University of Tartu
Faculty of Social Sciences
Institute of Psychology

Andres Käosaar

FANTASTIC TEAMS AND WHERE TO FIND THEM: UNDERSTANDING TEAM PROCESSES IN SPACE AND ANALOG ENVIRONMENTS THROUGH THE IMOI FRAMEWORK

Master's thesis

Supervisors:
Pedro Marques-Quinteiro, PhD (*William James Center for Research, ISPA – Instituto Universitario, Lisboa, Portugal)*
Shawn Burke, PhD (*University of Central Florida, Orlando, USA)*
Andero Uusberg, PhD (*University of Tartu, Tartu, Estonia)*

Tartu 2021

Fantastic teams and where to find them: understanding team processes in space and analog environments through the IMOI framework

Abstract

This master's thesis is based on a research paper[1] aimed to propose a synthetic model of teamwork effectiveness in space and analog environments (SAE). A systematic literature review approach was adopted to examine the state-of-the-art of the teamwork literature in SAE. Thirty-six research papers were reviewed, and the results were organized according to the Input-Mediator-Output-Input (IMOI) framework.

The findings suggest that the teams working in SAE are challenged with contextual (e.g., time, isolation, and confinement), collective (e.g., autonomy, culture), and individual (e.g., personality) attributes. These are inputs to team processes (e.g., interpersonal processes; communication) and emergent states (e.g., climate; emotions), which mediate team outputs such as team performance, team cohesion, and psychological well-being. The extracted connections are described, and a coherent model is proposed.

This paper focuses on the SAE teamwork literature from a proven perspective but new angle, proposing an original coherent model for structuring the related variables. It furthers both theory and practice, emphasizing important aspects on which space organizations should additionally concentrate regarding long-duration space exploration.

Keywords

Team Processes; Effectiveness; Teamwork; Space analog environments; Extreme teams

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[1] The paper was submitted to the journal Team Performance management on 10th of February 2021 and received back with review's comments in 10th of April 2021 with a deadline of revised submission in 10th of July 2021

Fantastilised meeskonnad ja kust neid leida: meeskonnaprotsessid kosmoses ja analoogkeskkondades läbi IMOI raamistiku

Kokkuvõte

Käesoleva magistritöö aluseks on teadusartikkel[2], mille eesmärgiks oli püstitada erinevaid kosmoses ja kosmose analoogkeskkondades (*space and analog environments* – SAE) töötavate meeskondade meeskonnatöö aspekte hõlmavaid muutujaid ühendav mudel. Mudeli loomiseks viidi läbi süstemaatiline kirjanduse ülevaade, mille käigus leiti kolmkümmend kuus huvipakkuvaid aspekte kirjeldavat teadusartiklit. Leiud organiseeriti sisend-vahendaja-väljund-sisend (*input-mediator-output-input* – IMOI) raamistiku järgi.

Uurimuses tuvastati kolme tüüpi sisendeid, mis SAE meeskondi mõjutavad – kontekstuaalsed (ajataju, eraldatus ja kitsad elamistingimused), meeskonnaülesed (nt autonoomsuse määr, organisatsioonikultuur) ja individuaalsed (nt isiksus). Need sisendid on käivitajateks meeskonnaprotsessidele (nt indiviididevahelised protsessid, kommunikatsioon) ja avalduvatele seisunditele (nt sotsiaalne kliima, emotsioonid), mis vahendavad mõju meeskonna väljunditele nagu meeskonna sooritusvõime, ühtsus ja psühholoogiline heaolu. Seoste kirjeldustele vastavalt on muutujad organiseeritud terviklikku mudelisse.

Käesolev töö keskendub SAE meeskonnatöö kirjandusele ennast tõestanud perspektiivist (IMOI raamistik), kuid uue nurga alt, kirjeldades originaalset terviklikku mudelit, et seotud muutujaid organiseerida. Töö täidab olulist lünka kaasaegses ekstreemsete keskkondade meeskonnatöö kirjanduses ning pakub praktikutele võimalust saada tervikpilti erinevatest olulistest seotud muutujatest.

Märksõnad

Meeskonnaprotsessid, efektiivsus, meeskonnatöö, kosmos ja kosmose analoogkeskkonnad, ekstreemsed meeskonnad

[2] Artikkel esitati avaldamiseks ajakirja Team Performance Management 10. veebruaril 2021. Artikli retsensentide kommentaarid saadeti autoritele 10. aprillil 2021 ning tähtaeg täiendatud töö esitamiseks on 10. juuli 2021

1. Introduction

Human performance in space and analog environments (SAE) has granted humankind some of our greatest achievements. We have explored the South Pole, reached Mariana's trench, and walked on the Moon. In the years to come, the goal is to establish a permanent human presence on the Moon and set foot on Mars (Dunbar, 2020).

However, the extent to which we will be psychologically capable of performing such missions remains uncertain (Salas et al., 2015). Although space agencies (e.g. Eurpean Space Agency (ESA) and National Aeronautics and Space Administration (NASA)) have highlighted the importance of addressing the psychological drivers of effective teamwork during short and long duration space missions (ESA, 2016), most empirical (Tafforin et al., 2019) and theoretical (Leon and Sandal, 2003) contributions on human performance in SAE have focused on individual psychological aspects such as mood (Sandal et al., 2011) and personality (Kjærgaard et al., 2015), thus neglecting teamwork.

The number of contributions specifically focusing on the drivers of effective teamwork on SAE is scant. This should be regarded as a meaningful gap in the space-related human performance literature since most ongoing and future space operations will be performed by teams (Salas et al., 2015). This paper addresses this gap by reviewing research on teamwork in SAE (Cook et al., 1997). Through this research we will highlight the main research findings and present a synthesis of the research literature.

1.1. Teamwork theories: A brief overview

The focus of the current research is on teams who operate in space and space analog environments. Teams, crews and small groups are regarded as synonymous, i.e. two or more interdependent individuals that perform under task conditions that may vary on a continuum of very high to moderate demand (Driskell et al., 2018). The teams in focus are subject to difficult working and living conditions, persistent danger, and a wide range of other challenging stressors (Golden et al., 2018).

Two contributions that offer a rich description of how teams work are the episodic theory of group processes (Marks et al., 2001) and the input-mediator-output-input framework (IMOI) of team effectiveness (Ilgen et al., 2005). The episodic theory of group processes argues that teams perform across episodes over which performance accrues and feedback is available. Episodes consist of transition phases (i.e., when teams focus primarily on evaluation and or planning activities) and action phases (i.e., when teams are engaged in acts that contribute directly to goal accomplishment).

Following the IMOI framework, inputs regard those variables steaming from individual (e.g., personality), group (e.g., team familiarity), and contextual (e.g., environment) factors that trigger group behavior over time. These can be stable individual attributes such as knowledge, or contextual factors such as internet access.

Mediators, team processes and emergent states, usually regard psychological variables (e.g., mood, emotions) and collective behaviors (e.g., coordination, leadership) (Marks et al., 2001). Whereas team processes are comprised of team members' interactions (e.g., coordination; proving back-up), emergent states are comprised of the cognitive, motivational, and affective states of teams (Golden et al., 2018; Marks et al., 2001). Team processes include transition processes, (i.e., those more common during transition phases) action processes (i.e., those more common during action phases), and interpersonal processes (i.e., those that happen across transition and action phases, when team members manage relationships and build motivation). Across transition and action phases, team processes and emergent states are the main drives of teamwork outcomes such as performance, satisfaction, and cohesion (LePine et al., 2008; Mathieu et al., 2019) - outputs are the results of teamwork and can include both objective and subjective dimensions of effectiveness. Finally, the inputs in the last I in the framework acronym (IMOI) represent an ongoing cycle of input-mediators-outputs where the outputs of one cycle will feedback as inputs of the next cycle (Ilgen et al., 2005).

2. Articles search and selection

Following the Systematic Literature Review (SLR) guidelines (Cook et al., 1997; Tranfield et al., 2003) we begun by defining the criteria to search, filter and retain research papers. Next, we organized these according to the episodic theory (Marks et al., 2001) and the IMOI framework (Ilgen et al., 2005). Finally, we elaborate several conclusions about the lessons learned about teamwork in space.

All these steps were conducted by the author of the thesis. The supervisors guided the execution of the method, aided with compiling the findings, and reviewed the written part regularly.

In June 2019, as the first phase, three rounds of searches were conducted. In each round, apart from one exception, the search was conducted in the following repositories: EBSCOhost database, Web of Science, NASA ADS, Acta Astronautica database and the Journal of Human Performance in Extreme Environments database. The articles were retrieved based on the relevance of their titles to psychology and SAE. No temporal range criteria were set as a restriction.

For the first round, the following keywords were used: *(psychological OR emotional OR non-physical OR cognitive OR neurological OR behavioural) AND (space OR zero gravity OR extreme OR arctic) AND (team* OR astronaut* OR individual).*

For the second round, the following keywords were used: *(psychological OR emotional OR non-physical OR cognitive OR neurological OR behavioural) AND (space OR zero gravity OR extreme OR arctic) AND (team* OR astronaut* OR individual) AND (danger* OR risk OR harm* OR threat OR issue* OR effect*).* In the second round the search was also conducted in the Erasmus Experiment Archive database.

For the third round the following keywords were used: *(psycholog* OR mental OR emotional OR cognitive) AND (danger* OR risk OR threat* OR issue*) AND (space OR extreme) AND (flight* OR mission* OR travel* OR exploration*).*

296 seemingly relevant articles were retrieved from the search and during the process four more relevant articles were retrieved from the author of one retrieved article, after asking for access to the full article.

The second phase started with the filtration of the articles via reading the abstracts. Based on relevancy to SAE psychology, 195 articles were identified. During the second filtration, all the review articles were removed from the main list, 147 relevant articles remained for further analysis.

The above searches were repeated in March 2020 to capture any relevant newly published articles. Through this latter search, 23 additional relevant articles were added to the first 147.

During the last filtration phase, articles which reported empirical studies discussing team level phenomena remained. Papers which focused on individual level phenomena but described connections between individual and team dimensions, were also included. Through this procedure, the final number of papers retained for analysis was 36 articles, of which 28 primarily used quantitative methods and 7 primarily used qualitative methods.

3. Systematic review results

3.1. Description of the studies

In the extracted papers 30 different experiments or missions were used. The most popular being the Mars-500 simulation used eight times. The CELSS simulation was used three and four others twice.

The Mars-500 simulation was a study conducted by Russia, ESA, and China in 2010-2011 to gather data, knowledge, and experience to help prepare for a real mission to Mars (ESA, n.d.). Six crewmembers (three Russian, two European, and one Chinese, all male) were sealed in an isolation chamber for 520 days. The crew had voice contact with simulated control center (with 20-minute delay) and family and friends, as in the case of a normal spaceflight. The mission was divided into three stages – flight to Mars, mock Mars surface operations, and return to Earth.

The CELSS simulation was a study conducted by China in 2016 (Ma et al., 2019). Four subjects (three male, one female, all Chinese) were sealed in an isolation chamber for 180 days. The aim of the CELSS study was to document personal value change over time in a confined and isolated environment.

The shortest experiment/mission lasted 10 days and the longest 720 days. Mean duration being 229 days (*SD* = 200, *Mdn* = 155). Median sample size was 7 (*SD* = 50.1, *M* = 24.8), from the range of 1 to 216. Apart from restrospective (data collected after experiments/missions, not in situ) and histriometric (data collected from historical accounts) approaches, only one team per analog was described.

3.2 Summary of SAE research environments

The environments used in the extracted studies have different constraints and allow different generalizations to be made from the data. Experiments/missions in five distinctive environments i.e., analogs, were described – space (10 papers), simulations (21), polar expeditions (6), submarine crews (1), and mission control (5), of which the latter was used to draw conclusions about organizational attributes, communication with mission control and extent of autonomy. Simulations, polar expeditions, and submarine crews go under the ‘space analog’ category.

The main stressors encountered during human space missions belong to four main categories (Kanas and Manzey, 2008): (a) physical stressors; (b) habitability related stressors; (c) psychological stressors; and (d) interpersonal stressors. Physical stressors include acceleration, microgravity, ionizing radiation, meteoroid impacts, and light/dark cycles. Habitability related stressors cover vibration, ambient noise, temperature, lighting, and air quality. Psychological issues include isolation, confinement, danger, monotony, and workload. Finally, gender issues, cultural effects, personal conflicts, crew size, and leadership issues belong under interpersonal stressors. While most of the psychological and interpersonal factors are eminent in all the analogs, habitability factors are present in only a few and the only physical factor present in space analogs was light/dark cycles.

Over half of the selected papers described findings from simulation studies. One advantage of simulations is that it is possible to alter the environment to manipulate any variable of interest, under a context of isolation and confinement. However, the lack of true danger and the possibility to conduct a rapid rescue lower the extremeness of such analogs. Furthermore, the lack of 3rd quarter and 2nd half phenomena (experiencing significant psychological and interpersonal changes after corresponding temporal point of the mission) in case of space missions might suggest that the excitement and potential danger of being on orbit is not replicated in the case of simulations (Kanas *et al*., 2007).

Submarine and polar expedition teams however are probably the most representative space analogs on Earth. In those environments, crews experience genuine isolation, confinement, extreme environmental aspects, unnatural light and dark cycles, and the inability to conduct a rapid rescue, thanks to remoteness and/or weather conditions. The only factors not replicable in these two analogs are microgravity, radiation, and the immediate threat of impact with space debris.

Thus, space analogs are an approximation of space and therefore generalizations of research findings should be made carefully.

4. Results from the SLR

In this paper, we have combined the episodic theory of group processes (Marks et al., 2001) and the IMOI framework (Ilgen et al., 2005) to organize and present the results of the SLR as they reflect current state-of-the art in the team literature and have received extensive empirical support (see Figure 1).

We start by describing the main input variables that we found through our SLR, followed by the mediators and outcomes. Team processes and emergent states will be integrated within the mediator variables.

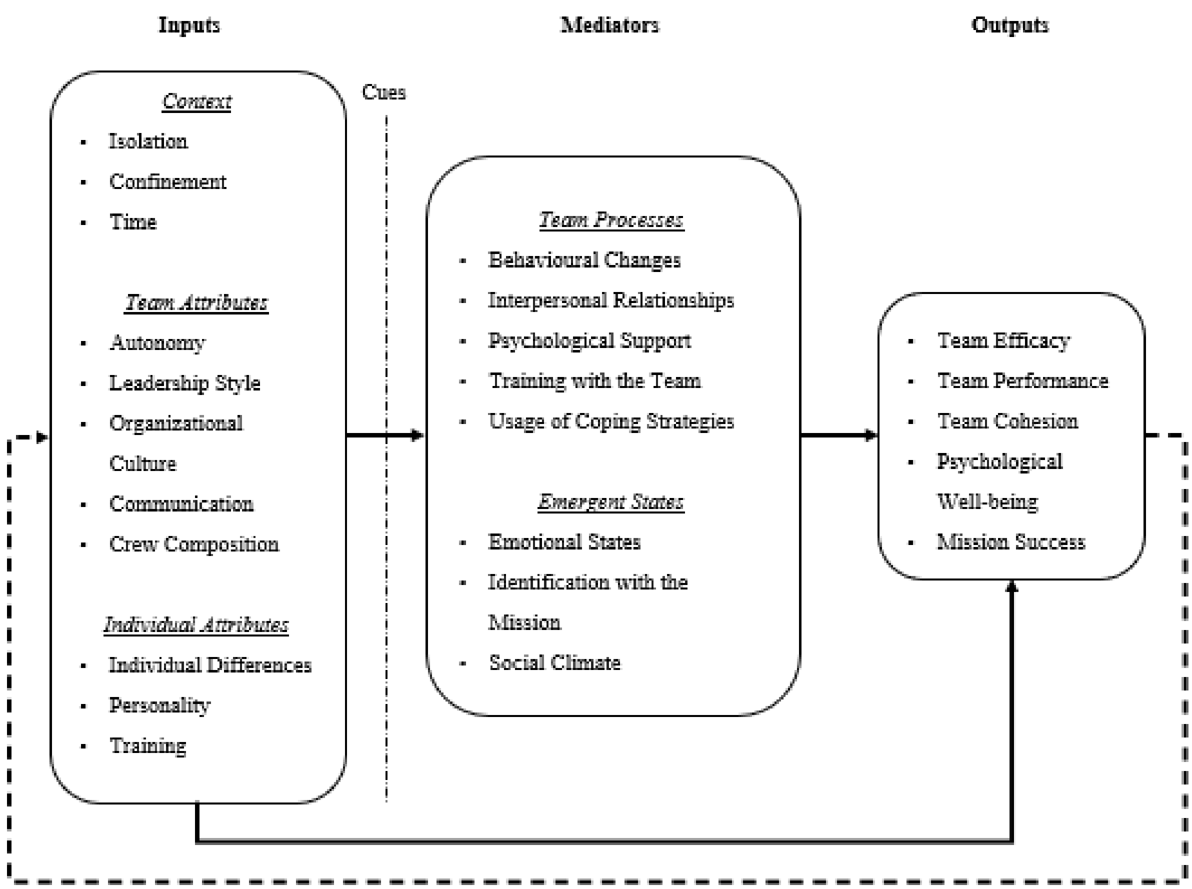

Figure 1. Model of Inputs, Mediators, and Outputs integrating the episodic and the IMOI frameworks representing the findings described in the current paper

4.1. Inputs

Results indicated three input variables: (a) contextual attributes, (b) team attributes, and (c) individual attributes.

Contextual attributes cover the variables which are related to the context in which teams perform. These attributes come from the mission characteristics, namely: the extent of isolation and confinement, and the perception of time (i.e., how fast, or slow time seemingly passes). The evidence suggests that depending on the individual coping mechanisms (Rosnet et al., 1998), character of the team member (Tafforin, 2013), and the length of the mission (Basner et al., 2014), individuals experience different levels of isolation-related stress. “Isolation impacts the way a team occupies the collective space by frequent changes”, while confinement induces more stable, i.e. monotonous patterns of moving in the habitat (Tafforin et al., 2015).

Time as a variable has seemingly the largest effect of the inputs – the other variables are measured and described through the dimension of time, since the duration of perceived stressors affect the way, one reacts to them and the extent to which they are a stressor to begin with. This is illustrated by the alterations in personal values – a decreased emphasis on tradition, benevolence, and stimulation during simulation studies (Ma et al., 2019; Sandal and Bye, 2015). The existing literature makes it difficult to determine in which direction the temporal variable may affect a team in SAE – since all the variables are affected and each of them might affect others, the system gets too chaotic to propose any direct connections. This is explicitly represented by the 3rd quarter phenomenon – in the previous literature it has been treated as being typical (Bechtel and Berning, 1991), but in the current SLR several studies have described it being atypical (Basner et al., 2014; Kanas et al., 2001; Kanas et al., 2006; Kanas et al., 2007). Conclusively, time and how the perception of isolation and confinement changes respective to it, is important to consider in projecting the efficacy or performance of any team.

Team attributes cover the variables which apply to the team as a whole, i.e. leadership, the extent of autonomy, organizational culture (e.g., is the team as an entity valued or not), communication, and crew composition. It has been suggested, that team leadership has different functions in the life cycle of a team and depending of the phase, different styles of leadership foster different outcomes (Burke et al., 2018). Leadership is described to be tightly connected with the extent of autonomy the team has and how the team reacts to being more or less autonomous (Hsia, 2015; Mulhearn et al., 2016; Sandal et al., 2011). Many studies have found that a supportive leadership style and setting team goals before individual goals help increase team cohesion (Goemaere, Brenning et al., 2019; Kanas et al., 2006; Kanas and Ritsher, 2005; Wu et al., 2020).

Organizational culture, i.e. mission management styles, the social environment of the organization, and communication styles (Lapierre et al., 2009), has been described to affect team performance and psychological well-being. Altogether, findings suggest that in long-term and deep-space missions, higher crew autonomy is crucial for a successful mission (Mulhearn et al., 2016) through reducing conflicts between crew and mission control and providing the crew with a sense of self-direction (Basner et al., 2014; Goemaere, Brenning et al., 2019; Goemaere, Van Caelenberg et al., 2019).

Autonomy as a variable has been studied with complex results. Sandal et al. (2011) have found that autonomy increases the level of the crew's interpersonal tension rising from individual differences (i.e., value differences). On the other hand, in this study, higher autonomy also improved social climate through reducing the amount of negative affect coming from the communication with mission control. In the case of communication delays a similar finding arises – poor communication increases stress and frustration (Hsia, 2015; Kintz et al., 2016; McIntosh et al., 2016) but enhances teamwork and communication between the crew (Kintz et al., 2016). From this it is possible to speculate that high autonomy and good communication with mission control is the preferred setting for the future long-duration space missions but countermeasures for tackling the negative effects of high autonomy and lack of guidance from the mission control are needed to consider.

Crew composition has been described to influence the social climate and interpersonal relations of the team (Hsia, 2015) - namely sex ratio (Leon and Sandal, 2003; Wu and Wang, 2015), cultural (Sandal and Bye, 2015) and occupational composition (Boyd et al., 2009), and the familiarity between crew and ground control (Kanas et al., 2007). Gender, individual, and cultural characteristics contribute to diversity within the team; this diversity shapes the evolving social habits of the SAE teams with reference to group cohesion and mission success (Tafforin and Giner Abati, 2017). As sex ratio and cultural differences increase crew's heterogeneity, they can increase the interpersonal tension and number of conflicts but mainly, when the ratios are out of balance and bigger vs smaller subgroups appear (e.g., one American with three Russians in Russian space station or one female and three males in a simulation study). If the balance of subgroups is considered, heterogeneity seems to foster higher team resilience and team adaption.

The evidence suggests that giving the SAE teams a part in decision-making regarding their life and tasks, together with supportive and inclusive leadership, greater autonomy, and clear communication is a must-be for long duration missions where disruptions of communications with mission control are projected (Lapierre et al., 2009; MacCallum et al., 2004).

Individual attributes refer to the attributes held by individual team members (i.e., individual differences). Individual attributes researched in SAE include cultural differences, personality, and training. Several studies have described how team members respond to the stressors of SAE differently mostly due to individual differences (Ehmann et al., 2011; Tafforin, 2015). Expanding on these findings are studies explaining the effect of personality and individual coping mechanisms on team cohesion and psychological well-being (Kahn and Leon, 2000; Rosnet et al., 1998). Not only has the overall set of the big-five personality dimensions a team member possesses been described to influence behaviour, but also the flexibility of showing both extraversion and introversion characteristics depending of a situation is positively related to team cohesion (Lapierre et al., 2009; McIntosh et al., 2016; Mulhearn et al., 2016). It has been found that individual skills and abilities and the presence of 'soft skills' (e.g. teamwork skills) generally positively affect team performance and cohesion via moderating intrapersonal tensions (Hsia, 2015; Kahn and Leon, 2000; Sandal et al., 2011; Sandal and Bye, 2015).

These findings together emphasis the importance of the paradigm shift towards less task-oriented and more teamwork-oriented focus of composing the crew for coming space endeavors (Landon et al., 2017).

4.2. Mediators

Eight main mediators – team processes (a, b, e, f, h) and emergent states (c, d, g), were extracted from the papers: (a) behavioural changes, (b) emotional states, (c) identification with the mission, (d) interpersonal relationships, (e) psychological support, (f) social climate, (g) training with the team, and (h) usage of coping strategies.

Behavioral changes. From one period to other, the crew may adapt to SAE through a dynamic behavioral profile, resulting in an increase of team cohesion and performance (Tafforin, 2013). Behavioral changes may often be the result of mood variations, but help the crew to optimize the relationship between the individual and the surrounding environment in order to reduce the environmental stressors' effect on psychological well-being of the individual (Tafforin, 2015; Tafforin et al., 2019).

Emotional states tend to fluctuate in some cases, resulting in projecting of problems on other team members (Rosnet et al., 1998), and boredom which increases the rate of conflicts (Lapierre et al., 2009). Although even during fluctuating emotional states, expressing one's feelings in a positive way has been found to enhance team success (Leon and Sandal, 2003) and suppressing and neutralizing negative emotions and overtly expressing positive ones have been found to increase crew cohesion (Polackova Solcova et al., 2014). On the other hand a study (Polackova Solcova et al., 2014) found that changes in positive affectivity are more valuable indicators of the crew's affectivity dynamics than changes in negative affectivity and when mood increased in one crewmember, it was compensated by a decline of mood in another, resulting in decreased crew cohesion. Furthermore, leaders who are more capable to express themselves and their emotions actively, tend to attract others who experience more social frustration, negative emotions, and anxiety, enhancing psychological well-being and team cohesion (Tafforin et al., 2015).

Conclusively the findings state that team members are dynamically affected by the emotional states of others, hence the effective skill of emotion regulation would help maintain crew cohesion.

Identification with the mission. Bishop (2006) describes how higher identification with the mission is positively related to higher mission culture, higher pro-mission organizational behaviour, lower stress, higher recognition, higher goal sharing and higher motivation. A study has found that identification with the mission through task orientation may decrease over time, as the novelty of the spacecraft and mission itself diminishes (Kanas et al., 2001). Finally, the salience of the expeditionary goal was found to be an important factor in coping and striving for optimal work performance (Leon and Sandal, 2003).

These findings reinforce the argument that crew involvement in mission-related decisions increases feelings of involvement and identification with the mission, thus increasing team performance.

Interpersonal relationships. Based on analysis of archival data (Burke et al., 2018), positive interpersonal relationships are important for the development of team cohesion and performance. Though interpersonal relationships can often be a source of conflict and be a main type of stressor (Kahn and Leon, 2000; Sandal and Bye, 2015), they can also be a source of pleasure, especially when stable relationships act as coping mechanisms (Lapierre et al., 2009). Van Wijk and Dalla Cia (2016) found on a submarine crew, that humor can reduce conflict hence improving group morale and team cohesion. Furthermore, collective mental states stemming from social relationships related to life in the simulation may increase crews' well-being and hence team performance and cohesion (Lapierre et al., 2009). Tafforin et al., (2015) noted on the Mars-500 crew that the more someone communicates with other crewmembers, the more valued one is in the group. Furthermore, they describe that people who experience social frustration, negative emotions, and anxiety tend to be attracted to people who are more confident, relaxed and who experience lower levels of psychosocial strain, leading to improved leadership perception and dynamics.

Psychological support. Regular evaluation of psychological and cognitive performance is important to address possible problems with the mental states of astronauts to prevent possible reductions in team cohesion and team performance resulting from negative mental states (Hsia, 2015). As previously mentioned, social support has proved to be a successful coping mechanism (Kahn and Leon, 2000) (i.e. psychological support).

Positive **social climate** has been reported to be crucial for teams to operate functionally and to keep the team motivated (Burke et al., 2018). Social climate is heavily intertwined with the characteristics of interpersonal relationships (Van Wijk and Dalla Cia, 2016), but covers the team as an whole and thus the social schemes of all the team members rather than individual connections.

Although cultural sophistication of crew nor ground control was found to not affect the mean overall social climate, there is evidence that different cultures foster different levels of mean social climate (Boyd et al., 2009; Lapierre et al., 2009), making multicultural crews a complex system. Since most of the space teams are multicultural, developing a culturally respectful social environment amongst the crew is crucial for successful multinational partnerships.

Training with the team. Several studies (Basner et al., 2014; Hsia, 2015) highlight the importance of training together with the crew as well as training the crew and ground control together, especially in the case of an international team - joint training has been found to be crucial and through that team performance and cohesion could be improved (Kanas et al., 2007; Leon and Sandal, 2003; Vinokhodova and Gushin, 2014).

Usage of coping strategies. Another focus apparent in the articles reviewed was different coping mechanisms and their effect. Denial mechanisms and suppressing negative emotions have been reported beneficial to crew cohesion and crew well-being (Polackova Solcova et al., 2014; Rosnet et al., 1998). Venting negative emotions out on external sources, communicating with friends and family, use of humor, friendly bantering and talking nonsense, showing oneself ideally, use of active problem solving strategies, interacting with someone emotionally close and maintaining self-esteem at difficult times have all been reported as successful coping mechanisms resulting in increased psychological well-being, team cohesion and team performance (Basner et al., 2014; Hsia, 2015; Rosnet et al., 1998).

These findings further illustrate how psychological and social dimensions contribute to the outcomes of the mission itself, thus emphasizing the need for more studies to prepare for the era, where space organizations might not be able to choose the very best to travel to space.

4.3 Outputs

As the IMOI model suggests, the main outputs of dynamic team processes are team performance, cohesion, and efficacy, which have been described as such in most of the papers. From the extracted papers used in this research, mission success is another variable often identified as an output. Similarly with psychological well-being, which, by the model, can act as mediator as well, but was described as an output in a number of papers (Leon and Sandal, 2003; Tafforin et al., 2019). Given the dynamism depicted in the IMOI model all the variables can act as inputs, mediators, and outputs at different points in time, but identifying all those linkages and modelling the reality in perfection is impossible. Nevertheless, we have identified the linkages mentioned in the current literature and compiled them into a model (Figure 1) to propose a more complete picture of SAE teams' dynamics in order to help the stakeholders acknowledge the known variables affecting teamwork in SAE.

5. General discussion

We have organized current empirical knowledge, hoping that it induces the development of further research that unravels the drivers of effective teamwork in space. Through our revision, we were able to identify context, team, and individual level inputs, thus proposing a causal link between those, and the multiple mediators and outputs that define team effectiveness in space. Furthermore, we have differentiated between team processes and emergent states to improve the level of detail within the group of variables with a mediator role (Ilgen et al., 2005). The understanding of these constructs aids the organizations and teams themselves to take these variables into account and be aware of the processes which affect the teamwork outcomes and mission success to a great extent.

Despite the importance of related research findings, the number of empirical studies about teamwork in SAE remains low (< 37). This is particularly striking, given that the oldest article we found that explicitly addresses teamwork is 32 years old (Rosnet et al., 1998). We tentatively suggest three main reasons for the scarcity of empirical studies. First, most data collection opportunities include only one team or crew, which depending on the research design might limit the richness and generalizability of the data collected. Second, the nature of most research contexts themselves often determines that available team sample size is 1. Finally, the interest for team-focused studies is relatively new if we consider that most calls from national space agencies like NASA or ESA have explicitly highlighted crew cohesion (as an example) as a relevant topic only in the last decade. Nevertheless, with the regained interest in human space exploration and the establishment of permanent colonies on the Moon and Mars, the importance of teamwork research in SAE is growing (Driskell et al., 2018; Golden et al., 2018).

From the current review, it appears that it would be beneficial to study some aspects of team effectiveness more thoroughly. Hereby we point out the importance of communication, leadership, and autonomy – although each of the three variables were discussed in several papers, variables related to individuals (e.g., individual differences and personality) and crew interpersonal relations were discussed the most. Furthermore, the understanding how exactly different communication characteristics, leadership styles, and the extent of autonomy affect team performance and well-being in long-duration space exploration, is unclear due to the complexity of the variables. In the following rationale, we further point out, why exactly these three variables need special evaluation in the scope of future long-duration space exploration.

For a long-duration Mars mission, it is inevitable that communication delays with mission control will occur; hence the team must be more autonomous and self-sufficient regarding task competence and decision making (Larson et al., 2019). To endure in such conditions, teams will need leaders and team members specifically trained to collaborate and enable effective teamwork during long duration space missions (Burke et al., 2018; Salas et al., 2015). But these aspects are not inevitable during Moon missions, thus it is important to understand the effect that the inputs may have on the team outputs and mission success.

While training is provided and should get more and more demanding, space organizations and companies might be reluctant to enable autonomy mostly for two reasons. Many of the protocols and procedures delivered in space are too complex and they are too numerous for the astronauts to learn and risking human error during space missions by reducing control can seemingly increase financial expenses. However, research findings suggest that finding ways to enable crew autonomy will be fundamental for successful long duration space missions (Burke et al., 2018; Goemaere, Brenning et al., 2019). Since there will not be noticeable communication lag with teams operating on orbit of or on the Moon itself, it is as easy to keep the control over the decision processes and the tasks teams will have to conduct as it is right now in the case of International Space Station's (ISS) teams, hence alas, the positive effect of autonomy and rather supportive than directive communication styles might be overlooked. For example, when the Lunar Gateway will be completed and operational and the first manned colonies will be settled on the surface of the Moon, more people with different agendas start to work at these facilities. It is then easy to forget that establishing a dynamic leadership style is still a useful aspect to encourage motivation of the individuals, although it will lessen the direct control over the team members, but surely gives them a greater feeling of autonomy (Burke et al., 2018). Nevertheless in the case of that kind of scenario, it is important to not forget that the team is still a team with a common goal and should be a coherent social structure – hence setting team goals over the goals of individuals is needed (Venables and Leon, 2019), but at the same time the leaders must understand that each person, might they be technicians, mechanics, scientists or the leader, have their individual tasks and goals which might seem more important for the individual than the common team goal.

Furthermore, since the teams will come back on Earth soon and enduring the harsh conditions and directive approach for a shorter period does not seem to have noticeable consequences, it is easy to be faithful to the traditional style. However, if the positive outcomes of supportive and caring communication style, greater autonomy and dynamic leadership are considered and practiced, the work teams will endure the difficulties more efficiently and will complete their specific tasks more productively. Also, the team members will probably be more motivated to return to the base and will be more productive back on Earth as well.

All in all, it means that both directive and empowering leadership styles and organizational cultures will work on the Moon, but while directive leadership will enable swift action (i.e. greater efficiency during emergencies), empowering will enable better action (i.e. greater quality and more prospective teamwork) (Sanchez-Manzanares et al., 2020).

6. Research implications and future directions

Through this SLR, we have identified four emerging themes and research opportunities that we encourage others to explore. The first emerging theme regards leadership and how specific leadership functions such as providing feedback or managing conflict can contribute to enable long-term effective team behaviors during long duration space missions (Basner et al., 2014; Bishop, 2006; Polackova Solcova et al., 2014). The second emerging theme regards crew autonomy during long-duration space mission and how individual attributes (e.g., task orientation) and collective affect (e.g., crew cohesion) can enable team performance under such working and leaving conditions (Bishop, 2006; Kanas et al., 2007; Sandal et al., 2011). The third emerging theme regards how crew composition in terms of gender, coping styles (e.g., humor, friendly bantering, talking nonsense), cultural differences, and team stability (Hsia, 2015; Larson et al., 2019) shape optimal team functioning. Indeed, it is not yet clear what should be the optimal mix of individuals for a specific group, based on a combination of personality characteristics as well as gender, culture, and work skill requirements (Polackova Solcova et al., 2014).

Finally, a more general research topic would address such issues as how is cognitive performance affected by SAE (Kahn and Leon, 2000), what are the motivational communalities between space and space analog environments (Kanas et al., 2001), what effects might have the communication delay (and what lags are meaningful) between crew and relevant people on Earth (e.g., family; (MacCallum et al., 2004)), and how does effective psychological support looks like for long duration space missions (McIntosh et al., 2016).

7. Limitations

Being a literature review, the current manuscript lacks the empirical validation of the summary model outlined in Figure 1. Another limitation of the current review is that empirical studies that included space crews or space analog crews, but where the research focus was the individual crew members were not included. Although the reason of such exclusion is explained earlier in the paper, we acknowledge that this decision might reduce the scope of the current research.

8. Conclusion

In the current paper, we have reviewed the state of the art of scientific knowledge on teamwork in space and space analog environments. We have brought out the connections between different inputs, emergent states, team processes and teamwork outcomes through the IMOI framework (Ilgen et al., 2005). Furthermore, we have highlighted what specific variables should receive further attention given their importance to space exploration and we have discussed how such research can contribute to the Space sector and society in general.

Conclusively, it could be said that on the basis of findings of this SLR, the recipe for a successful mission is proper and thoughtful space organization and ground control; thorough mission planning; intercultural crew composition including both men and women, where each crewmember has qualities which complement the whole team and each individual is dynamic, goal-oriented, empathic, skillful and a good team-player; intense prior psychological and task training of the crew; training together with the team and ground control; and a healthy amount of autonomy of the crew. That kind of ideal team with the *right stuff* is surely difficult to compose, but if that happens and the team is provided with proper capabilities, humankind should not worry about the endeavor of working and thriving in Space.

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