

# Child Neurodevelopment on Mars

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## ABSTRACT

This review article aims to gather differences and similarities between planet Mars and planet Earth to determine the necessities for the proper growth and development of the neonatal brain. Factors such as Environmental, Nutritional, Social, Stress, and Education are juxtaposed to understand the difference between pediatric neurodevelopment on both planets. The variation between each factor was analyzed to determine how significant the impact is on neurodevelopment for children. The factors to be discussed were generated based on extensive research on what is most important for proper early neurodevelopment. The five factors are the main categories branched out into subcategories to delve into more detail regarding neurodevelopment. Factors may vary based on the location on each planet, but the best average was cultivated to create a fair evaluation of the differences. Although each factor influences a different part of the brain, each factor (Environmental, Nutritional, Social, Stress, and Education) is equally vital for development anatomy and physiology of the brain.

## 1. INTRODUCTION

### 1.1. Purpose

Mars is the most suitable planet, after Earth, for humans to inhabit for several reasons: its location from the sun is optimal, any closer and human life will burn up, any further and human life will freeze. Water is also available in ice form, whereas other planets do not contain ice nor water. However, other aspects of the atmosphere are very harmful to humans, such as the reduced oxygen levels and air pressure. Humans may not live on the ground of Mars just yet, but habitats in the forms of domes will eventually become entire cities in bubbles for humans to thrive in. By the year 2026, Elon Musk, CEO of SpaceX, expects the first human trip to Mars to be successful and cohorts of other humans to arrive every two years after that. This article will expand the knowledge of the community traveling to Mars by focusing specifically on the child brain and its development. As of now, the community is aware of how spaceflight and life on Mars will affect the adult human body, but not much research has been done on the child's brain

from the neonatal stage to the age of 18 years, yet this is a significant population that needs to maintain proper function in order to continue inhabiting Mars. Analysis of previous works can lead to further Mars research which will increase our chances of becoming a multi-planetary population.

## 1.2. Significance





This qualitative study aims to gather differences and similarities between n planets Mars and planet Earth to determine the necessities for the proper growth and development of the neonatal brain. Factors such as Environmental, Nutritional, Social, Stress, and Education will be juxtaposed to understand the difference between pediatric neurodevelopment on both planets [1]. The variation between each factor will be analyzed to determine how significant the impact is on neurodevelopment for children. The factors to be discussed were generated based on extensive research on what is most important for proper early neurodevelopment. The five factors are the main categories that will branch out into subcategories to delve into more detail regarding neurodevelopment. Factors may vary based on the location of each planet, but the best average was cultivated to create a fair evaluation of the differences. Although each factor influences a different part of the brain, each factor (Environmental, Nutritional, Social, Stress, and Education) is equally vital for adequate anatomy and physiology of the brain.1.3.Milestone Neurodevelopment.

## 1.3. Risks

Pathophysiology risks of the brain will also be discussed and the many different components that make diseases or conditions more prevalent on Mars than on Earth. The true significance of this article lies within the risks because this is where the problem to be solved is. The prevalence of certain diseases will undoubtedly vary between the two planets, and adequately assessing the possible neuro conditions and preparing will prevent further complications. These prevailing diseases will prevent the genealogy's success on Mars and must be noted before birthing children. An ethical component is also present when determining if a generation should be born on Mars and rooted to live there. If a child is born on Mars, researchers suspect they will not be able to travel to Earth because of the compressed pressure to which the bones are not accustomed. However, children born on Earth can travel to Mars, which causes a disadvantage for children born on different planets. Another risk of being born on Mars, especially as one of the founding generations, is all the unknown risks. Many people will pass away during the first cohorts due to mistakes, technical errors, and uncontrollable factors. The question begs—should children be born into this kind of lifestyle? Will space travelers resolve enough of the conflicts before repopulation is needed? Although the risk is a barrier, it can be overcome with the proper research and knowledge prepared beforehand to lead humans on a successful mission.

## 1.4. Milestone Neurodevelopment

The CDC, Centers for Disease Control and Prevention has developed an insightful database that mentions the important milestones for children and their brain development. The website contains a printable tracking sheet, a link to a mobile app, and literature on the stages a child will move through. This article contains an original figure summarizing the main milestones that will be important to track while on Mars. **Figure 1** (shown below) indicates the four main categories to be monitored: social/emotional, language/communication, cognitive, and movement/physical milestones. Space Travelers need to be aware of the milestones because most brain development occurs before the age of 18; thus, signs of long-term conditions will be present at an early age if not detected. At birth, the brain is 1/4 its full size, and the most important milestones to check for will be present around two months post birth. Signs to look for are as follows: begin to smile at people, self-soothing, look at parents, coo and gurgle, react to sounds, follow and focus on people, cries when there is no change in activity, hold head up, make smoother movements. By 1.5 years (18 months), the brain will be 1/2 of its adult size, indicating that much growth has already occurred and the risks of deficits are present if milestones were not tracked. At 18 months, the child should be able to do the following: begin to interact with others by playing, cling to caregivers, avoid strangers, use several words to point to needs, know everyday objects, follow verbal commands, walk alone, drink,

<b>Birth</b>	<b>1.5 years</b>	<b>6 years</b>	<b>18 years</b>
1/4 full size	1/2 full size	9/10 full size	Full Growth
			
<b><u>2 months</u></b> <b><u>Milestones</u></b>	<b><u>1.5 year</u></b> <b><u>Milestones</u></b>	<b><u>6 year</u></b> <b><u>Milestones</u></b>	<b><u>Adult</u></b> <b><u>Milestones</u></b>
<ul style="list-style-type: none"> <li>-Begin to smile at people</li> <li>-Self soothing</li> <li>-Look at parents</li> <li>-Coo and gurgling</li> <li>-Reacts to sounds</li> <li>-Follow and focuses on people</li> <li>-Cries when no change in activity</li> <li>-Hold head up</li> <li>-Make smoother movements</li> </ul>	<ul style="list-style-type: none"> <li>-Begin to interact with others by playing</li> <li>-Cling to caregivers, avoid strangers</li> <li>-Several words</li> <li>-Points to needs</li> <li>-Knows common objects</li> <li>-Follow verbal commands</li> <li>-Walk alone</li> <li>-Drink and eat independently</li> </ul>	<ul style="list-style-type: none"> <li>-Wants to please others</li> <li>-Agrees with rules</li> <li>-Wants to play, dance, sing, act</li> <li>-Speaks clearly in full sentences</li> <li>-Can print shapes, letters, numbers</li> <li>-Knows about daily functions</li> <li>-Full development of movement</li> </ul>	<ul style="list-style-type: none"> <li>-Fully functioning and independent in all the following categories discussed to the left:</li> <li>Social/ Emotional</li> <li>Language/Communication</li> <li>Cognitive</li> <li>Movement/ Physical</li> </ul>

**Figure 1. Neurodevelopment Milestones to consider on Mars.**

and eat independently. The following important milestone is that by the age of 6 years, at this point is 9/10 of its full size. Most of the child's behavioral and cognitive components have been developed and will be expanded upon or changed due to external influences. At the age of 6, the child should be preparing or at school because they can now be semi-independent from the parents and will go on to learn math, reading, science, etc., to further the brain's intellectual abilities. The milestones that must be met before this can occur are as follows: wants to please others, agrees with rules, wants to play, dance, sing, act, speaks clearly in complete sentences, can print shapes, letters, and numbers, knows about daily functions, full development of the movement. The next milestone is a fully developed brain at the age of 18 - 25, where the child, now an adult, should be fully independent in all aspects of life and is now ready to complete their own life, reproduce, and ensure their children meet all the necessary milestones to fulfill the same cycle.

## **2. ENVIRONMENT**

The physical environment in which a child is born and raised plays a vital role in the development of the brain. Individual neurons can be directly affected by the physical environment and lead to detrimental early damage to the brain. On Earth, the environment favors human life by creating an equilibrium that provides the brain a safe location to flourish in. However, on Mars, the environment varies from that of Earth, and this will undoubtedly lead to changes in the early brain.

### **2.1. Gravity**

Gravity is the first concern that comes to mind when people mention space travel, and rightfully so as this is a crucial issue since it affects the entire human body, including all human body systems. Gravity is essential for the proper development of the neonatal brain until the age of 25 years when the brain is at its

peak of development. On Earth, gravity measures  $9.8 \text{ m/s}^2$ , while on Mars, gravity measures  $3.7 \text{ m/s}^2$ , which is a 62.2449% decrease [2]. This substantial change in the amount of gravity affects daily functions such as walking, bathing, and exercising but also causes mechanical trauma to the brain. The brain is more malleable at such an early stage, and any off-putting movement can cause damage. According to a study done in low gravity, “intracranial fluid shifts, gray matter changes, and white matter declines” will be a few of the risks associated with low gravity on Mars [3]. Intracranial fluids are especially important for the younger brain since the fluid provides a safe suspension for the brain to reside in. Without this fluid, harm is more likely susceptible, and with shifting intracranial fluid, there is less support present. Intracranial fluid also provides nutrients to the immature brain, such as glucose, proteins, lipids, and electrolytes, aiding in keeping the younger brain well-nourished and neuron cells stabilized. As stated previously, the gray matter will also be altered. Gray matter is vital in the pediatric neurodevelopment stage because as the child grows from neonatal to adolescence, gray matter continues to thicken and store a large part of the necessary neuronal cell bodies. Neurons are responsible for muscle control which will aid the child’s first step on Mars. Gray matter neurons also play a significant role in sensory perception, which is vital on Earth and Mars. However, they will certainly aid with the busy and impactful life the first Mars generation will have to live by reporting to Earth using all five senses (sight, touch, hear, smell, and taste). White matter is the myelin sheath that protects the axons of the brain, which send signals to nerves throughout the body, and takes twice as long to develop as gray matter; therefore, it must be maintained to ensure proper neurofunction. With a decline in white matter, the axons will no longer be shielded from any physical trauma the brain may experience. Damaging those axons will lead to a disconnect between the brain signals and the rest of the body. A decline in white matter will lead to several deficits as Mars children grow older, including delayed memory, linguistic conflicts, and spatial recognition loss, along with several others since axons transfer all information from the brain to the body and without them, neither can function to the fullest. Gravity will affect the child brain by increasing the susceptibility to mechanical trauma. The brain’s physical elements will be altered, thus resulting in less protection and causation of deficits in bodily functions that are programmed by the brain’s connections.

## 2.2. Oxygen

As stated previously, humans will not be able to reside on Mars without being in a controlled room or attire that provides oxygen with a secure flow. Oxygen on planet Earth is about 21% of the atmosphere and on planet Mars Oxygen is 0.13% of the atmosphere. The difference between the two planets calculates to a 99.381% decrease in oxygen from Earth to Mars. According to The Cleavand Clinic “cerebral hypoxia or hypoxic-anoxic brain injury” occurs when oxygen is not steadily applied to the body [4]. Therefore, this may be a very prevalent injury on Mars if a seal is broken in an oxygen-controlled room or if the glass breaks on an oxygen helmet. Many different scenarios can leave a space traveler in a situation in which the brain will not receive oxygen. The effect of undergoing cerebral hypoxia causes “brain cells to die within 5 minutes of low oxygen.” If a child undergoes hypoxia, the child may die or develop several complications due to cell death, several complications could occur since the brain is still growing. Having a loss of brain cells at a young age will cause two major changes to the younger brain. The 1st suspected change would be very noticeable in memory loss since memory function develops tremendously at the age of 18 and under. The next major decline will be in motor function. Most hand functioning properly since many of the foundational human movements are practiced before the age of three years old. The solution to saving a child who has lost oxygen flow is to “quickly restore oxygen flow to the brain... and perform CPR” if breathing stops completely [5]. Cerebral hypoxia can be prevented on Mars with the correct precautions being taken but if it were to occur a quick reaction time to the incident will greatly reduce the long-term consequences.

## 2.3. Temperature

Temperature varies on both planets based on location, for example being farther or closer to the

equator can result in a range of temperatures, but the averages have been computed to provide the best comparison. The average temperature on Earth is 14°C and on Mars is -63°C, presenting a 550% decrease in average temperature from planet to planet [6]. This very concerning statistic will unquestionably pose a risk to the children on Mars. Hypothermia will be a more prevalent condition on Mars than Earth due to the decrease in temperature and lack of supplies and/or protection. “Hypothermia in infants and newborns can cause psychological and neurodevelopmental disturbances in survivors” [7]. Besides neurodevelopment, psychological occurrences for children on Mars will be a major factor affecting their lives. Reducing trauma and fear for the kids will be the ultimate goal to maintain a healthy mental state. Undergoing a hypothermic experience can certainly lead to negative implications for the child and in the future lead to anxiety, depression, and PTSD (Post Traumatic Stress Disorder) inflicted by the occurrence. Along with psychological consequences is the neurodevelopmental factor in surviving hypothermia. According to a study done with children on Earth who experienced an episode of hypothermia, “cognitive, language, and motor development were assessed with the Bayley Scales of Infant and Toddler Development, Third Edition (BSITD-III)”. A positive discovery was made indicating the scores of unaffected children “may not be significantly different from those of survivors” [7]. Thus revealing that hypothermia may not have a very significant effect on neurodevelopment as some of the other factors previously discussed but the risk is still present. Also to note, the psychological component is one that matters greatly in surviving hypothermia since it will alter the mental health of a child. Similar to oxygen, temperature can be easily regulated with the proper equipment and technology on Mars so although hypothermia is a risk, being knowledgeable about treatment and careful with actions will yield better results for the children of Mars.

### 3. NUTRITION

The nutrition in which a child receives impacts the development of the brain. Nutrition is especially important to babies while in the womb and throughout infancy. Proteins, Lipids, Carbohydrates, Minerals, and Vitamins are all extremely necessary for the brain to fully develop. On Earth, humans have a thorough understanding of how to nourish a baby to phenomenal health when all is provided but on Mars getting the supplies necessary will be a challenge on its own. Hopefully Space Travelers will already have a solution so that food can be grown and replanted to provide proper nourishment but all scenarios following will assume that there are still complications with attaining full nutrition from this solution.

#### 3.1. Vitamins and Minerals

Proper vitamin and mineral health is difficult to attain even on Earth, with iron deficiency being one of the most common deficiencies for all ages. The risk on Mars for a child to miss the adequate amounts of substance could possibly lead to malnutrition, depending on the severity of the case, causing significant consequences within the brain. For child brain development, lacking vitamins and minerals is “concurring with sensitive or critical periods early in life [which] results in long-term dysfunction” [8]. In order to alleviate the long-term dysfunctions caused by malnutrition it is important to note which vitamins are most necessary at such a young age. For example, for a neuron to grow and function properly “Proteins, Carbohydrates, Iron, Copper, Zinc, LC-PUFA (Long-chain polyunsaturated fatty acids), Iodine, Vitamin A, Vitamin B6, Vitamin D, Vitamin C” are all necessary in order to prevent damage to the “Global, Hippocampus, Striatum, Cortex, and Retina” [8]. A considerable way to attain all the essential vitamins is through the mother’s breast milk, assuming she is getting proper nutrition and living a healthy lifestyle. The brain also craves more of the essential nutrients at young stages such as the neonatal and till the age of 2 years since this is the time in which the brain is growing so rapidly. Being that the change is so rapid, any gap in nourishment can cause significant damage to the brain such as a decrease in brain volume and neurons present. All of these conflicts will lead to dysfunctions mentioned previously, the conflicts being a delay in learning and lack of memory. Once more putting the children of Mars inferior, in terms of health, if no solution is provided.

### 3.2. Water

The Earth is covered with about 70% water whereas Mars has no liquid water, only in the form of ice. Being that human's use water on a daily basis for many different activities this will be a major challenge for space travelers. Luckily, a rover has been created that can extract water from the soil on Mars. However, scholars must always assume the possibilities for failure. Therefore dehydration may occur on Mars and of course this will impact the child brain as human brains are about 73% water. A study conducted on mice sought out to determine the effects of dehydration on a developing brain and found "dehydration significantly dysregulated long-term potentiation signaling and specifically decreased hippocampal brain-derived neurotrophic factor (BDNF) expression" [9]. Analyzing these results, the decrease in hippocampal brain-derived neurotrophic factor can lead to complications such as memory impairment but also create a large anatomical problem. The BDNF is responsible for leading the production of proteins found in the brain and spinal cord. If the factor is absent there will be a lack of neurons, and healthy spinal fluid which completely deteriorates the pathway for the brain to communicate with the rest of the child's body. Water is an important polar molecule for several reasons but one of the most important functions is to provide for the brain thus signs of dehydration in children on Mars should be constantly monitored.

### 3.3. Food

Food will not be as readily available on Mars as on Earth and therefore it is important that we assume the risks associated with pediatric neurodevelopment. When a child does not receive the nutrients and vitamins that are needed to develop the brain properly there is a physical lack which also leads to a psychological lack. Being aware that there may not be food to eat each day can lead to undue stress. A study completed on 99 human subjects indicated a significant "correlation between poorer nutrition status and level of psychological distress" [10]. Although a child may be too young to realize they are being undernourished the brain recognizes the issue and undergoes shock. The change can reflect many different mental disorders for a child such as "severe fatigue, insomnia, anxiety, and depression" [10]. The only solution to prevent mental trauma to the brain, such as the ones listed above, is to plan and prepare for the flight and time on Mars in terms of food. This will reduce the risk of psychological damage to the brain for the children and offer them better mental health as they age. When the brain has no psychological conflicts this yields a more successful neurodevelopment so it is important that the brain is well fed to fulfill all requirements, food health and mental health.

## 4. SOCIAL

The social atmosphere in which a child lives can affect the brain both physically and mentally. Changes in a social climate, especially at a young age, can lead to significant changes in the brain. Although social structures vary based on culture and locations around Earth the most common format for a child is to have a mother and father with possible siblings. Children also attend school starting at the age of 4 - 6 till 18 years in order to socialize with others their age. This "average" social layout is not a must for proper neurodevelopment but lacking an alternative positive social layout can lead to negative implications which will be discussed in the following subtopics.

### 4.1. Family

A standard family consists of a mother, father, and children, sometimes including grandparents, aunts, uncles, and cousins. This is just the members present in the family but other components of family such as "family socioeconomic status, family composition and home environment, parenting behaviors and interaction styles, parental mental health and functioning, and parental substance use" affect the child brain [11]. It is important that on Mars, the children have a safe, caring, and providing family present in order to aid the child in daily activities but also to promote healthy brain growth. A negative family environment can lead to destruction of a child's "motor and sensory development, temperament, cognitive

abilities, and behavioral and emotional responses” [11]. These symptoms are similar to many neurodegenerative diseases but one common disease that relates to structure and child behavior is Autism. Autism is not caused by a failed family structure but according to Autismspeaks.org “autism develops from a combination of genetic and nongenetic, or environmental influences.” However, having that family structure present and willing to help the child flourish in therapies and supporting them 24/7 to increase social capabilities is important. This is the same as applied on Earth but space travelers just need to be cautious if they start noticing any of their children need additional attention such as a child with Autism, ADHD, Down syndrome because family assistance can make all the difference for the child and their neurodevelopment. Besides caring for the child the parents must take care of themselves. While trying to reproduce, the parents must remain healthy and avoid toxins such as drugs and alcohol. Genetic testing is also an option for parents to undergo before choosing to have a baby on Mars because this may reveal the percentages of the child having a disease passed through the genes. Parents will have many roles while being on Mars and their mental health is just as important as the children’s.

#### 4.2. Maternal Care

Parental care is vital to the development of a child, including the child’s brain, but maternal care is just as important in an independent role. As discussed in previous sections (3.1 Vitamins and Minerals) breast milk from the mother can have positive impacts on the child brain but the presence of a mother can too. In a study conducted it was found that “hippocampal volume increased faster with age among subjects with higher levels of maternal support” [12]. An increase in hippocampal volume leads to higher functioning memory and increase in BDNF (discussed in 3.2 Water). Both of these increases will have positive implications on the child brain and therefore practicing time with the mother is important on Mars. Having the maternal support on Mars from a young age and throughout adulthood will lead to a higher success rate of proper brain development for the child. Not having a mother will not destroy the child’s brain, but having that extra support increases the chances of having less neuronal complications. All Space Travelers, especially females should consider all the roles that must be fulfilled while on Mars including: Mars duties (such as projects, exploring, etc.), and Maternal duties (such as feeding, bathing, caring, and supporting a child) before making the difficult decision to nurse a baby to health on a foreign planet. The decision must be considered because the mother plays a fundamental role in the child’s wellbeing and development as they age.

#### 4.3. Other Peers

On Earth there are about 385,000 babies born per day (according to the UN). On Mars there are 0 babies born per day, at least for now. The significance of this difference is that on Earth children have many peers near their age to socialize with while on Mars the first groups of people will have varying ages and not many of similar age groups. Children on Mars may struggle to find friendly companions as they do on Earth, especially if a school is yet to be established. In the beginning, finding peers may be a problem but as the Mars generation develops this problem will decrease. For now, it is important to note how the first generations will cope with this obstacle because they are the foundation of the future generation. Social deprivation is the coined term for when adolescents do not receive the adequate amount of social interaction. The term can be used for any age group but adolescents seem to be the age group that relies on social interactions the most. A study done with rodents was conducted to see how the brain is affected by social isolation which presented “structural and functional changes in the brain, most prominently in neuromodulator dopamine and serotonin systems and particularly within cortical and striatal targets” [13]. All of these changes are detrimental to the development of the adolescent brain and can lead to “behavioral changes such as increased anxiety and hyperactivity” [13]. Both anxiety and hyperactivity provide a brain that is in a disrupted equilibrium and can disrupt the proper development. It is important that adolescents have access to children their age and can socially interact with in order to reduce the risks of anxiety and hyperactivity.

## 5. STRESS

Stress defined as a disturbance or damage to the natural state is the type of stress to be discussed in the following subtopics. Stress defined to this capacity can include stress to the environment, mental stress, and bodily stress. The different modes of stress bring a lot of unknowns but will certainly impact the development of children's brains on Mars.

### 5.1. Mother's Mental Health

Mental health is essential to all humans both on Mars and Earth, but it is important to note the risks of how a mother's stress will impact a child during pregnancy on Mars. Even beyond the term of pregnancy the mothers on Mars will undergo much stress that will translate as the children develop. Mothers in space experiencing traumatic events such as spaceflight, crew members passing, lack of supplies and/or support "may have negative effects on fetal and infant neurodevelopment, including delayed mental and motor development, difficult temperament, and impaired cognitive performance" [14]. All of these impacts will result in a decrease of quality of the child's life as they grow older. Although the events brought upon the mother were not her doing, having the proper support and psychological care can reduce the amount of stress induced to the mother thus decreasing the consequences for the child. Science has proven that there is a link between the mother's stress and the child's development concluding that "children born to mothers who experienced high levels of anxiety in the early second trimester of pregnancy had region-specific reductions in gray matter volume and impaired executive function in middle childhood" [14]. As discussed previously (2.1 Gravity), gray matter is essential to pediatric neurodevelopment since it develops and changes with the child. Gray matter is tasked with storing a large part of the necessary neuronal cell bodies all of which are extremely important and any significant reduction can lead to damage of the brain and communication with the rest of the body. Impaired executive function is not diagnosed as a single condition but paired together with other mental diseases. Essentially executive function disorder is a set of mental skills that control a child's ability to organize themselves and control their behavior and can be connected with other conditions such as ADHD and Autism. With the guidance of a mother, executive function can be improved upon alongside proper therapies and support.

### 5.2. Weather Changes

Weather on Mars will be dissimilar to that of Earth and this will be a stress to the environment and to the humans inhabiting the area. Besides temperature, vast dust storms will be a problem that space travelers will have to face and to protect their children from. Past dust storms have been so strong that the solar panels of rovers on Mars have been completely covered and were not able to recuperate. Children undergoing huge storms, such as the dust storms, more often than storms on Earth can lead to ramifications on their mental health such as "symptoms of posttraumatic disorder depression, and anxiety" [15]. Studies done around the world comparing groups of different children all experiencing traumatic weather but in different forms such droughts, tsunamis, tornadoes, and hurricanes all had common elements. Thus, revealing that these symptoms should translate to Mars with the dust storms since dust storms are not prevalent on Mars, as mentioned previously. One common element to be found is that children "self-reported themes of grief and loss" which is alarming because this indicates that they are reaching out for help and are truly feeling the effects of in climate weather [15]. As time persisted the recovery time of the children was studied and it was found that this statistic varies vastly from child to child, even if being in the same weather event. The suspected difference relates to the presence of "resiliency, coping skills, and support networks" that the children had at their disposal [15]. Once again revealing the importance of family and mental health support while inhabiting a foreign planet. The entire recovery trajectory can be altered with the right family members present and lessons taught from a young age. The part of the brain that controls learning such as those resilient and coping skills is the cerebrum however this part of the brain may not be fully developed until the age of 18 to possibly 25. Thus proving why children suffer more from traumatic weather events compared to adults and need that extra support and protection during the foreseen dust



storms.

### 5.3. Infection: Bacteria, Virus, Parasite

On Mars the microbe agents such as bacteria, parasites, and viruses will be dissimilar to that of Earth since the evolution varies. The risk of infection increases immensely since Space Travelers will be unaware of the agents that will be present on this foreign planet. On Earth, some viruses, bacteria, and parasites have caused “alterations in fetal brain structural anomalies including brain calcifications and hydrocephalus” [16]. Brain calcifications can lead to many behavioral and psychological disorders for the child as they grow. Some of the possible conditions could be dementia, Parkinson’s, seizures, and psychosis. Doctors hope that signs of infection will be translated from Earth to Mars, that way it is easy to detect when an infection has occurred so it can be managed before any long term consequences have been determined. Hydrocephalus is also a risk when it comes to microbial infections. This occurs when there is a buildup of fluid in the child brain which causes an increase in pressure against the brain. Due to the increased pressure, the child’s head may begin to swell and disturb the fontanel (soft spots in the young skull) leading to complications as they grow older. Complications can consist of learning disability, reduced memory, and seizures. The risk of infections causing hydrocephalus and brain calcifications is present on Mars but not for sure, as stated previously the microbial agents present will be different from Mars so it is hard to predict until humans get there. However, it is important to assume the risks and assume severe cases in order to prepare for the future.

## 6. EDUCATION

Education is extremely important to the brain as humans now rely less on natural instincts but learn from their parents and other social beings around them. In order to aid with proper education for children on Earth, schools have been established that provide children with academic and social skills. For the first generations on Mars, schools may not be as established and on Earth therefore the children will have to gain the knowledge through other means until a full solution is provided.

### 6.1. Physical Activity

On Earth, the CDC recommends children between ages 6 - 18 exert energy to build muscles and bones for at least 60 minutes a day or more. Toddlers should practice even more physical activity summing to about 120 minutes per day. Exercising is not only good for the muscular, skeletal, cardiovascular, and respiratory systems but also extremely important for brain development thus should be practiced on Mars just as much as on Earth. Due to the lack of gravity, children will need to undergo physical activity more often on Mars than on Earth. For adults the Earth to Space exercise time ratio is 30 minutes: 2 hours so for children that would be 1 hour: 4 hours. This may seem to be too much time out of a child’s day but it is necessary to reduce bone and muscular atrophy and will be altered based on results when on Mars. Besides the risks of atrophy, the brain also thrives on physical activity. In a research conducted it was found that “not all forms of aerobic exercise benefit executive function equally” [17]. As mentioned previously (5.1 Mother’s Mental Health), executive function is a set of mental skills that control a child’s ability to organize themselves and control their behavior which is exactly what school on Earth is designed to teach children. In order to benefit, executive function exercises must include “cognitive demands inherent in the structure of goal-directed and engaging exercise [and] cognitive engagement required to execute complex motor movements” [17]. For children, the recommended form of these exercises would be group engaging games that include running or other aerobic movements. Also to note, aerobic movements provide more oxygen to the brain which increases hippocampal function which increases opportunities for learning and memory. “Cognitively-engaging exercise appears to have a stronger effect than non-engaging exercise on children’s executive function” and is a viable option for children on Mars being that they are kids and would love to play with their peers and account that encounter as exercise [17]. Parents should be aware and promote the best types of exercise to enhance executive function as it is paramount to pediatric neu-

rodevelopment.

## 6.2. Mental Games

Along with the development of school is the academic portion for young children, where they learn the fundamentals that will be needed as adults such as learning how to read, compute basic math, and analyze scientific scenarios. All of this is vital to growing into a successful adult and can be furthered with the use of mental games while not in school. This practice can be completed both on Mars and Earth but will be more needed on Mars if there is a deficiency in school for the first generations. Mental games would include activities such as puzzles, arts and crafts, and role playing all of which are fun for children but help develop the brain in other ways that math and reading do not. A study conducted discovered that “puzzling strongly engages multiple cognitive abilities and long-term” memory [18]. Puzzles can be started from the time children start to sit up independently, around the age of 6 - 8 months, and should be practiced if enjoyed throughout their lives. Arts and crafts can also be seen as a type of puzzle if you have an end goal of what the child is designing. There are many ways to incorporate different types of puzzles throughout daily life and parents should implement them. Puzzles increase “multiple visuospatial cognitive processes including perception, constructional praxis, mental rotation, speed, flexibility, working memory, reasoning, and episodic memory” [18]. All of these capabilities increase brain function and aid in neurodevelopment, especially working the parietal lobe with spatial reasoning. The parietal lobe develops by the age of 5 so mental game training must be applied as early as possible to yield the best results.

## 6.3. Virtual Component

Technology is around humans every minute of every day on Earth and the same will be for Mars since technology is the consequential factors that will bring us to Mars. Screens that warn Space Travelers and provide advice on next steps, phones similar to the ones on Earth, and all machines to help sustain life will be prevalent every day. For children, blue light is not something they should experience at such intense levels. Although kids on Earth also experience screens frequently, negative consequences are present but many parents do not notice since they too were raised with screens for part of their lives. There is a difference between screen time for viewing and screen time for the use of technology but at such a young age the screen is only used for means of viewing. A research completed showed that “more than 2 hours/day by infants younger than 12 months [cause] significant language delays” [19]. Broca’s area is the region of the brain in which language delays present themselves and this part develops by the age of 18 months. Prior to 18 months, it is crucial that parents speak, read, and socialize with their children in order to develop Broca’s area and avoid screen time as a replacement for teaching the children, being that the screen does more harm than support. Further research concluded that “cognitive abilities, especially related to short-term memory, early reading and math skills and language development” were also affected due to prolonged screen time exposure [19]. Essentially, the skills that are developed at school or based on a school based curriculum are counteracted by the prolonged use of screen time. Parents on Mars should not allow screen time but instead encourage their kids to go out and play with other friends and perform aerobic activities as discussed previously (6.1 Physical Activity). Encouraging this type of behavior will increase executive function and decrease the risk of language delays.

## 7. CONCLUSION

Inhabiting Mars will be a feat for the human race but is entirely possible with the proper research, plan development, and of course adequate care for the children as they will be the next generation to continue the mission. The development of the child brain while on Mars should be the concern for all adults hoping to create a successful genealogy. From reading this article, the hope is that other scholars will design a safe and viable planet, based on the factors discussed, to create a healthy and prosperous genealogy on Mars with the ability to travel to and from Earth and Mars without medical complications. Further-

more, learning about the anatomy, physiology, and pathophysiology of the young brain and its suitable development will allow for solutions to be constructed.

## CONFLICTS OF INTEREST

The author declares no conflicts of interest regarding the publication of this paper.

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