For example, there will probably always be cases of wrongly convicted people, whereas nobody consents to a long-distance space mission by accident.

Thus, we suggest that biomedical moral adherence enhancement should be considered to be made mandatory for such long-distance space missions where the stakes are especially high. Further on, one could make a stronger point and claim that in the current state of the world, all long-distance space missions are enterprises where a lot is at stake. To elaborate on this point, consider a case of a crewed mission to Mars. A failure on such a mission would not only likely kill the whole crew (already terrible in itself) and waste tons of resources but could also halt the progress of interplanetary travel for a long time. Due to the public interest, the media usually reports on any major space mission extensively. As a result of this, if a crewed mission were to fail dramatically, the general attitude toward space exploration could quickly change from excitement to opposition and even public outrage. The consequences of this may significantly delay the progress of space exploration. After all, many space programs are government-funded and private companies are also responsive to public opinion through markets.

All of this could shatter our hope of securing a place of refuge outside Earth any time soon and therefore the ripple effects of this could be devastating. Having 'all eggs in one basket' makes humanity more vulnerable to extinction risks (e.g., [42–45]). Nuclear war, natural or engineered pandemics, runaway climate change, ecological collapse, unaligned artificial intelligence, supervolcanic eruption, asteroid or comet impact, and other unforeseen risks could lead to an extinction event (e.g., [42,46,47]). Furthermore, it has been argued that we live in a time of perils where humanity is currently facing a relatively high risk of extinction [42,47]. Because of this, the longer it takes for humans to settle beyond Earth, the riskier the future of humanity becomes. This further on means that the costs of failing a crewed long-distance space mission might turn out to be colossal.

Here is a back-of-the-envelope calculation that illustrates the point. Suppose that because of a failed long-distance space mission a sufficiently self-sustaining human settlement being established on Mars (or elsewhere) is postponed from the year 2198 to the year 2223. This 25-year halt translates to 5000 lost years of expected human civilization assuming that there is a 1%[11] chance that humanity exists a hundred million years,[12] that the risk of humankind facing an existential catastrophe on Earth that does not affect a possible space settlement in the next 200 years is 4%,[13] and that because of the extraterrestrial settlement humanity could avoid extinction in the case of an extinction-level catastrophe on Earth. The calculation would go as follows: $(0.01 \times 0.04 \times 10^8) - (0.01 \times 0.035 \times 10^8) = 5{,}000$. Now further on, if you assume that there is a 1%[14] estimated risk of a failure on a crewed long-distance mission that can be lowered to a 0.75%[15] risk by using biomedical enhancement, then the value of enhancing the crew members is 12.5 expected years of human civilization since 0.0025 times 5000 is 12.5. In human lives, this would then translate to 1.25 billion lives assuming that the average carrying capacity for humans per century is 10 billion lives.[16] One billion two hundred and fifty million (1,250, 000, 000) expected human lives is a very high gain for such a minor intervention as biomedically enhancing the early-stage travellers on future long-distance space missions.

The calculation just presented obviously contains a lot of uncertainty and should thus be taken with a grain of salt. However, it still illustrates the possible path dependencies and foreseeable positive ripple effects that enhancement can have on future crewed space missions. If biomedical enhancement becomes a cost-effective, efficient, and safe way to improve the chances of a successful mission, according to what we have argued above, it should be mandatory on long-distance space missions. This of course means that if in the future humanity has already achieved a significantly higher level of existential security and spacefaring is more common and safe, there is no pressing need for biomedical enhancement to be mandatory on spaceflights. This is because then the stakes are not as high as they would be in the initial phase of space expansionism. Also note that, compared to Persson's and Savulescu's argument about the need for moral enhancement, it is much more feasible to enhance a small number of astronauts and other space travellers rather than *every* human on Earth.

As a response to what has just been outlined, one might argue that if we really want to avoid human extinction, we should not rush to space,

[11] We acknowledge that giving this kind of an estimate is very speculative, but it seems unreasonable to be highly confident that our descendants could not survive for at least a hundred million years. Thus, giving a 1% probability here seems reasonable to prove our point.

[12] This is in some sense a conservative assumption because in theory humanity could survive on Earth for at least 500 million years more and perhaps even much longer if humans migrate into outer space [62].

[13] It is extremely difficult to estimate the probability of extinction risks (they are, after all, unprecedented events by their nature) and consequently we have arrived at choosing a conservative assumption. It has been argued that the total risk of human extinction in the next century is much higher than our suggestion for the next couple of centuries, ranging somewhere between 10 and 20% [46,47,63]. In this calculation, we also assume that the risk rate is constant throughout the 200-year period. It should also be noted that it may well be that some extinction risks are more or less correlated between Earth and space settlements. For instance, a rogue super artificial intelligence might affect both ([47]; 194). Hence, the number given in our calculation should be lower than the total risk of human extinction.

[14] Jacques Arnould ([64]; 53) has noted that the US and Russia had a fixed 1% mission failure rate for early space missions, a rate accepted commonly for high-risk professions, such as the army.

[15] This 0,25% reduction is frankly somewhat of a shot in the dark because we are discussing hypothetical future technologies.

[16] The United Nations Department of Economic and Social Affairs [65] has estimated that the world population in 2100 is 10,9 billion people. So, our estimation aligns with this.

since it is not a cost-effective way to reduce extinction risks. We are sympathetic to this objection, and we do not argue that we should aggressively expand to space and settle other planets. Quite likely there are much cheaper ways to reduce the risk of human extinction. These could include developing a capability to deflect large asteroids and comets, enhancing pandemic readiness, investing in extinction risk research, and preparing for a nuclear war, asteroid impact or supervolcanic eruption by, for example, preparing food stockpiles and building resilient refuges in isolated locations on Earth ([43,48,45,47]; 394). In addition, there are many ethical conundrums related to human expansion beyond Earth, and therefore it is not clear whether settling beyond Earth in the near future is ethically justified (see e.g., [49–51]). Instead, what we claim is that due to various reasons human activity in space will likely accelerate, alongside which long-distance space missions will become reality. These reasons include, for example, commercial and scientific interests of space exploration. Additionally, it is not guaranteed that humanity will get its act together and do the measures needed to mitigate the risk of premature human extinction. Facing uncertain futures such as these, we should make the most of space exploration by ensuring that crewed deep space missions do succeed. Thus, our argument is one of a practical kind.

Even if we do not take into account these long-term considerations about extinction risks and the value of the far future, we still have good reasons to consider moral adherence enhancement for long-distance space missions. As already discussed, the coming deep space missions are presumably going to be challenging and relatively dangerous (at least in the beginning). When put like this our argument is a rather modest one, and the argument from extinction risks only reaffirms the case for enhancement.

It is worth noting that some space agencies already use nootropics resembling early versions of the cognitive enhancers envisioned in this paper as part of their medical kit ([35]; 44–45). For example, pyritinol, pantogram, phenibut, and piracetam are reported to be used to improve cognitive function and to decrease anxiety. Some of these are used in a similar fashion to common vitamins and nutritional supplements ([35]; 48). In the future, the same could be done with biomedical moral adherence enhancement interventions, provided safe and effective products are available.

As a final point to this section, we want to once more emphasise that discussion about biomedical enhancement needs realism and context. By this, we mean that in ethical analysis the empirical complexity of the issue at hand should be taken into account (see [52]). The same applies to debates about space exploration and settling space. The study of futures and emerging technologies are always more or less speculative. Hence, in the future, the need for biomedical enhancement for space missions should be re-evaluated when the envisioned enhancement interventions have been developed; only then can we form a detailed picture of the interventions and the relevant context needed for a full ethical evaluation. Therefore, our discussion is not the final word on the matter. Instead, we only aim to demonstrate a strong plausible case for biomedical moral adherence enhancement.

5. Possible objections

A central objection that could be made against our case is to appeal to risks: biomedically enhancing people with novel pharmaceuticals entails significant uncertainties and the dangers these present outweigh the positive benefits of enhancement. We obviously concede that we should not rush to enhance humans before we have a robust understanding of the technologies being employed. Thus, our argument stands only in the case where the envisioned interventions are safe and effective (see note 7).

Further on, an argument could be made that conducting research on biomedical enhancement is a frivolous way to spend limited resources that would be better used elsewhere. We agree that there are more pressing concerns than enhancing astronauts. However, as already stated, our argument is practical in nature. The global rise in the use of nootropics suggests that there is a demand for enhancement interventions. Thus, pharmaceutical companies and researchers already have ample incentives to continue their work in the field. As such, we are not advocating for diverting additional resources to biomedical enhancement development but for co-opting the potential benefits of the ongoing research to the service of space exploration. A similar worry might be that due to strict weight and space limitations, bringing enhancement interventions onboard the spacecraft would take up valuable space that could be used for other mission-critical equipment. This is, in the end, something for the mission planners and space medicine experts to decide. They need to evaluate whether the benefits from enhancement interventions outweigh the trouble of making room for them. However, since there will already be medical equipment on board, it is hard to imagine that bringing a supply of moral adherence pills will be the straw that breaks the space camel's back. After all, a very average pharmaceutical tablet can weigh 0.4 grams, and if we imagine a crew of six taking two tablets every day for two years, this will only mean an added weight of about 3.5 kilograms. We must assume that this is not an unsolvable issue for space agencies.

Additionally, an objection could be raised that we need astronauts to be successful without biomedical human enhancement so that the masses can follow. The idea could be that, as we do not want mandatory enhancement for everyone that ever goes into space, the first astronauts should demonstrate that humans can travel to (for example) Mars, under the conditions of normal human function. Here we would wish to remind the readers that we do not believe that the type of enhancement that we are proposing is such that missions could not succeed without it. Rather the moral adherence enhancement is more like wearing a seat belt: it lowers the risk of catastrophic failure. Furthermore, our proposal for mandatory moral adherence enhancement only concerns the early phases of space expansionism. We assume that in the future technology advances and space travel becomes more commonplace and safer. Alongside this development, biomedical enhancement on spaceflights becomes naturally less imperative. It might also be worth noticing that the early deep space astronauts might want to use moral adherence enhancement interventions due to the added safety it provides. Would it be morally justified to forbid them just due to wanting to demonstrate that the mission can succeed without the help of biomedical enhancement? Probably not.

An additional concern could be that since biomedical moral adherence enhancement does not provide anyone with a virtuous character, how is it any help against individuals with flawed or bad morals? In this situation, the biomedical enhancement could indeed plausibly make these actors better at following their bad morals. We concede that this is true, and that is why everyone about to participate in a space mission should be vetted rigorously and subjected to an exhaustive psychological evaluation as well as an array of exercises and training meant to promote good morals, communication, and teamwork (as they already are). Even if some bad actors could slip through precautions such as these, they will then probably be an extremely small minority. Thus, the benefits of morally enhancing the many outweigh the risk of accidently strengthening the bad convictions of the few. After all, if someone aboard a spaceship has a mind for sabotaging it or neglecting their duties, these intentions will hardly be made much more disastrous by enhancement.

A further argument against biomedical enhancement on space missions can be drawn in the form of a slippery slope argument. One could claim that biomedical enhancement in high-risk situations such as the possible crewed mission to Mars is acceptable. Yet, even so, we should abstain from such practices because the use of neuroenhancers on space missions would likely mean that biomedical enhancements become more acceptable in other areas of life. This could have negative effects that outweigh the positive effects of having morally enhanced crew members on long-distance space missions. Already nootropics pose a problem in electronic sports as they can give an unfair advantage.

Because of this, some organisations have started taking measures against e-doping [53]. Respectively, it is not hard to imagine a future where biomedical enhancements increase inequality. Our contemporary societies are more or less unequal and have been described as hypercompetitive. In this kind of environment, the introduction of effective, but at the same time expensive, biomedical enhancement interventions could very well leave the already worse off in a weakened position. This is a weighty objection. But the lesson to draw from it is *not* that we should never develop biomedical enhancements (because in some areas of life they can have significant benefits) but rather that we should *regulate* such interventions and technologies carefully.

Related to the previous objection, some could argue that there is an analogue between making it mandatory for astronauts to be biomedically enhanced and requiring athletes to use performance-enhancing drugs. While on the surface these two cases share some similarities, they are importantly different. Even though emotionally sports might be a very high-stakes endeavour for athletes (and fans and perhaps even nations), being unable to perform on the highest possible level as an athlete is very unlikely to lead to consequences as severe as a failed long-distance space mission would. Frankly speaking: sports are rarely a matter of life and death, especially in a way where a mistake made by one athlete could cost the lives of the whole team. Enhancement in space missions is primarily about safety and mission success. While there are arguments that can be made in support of performance-enhancing drugs that relate to athlete safety [54], in the end, the primary motivation behind using enhancement in sports is about competitive advantage. There is also something to be said about the scale of these two endeavours. It might seem like deep-space astronauts and professional athletes are both very small groups. However, in reality there are, even conservatively estimated, hundreds of thousands of professional athletes. Moreover, while only a small number of humans will ever go on to become professionals at their given sport, in contemporary hypercompetitive societies the decision of when to start to seriously pursue a career in sports must be made early on. If performance-enhancing drugs were both readily available and allowed for by the rules, the pressure of using them would be heavy indeed. There will, for the foreseeable future, be only a very small number of astronauts going into deep space, while there will be millions of athletes competing on various levels just within the next couple of decades. Hence, we easily end up in a situation where taking performance-enhancing drugs becomes practically mandatory for a great number of people – something which will not be an issue inside space programs.

Also, one could argue that our moral psychology is actually fit for space travel because space travel would happen in small and tight groups, and thus we would not need moral enhancement. The idea behind this is that on a space mission everybody would belong to the same inner group and people would likely be motivated to act altruistically for each other.[17] This most certainly might be the case, but it does not undermine the need for biomedical moral adherence enhancement. Even though our moral psychology might be better suited to function properly in small groups, there are other things that undermine one's moral behaviour on deep space missions that are not present in everyday life on Earth. Namely, the extremely stressful and challenging environment in outer space that is psychologically demanding and can bring tension between crew members.

It might be justifiable to ask that if humans are so prone to endangering their voyage through space that they need to be biomedically enhanced, why not just have robots take over instead? Artificial intelligence does not tire or lose focus, will not compromise mission objectives for the sake of personal grievances, and will not become stressed under the pressure of isolation and a hostile environment. Our answer to this argument is that missions that can be carried out by robots, and where human presence does not add anything of significant value, should indeed be carried out by machines. Further on, if it ever becomes possible to have humans travel between planets simply as cargo in something resembling suspended animation, we should take the opportunity to do just so. This would not only eliminate the possibility of human error but also perhaps be more humane, as it would not expose the travellers to all the anxiety inherent in the process of travelling through vast expanses of space. Our recommendation for applying biomedical enhancement only stands in a scenario where humans must be an active force on the ship during its travel – though it is likely such interventions could also be of use when they finally reach their destination. After all, there might not be much of a difference between spaceships and space habitats when it comes to dangers, psychological challenges, and the need for cooperation and strong moral commitment.

Finally, we recognize that some might want to contend whether biomedical moral adherence enhancement is actually moral or even cognitive in nature. We have already talked about how some authors have argued that in order for something to be categorised as moral enhancement, it should leave the enhanced with better morals or motivations. Similarly, an argument could be made that since in a completely stress-free environment an enhancement that raises human tolerance to stress does not lead to improved cognitive ability, it should not count as a cognitive enhancement, but perhaps rather a physical enhancement that, under some conditions, also has cognitive benefits. There is some truth to this. However, we argue that stress, loss of focus, fatigue and other such factors are an almost constant facet of human life – especially in space. Thus, steadily lessening their effects always increases human cognitive (and moral) capabilities within a longer observation period, even if there were singular moments when an enhanced person would have operated at the same capacity without their help. However, should it turn out that moral adherence enhancement is actually some other type of enhancement entirely and should not be categorised under either cognitive or moral enhancement interventions, this would not be a problem from the viewpoint of our argument. No matter how it is labelled, moral adherence enhancement would still be beneficial for the safety of long-distance space missions.

6. Conclusions

In this paper, we have argued that applied ethical arguments about moral enhancement need realism and focus. Furthermore, we have suggested that for the time being, a more grounded way to picture biomedically heightening human capability for moral action is through a form of cognitive enhancement that also confers some moral benefits by aiding a person to act according to their subjective moral code. We call this type of intervention moral adherence enhancement. We then applied this understanding to the case of long-distance space missions. We argued that should humans attempt crewed deep space missions, the travellers should not only be properly vetted and trained but also biomedically moral adherence-enhanced to ensure they have every possible advantage on their long and challenging journey. While our argument is limited in scope and says little about whether biomedical moral enhancement should be compulsory or voluntary in general, it is a conversation worth having nonetheless due to human space activity rapidly increasing as we speak. With NASA, SpaceX, and a myriad of other companies and nations planning on taking humans to Mars within the coming decades, there is a need for research into the possibility of safe and effective enhancement interventions. Even if we are not yet planning on founding a long-term settlement beyond Earth (and it seems we are), a failed mission could additionally sour the atmosphere for long-distance space missions for decades to come, potentially halting progress in spacefaring technology and thus denying humanity the enormous positive ripple effects that it may provide.

[17] We thank Mikko Puumala for bringing this objection to our attention.

Author statement

Henri Huttunen and Oskari Sivula contributed equally to: Conceptualisation. Methodology. Investigation. Resources. Writing - Original Draft. Writing - Review & Editing. Supervision. Project administration.

Declarations of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgements

We thank Mikko Puumala, Helena Siipi, Olivia Mörck, and Janna Ruuskanen for their valuable comments on earlier drafts of this article. We also thank the audience at the Philosophy and Outer Space seminar at the University of Turku (March 2023) for the discussion following the presentation based on this article.

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