Human Enhancement and Reproductive Ethics on Generation Ships

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Abstract

The past few years have seen a resurgence in the public interest in space flight and travel. Spurred mainly by the likes of technology billionaires like Elon Musk and Jeff Bezos, the topic poses both unique scientific as well as ethical challenges. This paper looks at the concept of generation ships, conceptual behemoth ships whose goal is to bring a group of human settlers to distant exoplanets. These ships are designed to host multiple generations of people who will be born, live, and die on these ships long before they reach their destination. This paper takes reproductive ethics as its lens to look at how genetic enhancement interventions can and should be used not only to ensure that future generations of offspring on the ships, and eventual exoplanet colonies, live a minimally good life but that their births are contingent on them living genuinely good and fulfilling lives. The paper further claims that if such a thesis holds, it also does so for human enhancement on Earth.

Keywords: Space ethics, Human enhancement, Reproductive ethics, Generation ships.

1. Introduction

Over the past several decades, both scholarly and popular literature has actively attempted to highlight and explore the various existential risks that might jeopardise continued life on planet Earth. Ranging from nuclear winter (Baum 2015) and climate change (Butler 2018) to runaway nanotechnology (Umbrello and Baum 2018) and artificial superintelligence (Bostrom 2016). Despite some of these existential risks being more plausible, what has concerned scholars is how to avoid, ameliorate, and mitigate some of the threats. More recently, one of the proposed solutions made quite popular by science fiction in shows like The 100 (2014) and movies such as Passengers (2016) and Interstellar (2014) is to have humans leave Earth and colonise other planets. Recently, Tesla and SpaceX CEO Elon Musk stated that to ensure the species' long-term survival, humans must become a multi-planet species (Sheetz 2021).

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In lieu of the ability to travel beyond the speed of light or harness the power of a theoretical gravity propulsion system (i.e., Tajmar and Bertolami 2005), habitable planets within the perennial circumstellar habitable zone remain beyond reach for us currently (Schulze-Makuch 2020). Mars has been the subject of much recent attention as the most likely candidate for initial extraterrestrial colonisation. However, it will require significant geoengineering efforts for the planet to be able to sustain large and growing populations, a considerable engineering challenge (McInnes 2009). Exchanging one engineering challenge for another, should habitable planets present themselves in the perennial circumstellar habitable zone yet lie beyond reach within the average human lifespan (i.e., outside our solar system), what will be required is an interstellar ark starship or simply a generation ship. These are hypothetical spacecraft meant to travel between star systems at sublight speeds. This means that the original crews of the ships, and in many cases multiple generations following them, would not live long enough to arrive at their destination planets. They would be born, live, and die on the ships with the goal of becoming the carriers of the genetic heritage of future generations that would populate their destination planet(s) and (Szocik 2021); beyond that, the shepherds of cryopreserved human and animal embryos that can be used to seed new planets (Edwards 2021). The motivations underlying the need for such vessels could be (1) life on Earth may remain habitable, at least for a finite number of people; hence, using these ships, current inhabitants of Earth can leave for a new habitable homeworld and/or (2) generation ships can be a means of last resort for the survival of the species, i.e., perhaps as a consequence of global climate change (i.e., as depicted in *Interstellar* 2014).

Although such ships pose a gargantuan engineering obstacle, they have nonetheless drawn scholarly attention from projects like Project Hyperion, which looked at the ideal population sizes to man these ships as well as what current and future technologies would be required to ensure the success of such enterprises (Smith 2014; Hein et al. 2012). Not only this, but various ethical issues emerge as a consequence of such a venture. Ethicist Niel Levy (2016) noted several ethical considerations to take into account when considering generation ships, primarily that despite the original crews will almost certainly have a better quality of life on the vessel in terms of access and quality of health care, education, and nutrition, they will almost certainly have little if any control over personal, career, or reproductive choices given the need to tightly control and ensure the long-term success of the mission. Hence, such individuals will have their freedoms almost entirely curtailed despite having the best versions of the things that are required to meet the minimum threshold for well-being (Lester 2013).

In this paper, we argue that it is not *a priori* morally responsible[1] to have children on a generation ship despite their ensured and perhaps abundant access to the minimum necessary conditions for survival. We argue that in order for the choice to have a child on a generation ship to be morally responsible, parent crew members must ensure to the best extent possible that they give their children a good life, a life worth living[2] beyond that of a means to some extremely distant

[1] Moral 'responsibility' here is best read as moral 'permissibility'.

[2] In this sense, a 'life worth living' is best understood as internal, that is life is of sufficient value for the individual concerned to be worthwhile; not unlike that of that delineated by McMahan (1998: 226-28).

end (i.e., genetic carriers for future planet colonisers).[3] Not only this, but we use this scenario to demonstrate that this principle not only obtains to generation ships but on Earth as well.

2. Born, Living, and Dying on a Starship

Given the extreme distances of other exoplanets (i.e., planets beyond our solar system) that have currently been discovered and even if we could overcome the monumental engineering challenges of building a generation ship large and sophisticated enough to ensure the long-term survival of the humans aboard so that their descendants could reach their new home world, this would necessarily take many generations, feasibly more generations than there has been up until this point on earth (Szocik 2021). Still, such a multi-generational journey aboard a craft that is fundamentally different in almost every way then the environment on Earth, one that poses existential challenges to the biology of those on board, would almost certainly require genome editing interventions so that the crew members could more safely survive such a long journey with the greater risk of being exposed to stellar radiation and potential changes in gravity conditions. Aside from technical requirements, such a ship would need to ensure that such radiation and gravitational anomalies would be at a minimum, so it makes the most sense to intervene at the crews' genetic levels to make them as impervious as possible.

Intervening at the individual (human) level rather than at the environmental (starship) level would naturally be the least costly of the two options; although it would be reasonable to hypothesise that both strategies should be taken in unison to a degree to ensure that redundancies increase the likelihood of mission success. Still, this latter suggestion may be the most technically feasible in the interim, given current trends in genetic biology (e.g., Daly 200; Singh et al. 2011). This would initially mean intervening at the genetic level on the pioneer crew who board the ship before takeoff, and perhaps, should the ship be carrying human embryos on those embryos on Earth before takeoff. Even if one assumes that modifying an eventual exoplanet via geoengineering techniques raises no morally relevant concerns, we take the position that the more straightforward approach of intervening on the individual genetic level poses the least, if any, moral problems.

Some would indeed argue that genetic interventions of any kind are immoral given that our genetic heritage is sacred or is held in common. Thus, intervention at the individual level to change this heritage would be fundamentally immoral (e.g., Sandel 2007; 2009; Kass 2003). Despite many issues with this position (e.g., see Kudlek 2021), biologically speaking, such a position is simply without grounds. Sexual reproduction (or assisted reproduction) *de facto* modifies the

[3] Dominic Wilkinson (2011) distinguishes between various ways of understanding a life worth living (see also, Parfit 1984: 493-502; DeGrazia 1995; Griffin 1986: 7-74. There is an internal sense of a life worth living (life is of sufficient value for the individual concerned to be worthwhile) and an external sense of a life worth living, and its value to others (Buchanan and Brock 1986, p. 74). In addition, some authors make a distinction between the level of a life worth starting (for an individual who does not yet exist) and the level of a life worth continuing (for an existing individual) (Benatar 2006: 22-23). Some authors also argue that it is possible to distinguish whether life is above or below the zero point (Buchanan et al. 2000: 224; Wilkinson 2011; Glover 2006: 57; Garrard and Wilkinson 2006: 486; Wyatt 2005).

genetic heritage of each offspring it produces. Hence, each time a child is born, its genetic makeup is necessarily diverse from that of its progenitors. To support a position where the genetic heritage of humans is monolithic is simply incorrect; rather, what is an immutable feature of human nature is that such heritage is dynamic and changes from birth to birth. Even in the case of cloning, where we produced an embryo using the nuclear DNA of the somatic cells of an adult, such genetic heritage would nonetheless be diverse from that person (Ayala 2015). Likewise, the argument for a monolith genetic heritage via cloning fails even more given that only females can receive both the mitochondrial and nuclear DNA of the same person, meaning that cloned males will necessarily have diverse outcomes, lest we condemn that sex to die out, which, as a consequence again, would render the genetic heritage of humanity to change (Balistreri and Umbrello 2022b).

Furthermore, it would be hard to sustain the position that genetically engineering our offspring is morally egregious when such modification produces outcomes that positively impact the quality of those offspring's lives. A simple hypothetical example would be the use of such genetic engineering techniques to intervene in our offspring's genetic code to ensure that, when born, they are more resistant, if not entirely immune, to certain diseases (even presently terminal ones) as well as physical and cognitive enhancements that can make them and their descendants better apt at coping with the rigours of their lives and environments (i.e., Hofmann 2017). The moral challenges often levied against these types of techniques are those raised by making the distinction between therapeutic interventions and those that are for enhancement purposes. Still, these arguments make a distinction without a moral difference and have yet to provide watertight arguments (i.e., see Kudlek 2021, who challenges these positions; see also Balistreri and Umbrello 2022a). On such arguments is that those born with such enhancements would have had such enhancements chosen for them, and, as a consequence, would no longer be the master of their own lives, but mere passengers in the driver's seat given that those who were not subject to such interventions (the unenhanced) would not recognise them as part of the same species and thus not *de facto* attribute them the same degree (if any) of human dignity and all those rights/benefits as a consequence. Although this latter suggestion is not necessarily true given the marked rise in the suggestion and application of the attribution of such dignity and subsequent legal rights to nonhuman animals and other entities like AI systems, hence the attribution of such would not be far-fetched for humans who have received enhancements (e.g., Vink 2020; Pagallo 2018). This application of rights and dignity has even been proposed for (sufficiently anthropomorphic) potential extraterrestrial life, something that would be used as a designation after millions of years of speciation pressures on a generation ship and eventual exoplanet colony (Frietas 1977).

Still, beyond this, the argument that the freedom of enhanced individuals is *de facto* curtailed does not hold water. Such individuals would still have the freedom to use those enhancements in the ways that they desire, as well as to further modify/remove such enhancements or to augment themselves further. Even further, such enhancements do not expropriate the needs for skill and effort to be exerted in order to take advantage of their benefits, like the skill that current humans possess now, they are best understood as propensities and dispositions that require work and training in order to benefit from their use. Finally, certain moral enhancements can feasibly augment the enhanced person ability to empathise,

disposing them to greater sensations of gratitude towards their progenitors for their currently enhanced dispositions and make them better apt at putting the interests of their community members ahead of their own (i.e., see Rakić 2017; Ahlskog 2017). Taking these arguments into account, the genetic enhancements that potential generational ship members would undertake should not be considered elective or vanity medical procedures, but therapeutic, as they would permit the astronauts to have a greater probability of success in both surviving the many generations that such a ship would need to make its journey and the survival on certainly diverse (in comparison to Earth) exoplanets.

Here the reader would surely raise the notion that such interventions would be best undertaken only *after* the child is born rather than in anticipation. This ex-post intervention would be described as somatic line enhancement (Balistreri 2020), where the person's cells are directly intervened on while leaving the oocytes and/or spermatozoa untouched, thus, such enhancements would not be passed down through reproduction into the next generation. Such methods would require each born generation to undertake the interventions. Naturally, this would permit more research and innovation to take place, thus increasing the potential safety of the interventions prior to their application, if, hypothetically, in such a future scenario of intergeneration ships such a technology has not already been perfected. Still, adopting the somatic line enhancement approach would potentially risk the lives of newborns to the environmental hazards (i.e., potential celestial radiation, gravitational anomalies, etc.) that they would otherwise not be exposed to if they were born with the enhancements. Germline enhancement interventions then pose themselves as the more ideal solution. This approach would take place by intervening on the level of embryos or gametes prior to their fertilisation. Theorists who have explored extraterrestrial colonisation argue that the transportation of large quantities of embryos and gametes serves as one of the best methods for large-scale colonisation endeavours. Such could even be fertilised and gestated in artificial wombs via ectogenesis (Edwards 2021). Regardless, germline enhancements would remove the need for somatic line interventions post-birth since the enhancements of any given individual would be passed down to subsequent offspring. This latter (germline) approach could, and perhaps should, take place prior to the departure of such a ship, and, would therefore take place on Earth. This latter point is not insignificant, given that an important thesis in this paper is that the place in which these types of enhancement interventions take place do not post any *per se* moral quandaries. Similarly, given that germline enhancement approaches take place prior to birth, this means that the beneficiaries of such enhancements could not have *a priori* consented to such interventions, however, like the previous point, we are that this too is not *mala in se* as long as the interventions are proven safe and does not expose the offspring to any unwarranted risks.

The latter point, concerning consent, is particularly important to address head-on. One would think that somatic line enhancement approaches would be more ethical. However, despite the safety concerns raised above on why they may be best avoided, it does not explain how children, enhanced or otherwise, are not capable at a young age at making autonomous choices. As such, parents have the moral responsibility to make choices in their place, as their *de facto* representative, all while *not* being considered unduly paternalistic nor in violation of the child's autonomy or right to consent (i.e., Scanlon 2000; Orfali 2004). Should we oppose such a position, which runs contrary to the accepted positions in bioethics

concerning parental roles in neonatal medical decision-making, then we would have to accept the position that permits preventable risks to newborn offspring on generation ships and future exoplanets to take place. Here, the reader may induce that the position we are arguing for can be boiled down solely to that of a principle of minimal well-being where genetic enhancement interventions are morally permissible, if not morally obligated, in order to, but not beyond, ensuring that those born have a minimally sufficient capacity to meet the demands and challenges of prolonged space flight and exoplanet habitation. We, instead, take the position that this principle of minimal well-being via genetic enhancement is not a sufficient condition for making the morally responsible choice of having a child on a generation ship. We argue that, although the initial (adult) pioneers made the informed choice to face significant challenges and make arduous sacrifices, these challenges and sacrifices should not automatically be subsumed onto subsequent generations that will *necessarily* be born on a generation ship without first being able to ensure that they can be given a sufficiently good life beyond that of mere survival. We argue that genetic enhancements are one of the means by which this can be achieved.

3. Morality of Birth on a Generation Ship

As we mentioned, our goal is to show that a principle of minimal well-being is not a sufficient condition to be considered responsible when deciding to give birth to a child on a generation ship. Naturally, one can make the argument, and they would probably be correct in doing so, that as time progresses, and thus scientific research and innovation, such germline genetic enhancement interventions will continually advance, bringing with them not only novel and more efficacious outcomes but all this in a more safe way. We can, therefore, say that in some hypothetical future in which the technological readiness level of Earth is sufficient enough to permit or necessitate the creation and manning of a generation ship, then we can say that such a readiness level would allow a sufficiently advanced form of genetic enhancement that would make those who are born, live, and die on a generation ship relatively safe. This means that we can safely assume that those who are the beneficiaries of these enhancements on those ships would be quite resilient against the environmental hazards native to the hostile environments of such a journey. Still, despite the efficaciousness and safety of such interventions, simply ensuring the minimum well-being (i.e., not exposing offspring to preventable harms), and thus, is only a necessary but not sufficient condition for being considered moral in the decision to have offspring on a generation ship.

However, despite the 'technofix' proposed (i.e., germline genetic enhancements), these environmental hazards do not necessarily account for the psychosocial issues that such individuals will face on a generation ship and on the initial settlements on the destination exoplanets. Conceptually, such ships will be limited in size; thus, the crew will necessarily be constrained by the space provided to them within the internal space of the ship. Given that such a journey is necessarily life-long, confined proximity with a finite number of individuals poses unique social and psychological pressures on crew members. Although scholars have proposed that should the sufficient technological readiness levels that permit generation ships actually arrive, that readiness level would similarly permit a large enough ship so vast to ameliorate or negate this issue entirely (Levy 2016). Still, this remains to be seen. If we take the issue of lifelong close proximity on a ship

seriously, as our current technological readiness level allows us to explore, then we can already begin to investigate means to ameliorate these challenges. Szocik et al. (2020: 7), for example, imagine a panopticon-style internal ship to permit more open spaces so that members can be continually exposed to novel stimuli. However, this raises privacy concerns which further raise other psychosocial challenges. Others, however, have proposed the use of virtual, augments, and mixed reality technologies (not dissimilar to the *Holodeck* in the Star Trek TV and film series) to permit crew members not only to be exposed to novel stimuli but to integrate themselves into more familiar natural environments that stimulate the evolutionary propensities innate in human development (Salamon et al. 2018; Joshi and Mardon 2021; Del Mastro et al. 2021).

Still, even if such technologies present themselves as a potential solution, it remains more probable than nought that crew members, if/when they arrive at their destination exoplanet, will remain, live, and work in relatively close proximity for more of their waking time to promote the cause and support the success of their mission to ensure a working and sustainable colony. This does not mean that these pioneers will not have any individual time, which would be a difficult position to hold; however, it does make sense to say that such time would be relatively limited, and all the time they are not alone would be dedicated to the coordinating work of the mission., not unlike we see currently and historically with space exploration endeavours (Struster 2010). This constraining feature that would most likely be necessary for such enterprises will undoubtedly affect the quality of life of those who would unquestionably see their preprogrammed lives quite constrained as means towards so future end, a future which they will almost certainly not live long enough to experience. VR/AR/XR techniques would be helpful here to permit the most diverse access to experience possible. However, this *Matrix*-like solution would certainly not resolve the more substantial issue of lack of freedom in the choice of the crew members to self-determine their own goals and desired outcomes. The success of such a mission may be determined by limiting these very freedoms, dedicating all efforts and cultivating skills towards the mission's goals. Levy is clear in this thesis, saying that

> A generation ship can work only if most of the children born aboard can be trained to become the next generation of the crew. They will have little or no choice over what kind of project they pursue (Levy 2016).

Hence, despite the access to the best healthcare, nutrition, and safety on board a generation ship (such would be necessary to ensure success), it is certainly offset by the psychosocial constraints likewise necessarily imposed on those who have such access to likewise assuring mission success. So, we see a context of minimally sufficient well-being offered, perhaps much more than many currently living on Earth have access to, yet this is hardly a sufficient condition to have a "good" or "fulfilling " life, regardless of the definition used to conceptualise those arguably abstract adjectives. The source of the issues, fundamentally, is an issue of timespan. Here, we can hardly argue with the moral responsibility assumed via the sacrifices of the original crew members. These pioneers decided to undertake the mission and accept the challenges and consequences. However, by doing so, they also assume the explicit assumption that such a mission necessitates future generations to be born on board, who could not make the same choice to make those sacrifices towards the mission's objectives.

It would be hard to argue that those born on board should not be able to self-determine their interests, goals, career, and lives. One could feasibly imagine that those born aboard the generation ship could, once reaching adulthood, or the age in which their ability to make fully autonomous choices can be made (i.e., Leisman et al. 2012), could choose not to sustain the mission's goals, to abandon the enterprise, and to return to Earth. However, this would certainly be impossible, or at least existentially challenging, given that generation ships are predicated on the fact that faster-than-light speed travel is not discovered or possible. Hence, the vast distances such a ship is designed to traverse exclude the necessity and possibility of return journeys. Consequently, those born on board are condemned to remain on board. Likewise, the genetic modification interventions that will almost certainly be required to ensure the survival of the people who arrive on the destination exoplanet will certainly not permit, at least not without further modifications, the seamless return to Earth, which will have a non-native environment for those exoplanet colonisers. These more material challenges aside, there remains the apparent issue of biological and cultural speciation, which would occur at an evolutionary rate in missions that last thousands and millions of years. The differences, despite the potential choice of the crew members to return, may make the similar cultural and biological speciation that will, in the meantime, happen on Earth an obstacle for integration by the crew members. Simply put, the culture on both Earth and the generation ship will necessarily evolve, with natural evolutions divergences which will, over long periods, create fundamental differences making reintegration between the two groups difficult, if not impossible (i.e., see issues of speciation in Avise and Walker 1998).

4. Surviving on a Generation Ship is not Living on a Generation Ship

The lives of those who will board generation ships, and certainly more of those born on those ships, will almost certainly be different from those of most people born, live, and die on Earth. Many of the unique environmental, social, and psychological challenges that emerge as a consequence of such an endeavour require a substantial investment in ensuring that those who populate such ships have access to the necessities to ensure that their existence, their survival, is not jeopardised by any possible or emergent threats. In many ways, those who will live on such generation ships will have, whether they know it or not, access to many fundamental necessities to survival those currently living on Earth are not privy to. Access to optimal healthcare (both psychological and physiological), nutrition, entertainment, and knowledge (i.e., access to Earth's repositories (locally stored or via quantum connections to Earth, e.g., see Sidhu et al. 2021)).[4]

Of course, critics may argue that access to these unprecedented resources and being part of an unprecedented and monumental endeavour such as exoplanet colonisation via a generation ship will ameliorate or provide the fundamental meaning to sustain those born on board despite the constraints on their individual freedom. Likewise, an argument could be proposed that life, even that of mere

[4] The latter, arguably, would permit cultural co-evolution by a constant and lag-free exchange of knowledge development and dissemination. Of course, that would be contingent on the time constraints put on the crew members to engage in scientific and cultural developments given their potentially constrained conditions.

survival, is sufficient to deem it worth living (e.g., Magni 2021). Although this choice may be adopted by the individual decisions of the original pioneers of the generation ship, it cannot be *a priori* abdicated to subsequent generations. As such, the minimum threshold for well-being cannot serve as the exhaustive condition for determining the moral acceptability of reproductive decision-making on generation ships (Glover 2006).

To begin, if we take the minimum threshold for well-being as the criterion for determining the morality of reproductive choices, then the vagueness of what would be considered such well-being would mean that it would be difficult, if not impossible, to determine cases of irresponsible reproductive choices clearly. More precisely, the threshold is not delineated, consequently permitting violations. Of course, this threshold's philosophical and pragmatic benefit is that it is partial to the difference between well-being and a life full of suffering. This means that giving birth to someone who cannot be birthed into or beyond this threshold is absolutely immoral; likewise, it does not morally obligate progenitors to birth children into lives beyond that threshold (even though it is naturally preferable than nought). To a certain degree, the use of this principle exclusively can obtain on Earth, with highly dynamic and unfixed variables that impact the contexts of birth. However, in the highly fixed contexts of generation ships, birth, particularly those selected and directed via embryonic fertilisation and subject to genetic modification, should be gestated if and only if their lives can not only meet the threshold but are allowed to achieve a full and good life.

We thus shift the threshold above that of the classical understanding of the minimum threshold of well-being. Given these available choices (of which embryos and which modifications) we have access to, if we cannot guarantee that the offspring can have a fulfilling life, the crew members shouldn't reproduce. This, of course, undermines the underlying principle of generation ships entirely. Hence, the philosophical principle of this higher threshold for a fulfilling life either morally jeopardises the generation ship project or, more optimally, provides the philosophical norms for ensuring responsible reproductive practices for the future of such ships and eventual exoplanet colonies.

More fundamentally, however, the classical minimum threshold is that it does not make sufficient nuance between the variety in the lives of the offspring that could feasibly be birthed. For example, as long as the offspring has access to the minimally necessary resources for well-being, then it would be considered responsible in this principle to *knowingly* give birth to offspring with physical disabilities such as blindness, anhidrosis, and/or congenital insensitivity to pain, among others even if it were possible to give birth to the offspring without such issues (e.g., see Savulescu 2001: 417; see also Schon et al. 2020). If knowing that the outcome could be directed in a different, better direction, it would be difficult to sustain the position that the minimum threshold of well-being is a sufficient criterion to evaluate the moral acceptability of reproductive choices. Likewise, there is an inherent vagueness in adjudicating when the threshold is traversed. If we consider the same offspring with further illnesses or disabilities, we can reasonably imagine that, for the child, their existence is so consumed by suffering that such a life does not meet the minimum threshold for well-being. This, of course, is a non-subjective perspective. The child itself may be driven to such suffering that they subjectively determine that their life is no longer worth living; however, they may, despite all this suffering, still determine for themselves that

their life is still worth living. However, the principle does not make such distinctions *a priori* and thus undermines itself.

These cases, however, are not necessarily relegated to space *per se*; in fact, the above examples are fairly common on Earth today. Nonetheless, the philosophical underpinnings of such cases can likewise be extended to contexts that may be found on generation ships, i.e., imagining cases in which life on a generation ship would no longer be worth living. Let us imagine a relatively large-sized generation ship that can hold a few thousand crew members. As we mentioned, the relative success of such a mission would more than likely constrain the individual freedom of any given crewmate. To this end, even if a return to Earth mid-journey were technically feasible, it is reasonable to assume that such would not be permitted given that each member would necessarily need to be trained and consequentially contribute labour and a particular set of skills and expertise that are mission-critical (i.e., Pellerin 2009; Galarza and Holland 1999). Hence, given the necessarily multi-generational nature of the mission (aside from the last generation on the ship before arrival), the direct benefits of the work done to ensure mission success cannot be derived by those who are born, live and die on board. Their lives, of course, would be quite good (materially speaking), so it is unlikely they would live lives of great physical suffering. Likewise, the natural periods in which crew members will suffer from psychological issues concerning their constraints of freedom, such as depression and boredom can be feasibly ameliorated via pharmaceuticals or entertainment systems. Even in such cases, where one's life is not their own, but functionally a vehicle for the success of future generations yet to be born does not entail that those living those lives in the present are lives not worthy of being lived.

One may then argue that we can modify such an example by inserting progressively degenerative conditions. Life on the generation ship is necessarily adaptive to the minimum crew necessary for mission success. The ship necessarily functions as a closed system to a degree. However, upon arriving at the new exoplanet, settlement and expansion can begin, necessarily increasing resource demand, something that would not have occurred within the closed system and controlled system of the generation ship. Life within this new settlement, particularly for those born on the ship and settling on the new world, will arguably be more complex and challenging to adapt to. Still, even in this worsening case, the argument cannot be sustained that their lives have ceased to be worth living given the worsening conditions. We would continue to add to this degeneration of states without *a priori* arriving at some logical conclusion where we can determine that the lives of these settlers are no longer worth living. Such conditions can be imagined to be increasable, isolating, constrained, and psychophysically strenuous without logically being able to determine the unworthiness of that life. To remind the reader, these cases are the logical conclusions of the minimum threshold of well-being. The principle makes no distinction between these cases, even where degeneration of conditions *ad absurdum* is present. To remind the reader, we take the position that this principle is flawed for this reason, i.e., that the principle of the minimum threshold of wellbeing is flawed given that it makes no distinction on the wrongness of a child born into a life that is barely worth living (i.e., directly on the threshold).

Beyond this fundamental issue, an issue fundamentally predicated on the vagueness of thresholds is the difficulty, if not impossibility, of objectively setting limits that determine moral responsibility. Likewise, concentrating overly on

establishing such a precise threshold, the principle also misses the mark in its ability to properly characterise the problems and challenges that characterise those lives it aims to evaluate as worthy or not to be lived. Adults could be said to be autonomous in the capacity that they can decide that a sacrifice that necessarily diminishes their well-being is worth it, and thus, their life as a consequence, remains worth living. However, this is different for a child who we may overestimate to be worth living in harsh conditions like those we purport will be most plausible on a generation ship and eventual exoplanet colony. This overestimation, even if made with the best intentions for the child, does not mean our choice is unquestionably morally acceptable. On the contrary, even with the noblest intentions for those offspring, we may nonetheless condemn them to a challenging life that is not worth living. Or, more clearly, it is never acceptable to be born into a life that is barely worth living. The principle of the minimum threshold of well-being would argue that the preceding sentence is morally unacceptable. This is because, as we explained, the principle does not make moral evaluations on progenitors as long as they are above that threshold, even if living at that threshold is one of extreme suffering. (i.e., the principle defends the notion that it is better to be born into a life barely worth living and full of suffering than no life at all). We contend that this is morally irresponsible, given that the slightest change in any person's life at the threshold can instantly make their life no longer worth living.

5. Moral Obligations for Progenitors on Generation Ships

If we then take the stand against the minimum threshold of well-being principle, where does that leave us concerning our moral responsibility and obligations concerning reproduction on generation ships? We argue, similar to that of Julian Savulescu and Guy Kahane, that we not only must *not* have offspring whose lives are barely worth living but, more radically, that we have a moral obligation to give birth to the *best* offspring. Savulescu and Kahane take the position that:

> If reproducers have decided to have a child, and selection is possible, they have a relevant moral reason to [should] select the child, of the possible children they could have, whose life can be expected, in light of the relevant available information, to go best or at least not worse than any of the others (Savulescu and Kahane 2009: 274).

A closer look at this position reveals that logically speaking, it does not present itself as a negation of the principle of the minimum threshold for well-being, which we argued is fundamentally flawed (cf. McMahan 2002: 170; 2009). Consequently, we contend, at least *prima facie,* that Savulescu and Kahane's position does not add any (problematic) moral elements to the issue of reproduction on generation ships. Regardless, we find some problems with their conception of this moral reason they stipulate. Firstly, they argue that progenitors have moral reasons but that there is no clear moral obligation to choose, among the open options of potential offspring they may be presented with, is the best option. Secondly, they relegate their decision for making the best choice to the level of genes. This can be expanded to the potential embryo selection created via reproductive enhancement techniques. Finally, they argue that using the adjective 'best' in reference to the child chosen is never objective but relative concerning the possibilities and *not* the potentials available (Savlulescu and Kahane 2017).

Hence, we can imagine that on the generation ships, the best offspring can be conceived via genetically modified embryos and potentially enhanced to ensure that the child is more resistant to the risks persistent in long-term space journeys. Savulescu and Kahane would argue that there would be nothing morally dubious about having offspring, even with genetic enhancements that were not the best *per se*. We argue that this point is morally criticisable. Even if we choose the best genetic modifications for our offspring does not mean that we automatically put them into a position to have a good life, given the various ethical issues delineated above. This position aligns better with the principle of parental responsibility forwarded by Bonnie Steinbock and Ron McClamrock (1994), which provides progenitors with a more stable condition concerning the selection of how they should support the kind of life their offspring will have and ensure that their life is worthy of living. Parents, hence, should actively conceive of what the best life for their child looks like, rather than a minimally worthy one, and actively endeavour to promote and support such a good life. Logically speaking, should all the arguments in this paper obtain, then the context of generation ships serves as a helpful context that demonstrates that such principles obtain regardless of their loci of application. Hence, what obtains on a generation ship or exoplanet obtain also on our home world, Earth.

6. Conclusions

In this paper, we explored the unique ethical issues that emerge when we consider the concept of generational ships designed for multiple generations to be born, live, and die to fulfil the mission of making humans a multi-planet species. We explored how it may not be *a priori* ethical to give birth on such ships, as is their innate function, simply if we guarantee the offspring a minimally sufficient life worth living, i.e., *de facto* abdicating to them the challenges and sacrifices that their original progenitors assumed when accepting their mission. We argue in this paper that such a position is not morally responsible, and that, before giving birth on such ships, and perhaps in the initial settlements on the destination exoplanets, the progenitors must ensure that their offspring live not only a minimally sufficient life worth living, but also a good life. We argue that human enhancement techniques are a suitable means for achieving both a minimally sufficient life and a good life for offspring on generational ships. Likewise, and philosophically important, the arguments used to support this thesis, if they obtain, obtain also for those currently living on Earth!

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