FACULTY OF PSYCHOLOGY
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Human Space Exploration from a Self-Determination Theory Perspective: An Experimental and Diary Investigation

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هاها هیچ کس نمی تواند این را بخواند
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دوستت دارم

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GENERAL INTRODUCTION

Human Space Exploration from a Self-Determination Theory Perspective: A Brief Introduction

In 2010, I applied at KU Leuven to enroll in their brand-new advanced master's programme *Master of Space Studies*, designed to prepare students for the multidisciplinary challenges of a career in the space sector. Unlike other candidates with astrophysical, engineering, or law and policy backgrounds, I was asked to motivate my application during an intake interview. After all, what does psychology have to do with space exploration?

One of the master's courses, *Questions in Space Studies*, was taught by former Belgian astronaut and ISS crew commander Frank De Winne. I remember him saying, much to my surprise, that good astronauts are people who can refrain from taking initiative, since their primary function is to follow orders from the ground. To illustrate this point, he elaborated on a personal anecdote regarding a rather annoying episode during one of his ISS missions: in the middle of a technical task, he encountered an obstacle not accounted for in the written instructions accompanying the task. Although the solution was clear, and the problem simple and easy-to-fix, as an astronaut, he was not allowed to take the decision to deviate from instructions and proceed with solving the issue himself. Instead, he had to alert Mission Support, and the job had to be postponed until they had given their green light, which could easily take several days. However, the sense of frustration for crew members that can arise from lacking decision-making authority in space was, to the best of my knowledge, never mentioned before in scientific literature on the psychological issues in space (see Kanas & Manzey, 2008, for a review).

A potential reason for that became clear to me, when Frank mentioned that, generally speaking, astronauts are not too keen on psychologists, since they regard them as the people who can stand in their way of getting appointed to a flight. It is true that, in space agencies, psychologists mainly hold the task of selecting candidates fit to sustain the multiple thrills and challenges of spaceflight. As such, their main responsibility is to "*weed out those candidates who might not be suited to training, working, and living in the extreme environment of space*" (Anania, Disher, Anglin, & Kring, 2017, p. 1). During actual space missions, private phone call appointments between astronauts and a psychologist are scheduled at a regular interval (called Private Psychological Conferences, or PPCs), in case an astronaut would be in need of psychological support. However, according to Frank De Winne, astronauts rarely make use of these opportunities, and instead prefer to confide their issues with partners, family members, or friends. After all, one wouldn't want to be deemed psychologically unfit for the next flight! In fact, astronauts seem to be reluctant to utter dissatisfaction or admitting issues with adaptation to their new work environment in general, as exemplified by the following entrees in astronaut journals (Stuster, 2016):

"*I was pissed because I saw zero reason to record me (doing nothing). Not even moving, just standing. Plus, there was Ku coverage so the ground could have recorded it. Anyway, I wanted to call down and ask why. Cardinal error for a crew, and luckily both my crew mates jumped on me and talked me out of it*" (p. 16).

"*Telling the ground that it took longer to perform a task than scheduled is an admission of lack of ability*" (p. 24).

"*What is scheduled is what is expected, and another astronaut probably got all this work done and on time on some past mission. No one wants to be seen as a slacker or as incapable (or as a complainer)"* (p. 24).

"*(It bothers) me how the ground treats the crew. We work trivial and mundane tasks for weeks and even still, they do not trust us to do the simplest of things. Then, when we get frustrated we are labeled as hard to work with*" (p. 54).

Apparently, being an astronaut in outer space is not all glory and excitement, and psychological stressors do occur, for instance, through accumulation of daily hassles, even if astronauts are reluctant - perhaps discouraged by space agencies - to voice them. Although space psychology has come a long way since the beginning of spaceflight (see Suedfeld, 2005, for a review), psychologists have not gained or received the trust of astronauts yet. Indeed, at least from an astronaut's perspective, psychology is a discipline that rarely functions to their benefit. Clearly, there is work to be done.

Aside from the specific research objectives of this study that will be elucidated in the following sections, this dissertation aims to attain two more general, overarching goals, namely:

(1) Granting a voice to astronauts by investigating overlooked or understudied psychological stressors of spaceflight, which have been reported in anecdotal sources such as astronauts' social media accounts (e.g., Peldszus, Dalke, Pretlove, & Welch, 2014), journals and crew log books (e.g., Stuster 2010, 2016) and interviews with space experts (e.g., McIntosh et al., 2016; Morgeson, 2015).

(2) Introducing psychological insights into the human spaceflight domain by focusing on the psychological needs of astronauts. In doing so, trying to identify and study contextual factors that promote astronaut need satisfaction and motivation, instead of focusing on the identification of psychological criteria to eliminate astronaut candidates who are judged unfit for the space environment.

The following sections present an overview of the practical side of working in space, and the consequences that such a particular work environment might have on flight crews. This overview will be rather concise, as we will present a more extensive theoretical review in the first chapter. Self-Determination Theory (SDT, Ryan & Deci, 2000, 2017) will be introduced as a theoretical framework to help understand the processes explaining the effects of the astronautical work environment on astronaut well-being, motivation, and performance. Finally, the general research objectives and specific research questions of this dissertation are put forward.

1. Outer Space as a Work Environment

Human space exploration has come a long way since Yuri Gagarin's pioneer flight in 1961, from the sensational Apollo moon missions, to a more prolonged human presence in space with the space stations Salyut and Mir. Today, human spaceflight mainly revolves around the International Space Station (ISS), an international collaboration of the Canadian Space Agency (CSA), European Space Agency (ESA), Japan Aerospace Exploration Agency (JAXA), Federal Space Agency of Russia (Roscosmos) and the National Aeronautics and Space Administration (NASA). The ISS's primary objective is to function as a science laboratory in a unique microgravity environment. Since its launch in 1998, thousands of scientific investigations, technology demonstrations and educational activities have been conducted (Thumm et al., 2014). The station is permanently inhabited by six crew members, for a stay of six months to one year. Their primary tasks consist of performing scientific experiments in a variety of disciplines, including biology and biotechnology, Earth and space sciences, human research, physical science, and technology development and demonstration. Additionally, astronauts are also responsible for more thrilling and captivating space operations, such as visiting vehicle docking or Extra-Vehicular Activities (also known as EVAs, or spacewalks). Due to the high-risk and costly nature of ISS operations, space agencies are keen on selecting the best of the best to join their crew. Astronaut candidates go through an extensive application process, including intensive interviewing, and thorough performance and psychosocial testing (Anania, Disher, Anglin, & Kring, 2017; Collins, 2003; Landon, Rokholt, Slack, & Pecena, 2017). The fortunate ones who make the cut, are then rigorously trained for several years before being appointed to a specific flight.

However, contrary to what many people believe, the majority of astronaut activities are not always exciting or challenging. Performing scientific experiments, for instance, can quickly become tiresome or tedious as many test trials and routine tasks need to be repeated over and over. Moreover, far less scientific activities than expected have been performed on the ISS during the course of the past years, mainly due to the many maintenance requirements of the station, such as upkeep, repairs, cleaning and storage (Russel, Klaus, & Mosher, 2006). On top of that, astronauts hold a primarily executive function on the ISS, and do not have the decision-making authority to deviate from the many rules, guidelines, and activities introduced by ISS (Kalery, Sorokin, & Tyurin, 2010; Krikalev, Kalery, & Sorokin, 2010). For every space operation, even the simple maintenance tasks, astronauts are provided with visual instructions, usually displayed on a computer screen, from which they are not permitted to deviate. In case of contingencies, astronauts need to alert Mission Support members, who then decide on the appropriate action by which to proceed, to be strictly followed by the astronaut. Since these instructions, also called operating procedures or Operations Data Files (ODF; Hoppenbrouwers, Ferra, Markus, & Wolff, 2017), are meant for an international crew, changing every three months, they are highly standardized and very elaborate, detailing every intermediary step to successfully accomplish the task at hand, and they need to be reviewed by several safety boards (ODF boards). Although space agencies have recently made some efforts to innovate instructions, for instance by introducing new technical features or visual formats, such as wearable displays (e.g., Boyd, Fortunato, Wolff, & Oliveira, 2016) or 3D visual training (e.g., Nicolini, Scott, Seine, & Wolff, 2016), astronaut input is still very limited. In fact, the position of an astronaut onboard the ISS is often referred to as "*the tip of the spear*" or "*an extension of ground control*" (Gibson et al., 2015, p. 2). The chief medical officer of JAXA put it as follows: "*The ideal astronaut has been an exceptionally high-achieving adult, who takes direction and follows rules like an exceptionally well-behaved child.*" (Roach, 2010, p. 37). Consequently, working days on the ISS can quickly become routine, and in some cases, even boring (Peldszus, Dalke, Pretlove, & Welch, 2014):

"*Sometimes it's a little bit like Groundhog Day. You wake up at the same time every day. You look at the schedule and figure out what you're going to* *do. Even though the tasks are different, it feels like you're doing the same thing over and over again*" (entree from an astronaut journal; Stuster, 2016, p. 19).

"*Wish I had more to say, but after 52 days in space, life is 100% routine. If I went home tomorrow I wouldn't be bummed*" (entree from an astronaut journal; Stuster, 2016, p. 19).

"*I am not writing as much in the journal because there is not much to talk about. Most everything is the same up here. In general I am to the point where I would be happy to go home and call it a mission*" (entree from an astronaut journal; Stuster, 2016, p. 19).

"*Not much to write in the journal since the days are the same as they have been for the last 4 months.*" (entree from an astronaut journal; Stuster, 2016, p. 20).

Although astronauts rarely overtly rebel against these organizational circumstances, deviant behavior and so-called insubordination issues (Morgeson, 2015) do sometimes occur, for instance when astronauts fail to inform Mission Support of a particular contingency (e.g., Hendricks, Mauroo, & Van Spilbeeck, 2009), ignore certain requests made by the ground (e.g., Morgeson, 2015), or discard operating procedures (e.g., Mcphee & Charles, 2009). As a consequence, performance slips are known to occur (e.g., Britt, Jennings, Goguen, & Sytine, 2016).

"*I still seem to not pay attention to details sometimes like I should, and then make small mistakes. I know it is a continuing issue, that I make a lot of assumptions when I read a procedure and believe I know what they want. I will work on that*" (entree from an astronaut journal, Stuster, 2016, p. 26).

Some experts have ascribed such deviant behavior from astronauts to their big ego’s (e.g., Britt et al., 2016; Manzey, 2013). However, from a psychological viewpoint, the affective, motivational and behavioral responses of astronauts are not unexpected. One theory ideally suited to elucidate the nature of these responses and to provide a richer account of astronauts’ functioning is Self-Determination Theory.

2. Self-Determination Theory and the Universal Psychological Needs

Self-Determination is an overarching theoretical framework that puts forward three psychological needs essential for motivation, growth and optimal functioning (Ryan & Deci, 2000). The need for *autonomy* suggests that individuals must experience a sense of volition and psychological freedom, and be able to act in accordance with their values. The need for *competence* specifies that individuals must experience a sense of mastery during their job, thereby being challenged to elaborate and refine their skills when pursuing meaningful outcomes. The need for *relatedness* is defined as the desire to experience care by others, and likewise, care for others.

Over the past decades, an abundance of studies in a variety of settings, using a multitude of empirical methods, have consistently demonstrated the benefits of need satisfaction (See Deci & Ryan, 2008; Ryan & Deci, 2017; for reviews). Specifically, studies in organizational settings have found that employees working in environments that facilitate need satisfaction experience more positive work outcomes, such as increased performance (e.g., Baard, Deci, & Ryan, 2004; Trépanier, Forest, Fernet, & Austin, 2015), work engagement (e.g., Gagné, Chemolli, Forest, & Koestner, 2008; Haivas, Hofmans, & Pepermans, 2013), and job satisfaction (e.g., Andreassen et al., 2010; Van den Broeck, Vansteenkiste, De Witte, Soenens, & Lens, 2010), and less negative outcomes, such as organizational deviance (e.g., Lian, Ferris, &

Brown, 2012). In contrast, employees working in environments in which their needs are actively thwarted are more likely to experience dysfunction at work, such as more stress (e.g., Olafsen, Niemiec, Halvari, Deci, & Williams, 2017) or higher exhaustion (e.g., Vander Elst, Van Den Broeck, De Witte, & De Cuyper, 2012). Moreover, dozens of studies have created experimental conditions where the degree of need satisfaction is manipulated to look at its contrasting consequences. For instance, involving people in decision-making procedures by providing choice (Patall, Cooper, & Robinson, 2008), showing empathy (Deci, Eghrari, Patrick, & Leone, 1994) or giving people a meaningful rationale for a particular task (Jang, 2008), have been shown successful in enhancing need satisfaction, engagement and performance.

Let us now consider the above-mentioned job characteristics of a substantial proportion of astronaut activities on the ISS, i.e., having to execute simple routine tasks and having to follow elaborately detailed step-by-step instructions without any decision-making authority. Possibly, this combination of job characteristics evokes a sense of distrust from Mission Support towards astronauts. Moreover, astronauts might start to feel insufficiently challenged, underutilize their skills and talents, and loose a sense of meaning and significance in their work. According to SDT, in such situations, astronauts' needs for autonomy and competence might not get satisfied, which could explain the behavioral, affective, and motivational deficits that have previously been reported. Although Self-Determination Theory and the importance of need satisfaction and need frustration have been observed and tested in traditional organizational settings (see Deci, Olafson, & Ryan, 2017, for a review) and other domains such as sports (e.g., Carpentier, Mageau, 2013; De Muynck et al. 2017), classrooms (e.g., Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009), parenting, (e.g., Mabbe, Soenens, Vansteenkiste, van der Kaap-Deeder, & Mouratidis, 2018) and the clinical sector (e.g., Savard, Joussemet, Pelletier, & Mageau, 2013), the domain of human spaceflight remains to be explored. Moreover, the current dissertation aims to contribute to the literature in several other ways:

(1) Although SDT and the importance of psychological needs have been researched in organizational settings before, few studies have implemented diary studies of within-person fluctuations in employee need satisfaction and functioning in authentic work environments. (e.g., De Gieter, Hofman, & Bakker, 2018; Olafsen, Deci, & Halvari, 2018, as exceptions)

(2) While most scientific research on instructions focuses on the provision of the optimal amount and format of instructions to present learners with sufficient guidance to accomplish certain learning goals (see Van de Pol, Volman, & Beishuizen, 2010 and Landers & Reddock, 2017, for reviews) very little is known about the consequences of giving individuals an overload of instructions (e.g., Nadolski, Kirschner and van Merriënboer, 2005; Richey & Nokes-Malach, 2013, as exceptions), particularly in procedural tasks (e.g., Agrawala et al., 2003; Irrazabal, Saux, & Burin, 2016, as exceptions)

(3) Few experimental studies have explored the consequences of having to pursue uninteresting activities, and the ways in which individuals can be encouraged towards greater volition, engagement and performance (e.g., Joussemet, Koestner, Lekes, & Houlfort, 2004; Reeve, Jang, Hardre, & Omura, 2002, as exceptions).

3. Research Objectives and Overview of the Dissertation

Based on the observations and literature discussed in the previous sections, the current dissertation aims to achieve two general research goals. First, in Chapter 1, findings with regard to the psychological stressors and benefits associated with human spaceflight are reviewed and approached from the perspective of SDT, in order to synthesize these rather scattered findings, and to advance our theorizing about critical psychological phenomena and processes within the rapidly growing field of space psychology. Specifically, we argue that the postulation of the psychological needs for autonomy, competence, and relatedness within SDT allows for:

(1) A deeper understanding of reported psychological phenomena in current human space exploration, particularly the issues of decreased crew autonomy and increased bureaucracy in space, and the positive effects of spaceflight.

(2) The development of measures to alleviate the negative psychological stressors as well as to enhance the benefits associated with spaceflight.

The following chapters present experimental and diary studies that provide empirical evidence for the general proposed theoretical model underlying the review and empirical studies, graphically represented in Figure 1.

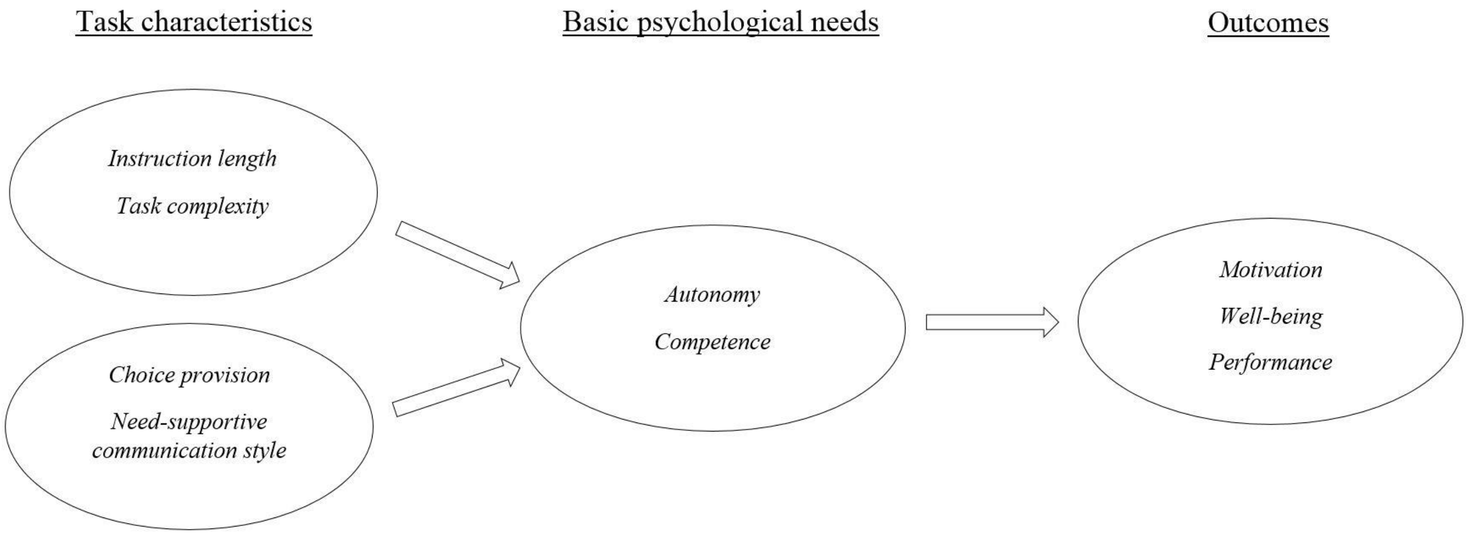

Figure 1. Schematic overview of the current dissertation's research model.

The first research goal of the dissertation involves finding empirical evidence for the consequences of providing long instructions for simple tasks (Chapter 2 and 3), while the second goal focuses on the development of potential countermeasures to alleviate the presumed detrimental effects of long instructions on motivation, well-being and performance (Chapter 3). The third and final research goal aims to collect evidence for the effectiveness of countermeasures in a naturalistic, more ecologically valid setting. In the following sections, these goals are discussed in more detail, together with a summary of the design, sample, included variables, general goals and specific research questions pursued in the different chapters of the dissertation. An overview of the empirical studies is presented in Table 1.

Chapter	Design	Sample		Independent Variables	Outcomes	Objectives	Research Questions
		Participants	M_{age} (*SD*)				
2	Experimental	*N* = 99 psychology students	19.75 (2.46)	*Instruction length* *Task complexity*	*Motivation* *Affect* *Performance*	1	1.1, 1.2, 1.3
3	Experimental	*N* = 123 psychology students	19.25 (3.16)	*Instruction length* *Choice provision* *Need-support*	*Autonomy* *Competence* *Motivation* *Affect* *Performance*	1, 2	1.1, 2.1, 2.2
4	Diary study	HI-SEAS I crew *N* = 6	39 (4)	*Autonomy-support vs. control* *Autonomy*	*Autonomy* *Motivation* *Collaboration* *Performance*	3	3.1, 3.2
5	Diary study	HI-SEAS IV crew *N* = 6	30 (4)	*Autonomy-support vs. control* *Autonomy* *Competence* *Relatedness*	*Autonomy* *Competence* *Relatedness* *Motivation* *Collaboration* *Performance*	3	3.1, 3.2

Table 1. Overview of the empirical studies.

3.1 Goal 1: Exploring the Effects of Long Instruction for Simple Tasks

Most research in instructional design is mainly concerned with learning tasks, indicating that the effects of instructions on learning outcomes are quite nuanced and complex, with a variety of student variables moderating the main effects (e.g., Gorissen, Kaster, Brand-Gruwel, & Martens, 2013; Mihalca, Salden, Corbalan, Paas, & Miclea, 2010; also see Landers & Reddock, 2017; Van de Pol, Volman, & Beishuizen, 2010, for reviews). In general, these studies focus primarily on the question regarding the optimal amount or dose of instructions (e.g., Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006), and are mainly concerned with the provision of sufficient guidance such that learners do not need to put excessive effort in the task, which takes away from performance. However, very little studies have examined instructional design for *procedural tasks*, and very little is known about the effects of an overload of instructions. Chapters 2 and 3 aim at gaining more insight into these dynamics.

Research question 1.1: What are the effects of providing long instructions for simple tasks on motivation, affect and performance?

In Chapter 2 and 3, the effects of instruction length on simple tasks are tested on a variety of outcomes through experimental set-ups. It was hypothesized that long instructions would have a detrimental impact on a variety of motivational, affective and performance outcomes.

Research question 1.2: Is there a moderating role of task difficulty?

The experimental study in Chapter 2 also addressed the question whether long instructions would be equally detrimental for complex tasks. We assumed that the negative effects of long instructions would be more pronounced for simple tasks, presumably because long instructions would be perceived as more useful when provided for tasks that are more complex.

Research question 1.3: Is there a moderating role of need for achievement?

Evidence suggests that achievement-motivated individuals view difficult tasks as challenges that hold the promise of reward, namely the pleasure of mastery (Enseger & Rheinberg, 2008; Baumann & Scheffer, 2010; 2011; Reeve, Olson, & Cole, 1987; Schultheiss, Wiemers, & Wolf, 2014). They therefore tend to avoid low-risk situations, presumably because the easily attained success is not truly experienced as an achievement. Since astronauts are specifically selected for their high need for achievement (Brcic, 2010; Mittelstädt, Pecena, & Oubaid, 2016), they might perceive long instructions for simple tasks as particularly redundant and even annoying. In Chapter 2, we therefore consider the possibility that the negative effects of long instructions would be aggravated for participants high in need for achievement.

3.2 Goal 2: Developing Effective Countermeasures

In Chapter 3, two specific countermeasures are tested as potential solutions for the presumed negative effects of long instructions for simple tasks, namely choice provision and a need-supportive communication style. While choice provision, a *participative* measure, has been studied in SDT research and computer-based instructional design, its effectiveness as a motivational technique has been debated (Patall & Hooper, 2017, Landers & Reddock, 2017), with the impact of choice being dependent upon a variety of variables, such as type of choice (e.g., Reeve, Nix, & Hamm, 2003) or choosers' personality (e.g., Orvis, Brusso, Wasserman, & Fisher, 2011). Alternatively, research on more *attuning* interventions have indicated that, when supervisors align themselves with learners' perspective, by accustoming to their interests, preferences and values, volition, engagement and performance increases (e.g., Jang, 2008; Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009).

Research question 2.1: What are effective countermeasures to alleviate the negative effects of long instructions?

The experiment presented in Chapter 3 examines the effectiveness of potentially need-supportive measures that would alleviate the negative impact of long instructions for simple tasks. Specifically, the effects of choice through implementation of user control instructions are tested, as well as the effects of presenting long instructions in a presumably need-supportive communication style by 1) showing empathy, 2) providing a meaningful rationale for instructions, and 3) increasing the personal relevance of the task.

Research question 2.2: What are the intervening variables of effective countermeasures?

Additionally, in Chapter 3, we uncover the underlying explanatory mechanisms of the effective countermeasures. We put forward an increase in autonomy and competence satisfaction as intervening variables for the effectiveness of user control instructions and a need-supportive communication style.

3.3 Goal 3: Ecological Validity of the Findings

While previous experimental studies were performed in laboratory settings, this dissertation also aims to examine the generalizability of the findings in more ecologically valid settings. To gain further insight into the dynamics of astronauts' well-being, motivation and performance, weekly variation in crew members' perception of Mission Support's communication style, crew need satisfaction and functioning were assessed during space simulation missions.

Although diary studies assessing within-person fluctuations in need satisfaction have been studied in other domains, for instance in education (e.g., Tian, Chen, & Huebner, 2014), parenting (e.g., Brenning & Soenens, 2017) and the clinical sector (e.g., van der Kaap-Deeder et al., 2014), they have rarely been examined in organizational settings, and never before in the astronautical context.

Research question 3.1: Do fluctuations in astronauts' need satisfaction predict fluctuations in astronaut functioning?

In Chapter 4 and 5, the question whether variation in crew need satisfaction at the within-level could account for variation in astronauts' motivation, collaboration with Mission Support members, and performance, was investigated through diary studies with the crews of the Mars simulation missions HI-SEAS I and IV. Chapter 4 focusses on the crew's need for autonomy, while Chapter 5 considers all three needs.

Research question 3.1: Do fluctuations in perceived autonomy-support from Mission Support predict fluctuations in crew need satisfaction?

Additionally, the diary studies presented in Chapter 4 and 5 examine whether weekly ups and downs in crew need satisfaction can be predicted by weekly ups and downs in the crew's perception of an autonomy-supportive communication style from Mission Support. It is assumed that, in weeks during which the crew views Mission Support as more autonomy-supportive, need satisfaction is likewise enhanced, while weeks during which Mission support is perceived to be more controlling relate to lower need satisfaction during that week.

References

Agrawala, M., Phan, D., Heiser, J., Haymaker, J., Klinger, J., Hanrahan, P., & Tversky, B. (2003). Designing effective step-by-step assembly instructions. ACM Transactions on Graphics, Proceedings of ACM SIGGRAPH, 22, 828-837.

Anania, E. C., Disher, T., Anglin, K. M., & Kring, J. P. (2017). Selecting for long-duration space exploration: Implications of personality. IEEE Aerospace Conference, Yellowstone Conference Center, United States, 2017.

Andreassen, C. S., Hetland, J., & Pallesen, S. (2010). The relationship between “workaholism”, basic needs satisfaction at work and personality. *European Journal of Personality, 24*, 3-17.

Andreassen, C. S., Hetland, J., & Pallesen, S. (2010). The relationship between ‘workaholism’, basic needs satisfaction at work and personality. *European Journal of Personality, 24*, 3-17.

Baard, P. P., Deci, E. L., & Ryan, R. M. (2004). Intrinsic need satisfaction: A motivational basis of performance and well-being in two work settings. *Journal of Applied Social Psychology, 34*, 2045-2068.

Baumann, N. & Scheffer, D. (2010). Seeing and mastering difficulty: The role of affective change in achievement flow. *Cognition and Emotion, 24*, 1304-1328.

Baumann, N. & Scheffer, D. (2011). Seeking flow in the achievement domain: The achievement flow motive behind flow experience. *Motivation and Emotion, 35*, 267-284.

Boyd, A., Fortunato, A., Wolff, M., & Oliveira, D. M. (2016). MobiPV: a new, wearable, real-time collaboration software for astronauts using mobile computing solutions, SpaceOps2016, 14th International Conference on Space Operations, Daejeon, Republic of Korea, 16-20 May 2016.

Brcic, J. (2010). Motivational profile of astronauts at the International Space Station. *Acta Astronautica, 67*, 1110-1115.

Brenning, K., & Soenens, B. (2017). A Self-Determination Theory perspective on postpartum depressive symptoms and early Parenting behaviors. *Journal of Clinical Psychology*, *73*, 1729-1743.

Britt, T. W., Jennings, K. S., Goguen, K., & Sytine, A. (2016). *The role of meaningful work in astronaut health and performance during long-duration space exploration missions* (NASA/TM-2016-219276). Houston, Texas, NASA Johnson Space Center.

Carpentier, J., & Mageau, G. A. (2013). When change-oriented feedback enhances motivation, well-being and performance: A look at autonomy-supportive feedback in sport. *Psychology of Sport and Exercise, 14*, 423-435.

Collins, D. L. (2003). Psychological issues relevant to astronaut selection for long-duration space flight: A review of the literature. *Journal of Human Performance in Extreme Environments, 7*, 43-67.

De Gieter, S., Hofmans, J., Bakker, A. B. (2018). Need satisfaction at work, job strain, and performance: A diary study. *Journal of Occupational Health Psychology, 23*, 361-372.

De Muynck, G-J., Vansteenkiste, M., Delrue, J., Aelterman, N., Haerens, L., & Soenens, B. (2017). The effects of feedback valence and style on need satisfaction, self-talk, and perseverance among tennis players: An experimental study. *Journal of Sport & Exercise Psychology, 39*, 67-80.

Deci, E. L., & Ryan, R. M. (2008). Self-Determination Theory: A macrotheory of human motivation, development, and health. *Canadian Psychology-Psychologie Canadienne, 49*, 182-185.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: the selfdetermination theory perspective. *Journal of Personality, 62*, 119-142.

Deci, E. L., Olafsen, A. H., & Ryan, R. M. (2017). Self-Determination Theory in work organizations: The state of a science. *Annual Review of Organizational Psychology and Organizational Behavior, 4*, 19-43.

Enseger, S., & Rheinberg, F. (2008). Flow, performance and moderators of challenge-skill balance. *Motivation and Emotion*, *32*, 158-172.

Gagné, M., Chemolli, E., Forest, J., & Koestner, R. (2008). A temporal analysis of the relation between organisational commitment and work motivation. *Psychologica Belgica, 48*, 219-241.

Gibson, C., McIntosh, T., Mulhearn, T., Connely, S., Day, E. A., Yammarino, F., Mumford, M. D. (2015). *Leadership/followership for long-duration exploration missions final report* (NASA/TM-2015-218567). Houston, Texas, NASA Johnson Space Center.

Gorissen, C. J. J., Kester, L., Brand-Gruwel, S., & Martens, R. L. (2013). Autonomy supported, learner-controlled or system-controlled learning in hypermedia environments and the influence of academic self-regulation style. *Interactive Learning Environments, 23*, 655-669.

Haivas, S., Hofmans, J., & Pepermans, R. (2012). Self-determination theory as a framework for exploring the impact of the organizational context on volunteer motivation: A study of Romanian volunteers. *Nonprofit and Voluntary Sector Quarterly, 41*, 1195-1214.

Hendricks, H., Mauroo, T., & Van Spilbeeck, B. (2009). *Het Ruimtedagboek van Frank De Winne: Dagelijks Leven in het ISS.* Leuven: Van Halewyck.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2006), Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and Clark. *Educational Psychology, 42*, 99-107.

Hoppenbrouwers, T., Ferra, L., Markus, M., & Wolff, M. (2017). Operations Data Files, driving force behind International Space Station operations. *Acta Astronautica, 138*, 255-261.

Irrazabal, N., Saux, G., & Burn, D. (2016). Procedural multimedia presentation: the effects of working memory and task complexity on instruction time and assembly accuracy. *Applied Cognitive Psychology, 30*, 1052-1060.

Jang, H. (2008). Supporting students' motivation, engagement, and learning during an uninteresting activity. *Journal of Educational Psychology, 100*, 798-811.

Joussemet, M., Koestner, R., Lekes, N., & Houlfort, N. (2004). Introducing uninteresting tasks to children: A comparison of the effects of rewards and autonomy support. *Journal of Personality, 72*, 140-166.

Kalery, A., Sorokin, I., & Tyurin, M. (2010). Human space exploration beyond the international space station: role of relations of human, machine and the ''Earth''. *Acta Astronautica, 67*, 925-933.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychology, 41*, 75-86.

Krikalev, S., Kalery, A., Sorokin, I. (2010). Crew on the ISS: creativity or determinism. *Acta Astronautica, 66*, 68-78.

Landers, R. N., & Reddock, C. M. (2017). A meta-analytic investigation of objective learner control in web-based instruction. Journal of Business Psychology, 32, 455-478. Lawton, R. (1998). Not working to rule: Understanding procedural violations at work. *Safety Science, 28*, 77-95.

Landon, L. B., Rokholt, C., Slack, K. J., & Pecena, Y. (2017). Selecting astronauts for long-duration exploration missions: Considerations for team performance and functioning. *Reviews in Human Space Exploration, 5*, 33-56.

Lian, H., Ferris, D. L., & Brown, D. J. (2012). Does taking the good with the bad make things worse? How abusive supervision and leader-member exchange interact to impact need satisfaction and organizational deviance. *Organizational Behavior and Human Decision Processes, 117*, 41-52.

Mabbe, E., Soenens, B., Vansteenkiste, M., van der Kaap-Deeder, J., & Mouratidis, A. (2018). Day-to-day variation in autonomy-supportive and psychologically controlling parenting: The role of parents' daily experiences of need satisfaction and need frustration. *Parenting Science and Practice, 18*, 86-109.

Manzey, D. (2013). *Ruimtemoe: Het gevaar van depressieve astronauten*. *Natuurwetenschap & Techniek, 3*, 20-25.

McIntosh, T., Mulhearn, T., Gibson, C., Mumford, M. D., Yammarino, F. J., Connelly, S., Day, E. & Vessey, B. (2016). Planning for Long-Duration Space Exploration: Interviews with NASA Subject Matter Experts. *Acta Astronautica, 129*, 477-487.

Mcphee, J. C., & Charles, J. B. (2009). *Human health and performance risks of space exploration missions* (NASA SP-2009-3405). Houston, Texas, NASA Johnson Space Center.

Mihalca, L., Salden, R., Corbalan, G., Paas, F., & Miclea, M. (2011). Effectiveness of cognitive-load based adaptive instruc- tion in genetics education. *Computers in Human Behavior, 27*, 82-88.

Mittelstädt, J. M., Pecena, Y., Oubaid, V., & Maschke, P. (2016). Psychometric personality differences between candidates in astronaut selection. *Aerospace Medecine and Humand Performance, 87*, 933-939.

Morgeson, F. P. (2015). *Issues in Maintaining Team Motivation over Long-Duration Exploration Missions,* (NASA/TM-2015-218586). Houston, Texas, NASA Johnson Space Center.

Nadolski, R.J., Kirschner, P.A., van Merriënboer, J.J.G. (2005). Optimizing the number of steps in learning tasks for complex skills. *British Journal of Educational Psychology, 75*, 223-237.

Nicolini, F., Scott, C., Seine, R., & Wolff, M. (2016). 3D Visual Training for operations on-board the International Space Station and beyond, IAC-16–B3.5.4, 67th International Astronautical Congress, Guadelajara, Mexico, 26-30 September 2016.

Olafsen, A. H., Deci, E. L., & Halvari, H. (2018). Basic psychological needs and work motivation: A longitudinal test of directionality. *Motivation and Emotion, 42,* 178-189.

Olafsen, A. H., Niemiec, C. P., Halvari, H., Deci, E. L., & Williams, G. C. (2017). On the dark side of work: A longitudinal analysis using self-determination theory. *European Journal of Work & Organizational Psychology, 26,* 275–285.

Orvis, K. A., Brusso, R. C., Wasserman, M. E., & Fisher, S. L. (2011). Enabled for e-learning? The moderating role of personality in determining the optimal degree of learner control in an e-learning environment. *Human Performance, 24,* 60-78.

Patall, E. A. & Hooper, S. Y. (2017). The role of choice in understanding adolescent autonomy and academic functioning. In B. Soenens, S.Van Petegem, and M. Vansteenkiste (Eds.), *Autonomy in Adolescent Development: Towards Conceptual Clarity (Studies in Adolescent Development)*. New York, NY: Routledge.

Patall, E. A., Cooper, H., & Robinson, J. C. (2008). The effects of choice on intrinsic motivation and related outcomes: a meta-analysis of research findings. *Psychological Bulletin, 134,* 270-300.

Peldszus, R., Dalke, H., Pretlove, S., & Welch, C. (2014). The perfect boring situation - Addressing the experience of monotony during crewed deep space missions through habitability design. *Acta Astronautica, 94*, 262-276.

Reeve, J., Jang, H., Hardre, P. & Omura, M. (2002). Providing a rationale in an autonomy-supportive way as a strategy to motivate others during an uninteresting activity. *Motivation and Emotion, 26*, 183-207.

Reeve, J., Nix, G., & Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *Journal of Educational Psychology*, *95*, 375-392.

Reeve, J., Olson, B. C., & Cole, S. G. (1987). Intrinsic motivation in competition: the intervening role of 4 individual-differences following objective competence information. *Journal of Research in Personality, 21*, 148-170.

Richey, J. E., & Nokes-Malach, T. J. (2013). How much is too much ? Learning and motivation effects of adding instructional explanations to worked examples. *Learning and Instruction, 25*, 104-124.

Roach, M. (2010). *Packing for Mars: The Curious Science of Life in the Void*. New York: W. W. Norton & Company.

Russel, Klaus, & Mosher (2006). Applying analysis of international space station crew-time utilization to mission design. *Journal of Spacecraft and rockets, 43*, 130-136.

Ryan, R. M., & Deci, E. L. (2000). The darker and brighter sides of human existence: basic psychological needs as a unifying concept. *Psychological Inquiry, 11*, 319-338.

Ryan, R. M., & Deci, E. L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. New York: Guilford Press.

Savard, A., Joussemet, M., Pelletier, L. G., & Mageau, G. A. (2013). The benefits of autonomy support for adolescents with severe emotional and behavioral problems. *Motivation and Emotion, 37*, 688-700.

Schultheiss, O. C., Wiemers, U. T., & Wolf, O. T. (2014). Implicit need for achievement predicts attenuated cortisol responses to difficult tasks. *Journal of Research in Personality, 48*, 84-92.

Stuster, J. (2010). *Behavioral issues associated with long-duration space expeditions: Review and analysis of astronaut journals* (NASA/TM-2010-216130). Houston, Texas, NASA Johnson Space Center.

Stuster, J. (2016). *Behavioral Issues Associated With Long Duration Space Expeditions: Review and Analysis of Astronaut Journals Experiment*. (NASA/TM-2016-218603). Houston, Texas, NASA Johnson Space Center.

Suedfeld, P. (2005). Invulnerability, coping, salutogenesis, integration: four phases of space psychology. *Aviation, Space and Environmental Medicine, 7*, 61-66.

Thumm, T., Robinson, J. A., Alleyne, C., Hasbrook, P., Mayo, S., Buckley, N.,… Pignataro, S. (2014). International space station accomplishments update: Scientific discovery, advancing future exploration, and benefits brought home to earth. *Acta Astronautica, 103*, 235-242.

Tian, L., Chen, H., & Huebner, E. S. (2014). The Longitudinal relationships between basic psychological needs satisfaction at school and school-related subjective well-being in adolescents. *Social Indicators Research, 119,* 353-372.

Trépanier, S.-G., Fernet, C., & Austin, S. (2013). Workplace psychological harassment in Canadian nurses: A descriptive study. *Journal of Health Psychology, 18*, 384-397.

Van den Broeck, A., Vansteenkiste, M., De Witte, H., Soenens, B., & Lens, W. (2010). Capturing autonomy, competence, and relatedness at work: Construction and initial validation of the Work-Related Basic Need Satisfaction Scale. *Journal of Occupational and Organizational Psychology, 83,* 981-1002.

Van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher-student interaction: a decade of research. *Educational Psychology Review, 22*, 271-296.

Van der Kaap-Deeder, J., Vansteenkiste, M., Soenens, B., Verstuyf, J., Boone, L., & Smets, J. (2014). Fostering self-endorsed motivation to change in patients with an eating disorder: The role of perceived autonomy support and psychological need satisfaction. *International Journal of Eating Disorders, 47,* 585-600.

Van der Kaap-Deeder, J., Vansteenkiste, M., Soenens, B., Verstuyf, J., Boone, L., & Smets, J. (2014). Fostering self-endorsed motivation to change in patients with an eating disorder: The role of perceived autonomy

support and psychological need satisfaction. *International Journal of Eating Disorders, 47*, 585-600.

Van der Kaap-Deeder, J., Vansteenkiste, M., Soenens, B., Verstuyf, J., Boone, L., & Smets, J. (2014). Fostering self-endorsed motivation to change in patients with an eating disorder: The role of perceived autonomy support and psychological need satisfaction. *International Journal of Eating Disorders, 47*, 585-600.

Vander Elst T, Van Den Broeck A, De Witte H, De Cuyper N. (2012). The mediating role of frustration of psychological needs in the relationship between job insecurity and work-related well-being. *Work Stress*, *26*, 252-71.

Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., & Lens, W. (2009). Motivational profiles from a self-determination perspective: The quality of motivation matters. *Journal of Educational Psychology, 101*, 671-688.

CHAPTER 1

Gaining Deeper Insight into the Psychological Challenges of Human Spaceflight: The Role of Motivational Dynamics[1]

[1] Goemaere, S., Vansteenkiste, M., & Van Petegem, S. (2016). Gaining deeper insight into the psychological challenges of human spaceflight: The role of motivational dynamics. *Acta Astronautica, 121*, 130-143.

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Introduction

With the launch of Yuri Gagarin on April 12, 1961, the first man in space, a brand new field in human sciences was born: space psychology. Since then, a substantial amount of research has been conducted to reveal the personal and interpersonal stressors astronauts face when in outer space. In fact, the field of space psychology has been rapidly evolving, thereby producing a number of interesting insights into a broad diversity of phenomena (Kanas & Manzey, 2008; Kanas et al., 2009). Unfortunately, the findings of these studies remain somewhat disconnected and rather descriptive in nature, thereby lacking a strong theoretical foundation that would allow for greater synthesis between them and for a deeper understanding of their underlying psychological dynamics. Therefore, at this point, the field may benefit from the reliance on an overarching theoretical framework, which would allow for a more unified, coherent, and efficient development of ongoing and future research.

One theory that is ideally suited to fill this void in the literature is Self-Determination Theory (SDT; Ryan & Deci, 2000; Vansteenkiste, Niemiec, & Soenens, 2010), a broad theory on human motivation, development, and well-being. The theory has received wide-spread attention and has been used as a source of inspiration to study the motivational functioning, thriving, and well-being of individuals in diverse life domains, including health care, parenting, education, and environmental sciences, to name a few (Deci & Ryan, 2012).

Central to SDT is the assumption of the existence of three inherent, psychological needs, that is, the need for autonomy (i.e., experiencing a sense of volition), the need for competence (i.e., experiencing a sense of effectiveness) and the need for relatedness (i.e., experiencing a sense of warmth). The satisfaction of these needs on a day-to-day basis is integral to individuals' well-being and flourishing, while also serving as a source of resilience against adversity (Vansteenkiste & Ryan, 2013). Herein, we forward and develop the broader argument that the satisfaction of these psychological needs is equally critical for astronauts' well-being and performance and that their support will be of utmost importance during future Mars missions. In fact, as we are entering a new and fairly unknown era of human spaceflight, which is bound to yield new psychological challenges, a more holistic view on astronauts' functioning is likely to be helpful in formulating predictions about the future psychological challenges for a Mars crew.

The present review consists of three parts. In part one, we briefly discuss two critical topics within space psychology, namely crew autonomy and the beneficial effects of spaceflight, a topic that gained attention under the influence of the positive psychology movement. We opted for these two topics for a number of reasons, including the increasing attention they receive among space psychologists and space agencies (Kanas & Manzey, 2008), the conceptual confusion surrounding the notion of autonomy which can be resolved by taking an SDT-perspective (Kalery, Sorokin, & Tyurin, 2010; Krikalev, Kalery, & Sorokin, 2010) the natural fit between the positive psychology movement and SDT, and the fact that both topics are of crucial importance for future interplanetary travel (Kalery et al., 2010; Kanas & Manzey, 2008). Many other topics in space psychology could have been addressed, such as the issue of social isolation (e.g., Manzey, 2004), family support (e.g., Johnson, Asmaro, Suedfeld, & Gushin, 2012) and crew-ground communications (e.g., Kanas, 2005), to name a few. However, space limitations required us to be selective. In part two, we discuss a number of critical principles of SDT which set the foundation for part three, that is, the elucidation of the theoretical potential and applied value of SDT for the field of space psychology. Specifically, we will discuss how SDT’s notion of psychological need satisfaction and its differentiated view on human motivation enable us to shed more light on the question of crew autonomy and the beneficial effects of spaceflight.

1. Critical Topics in Space Psychology

1.1 Crew Autonomy and Bureaucracy

A topic of great discussion among space agencies is the question of crew autonomy. This issue concerns the decision-making authority of the flight crew, and is differentiated from the concept of autonomy as conceived within the framework of SDT, as will be discussed in section 3.1. There is a tendency, especially in Western space agencies, to restrict the decision-making authority of the flight crew through a variety of detailed regulatory procedures (Kalery et al., 2010; Krikalev, et al., 2010; Sandal, & Bye, 2015; Suedfeld, Brcic, Johnson, & Gushin, 2012). The ISS crew, for instance, operates under a very strict set of rules and guidelines due to a combination of increasing bureaucratic demands and safety regulations imposed on astronauts. To illustrate, today's astronauts on the ISS cannot decide on their daily work schedule as their daily activities are completely planned by Mission Support on the ground and every change needs to be reported and evaluated by an expert team on Earth. Although Mission Support is sometimes willing to take astronauts' preferences into account, they generally are allowed little input and merely seem to be treated as "*executive personnel*", "*extensions of ISS*" or "*lab workers*" (e.g., Kalery et al., 2010, p. 925).

Yet, on the rare occasions that Mission Support considers astronauts' preferences, this seems to be very welcomed. As an example, ESA astronaut Frank De Winne's approved request to perform his physical exercises in two separate instead of two consecutive hours was greatly appreciated by him (Hendricks, Mauroo, & Van Spilbeeck, 2009). A further illustration is the following excerpt, which exemplifies how a successful autonomous decision made by the flight crew can produce inherent satisfaction and contentment. Frank De Winne, who was responsible for a technical maintenance on the ISS, shares the following experience:

"*Friday I had to replace a technical unit in the Columbus lab. When I wanted to place the spare unit, I noticed that eighteen screws were missing. Those were not ordinary screws, they're the kind that you can loosen without them floating around. Without warning Mission Support I found a way to remove the screws from the old unit, to place them in the new one and to install the new unit. This wasn't easy since as we don't have a workbench to do this in a comfortable way. But it worked. Then I told Mission Support and they were quite pleased with the result. They didn't have to find a solution anymore. When they do have to, it can easily take up two to three days because everything needs to be checked by everyone. Meanwhile, the astronauts have to clean up the whole mess so all that work and time would have been useless. By taking initiative I saved a lot of time. But of course, if something had gone wrong, I would have been at fault for not having warned Mission Support. The astronaut would have done it!*" (Hendricks, Mauroo, & Van Spilbeeck, 2009, p. 101).

Unfortunately, these sorts of anecdotal examples of the work schedule seem to be fairly rare. Astronauts are strongly recommended, if not pressured to stick to an imposed work schedule, which is based upon strict bureaucratic rules and safety regulations. Moreover, any change in the tight work schedule requires a considerable amount of time and effort for Mission Support. For these reasons, it is very difficult for astronauts to deviate from the assigned work schedules. Indeed, some anecdotal reports hint at the frustration that emerges from the mere executive role assigned to astronauts (e.g., Hendricks, Mauroo, & Van Spilbeeck, 2009; Kanas & Manzey, 2008; McPhee & Charles, 2009; McIntosh et al., 2016; Stuster, 2010).

Another aspect of restricted crew autonomy is the fact that astronauts are often under audio and video surveillance by Mission Support when performing their duties. These audio and video channels are actively monitored by Mission Support members and payload operators on the ground, and are sometimes readily available to the public via the NASA website.

Despite the managing and reassuring functions these surveillance measures can have, one cannot ignore their evaluative and pressuring effect on the crew.

Despite astronauts' desire to exercise more authority in their daily activities, Western space agencies remain reluctant to train their flight crew to take such autonomous decisions. To some extent, this is understandable. If astronauts make decisions during dangerous operations and emergency situations, for which they are not trained and without informing Mission Support, it may create an atmosphere of distrust. Moreover, such personal decision making may yield considerable risks, not only for the psychological well-being of the astronauts themselves, but also for the successful completion of the overall mission. On the other hand, the complete lack of transfer of decision-making power to astronauts is surprising. Especially with respect to rather small or routine tasks, taking personal initiative and seeking solutions without informing Mission Support may not pose a problem.

Also, the communication delay between the Earth and Mars during a Mars mission almost necessitates the partial transfer of the decision-making power to a Mars crew. Interestingly, instead of granting increasing decision-making power to astronauts, scientists have been searching for different solutions. That is, to provide flight support despite the absence of direct communication, some scientists are developing computer-interactive intervention programs that can assess the crew's cognitive and emotional state and provide them with prevention and intervention information for potential psychological issues (Kanas & Manzey, 2008; Kanas, Sandal, Boyd et al., 2009) or are proposing remote crew monitoring by audio recordings of crew interactions (Ehmann et al., 2011). Thus, rather than taking the more limited possibilities for communication during Mars missions as an opportunity and springboard to strengthen the crew's autonomy, technical solutions are sought so as to secure continued monitoring and the associated minimal input of astronauts. This has raised alarm among several Russian cosmonauts and space experts. Kalery et al. (2010), for instance, argued that, due to the increased focus on such technical solutions, the ISS's primary objectives are being overlooked, that is, being on the front edge of science and technology in the exploration of the unknown, and targeting the crew's "*ability to act autonomously, display initiative and sustain logical and technical adequacy during spaceflight*" (p. 925).

1.2 Positive Reactions to Spaceflight

Traditionally, the major concerns of space agencies involve the avoidance or reduction of the negative psychological consequences of spaceflight. Hence, psychological knowledge was mainly used for the selection of a crew capable of functioning under stressful conditions and for the development of countermeasures to diminish the psychological hazards of spaceflight (Kanas & Manzey, 2008; Suedfeld et al., 2012). However, Suedfeld (2005) highlighted that an exclusive focus on the negative aspects of spaceflight, such as astronauts' stress and social isolation, fails to explain the manifold positive reactions experienced by astronauts. If space is such a stressful environment, why do thousands of individuals apply to become astronauts? Why are experienced astronauts often eager to return to outer space? To resolve this seeming paradox, the concept of *salutogenesis*, which was previously studied in other contexts (Antonovsky, 1979; Lindström & Erikson, 2005), was introduced within space psychology. Salutogenesis refers to individuals' ability to emerge from stressful experiences with increased psychological or even physiological resistance to future stressors (Suedfeld, 2005).

The process of salutogenesis in extreme environments has mainly been studied through individuals' value shifts during spaceflight (e.g., Suedfeld, Brcic, 2011; Suedfeld, 2006; Suedfeld, Legkaia, & Brcic, 2010), polar expeditions (e.g., Kjaergaard, Leon, Venables, & Fink, 2013; Leon, Sandal, & Larsen, 2011) or space simulations (e.g., Sandal, Bye, & van de Vijver, 2011; Suedfeld et al., 2012). In one study on the beneficial effects of spaceflight, Ihle, Ritsher and Kanas (2005; 2006) developed the Positive Effects of Being in Space (PEBS) questionnaire, which is based on the Post

Traumatic Growth Inventory (Tedeshi & Calhoun, 1996), a valid and reliable measure of positive personal growth that can occur following stressful events. This questionnaire was administered to 39 astronauts to identify several positive changes resulting from being in outer space. Overall, all respondents reported at least some change, with the greatest change being found for the subscale *Perceptions of Earth* and *Perceptions of Space*. Some of these changes were so profound that they even led to behavioral change, such as increased environmental activism. Interestingly, also *Changes in Daily Life* were reported, with, for instance, a majority of respondents indicating that their relationship with their family grew stronger. Yet, cluster analysis revealed that individuals vary considerably in their specific positive reactions to spaceflight, with some of them reporting considerable and others minimal change, an issue that deserves further exploration.

Other studies have found similar results, including an increase in the appreciation of the unity of mankind and an increase in self-confidence, accompanied by a sense of accomplishment and satisfaction from spaceflight (Suedfeld, 2006; Suedfeld & Brcic, 2011; Suedfeld et al., 2012) and polar expeditions (Kjaergaard, Leon, Venables, & Fink, 2013). In general, these results show changes primarily in the direction of more concern with humanity and the planet, implying a more open-minded and caring orientation toward the collective good rather than benefits to oneself (Suedfeld et al., 2010).

Given the enthusiastic reports by space travelers, some authors have described countermeasures that astronauts developed themselves to highlight the positive experiences of outer space. For instance, Johnson (2010) has described four ways by which astronauts transform their sterile environment into a new home. First, astronauts *fill their free time* with a variety of meaningful and interesting activities, such as looking at the Earth and identifying various sites and personally relevant places, but also activities such as reading, watching movies, sketching or taking photographs. Second, Johnson (2010) highlighted the necessity of *making daily activities fun* as to nurture the psychological health of astronauts. Humor plays an important role in this and in some situation helps to smooth crew-ground interactions. According to many astronauts, practical jokes, playful interactions and experimenting with food are common practice on the ISS, and help to alleviate the burdens of daily activities. Third, *space traditions* have been extensively observed, especially in Russian spacefaring, but have also found their way to the ISS in the form of handover ceremonies when there is, for instance, a change of command. Celebrations of space activities include specific space history landmarks that occurred during their time on the station (e.g., the anniversary of the first man launched into space), personal landmarks of the crew (e.g., breaking a previous record of time in space), and recognitions of a job well done (e.g., Extra-Vehicular Activity). These are usually celebrated with a special meal that has been especially selected for the occasion. Finally, communication with, and thoughts about *friends and family* have helped to close the gap between home on Earth and outer space. Contact with loved-ones, either through direct audio or video messaging, regular updates on news from home and care packages were viewed positively by all astronauts, as it elicited the feeling they were involved in the daily life of their friends and families.

Overall, two conclusions can be drawn from these first studies. First, they suggest that positive reactions to human spaceflight are a fairly common instead of a rare experience. Second, these positive experiences may play an important role not only in safeguarding astronauts against experiencing ill-being, but they may even have a health-enhancing effect. Despite these findings, many researchers remain concerned with the fact that space agencies and space psychologists primarily focus on the negative effects of spaceflight, and do not pay sufficient attention to the beneficial long-term after-effects of spaceflight (Brcic & Della-Rossa, 2012; Sandal & Bye, 2015; Suedfeld et al., 2012). As a consequence, very little is known about how these benefits come about and how they can be promoted through the development of particular measures.

1.3 Conclusion

When considering the topics of crew autonomy and the positive effects of spaceflight, it is interesting to note that, although several studies described these phenomena in detail, little is understood about their underlying psychological dynamics. Such lack of deep understanding prevents us from developing effective countermeasures aimed at alleviating the detrimental effects of reduced crew autonomy and harvesting the favourable effects of spaceflight on psychological well-being.

Additionally, sending humans to Mars brings forward a series of potential new hazards, the effects of which remain difficult to study on Earth (Kanas & Manzey, 2008). With this unknown era of human spaceflight ahead, it is time to borrow and further develop ideas from other research areas of psychology. Indeed, as current knowledge of space psychology may have reached its limits when it comes to Mars missions, a more holistic view on human functioning could provide helpful predictions about potential psychological challenges and countermeasures during an interplanetary mission.

The question then arises which theoretical framework could shed some light on current issues in space psychology and allow for the formulation of predictions about future psychological challenges of a Mars mission? When looking for such a framework, several criteria need to be taken into consideration. One has to look for:

- A theory embedded in positive psychology, meaning the theory not only focuses on the avoidance or reduction of ill-being, but also on the nurturance of well-being and its underlying processes.
- A theory that is universal, that can be applied across cultures, age, educational level, and gender.
- A theory that is strongly evidence-based and that has been studied and implemented successfully across several life domains and settings.

- A theory that can provide specific predictions and countermeasures to reduce the stressful aspect of missions, while at the same time nurturing astronauts' psychological well-being.

When reviewing current psychological knowledge, the Self-Determination Theory (Deci & Ryan, 2000) seems to be a good fit for these criteria.

2. Self-Determination Theory

2.1 Nutrients of Growth

Self-Determination Theory is a macro theory of human motivation, behavior, and well-being (Ryan & Deci, 2000; Ryan, Deci, & Vansteenkiste, 2016), which investigates people's innate psychological needs that are at the basis of their motivation and personality integration, as well as the conditions that foster those positive processes. The theory can be used to make predictions about the way social environments can be designed to optimize people's development, performance and well-being. SDT is strongly embedded in positive psychology, as the theory helps to explain how people's natural tendency for growth and learning can be enhanced and elevated (Deci & Vansteenkiste, 2004; Sheldon & Ryan, 2011). At the same time, it accounts for ill-being and maladaptive behavior by regarding them as outcomes of encountered frustration of these same psychological needs. In doing so, SDT goes beyond most positive psychological theories because it provides a dialectic account of both the positive and negative processes in human development (Ryan & Deci, 2000; Vansteenkiste & Ryan, 2013).

According to SDT, people have three inherent psychological needs: competence, relatedness and autonomy.

When people experience *competence*, they feel effective and successful in dealing with the environment. It is the belief that one has the ability to influence important outcomes.

When people experience *relatedness*, they feel connected and experience care for important others, through satisfying, supportive social relationships.

When people experience *autonomy*, they experience a sense of personal choice, volition and psychological freedom, through acting upon personally endorsed values and interests.

Different from other motivational frameworks, including the Motive Disposition Perspective[2], which consider the needs to be personal preferences acquired through different childhood experiences (Schultheiss & Hale, 2007), SDT considers these needs to be inherent and universal. Also, whereas other frameworks focus on interpersonal differences in the strength of needs, SDT focuses on the very satisfaction of these needs. The argument is forwarded that the satisfaction of the psychological needs for competence, relatedness and autonomy would yield benefits regardless of people's cultural background, gender and socio-economic status. These needs are not merely theoretical constructs; they were proposed in an attempt to meaningfully interpret a wealth of findings obtained in studies relying on a variety of study

[2] The connection between SDT and the Motives Disposition Theory (Atkinson, 1985; Winter, 1973) has gained increasing attention in recent years. Although these theories deal with closely related topics, the psychological needs are defined differently (see Deci & Ryan (2000) for a more extensive discussion). The motive for affiliation is defined as the preference for warm, intimate relationships and is similar to the need for relatedness. However, whereas the need for competence involves the experience of a sense of effectiveness and mastery in dealing with the environment, the motive to succeed involves the recurrent desire to surpass standards of excellence (Brunstein & Maier, 2005; Schüler, Brandstatter, & Scheldon, 2013). The need for autonomy differs from the motive to exert power (Schüler, Scheldon, & Fröhlich, 2010). Most motive researchers regard the need for power as the desire to influence others in order to feel strong. In contrast, the need for autonomy reflects an individual's need to experience willingness and voluntariness in his actions (Schüler, Brandstatter, & Sheldon, 2013).

designs, making use of diverse methodologies, and sampling participants differing in age, educational and cultural background (Deci & Ryan, 2000)

Across these studies, satisfaction of the needs for relatedness, autonomy and competence have been found to foster well-being and development, and are therefore considered essential nutrients of growth (e.g., Chen et al., 2015; Deci, et al., 2001), while the very frustration of these needs engenders passivity, alienation, or even opposition (e.g., Van Petegem, Soenens, Vansteenkiste, & Beyers, 2015). To the extent that astronauts volitionally engage in daily activities, experience a sense of mutual care with the ground crew and other astronauts, and feel effective in dealing with the challenges they encounter, they are more likely to thrive. Although no single empirical study has provided empirical support for this claim among astronauts, abundant research in diverse populations has provided evidence for the benefits associated with need satisfaction and the costs associated with need frustration (see e.g., Ryan & Deci, 2000; Vansteenkiste & Ryan, 2013). For instance, in the work domain, research has shown that employees who experience greater need satisfaction report feeling less exhausted and more engaged in their job (Van den Broeck, Vansteenkiste, De Witte, & Lens, 2008).

Further, a variety of methods has been used to study people's experienced need satisfaction and need frustration. Within the SDT tradition, the assessment of need satisfaction or frustration is usually done by self-report. For instance, participants are asked whether they feel effective in executing their daily activities (competence), whether they feel connected to others (relatedness) and whether they feel pressured to do certain things (autonomy; e.g., Chen et al., 2015). Apart from explicit self-reports, nowadays scholars are developing a number of implicit measures to tap into need satisfaction as well (e.g., Van der Kaap-Deeder, De Houwer, Hughes, Spruyt, & Vansteenkiste, 2018). Additionally, to document the consequences of need satisfaction or frustration, several measures other than self-reports have been used to assess health, motivation, performance and behavior, such as teacher-rated school adjustment of children (e.g., Ahmad, Vansteenkiste, & Soenens, 2013), free choice persistence (e.g., Deci, Koestner, & Ryan, 1999), or peaks in cortisol secretion (e.g., Reeve & Tseng, 2011), to name a few (Vansteenkiste & Ryan, 2013).

Overall, from existing evidence we can conclude that individuals from different socio-economic and cultural backgrounds, different ages and genders benefit from need satisfaction (e.g., Chen et al., 2015). Increasingly, scholars (e.g., Ciani, Sheldon, Hilpert, & Easter, 2011) have examined whether the benefits of need satisfaction also emerge for those being low in the strength of these needs, as suggested from the Motive Disposition Perspective. It appears that the benefits of need satisfaction are more pronounced for those with a greater strength of these needs. Yet, this moderation effect seems to appear only for implicit measures (e.g., Schüler, Wegner, & Knechtle, 2014), and not for explicit measures of need strength (e.g., Chen et al., 2015).

As for the contextual support and undermining of the psychological needs, different methodologies have also been used. To illustrate, in experimental studies, the degree of need thwarting has been experimentally manipulated by creating conditions where people are approached in cold and dismissive ways (frustrating relatedness; e.g., Sheldon & Filak, 2008), are given judgmental feedback (frustrating competence; e.g., Vansteenkiste & Deci, 2003) or are subjected to pressuring deadlines, evaluations and monitoring (frustrating autonomy; e.g., Enzle & Anderson, 1993). In other experimental studies, people are shown care and made to feel welcome (fostering relatedness; e.g. Sheldon & Filak, 2008), they are provided with constructive feedback (fostering competence; e.g., Mouratidis, Vansteenkiste, Lens, & Sideridis, 2008) or they are involved in decision-making procedures (fostering autonomy; e.g., Patall, Cooper, & Wynn, 2010). To the extent that individuals' needs got supported, they reported enhanced engagement and well-being, continued persistence and improved performance, while they were more likely to defy or give up in need-thwarting circumstances.

2.2. Manifestations of Growth

Apart from documenting the well-being and performance benefits of the satisfaction of these psychological needs, SDT has also specified the processes through which these effects accrue. That is, need satisfaction is said to fuel three different growth manifestations, all of which are relevant for the functioning of astronauts. As can be noticed in Figure 1, these three growth manifestations concern the processes of (a) intrinsic motivation, (b) internalization, and (c) intrinsic goal pursuit (Ryan & Deci, 2000; Vansteenkiste & Lens, 2006).

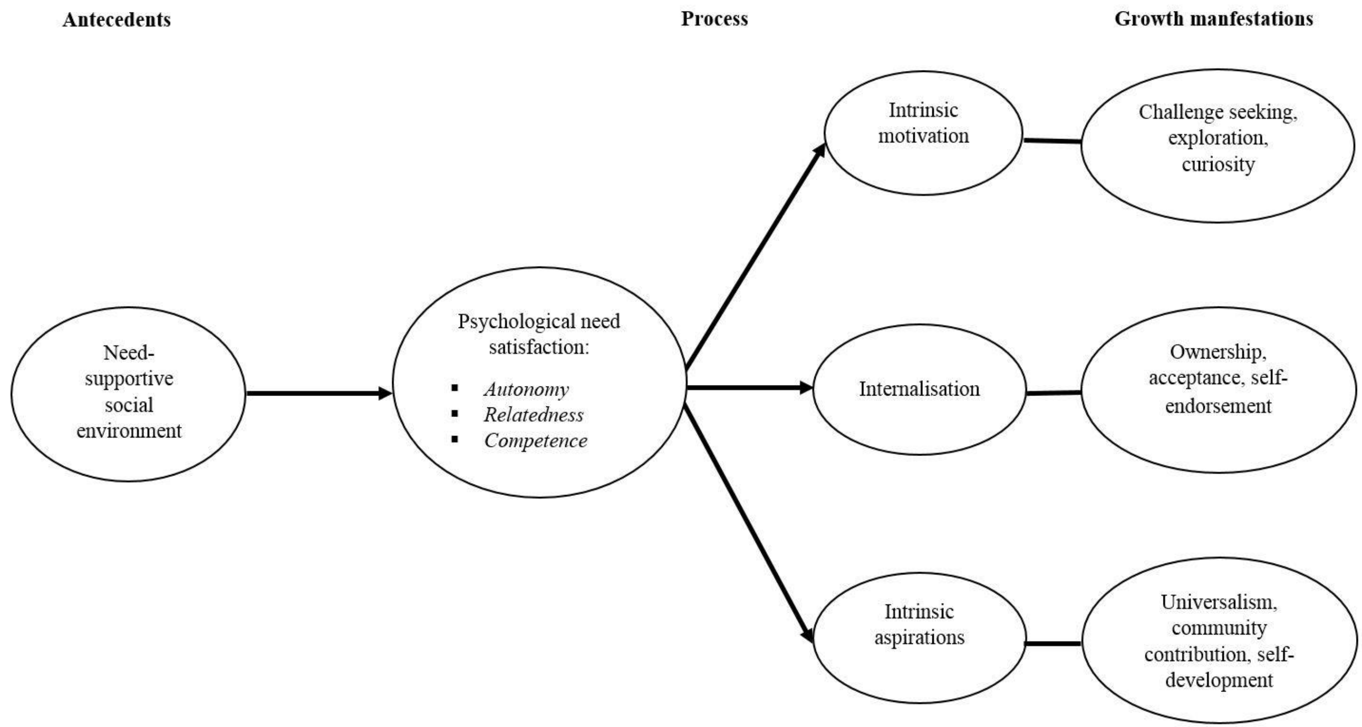

Figure 1. Graphic overview of growth model of Self-Determination Theory (Ryan & Deci, 2000; Vansteenkiste & Lens, 2006).

Intrinsic Motivation. Intrinsic motivation is described as the inherent assimilative tendency to seek out novelty and challenges, to extend and exercise one's capacities, and to explore one's inner and outer environment driven by curiosity (Deci, 1975) (cfr. Figure 1). When intrinsically motivated, people engage in the activity for its own sake as the reward lies in the satisfaction inherent to, or spontaneously following from, the activity itself. For instance, when intrinsically motivated, people find their jobs to be interesting and enjoyable and they may even be passionate (Gagné & Deci, 2005).

Astronauts who express excitement at the prospect of going into space to discover new things can be described as intrinsically motivated. Although individuals cannot be forced to enjoy and be interested in an activity, a social environment that supports individuals' needs for autonomy and competence has been shown to awaken and nurture intrinsic motivation and passion in individuals. Indeed, to the extent that individuals are offered choice (e.g., Patall, Cooper, & Robinson, 2008) and provided sincere, competence-affirming feedback (Mouratidis et al., 2008; Mouratidis, Lens, & Vansteenkiste, 2010), they are more likely to develop an interest in the activity at hand. In contrast, the use of autonomy-suppressing and pressuring language (e.g., Reeve & Jang, 2006) and criticism (e.g., Ryan & Deci, 2006) have been found to forestall need satisfaction and subsequent intrinsic motivation. Relatedness satisfaction is said to play a more distal role in the nurturing of intrinsic motivation (Deci & Ryan, 2000), as individuals can also enjoy engaging in leisure time activities by themselves. Indeed, astronauts may like to have some free time reserved for themselves, without much interaction with other crew members.

Internalization. Rather unfortunately, much of what people do is not intrinsically motivated. That is, many of our daily activities are not interesting, yet they are important to do. This is also true for astronauts, who may feel little challenge and interest in executing (some) routine activities. Does this imply that astronauts by definition feel pressured to execute such activities? No. To the extent that they have come to endorse or internalize the reasons for performing the activity, they are more likely to perform these activities with a greater sense of willingness.

In this respect, SDT differentiates between different types of extrinsic motivation, depending on the degree to which internalization has occurred (Ryan & Deci, 2000). Thereby, *internalization* refers to the adoption and full acceptance (i.e., endorsement) of an initially externally offered value or behavioral regulation. Internalization is high when people perceive the self-importance and personal value of a specific activity. In this case, people are said to be autonomously motivated as they engage in the activity with a sense of volition, willingness and ownership of their behavior (cfr. Figure 1). In contrast, when people engage in an activity because they feel externally pressured to do so (e.g., to avoid criticism or to gain appreciation) or to meet internal feelings of pressure (e.g., to avoid feelings of guilt, shame or to attain self-aggrandization), their actions are said to be regulated by controlling forces. In the case of controlled motivation, no or only partial internalization has occurred.

The satisfaction of all three needs is said to be integral for the internalization and full endorsement of activities. Indeed, requests that are formulated by significant others to whom one feels strongly attached are more likely to be accepted. Similarly, one is more likely to internalize the introduced requests when one feels efficacious in executing them. Yet, full internalization is only achieved when a sense of psychological freedom and autonomy need satisfaction is experienced (Deci & Ryan, 2000; Ryan & Deci, 2006). Indeed, one may comply with instructions and effectively carry out activities out of a sense of conflicted loyalty vis-à-vis the person introducing the request. Yet, only when this request is formulated in an autonomy-supportive way, for instance, by allowing a person to voice their opinion or by explaining the importance of the task at hand, one is more likely to fully endorse the reason for performing the activity (Vansteenkiste, Soenens, Van Petegem, & Duriez, 2014).

At this point, it is crucial to clarify the exact meaning of autonomy as conceived within the framework of SDT. In SDT, autonomy is not equated with *independence*, that is, as making decisions without reliance on external guidance. Instead, autonomy is defined as self-endorsement, which pertains to the degree to which one fully concurs with the reasons or motives underlying one's actions, such that one's actions are grounded in authentic values and interests (Ryan & Deci, 2006; Ryan & Lynch, 1989). In other words, autonomy does not relate to the locus of decision-making (i.e., *Who* is making the decision?), which varies from total independence (i.e., without relying on anyone) to total dependence (i.e., completely giving away ownership of the decision). Instead, autonomy relates to the motives for making decisions independently or dependently (i.e., *Why* is the decision made independently, or why is the decision given to someone else?) (Chen, Vansteenkiste, Beyers, Soenens, & Van Petegem, 2013). Although independent decision-making would grant more opportunities for the enactment and realization of one's self-endorsed convictions and interests (thereby contributing to a sense of volition and inner psychological freedom), autonomy satisfaction can also be experienced in a state of dependence, if the motives for the dependent behavior have been internalized (Van Petegem, Beyers, Vansteenkiste, & Soenens, 2012). Figure 2 provides a graphical overview of this idea as the dimension of independent relative to dependent functioning are crossed with the autonomous and controlled motives underlying these behaviors. When Mission Support grants astronauts the freedom to make independent decisions or when it provides astronauts with support and guidance on request, then Mission Support can be said to promote, respectively, independence and dependence in a volitional (autonomous) fashion (i.e., the upper left and lower left quadrant). Similarly, Mission Support can also promote dependence either in a volitional (i.e., the lower left quadrant) or in a controlling fashion (i.e., the lower right quadrant). When autonomy is operationally differentiated from independence, it has been shown to be positively related to psychological well-being, even in collectivistic cultures (e.g., Chen et al., 2013).

Figure 2. Graphic overview of the distinction between independence and autonomy dimensions as applied to the interaction between astronauts and mission control (adapted from Soenens and Vansteenkiste, 2010).

Intrinsic life goals. SDT is also concerned with the differential content of types of life goals that people pursue (Kasser & Ryan, 1996). Intrinsic goals, such as community contribution, self-development, and universalism (i.e., the promotion of welfare for all humankind and the natural environment (Schwartz, 2007), are goals that are inherently satisfying because they are more conducive to individuals' need satisfaction (Niemiec, Ryan, & Deci, 2009). Extrinsic goals, such as financial success, physical appearance, and image, are oriented towards external valuation because they require the contingent reaction of others and are therefore more likely to be at odds with the satisfaction of one's basic psychological needs (Unanue, Dittmar, Vignoles, & Vansteenkiste, 2014).

The satisfaction of the psychological needs is not only said to follow from the content of one's pursued life goals, but it also said to be rooted in a different degree of encountered need satisfaction. Specifically, when people experience need satisfaction, they are likely better in touch with their personal values and goals, and they therefore likely attach greater importance to intrinsic life goals. In contrast, when people experience need frustration, they become more likely to pursue extrinsic goals, as the approval of others would constitute a way to gain some sense of worth so as to compensate for encountered need frustration (Kasser & Ahuvia, 2002).

This idea is supported by several empirical studies. Indeed, individuals were found to be especially oriented towards extrinsic life goals when growing up in social environments that undermine growth and need satisfaction, such as in a cold and controlling family (Kasser, Ryan, Zax, & Sameroff, 1995), in situations where people feel threatened (Scheldon & Kasser, 2008) or are made to feel insecurity and self-doubt (Chang & Arkin, 2002), and when familial socio-economic status is low (Kasser, Koestner, & Lekes, 2002). By contrast, individuals growing up in need-supportive contexts were found to be much more oriented towards intrinsic life goals (e.g., Lekes, Gingras, Philippe, Koestner, & Fang, 2010).

Interestingly, some studies suggested that natural environments can also promote the valuation of intrinsic life goals and even engender greater vitality. For instance, experimental studies have demonstrated that people who were immersed in a natural environment (either simulated or real) reported an increased pursuit of intrinsic aspirations, greater vitality, and engaging in more generous behavior, when compared to people exposed to non-natural environments (Ryan et al., 2010; Weinstein, Przybylski, & Ryan, 2009). The authors suggested that natural environments may foster experiences of autonomy and connectedness with nature. Specifically, nature can nurture autonomy directly by affording stimulating sensations and opportunities to integrate experience by encouraging introspection and a coherent sense of self, and indirectly by providing an alternative to the pressures of everyday life.

Not only does need satisfaction predict people's orientation towards intrinsic life goals, but numerous studies across life domains (e.g., exercising, school, relationships, work) and in diverse age samples (e.g., adolescents, adults, seniors) have revealed that both the pursuit and the attainment of intrinsic goals, relative to extrinsic goals, is associated with greater health, well-being, and performance (for a review, see Vansteenkiste, Niemiec, & Soenens, 2010; Sheldon, Ryan, Deci, & Kasser, 2004). Indeed, a recent meta-analysis by Dittmar, Bond, Hurst and Kasser (2014) provided further confirmatory evidence for this claim.

It is important to note that intrinsic and extrinsic aspirations are distinct from autonomous and controlled extrinsic motivation, since both intrinsic and extrinsic goals can be pursued for either autonomous or controlled reasons. Although intrinsic goals usually tend to be pursued for autonomous reasons and extrinsic goals tend to be pursued for controlled reasons, the content of, and reasons for pursuing aspirations can be crossed. This was done in a longitudinal study by Sheldon, Ryan, Deci and Kasser (2014) in which the authors assessed participant's goal content (*what* they aspire), their motives for doing so (*why* they aspire) and their well-being. They found that both goal content and motives significantly predicted well-being, after controlling for each other. Beyond the fact that extrinsic goals are often pursued for controlled motives, and that controlled motivation is predictive of ill-being, it appears that people's intrinsic aspirations positively affect their subsequent well-being.

2.3. Summary

In conclusion, SDT postulates three basic psychological needs that are inherent and universal. Dozens of studies have confirmed that satisfaction of the needs for relatedness, autonomy and competence fosters well-being, while the frustration of these very same needs engenders passivity, alienation or even opposition. Need satisfaction yields these desirable outcomes because it forms the impetus for the actualization of three growth manifestations, that is, the engagement in enjoyable, challenging and interesting activities (i.e., intrinsic motivation), the full endorsement of external requests (i.e., internalization), and the pursuit of inherently valuable goals, such as self-development, community contribution and universalism (i.e., intrinsic goal pursuit).

3. SDT Applied to Spaceflight

Having reviewed a number of central theoretical constructs within SDT, we now turn to the application of SDT to the topics of crew autonomy and the positive effects of spaceflight. As will be argued, the satisfaction of the needs for relatedness, competence and autonomy and the growth manifestations it engenders, may play an important role in human spaceflight.

3.1. How to Promote Volitional Functioning During Spaceflight?

Much of the flight crew's work consists of routine, monotonous or unpleasant tasks, such as cleaning, maintenance tasks, physical exercise and medically invasive or monotonous experimental tasks. From the SDT-perspective, such tasks can be described as being low in intrinsic motivation. Yet, the degree of willingness to perform these non-enjoyable activities among astronauts will depend on the internalization of the reasons underlying their execution. Clearly, astronauts who went through very strict and demanding selection procedures are presumably highly motivated and willing to put effort into their profession. Yet, the way their ongoing daily activities are regulated by Mission Support will engender variable degrees of need satisfaction and need frustration and yield resulting consequences for the ownership of their daily behavior. In fact, it seems that the tendency in Western space agencies to increase bureaucracy, flight rules and safety regulations may hamper astronauts' need satisfaction. For such a highly trained and capable flight crew, this type of work environment may even thwart their need to feel volitional and competent in their activities. In an attempt to resist these need-thwarts, astronauts may make independent decisions without informing Mission Support so as to establish their autonomy. Yet, such independent decision making is not volitional, but rather reactive and hence, controlled in nature. That is, it reflects a form of opposition, which has been found to result from the frustration of the needs for autonomy and competence (Van Petegem et al., 2015). Perhaps, although not necessarily deliberate, it is a way for the crew to attempt to regain a sense of freedom and efficacy. Despite the constraints of the environment, from an SDT-perspective, Mission Support can steer astronauts in more motivating and need-supportive ways. Specifically, the flight crew could (a) be granted action choice and option choice in their daily tasks (Patall, et al., 2008; Reeve, Nix, & Hamm, 2003). However, even in situations of high dependency, Mission Support can still take autonomy-supportive measures, for instance by (b) explaining why they monitor astronaut's behavior, and by (c) providing effective and competence enhancing feedback.

Option and action choice. Although many space experts are dreading the increase in crew independence that is bound to happen for interplanetary travel, and fear for the potential threat of an isolated independent crew (Kanas & Manzey, 2008), SDT actually suggests that an increase in crew independence could provide new opportunities for the crew to feel more competent and volitional, by letting the flight crew choose which tasks to perform (option choice). These opportunities to choose between options generally facilitates the perception of choice and hence, a sense of autonomy or willingness. However, in cases where tasks have been assigned to crew members, they can still be given choice within the task (action choice), by for example deciding the timing and pace according to their preferences, which is likewise expected to increase autonomy.

Unfortunately, only a few pilot studies have provided preliminary support for the positive effects of an increase in crew choice. Specifically, a simulation study by Kanas et al. (2011) showed that an increase in crew action choice was well-received by the crew members, while no adverse effects were observed and mission goals were generally accomplished. Other studies provided evidence for the importance of choice for improved mood, personal discovery, and innovation. For instance, Roma et al. (2011) reported that when members were free to choose the way they performed their tasks (cfr. action choice), they showed better performance, less negative emotions, more socially-referent language and lower levels of salivary cortisol production. Similarly, Sandal et al. (2011) found that the Mars 500 crew members' perceptions of stress decreased when they were allowed greater option choice. They described the reduction in contact with Mission Support as 'a relief', resulting in a calmer atmosphere and decreased on-board tension. Overall, these studies suggest that an increase in the crew's volitional functioning, either through option or action choice, may enhance their well-being and performance, as predicted by SDT.

Of course, a number of critical questions remain. First, initial studies (Roma et al., 2011) also suggest that there might be cultural differences in the enactment of autonomy. From an SDT-perspective, this is no surprise. That is, the route to the experience of volition may be - at least to some extent - culture-bound. While astronauts from Western and individualistic nations may experience a greater sense of volition through independent decision making, astronauts from Eastern and collectivistic nations may achieve a greater sense of volition by acting dependently, that is, by complying with guidelines and instructions (Chen et al., 2013; Chirkov, ryan, & Kim, 2003). However, in spite of their elevated dependency, astronauts from collectivistic nations would not benefit from pressure!

Second, when space experts talk about the inevitable future increase in crew autonomy, from an SDT-perspective, they are actually talking about crew independence, i.e., the crew acting and taking decisions independently from Mission Support (see Figure 2). What ultimately matters from the SDT-perspective is whether such dependent or independent behavior is being forced upon astronauts, or whether it is being volitionally enacted by them. More research is needed to identify the appropriate degree of afforded crew independence. This will likely be determined by circumstantial elements, such as the difficulty and risks associated with the task at hand, whether the activity belongs to astronauts' personal territory or domain, and the presence of technical and physical restrictions. For instance, when tasks are more difficult, when more risks are associated and when technical or physical restrictions are present, astronauts' independent functioning is restrained. Instead, with respect to more personal issues (e.g., leisure time activities), they may be granted more choice and independence. Likewise, when astronauts are highly experienced with a certain task, the guidance may be less desirable as continued instruction may signal distrust to the astronauts, and therefore may be experienced as controlling and autonomy-suppressing. In other words, the ongoing support of astronauts' psychological needs is essentially about being sensitive about how and to whom certain tasks are presented, and about building in different degrees of choice. Such sensitivity requires Mission Support personnel to take the frame of reference of the astronaut as to estimate whether the task fits the astronaut's interest and expertise level.

Finally, crew members will need to be properly trained for an increase in crew independent decision making, preferably during actual space missions. The increase in independence can be a gradual process, in part because astronauts currently lack the routine of making their own decisions, in part because some choices made may yield considerable risks for which they may be made accountable. To facilitate this process, Mission Support could start by involving flight crew in decision-making processes. Their opinions should be heard and action could be taken in mutual agreement. By doing so, astronauts can regain a sense of volition, and will be better able to internalize the rationales behind their daily tasks, thus creating the possibility to enhance autonomous motivation and psychological well-being. Over time, astronauts could then be granted greater decision-making power over more difficult decisions involving greater risks. This evolution should not be dreaded but rather viewed as an opportunity for the crew to become more strongly engaged. The ISS could be used to simulate an expedition to Mars, as has been suggested by several authors already (Kalery et al., 2010; Kanas et al., 2009; Kanas et al., 2011).

Meaningful rationale for monitoring. Even in situations where no possibilities for either option or action choice are available, as is often the case in present-day ISS missions, astronauts can be approached in an autonomy-supportive way. Critical in this respect is that the astronauts' frame of reference is maximally supported, for instance, by fully recognizing the irritation that may arise from being denied choice and input. Also, the provision of a meaningful rationale for introduced instructions or ongoing monitoring is critical. As for the monitoring by Mission Support, astronauts frequently perform their tasks under constant audio and video surveillance. Surveillance as such is often viewed as fairly controlling and evaluative, with resulting implications for individuals' sense of autonomy and intrinsic motivation (Plant & Ryan, 1985). This effect may even be enhanced among astronauts given astronauts' videotaped behavior is at times made readily available to a broader public. The added value of such public monitoring for astronauts' daily functioning can be questioned, as it may increase pressure and even elicit anxiety. This does not imply that astronauts' behavior should not be monitored at all, yet, the way of doing so yields differential motivational implications.

In one informative experimental study, Enzle and Anderson (1993) experimentally varied the reason for monitoring participants' behavior so as to impact the perceived meaning of the monitoring. That is, the monitoring can be perceived as more informational and helpful or rather evaluative and pressuring (Deci & Ryan, 1985), with resulting consequences for individuals' need satisfaction and their willingness to comply with the requests of the surveilling individual. Specifically, in the Enzle and Anderson study (1993), participants were told that the aim of monitoring their behavior was either to ensure that participants would strictly comply with the instructions and to evaluate their performance (i.e., evaluative monitoring) or they were told that they were being watched out of pure curiosity, that is, to see how they were handling the tasks (i.e., informational monitoring). So, both groups of participants were monitored, yet, those in the evaluative monitoring group not only lost their interest in the activity when compared to participants in the informational monitoring group, but also when compared to the group who were not provided any rationale at all. Therefore, it is crucial for Mission Support to pay careful attention to the specific intent of monitoring measures and to explicitly provide the crew with informational and supportive rationales for surveillance. In this way, astronauts may come to better understand the necessity for continued monitoring and show less signs of resistance.

Effective feedback. Abundant research has demonstrated the importance of feedback for the satisfaction of individuals' need for competence (Deci, Koestner, & Ryan, 1999; Mouratidis et al., 2008). Positive feedback provides individuals with affirmative feedback regarding their capabilities and may boost their confidence to handle future challenges. However, the provision of corrective feedback, that is, feedback that is provided in response to lower performance or mistakes, is inevitable, as it is inherently tied with the learning process. Corrective feedback needs to be distinguished from negative feedback. Whereas negative feedback focuses on the end result and on the astronauts' failure to achieve a certain outcome, corrective feedback focuses more on the process itself and the way individuals can remedy their task performance.

Given that crew-ground conversations are monitored by thousands of people, the provision of authentic and honest feedback can be fairly challenging, especially if this information yields messages of failure. Nevertheless, there are different ways in which criticism can be delivered, and not all of them are necessarily need frustrating. Research has shown that even corrective feedback does not necessarily forestall individuals' competence, provided it is communicated in an autonomy-supportive way. Several strategies are vital in this respect (Mageau & Carpentier, 2013; Mouratidis et al., 2010). For instance, after task completion, Mission Support could solicit the astronauts' opinion about their performance instead of providing straightforward feedback and advice themselves. Further, Mission Support could ask permission to provide feedback, thereby creating a greater receptivity for the corrective feedback. In addition, the corrective feedback could be accompanied by a meaningful rationale so astronauts could come to fully understand the need for correction and change. Finally, the feedback would need to be sufficiently clear and informative so astronauts would understand clearly how to improve the situation, by preference and at their own pace.

Overall then, while positive feedback and stimulation is vital to guarantee competence need satisfaction and continued engagement, Mission Support will inevitably also provide corrective feedback. Their style of doing so may vary considerably though, with resultant implications for astronauts' experience of overall need satisfaction.

3.2. How to Promote the Beneficial Effects of Spaceflight?

From an SDT-perspective, the positive effects of spaceflight reported by astronauts can be explained as consequences of improved need satisfaction. Several actions can therefore be taken by Mission Support to safeguard these effects and harvest their benefits, such as a) increasing the experience of competence through the provision of challenges and celebrations, b) creating the possibilities for astronauts to personalize their stay in space so as to experience a feeling of autonomy and c) securing a strong connection with Earth to satisfy a sense of relatedness. To conclude, we discuss possible individual differences in need satisfaction.

Challenges and celebrations. When reviewing the experimental study by Ihle et al. (2005; 2006), it becomes evident that many of the subscales that were used to evaluate the positive effects of spaceflight yield a reference to the satisfaction of the need for competence. The subscale of *new possibilities* ("*New opportunities are available which wouldn't have been otherwise*") and *personal strength* ("*I know better I can handle difficulties*") reflect a feeling of competence that is being satisfied by successfully completing such an ambitious endeavor. The space environment provides new challenges and situations in which the astronaut can discover new talents and develop new capabilities. In fact, the whole idea of salutogenesis as presented by Suedfeld (2005) can be regarded as a redefinition of the satisfaction of the need for competence: the ability to cope with stressors and conceive them as challenges providing an opportunity to exercise competence and mastery. The importance astronauts attach to *space traditions and celebrations* (Johnson, 2010) can be regarded as an intense experience of competence that is being acted out during a ceremony. Celebrating the successful completion of a difficult task such as an EVA or a record of a hundred days in space helps to boost their vigour, and many astronauts have emphasized the importance of these rituals. Traditions and celebrations may therefore be actively encouraged by Mission Support. For a Mars mission, festivities can be simultaneously celebrated on Earth and recordings of these events could be exchanged between Mission Support and the flight crew.

Personalization of space. As has been previously discussed, experiencing a sense of autonomy can be challenging for astronauts in a space environment. At the same time, having *leisure time* and being able to execute *personalized routines* was repeatedly reported as a key path towards well-being by many astronauts. As astronauts are often subjected to bureaucratic rules and are subjected to ongoing monitoring from Mission Support, leisure activities allow one to temporarily get away from these pressures and to recharge one's batteries. As leisure time activities are often intrinsically motivated, that is, executed out of inherent enjoyment, they are accompanied with a sense of volition. Reports show considerable variability in favorite leisure activities and demonstrate the importance of personalizing leisure time, according to the astronaut's own interests. Likewise, *making daily activities fun* can be regarded as an attempt by the crew to achieve a sense of volition. Therefore, Mission Support should make sure astronaut's leisure time is respected, and the possibility to personalize leisure times should be guaranteed. For Mars missions, a possible change in preferences and interests in certain leisure activities may be taken into consideration.

Connection with Earth. A *stronger appreciation for the Earth and space*, and *stronger relationship with family members* (Ihle et al., 2005; 2006) are indicative of the nourishment of the need for relatedness. Presumably, when flying in an aluminum tube 400 kilometers above the Earth's surface, astronauts are both physically and psychologically taking a more observing perspective, which allows them to connect more deeply with humankind, nature, and the universe in general. Indeed, almost all astronauts reported an increased appreciation for the Earth’s beauty, along with more involvement in environmental causes. These results are in accordance with studies suggesting that natural environments increase valuing of intrinsic aspirations and vitality, because natural environments create experiences fostering autonomy and relatedness with nature (Weinstein et al., 2009). It seems as if the space environment and the views of Earth have a similar beneficial effect on astronauts, orienting them towards intrinsic goals and nurturing a sense of universalism and community (see figure 1). It is possible that the views of Earth encourage introspection and a more mindful stance, which foster autonomy and relatedness, and subsequently the valuing of intrinsic aspirations (Brown & Ryan, 2005; Vansteenkiste, Duriez, Simons, & Soenens, 2006). This increased valuing of intrinsic aspirations is something that may be further encouraged and exploited, as several studies found intrinsic aspirations to be conducive to individuals’ psychological well-being (Niemiec et al., 2009; Vansteenkiste et al., 2006).

While Mars missions may constitute an opportunity for improved autonomy and competence satisfaction, this may not be the case for relatedness. Due to the distance between Earth and Mars and the associated communication delay, direct contact with loved ones, a crucial factor for individuals’ psychological well-being (Johnson, 2010), will no longer be possible. Of course, the crew can still rely on email and possibly video recordings to keep in touch with friends and families, and they will still have each other to rely on for emotional support. However the potential frustration from such a situation is not to be underestimated, as feelings of loneliness may be more likely to surface. Indeed, based on SDT, one can predict that social isolation and the lack of intimate human relationships might constitute the major risk of a Mars mission. Therefore, more research should be performed and more countermeasures should be developed to take on this particular issue. Mission Supports primary focus could therefore be to assure a strong connection with Earth, through optimizing communication between the crew and their loved ones. Regular updates on important news, political changes, and sport events - depending on the crew's interests - could be sent to the crew, as well as frequent inquiries regarding their well-being. An increased reliance on computers to assess the crew's cognitive state and to present prevention and intervention information, as has been proposed by some space experts (Ehmann et al., 2011), might induce an opposite effect than intended. It could restrict the crew in their sense of relatedness, as having to entrust one's personal feelings to a machine might actually induce a sense of isolation and loneliness.

Individual differences. The study by Ihle et al. (2005; 2006) also highlighted substantial individual differences in the positive effects of spaceflight. According to SDT, the satisfaction of the needs for relatedness, competence and autonomy should yield universal benefits. Yet, there could be substantial variation, that is, individual differences, in the way these needs are satisfied, a possibility also recognized within the Motive Disposition Perspective. For instance, a person who shows less change in perceptions of the Earth, might simply be less dependent upon a view of the Earth for relatedness need satisfaction. This person might benefit more from interpersonal interventions to feel connected to their loved ones. These issues would need to be empirically confirmed in future research.

Although the positive reactions to spaceflight that have been described are considered to be desirable, it could be possible that those who have especially positive experiences in space may have a particular difficulty re-integrating with their family or other aspects of their social environment upon return (Ritsher, Kanas, Ihle, & Saylor, 2007). Individual differences in the way needs are satisfied could therefore also be examined in relation to post-flight adjustment. How will astronauts who seek to overcome tremendous challenges react when they return and face the conditions of everyday life? Will they manage to adjust or rather go through a difficult transitional period, given the immense contrast between the participation in the greatest adventure of humanity and the everyday terrestrial concerns? Unfortunately, so far, very little is known about the individual differences in the way needs are satisfied. As previously mentioned, it appears that the benefits of need satisfaction are more pronounced for those with a greater strength of these needs, when implicit measures are used, but not for explicit measures of need strength. Overall, this topic deserves further research.

Conclusion

Although dozens of studies in space psychology have generated fascinating insights into the psychological environment of astronauts during missions, more systematic research is needed to fully understand the influences, mechanisms and consequences of the stressors and benefits of human spaceflight. Throughout this review, we hope to have shown that SDT can be a valuable framework to synthesize these findings, bring further conceptual clarity, and offer a number of future research directions. The notions of the psychological needs for autonomy, competence and relatedness, and the essential nutrients of growth, provide a deeper insight into the dynamics underlying diverse observed psychological phenomena, shedding a refreshing light on potential future psychological stressors for interplanetary travel, and allowing for the formulation of possible countermeasures to alleviate these stressors as well as the formulation of measures to actualize the potential benefits. Yet, given that many of the suggested (counter)measures are purely derived from the theory, research is needed to test their effectiveness. Thus, multiple challenges still await psychologists and researchers working in the area of human spaceflight.

References

Ahmad, I., Vansteenkiste, M., & Soenens, B. (2013). The relations of Arab Jordanian adolescents' perceived maternal parenting to teacher-rated adjustment and problems: The intervening role of perceived need satisfaction. *Developmental Psychology, 49,* 177-183.

Antonovsky, A. (1979). *Health, Stress and Coping*. San Franscisco: Jossey-Bass Publishers.

Atkinson, J. W. (1958). *Motives in Fantasy, Action and Society: A Method of Assessment and Study*. New Jersey: Princeton.

Brcic, J. & Della-Rossa, I. (2012). Universal values of Canadian astronauts. *Acta Astronautica, 80,* 46-51.

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology, 84,* 822-848.

Brown, K. W., & Ryan, R. M. (2005). Are psychological and ecological well-being compatible? The role of values, mindfulness, and lifestyle. *Social Indicators Research, 74,* 349-368.

Brunstein, J. C., & Maier, G. W. (2005). Implicit and self-attributed motives to achieve: Two separate but interacting needs. *Journal of Personality and Social Psychology, 89,* 205-222.

Carpentier, J., & Mageau, G. A. (2013). When change-oriented feedback enhances motivation, well-being and performance: A look at autonomy-supportive feedback in sport. *Psychology of Sport and Exercise, 14,* 423-435.

Chang, L. C., & Arkin, R. M. (2002). Materialism as an attempt to cope with uncertainty. *Psychology & Marketing, 19,* 389-406.

Chen, B., Vansteekiste, M., Beyers, W., Boone, L., Deci, E. L., Duriez, B., Lens, W., Matos, L., Mouratidis, A., Ryan, R. M., Sheldon, K., Soenens, B., van der Kaap-Deeder, J., Van Petegem, S., & Verstuyf, J. (2015). Basic psychological need satisfaction, need frustration, and need strength across four cultures. *Motivation & Emotion, 39*, 216-236.

Chen, B., Vansteenkiste, M., Beyers, W., Soenens, B., & Van Petegem, S. (2013). Autonomy in family decision making for Chinese adolescents: disentangling the dual meaning of autonomy. *Journal of Cross-Cultural Psychology, 44*, 1184-1209.

Chirkov, V., Ryan, R. M., & Kim, Y. (2003). Differentiating autonomy from individualism and independence: a Self-Determination heory perspective on internalization of cultural orientations and well-being. *Journal of Personality and Social Psychology, 84*, 97-110.

Ciani, K. D., Sheldon, K. M., Hilpert, J. C., & Easter, M. A. (2011). Antecedents and trajectories of achievement goals: A self-determination theory perspective. *British Journal of Educational Psychology, 81*, 223-243.

Deci, E. L. (1975). *Intrinsic Motivation*. New York: Plenum.

Deci, E. L., & Ryan, R. M. (1985b). The General Causality Orientations Scale: Self-Determination in Personality. *Journal of Research in Personality, 19*, 109-134.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227-268.

Deci, E. L., & Ryan, R. M. (2012). Self-determination theory in health care and its relations to motivational interviewing: a few comments. *International Journal of Behavioral Nutrition and Physical Activity, 9*, 1-6.

Deci, E. L., & Vansteenkiste, M. (2004). Self-Determination Theory and basic need satisfaction: Understanding human development in positive psychology. *Ricerche di Psichologia, 27*, 17-34.

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin, 125*, 627-668.

Deci, E. L., Ryan, R. M., Gagné, M., Leone, D. R., Usunov, J., & Kornazheva, B. P. (2001). Need satisfaction, motivation, and well-being in the work organizations of a former eastern bloc country: a cross-cultural study of self-determination. *Personality and Social Psychology Bulletin, 27,* 930-942.

Deci, E.L., Koestner, R., & Ryan, R.M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, *125*, 627-668.

Dittmar, H., Bond, R., Hurst, M., Kasser, T. (2014). The relationship between materialism and personal well-being: A meta-analysis. *Journal of Personality and Social Psychology, 107,* 879-924.

Ehmann, B., Balázs, L., Fülöp, E., Hargitai, R., Kabai, P., Péley, B., Pólya, T., Vargha, A., & László, J. (2011). Narrative psychological content analysis as a tool for psychological status monitoring of crews in isolated, confined and extreme settings. *Acta Astronautica, 68*, 1560-1566.

Enzle, M. E., & Anderson, S. C. (1993). Surveillant intentions and intrinsic motivation. *Journal of Personality and Social Psychology, 64*, 257-266.

Gagné, M., & Deci, E. L. (2005). Self-Determination Theory and work motivation. *Journal of Occupational Behavior, 26,* 331-362.

Hendricks, H., Mauroo, T., & Van Spilbeeck, B. (2009). *Het Ruimtedagboek van Frank De Winne: Dagelijks Leven in het ISS.* Leuven: Van Halewyck.

Hofer, J., & Busch, H. (2011). Satisfying one's needs for competence and relatedness: Consequent domain-specific well-being depends on strength of implicit motive. *Personality and Social Psychology Bulletin, 37,* 1147-1158.

Ihle, E., Ritsher, J., & Kanas, N. (2005). Positive psychological effects of space missions. *Acta Astronautica, 57,* 630-633.

Ihle, E., Ritsher, J., & Kanas, N. (2006). Positive psychological outcomes of spaceflight: an empirical study. *Aviation, Space, and Environmental Medicine, 77*, 93-102.

Johnson, P. (2010). The roles of NASA, U.S. astronauts and their families in long-duration missions. *Acta Astronautica, 67*, 561-571.

Johnson, P. J., Asmaro, D., Suedfeld, P., & Gushin, V. Thematic content analysis of work-family interactions: Retired cosmonauts' reflections. *Acta Astronautica, 81*, 306-317.

Kalery, A., Sorokin, I., & Tyurin, M. (2010). Human space exploration beyond the international space station: role of relations of human, machine and the ‘‘Earth’’. *Acta Astronautica, 67*, 925-933.

Kanas, N. (2005). Interpersonal issues in space: Shuttle/Mir and beyond. *Aviation, Space and Environmental Medicine, 76*, 126-134.

Kanas, N., & Manzey, D. (2008). *Space Psychology and Psychiatry*. Dortrecht: Kluwer.

Kanas, N., Sandal, G., Boyd, J., Gushin, V., Manzey, D., North, R., Leon, G., Suedfeld, P., Bishop, S., Fiedler, E., Inoue, N., Johannes, B., Kealy, D., Kraft, N., Matsuzaki, I., Musson, D., Palinkas, L., Salnitskiy, V., Sipes, W., Stuster, J. , & Wang, J. (2009). Psychology and culture during long-duration space missions. *Acta Astronautica, 64*, 659-677.

Kanas, N., Saylor, S., Harris, M., Neylan, T., Boyd, J., Weiss, D., Baskin, P., Cook, C., & Marmar, C. (2011). High versus low crew member autonomy in space simulation environments, *Acta Astronautica, 67*, 731-738.

Kasser, T., Koestner, R., & Lekes, N. (2002). Early family experiences and adult values: a 26-year, prospective longitudinal study. *Personality and Social Psychology Bulletin, 28*, 826-835.

Kasser, T., & Ahuvia, A. (2002). Materialistic values and well-being in business students. *European Journal of Social Psychology, 32*, 137-146.

Kasser, T., & Ryan, R. M. (1996). Further examining the American dream: differential correlates of intrinsic and extrinsic goals. *Personality and Social Psychology Bulletin, 22,* 280-287.

Kasser, T., Ryan, R. M., Zax, M., & Sameroff, A. J. (1995). The relations of maternal and social environments to late adolescents' materialistic and prosocial values. *Development Psychology, 31*, 907-914.

Kjaergaard, A., Leon, G. R., Venables, N. C., & Fink, B. A. (2013). Personality, personal values and growth in military special unit patrol teams operating in a polar environment. *Military Psychology, 25*, 13-22.

Krikalev, S., Kalery, A., Sorokin, I. (2010). Crew on the ISS: creativity or determinism. *Acta Astronautica, 66*, 68-78.

Lekes, N., Gingras, I., Philippe, F. L., Koestner, R., & Fang, J. (2010). Parental autonomy-support, intrinsic life goals, and well-being among adolescents in China and North America. *Journal of Youth and Adolescence, 39,* 858-869.

Leon, G. R., Sandal, G. M., & Larsen, E. (2011). Human performance in polar environments. *Journal of Environmental Psychology, 31*, 353-360.

Lindström, B., & Eriksson, M. (2005). Salutogenesis. *Journal of Epidemiol Community Health*, *59*, 440-442.

Manzey, D. (2004). Human mission to Mars: new psychological challenges and research issues. *Acta Astronautica*, *55*, 781-790.

McIntosh, T., Mulhearn, T., Gibson, C., Mumford, M. D., Yammarino, F. J., Connelly, S., Day, E. & Vessey, B. (2016). Planning for Long-Duration Space Exploration: Interviews with NASA Subject Matter Experts. *Acta Astronautica*, *129*, 477-487.

Mcphee, J. C., & Charles, J. B. (2009). *Human health and performance risks of space exploration missions* (NASA SP-2009-3405). Houston, Texas, NASA Johnson Space Center.

Mouratidis, A., Lens, W., & Vansteenkiste, M. (2010). How you provide corrective feedback makes a difference: The motivating role of communicating in an autonomy-supporting way. *Journal of Sport & Exercise Psychology, 32*, 619-637.

Mouratidis, A., Vansteenkiste, M., Lens, W., & Sideridis, G. (2008). The motivating role of positive feedback in sport and physical education: evidence for a motivational model. *Journal of Sport & Exercise Psychology, 30,* 240-268.

Niemiec, C. P., Ryan, R. M., & Deci, E. L. (2009). The path taken: consequences of attaining intrinsic and extrinsic aspirations in post-college life. *Journal of Research in Personality, 43,* 291-306.

Suedfeld, P. (2005). Invulnerability, coping, salutogenesis, integration: four phases of space psychology. *Aviation, Space and Environmental Medicine, 7*, 61-66.

Patall, E. A., Cooper, H., & Robinson, J. C. (2008). The effects of choice on intrinsic motivation and related outcomes: a meta-analysis of research findings. *Psychological Bulletin, 134,* 270-300.

Patall, E. A., Cooper, H., & Wynn, S. R. (2010). The effectiveness and relative importance of choice in the classroom. *Journal of Educational Psychology, 102*, 896-915.

Plant, R. W., & Ryan, R. M. (1985). Intrinsic motivation and the effects of self-consciousness, self-awareness, and ego-involvement - an investigation of internally controlling styles. *Journal of Personality, 53*, 435-449.

Reeve, J., & Jang, H. S. (2006). What teachers say and do to support students' autonomy during a learning activity. *Journal of Educational Psychology, 98,* 209-218.

Reeve, J., & Tseng, C. M. (2011). Cortisol reactivity to a teacher's motivating style: The biology of being controlled versus supporting autonomy. *Motivation and Emotion, 35,* 63-74.

Reeve, J., Nix, G., & Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *Journal of Educational Psychology*, *95*, 375-392.

Ritsher, J., Kanas, N., Ihle, E., & Saylor, S. A. (2007). Psychological adaptation and salutogenesis in space: lessons from a series of studies. *Acta Astronautica, 60*, 336-34.

Roma, P. G., Hursh, S. R., Hienz, R. D., Emurian, H. H., Gasior, E. D., Brinson, Z. S., & Brady, J. V. (2011). Behavioural and biological effects of autonomous versus scheduled mission management in simulated space-dwelling groups. *Acta Astronautica, 68*, 1581-1588.

Ryan, R. M., & Deci, E. L. (2000). The darker and brighter sides of human existence: basic psychological needs as a unifying concept. *Psychological Inquiry, 11*, 319-338.

Ryan, R. M., & Lynch, J. H. (1989). Emotional autonomy versus detachment: revisiting the vicissitudes of adolescence and young adulthood. *Child Development, 60*, 340-356.

Ryan, R. M., Deci, E. L., & Vansteenkiste, M. (2015). Autonomy and autonomy disturbances in self-development and psychopathology: Research on motivation, attachment and clinical process. In D. Cicchetti (Ed.), *Developmental Psychopathology: Theory and method* (pp. 795-849). New York: Wiley.

Ryan, R. M., Weinstein, N., Bernstein, J., Brown, K. W., Mistretta, L., & Gagné, M. (2010). Vitalizing effects of being outdoors and in nature. *Journal of Environmental Psychology, 30*, 159-168.

Ryan, Richard M., & Deci, E. L. (2006). Self-regulation and the problem of human autonomy: Does psychology need choice, self-determination, and will? *Journal of Personality, 74*, 1557-1585.

Sandal, G. M., & Bye, H. H. (2015). Value diversity and crew relationships during a simulated space flight to Mars. *Acta Astronautica, 114*, 164-173.

Sandal, G. M., Bye, H. H., & van de Vijver, F. J. R. (2011). Personal values and crew compatibility: results from a 105 days simulated space mission. *Acta Astronautica, 69*, 141-149.

Schüler, J., Brandstatter, V., & Sheldon, K. M. (2013). Do implicit motives and basic psychological needs interact to predict well-being and flow? Testing a universal hypothesis and a matching hypothesis. *Motivation and Emotion, 37,* 480-495.

Schüler, J., Sheldon, K. M., & Fröhlich, S. M. (2010). Implicit need for achievement moderates the relationship between felt competence and subsequent motivation. *Journal of Research in Personality, 44*, 1-12.

Schüler, J., Wegner, M. & Knechtle, B. (2014). Implicit motives and basic need satisfaction in extreme endurance sports. *Journal of Sport & Exercise Psychology, 36,* 293-302.

Schultheiss, O. C., & Hale, J. A. (2007). Implicit motives modulate attentional orienting to facial expressions of emotion. *Motivation and Emotion, 31*, 13-24.

Schwartz, S. H. (2007). Universalism values and the inclusiveness of our moral universe. *Journal of Cross-Cultural Psychology, 38,* 711-728.

Sheldon, K. M., & Kasser, T. (2008). Psychological threat and extrinsic goal striving. *Motivation and Emotion, 32*, 37-45.

Sheldon, K. M., & Filak, V. (2008). Manipulating autonomy, competence, and relatedness support in a game-learning context: New evidence that all three needs matter. *British Journal of Social Psychology, 47*, 267-283.

Sheldon, K. M., & Ryan, R. M. (2011). Positive Psychology and Self-Determination Theory: A Natural Interface. In V. I. Chirkov, R. M. Ryan, & K. M. Sheldon (Eds.). *Human Autonomy in Cross-Cultural Context* (pp. 33-44). New York: Springer.

Sheldon, K. M., Ryan, R. M., Deci, E. L., & Kasser, T. (2004). The independent effects of goal contents and motives in well-being: It's both what you pursue and why you pursue it. *Personality and Social Psychology Bulletin, 30*, 475-486.

Soenens, B., & Vansteenkiste, M. (2010). A theoretical upgrade of the concept of parental psychological control: Proposing new insights on the basis of Self-Determination Theory. *Developmental Review, 30*, 74-99.

Stuster, J. (2010). *Behavioral issues associated with long-duration space expeditions: Review and analysis of astronaut journals* (NASA/TM-2010-216130). Houston, Texas, NASA Johnson Space Center.

Suedfeld, P. (2006). Space memoirs: Value hierarchies before and after missions - a pilot study. *Acta Astronautica, 58*, 583-586.

Suedfeld, P., & Brcic, J. (2011). Resolution of psychosocial crises associated with flying in space. *Acta Astronautica, 69*, 24-29.

Suedfeld, P., Brcic, J. Johnson, P. J., & Gushin, V. (2012). Personal growth following long-duration spaceflight. *Acta Astronautica, 79*, 118-123.

Suedfeld, P., Legkaia, K., & Brcic, J. (2010). Changes in the hierarchy of value references associated with flying in space. Journal of Personality, 78, 1411-1436.

Tedeschi, R. G., & Calhoun, L. G. (1996). The posttraumatic growth inventory measuring the positive legacy of trauma. *Journal of Traumatic Stress, 9*, 455-471.

Unanue, W., Dittmar, H., Vignoles, V., & Vansteenkiste, M. (2014). Materialism and well-being in the UK and Chile: basic need satisfaction and basic need frustration as underlying psychological processes. *European Journal of Personality, 28*, 569-585.

Van den Broeck, A., Vansteenkiste, M., De Witte, H., & Lens, W. (2008). Explaining the relationships between job characteristics, burnout, and engagement: The role of basic psychological need satisfaction. *Work & Stress, 22*, 277-294J.

Van der Kaap-Deeder, J., De Houwer, J., Hughes, S. J., Spruyt, A., & Vansteenkiste, M. (2018). The development and validation of an implicit measure of competence need satisfaction. *Motivation and Emotion*.

Van Petegem, S., Beyers, W., Vansteenkiste, M., & Soenens, B. (2012). On the association between adolescent autonomy and psychosocial functioning: Examining decisional independence from a Self-Determination Theory perspective. *Developmental Psychology, 48(*1), 76-88.

Van Petegem, S., Soenens, B., Vansteenkiste, M., & Beyers, M. (2015). Rebels with a cause? Adolescent defiance from the perspective of reactance theory and Self-Determination Theory. *Child Development, 86,* 903-918.

Vansteenkiste, M., Duriez, B., Simons, J., & Soenens, B. (2006). Materialistic values and well-being among business students: further evidence of their detrimental effect. *Journal of Applied Social Psychology, 36*, 2892-2908.

Vansteenkiste, M., & Deci, E. L. (2003). Competitively contingent rewards and intrinsic motivation: Can losers remain motivated? *Motivation and Emotion*, *27*, 273-299.

Vansteenkiste, M., & Lens, W. (2006). Intrinsic versus extrinsic goal contents in self-determination theory: another look at the quality of academic motivation. *Educational Psychologist, 41*, 19-31.

Vansteenkiste, M., & Ryan, R. M. (2013). On psychological growth and vulnerability: basic psychological need satisfaction and need frustration as a unifying principle. *Journal of Psychotherapy Integration*, *23*, 263-280.

Vansteenkiste, M., Niemiec, C. P., & Soenens, B. (2010). The development of the five mini- theories of Self-Determination Theory: A historical overview, emerging trends and future directions. In T. Urdan & S. Karabenick (Eds.). *Advances in Motivation and Achievement: Vol. 16. The decade ahead* (pp. 105-166). Bingley, United Kingdom: Emerald.

Vansteenkiste, M., Soenens, B., Van Petegem, S., & Duriez, B. (2014). Longitudinal associations between adolescent perceived degree and style of parental prohibition and internalization and defiance. *Developmental Psychology*, *50*, 229-236.

Weinstein, N., & Ryan, R. M. (2013). A Self-Determination Theory approach to understanding stress incursion and responses. *Stress and Health 27*, 4-17.

Weinstein, N., Przybylski, A. K., & Ryan, R. M. (2009). Can nature make us more caring? Effects of immersion in nature on intrinsic aspirations and generosity. *Personality and Social Psychology Bulletin, 35*, 1315-1329.

Williams, G. C., Cox, E. M., Hedberg, V. A., & Deci, E. L. (2000). Extrinsic life goals and health-risk behaviours in adolescents. *Journal of Applied Social Psychology, 30*, 1756-1771.

Winter, D. G. (1973). *The Power Motive*. New York: The Free Press.

CHAPTER 2

The Paradoxical Effect of Long Instructions on Negative Affect and Performance: When, for Whom and Why Do They Backfire?[1]

[1] Goemaere, S., Beyers, W., De Muynck G.-J., & Vansteenkiste, M. (2018). The paradoxical effect of long instructions on negative affect and performance: When, for whom and why do they backfire? *Acta Astronautica, 147*, 421-430.

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Introduction

Human space exploration has evolved considerably since the early days of spaceflight. Missions used to consist of short-term flights with crews composed of male astronauts from the same country with similar piloting or engineering backgrounds. However, as space missions changed, a variety of psychosocial pressures not faced during earlier missions were encountered (see Kanas & Manzey, 2008, for a review). For example, increased mission durations and crew heterogeneity in terms of gender, cultural, educational, and motivational background caused interpersonal problems, such as withdrawal, ostracism, crew-leader conflicts and deterioration of work performance, to name a few (Suedfeld, 2005). Perhaps because of these rapid changes and their potential risk for astronaut safety and mission success, some space agencies have tightened their grip on the daily routines of astronauts. For instance, astronauts on the International Space Station (ISS) have to follow strict operating procedures for their daily activities, from which they cannot deviate without explicit consent from mission support (Hendricks, Mauroo, & Van Spilbeeck, 2009; Roach, 2010).These procedures often consist of very long and detailed visual instructions, even for simple tasks (e.g., routine maintenance jobs).

Of course, extensive guidance and support are vital for the successful completion of difficult and intricate operations. However, for simple routine tasks, one can question their added value. Even more, such detailed instructions and the associated micro-management may yield counterproductive effects for the crew’s motivation, well-being, and performance. Although there exists some preliminary anecdotic evidence (e.g., Hendricks et al., 2009; Kanas & Manzey, 2008; Krikalev, Kalery, & Sorokin, 2010; Manzey, 2013) for such negative side effects, to the best of our knowledge, experimental research regarding this issue is currently lacking. In the present research, we sought to examine when (i.e., for which tasks?), for whom (i.e., for which persons?), and why (i.e., how can we account for it?)

the provision of long instructions for executing an assembly task would affect participants' negative affect and performance. That is, we considered the role of the complexity of the task (i.e., simple versus complex; *when*), participants' achievement orientation (i.e., *for whom*) and the role of the perceived usefulness as a potential explanatory mechanism (i.e., *why*).

1. When-question: Length of Instructions and Task Complexity

In the literature on instructional design, the question how tasks should be designed to promote engagement, motivation, and performance, has received substantial attention. Typically, this question has been addressed with respect to learning tasks, that is, tasks aimed at acquiring knowledge or a specific skill in an educational context (van Merriënboer, & Sweller, 2010), and two different design features have received attention, namely form and content. Studies examining the importance of instructional *form* are mainly concerned with the visual representation of instructions, such as format (e.g. text or pictorial; Schmidt-Weigand & Scheiter, 2011) and its impact on performance. Studies directed towards *content*, that is, the particular substance of the learning material being offered, have examined the impact of instructions on psychological well-being and motivation, in addition to performance. Keller (1979) first introduced the concept of motivation into instructional design. Since then, dozens of studies have shown the importance of several instructional characteristics to sustain continued motivation towards learning (e.g., Cheng & Yeh, 2009; Yair, 2000). For instance, studies have shown that instructions enhance motivation, confidence, performance and social functioning when they draw and sustain attention from their readers, build confidence, and are experienced as useful (see Keller, 2010, for a review).

The *length* of instructions is an important, yet somewhat understudied feature of instructions. In general, studies on instructional design tend to primarily focus on the question regarding the optimal amount or dose of instructions (e.g., Hmelo-Silver, Duncan, & Chinn, 2007; Kirschner, Sweller, & Clark, 2006, for reviews). In doing so, scholars are mainly concerned with the provision of sufficient guidance such that participants do not need to put excessive effort in the task, which takes away from performance, be it mental or physical. Yet, the provided dose of instructions cannot only be too low, individuals can also be given an overload of instructions. Unfortunately, to the best of our knowledge, little is known about the impact of an extensive amount of instructions, that is, whether these are deemed useless or redundant, and may potentially even have detrimental consequences for participants' motivation, well-being, and performance.

Available research on length of instructions for learning tasks points towards potential benefits of decreasing the level of guidance by withholding instructional information and reducing the number of intermediate steps for students who acquire knowledge (e.g., Damnik, Porske, Narciss, & Körndle, 2013; Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Nadolski, Kirschner, van Merriënboer, 2005; Richey & Nokes-Malach, 2013). By tailoring the length of instructions to the learners' emerging level of competence, the responsibility for the performance is gradually transferred to learners (see Van de Pol, Volman, & Beishuizen, 2010, for a review). The current study aimed to add to this body of work by addressing the impact of length of instruction and by studying the role of length in relation to procedural tasks, that is, tasks directed at the execution of a combination of physical activities (e.g., an assembly task) instead of learning tasks, which have been targeted in a more limited number of studies (e.g., Brunyé, Taylor, & Rapp, 2008; Martin & Smith-Jackson, 2008; Morrel & Park, 1993; Pekerti, 2013; Van Genuchten, Van Hooijdonk, Schüler, & Scheiter, 2014). Only a few studies have examined the impact of instruction length in procedural tasks, showing that performance deteriorated with increasing length (e.g., Irrazabal, Saux, & Burin, 2016; Novick & Morse, 2000). Yet, these studies did not experimentally isolate instruction length for the same assembly task as not only length of instructions but also the type of task (i.e., easy vs. difficult) was manipulated simultaneously. As a result, it remains unclear whether the observed effects were due to the varying length of instructions, type of task, or a combination of both. One study of Agrawala et al. (2003), in which participants were asked to rank instructions for an assembly task based on effectiveness, found that good instructions should consist of frames that represent as much information as possible. When information is split up across too many frames, they become tedious, unless the information is of particular importance for the assembly.

Similarly, anecdotic sources reveal that the provision of long instructions, especially for simple routine task, might not be optimally motivating, potentially even yielding a cost, among astronauts on the ISS (e.g., Hendricks et al., 2009; Kanas & Manzey, 2008; Krikalev et al., 2010; Manzey, 2013). Among these individuals, such elaborate instructions may be experienced as tedious, causing frustration and irritation. As a result, astronauts may limit themselves to a diagonal read of the instructions and, hence, avoid the inclusion of mission support. Therefore, they run the risk of overlooking important information, which ironically increases the probability of error making. In such cases, astronauts are blamed (Hendricks et al., 2009), and in some cases, astronauts' "*big egos*" are said to explain their disobedient behavior (e.g., Manzey, 2013).

Although this topic has never been studied experimentally, several space experts have raised concerns with regard to these detailed regulatory procedures (Kalery, Sorokin, & Tyurin, 2010; Krikalev et al., 2010; Goemaere, Vansteenkiste, & Van Petegem, 2016; Sandal & Bye, 2015; Suedfeld, Brcic, Johnson, & Gushin, 2012), as the ISS has become a space station assembly line, with the station performing repetitive operations. Because of this increased focus on issues related to crew and station safety, space agencies risk overlooking a primary objective of the ISS, that is, targeting the crew's ability to act autonomously and display initiative during spaceflight (Kalery et al., 2010). The chief medical officer of the Japan Aerospace Exploration Agency, Shoichi Tachibana, puts it as follows: "*The* *ideal astronaut has been an exceptionally high-achieving adult, who takes direction and follows rules like an exceptionally well-behaved child.*" (Roach, 2010, p. 37).

2. Whom-question: The Role of Need for Achievement

The impact of length of instructions may not only be dependent on task complexity, instruction length may also need to be tailored to the interests, personality, and capacities of the reader (Martin & Smith-Jackson, 2008). Individuals with a high need for achievement, who thrive on difficult challenges, might get especially irritated and show performance deficits when provided with long instructions for simple tasks.

Within the long-standing tradition of achievement motivation, interindividual differences in the need for achievement have received considerable attention (Atkinson, 1957; McClelland, Atkinson, Clark, & Lowell, 1953; Wang & Eccles, 2013). Individuals with a high need for achievement have a preference to develop and demonstrate high ability. Interindividual differences in this need manifest via the type of activities individuals seek and how they respond to difficult and challenging tasks (see Pang, 2010; Schultheiss & Brunstein, 2001, for reviews). Those high, relative to those low, in the need for achievement are attracted to tasks that allow them to improve their skills and demonstrate their ability, such as tasks of a moderate difficulty that are neither too easy nor unsolvable (see Elliot & Dweck, 2005, for a review). For instance, individuals with a high need for achievement have been found to experience more flow (Enseger & Rheinberg, 2008; Baumann & Scheffer, 2010; 2011), more positive affect and less stress when encountering challenging tasks (Reeve, Olson, & Cole, 1987; Schultheiss, Wiemers, & Wolf, 2014). Such evidence suggests that achievement-motivated individuals view difficult tasks as challenges that hold the promise of reward, namely the pleasure of mastery. As a result, they tend to avoid low-risk situations because the easily attained success is not experienced as a genuine achievement. As various activities differ in the challenge they pose and the opportunity they offer for expression of this motive, individuals with a high need for achievement should be given challenging tasks with reachable goals.

It should be noted that astronauts are exceptionally capable personnel: they are selected specifically because of their high need for achievement (Brcic, 2010; Maschke, Oubaid, & Pecena, 2011; Mittelstädt, Pecena, & Oubaid, 2016; Suedfeld & Brcic, 2011), they thrive on difficult challenges, and they are extensively trained before the flight. As a result, if elaborate instructions, that are meant to guide them and to be helpful, are provided for simple tasks, they might be perceived as redundant and even annoying, especially among individuals with a high need for achievement, like astronauts. Consequently, long instructions would provoke feelings of irritation, lose their meaningfulness, and cause astronauts to disregard them. Therefore, we considered herein interpersonal differences in the need for achievement to better understand for whom length of instructions may yield a well-being and performance cost.

3. Why-question: The Role of Perceived Usefulness

Finally, we sought to investigate why the provision of long instructions may backfire. If we want to understand astronauts' compliance with strict operation procedures and its consequences, it is critical to consider their reasons for compliance, which may be dependent upon the perceived usefulness of the procedures. Clearly, following guidelines and rules is in many cases not inherently enjoyable, that is, not intrinsically rewarding. At the same time, the lack of intrinsic motivation does not necessarily mean that one feels pressured to comply with rules and guidelines, given these are perceived to be meaningful. Indeed, many uninteresting activities can be performed with a sense of willingness and ownership, when the initially externally offered value of the task or regulation is adopted in the self and fully endorsed (Vansteenkiste et al., 2017).

Several motivational theories have put forward the importance of task value or personal relevance to explain an individual's motivation to engage in a particular task. A central notion to the Expectancy Value Theory (EVT; Eccles, 1983; Eccles & Wigfield, 2002) is the concept of *utility value*, which reflects the subjective belief that engaging in an activity will be useful for achieving a short- or long-term outcome (Eccles & Wigfield, 2002). Several studies have shown that promoting the personal meaning or value of an activity positively impacts interest (e.g., Hulleman & Harackiewicz, 2009) motivation (e.g., Brown, Thoman, & Smith, 2015) and performance (e.g., Hulleman, Godes, Hendricks, & Harackiewicz, 2010). Along similar lines, within Self-Determination Theory (Ryan & Deci, 2017), the process of internalization refers to the extent that individuals come to fully endorse the activity at hand because the reason for engaging in the activity has been accepted as their own. Specifically, the notion of *identified motivation* refers to the extent that individuals can identify with the self-relevance of the activity such that they engage in them more willingly. Identified motivation thus occurs when individuals come to personally value a task and various studies have shown that more identified work motivation relates to a host of positive outcomes, including work effort (e.g., Kuvaas, Buch, Gagné, Dysvik, & Forest, 2016), higher commitment (e.g., Gagné, Koestner, & Zuckerman, 2000) well-being (e.g., Gillet, Vallerand, Lafrenière, & Bureau, 2013), and performance (see Cerasoli, Nicklin, & Ford, 2014, for a review). Experimental work has further shown that the promotion of identified motivation, for instance via the offer of a meaningful rationale, increases positive affect (e.g., Savard, Joussemet, Pelletier, & Mageau, 2013), more voluntary persistence (Deci, Eghrari, Patrick, & Leone, 1994; Reeve, Nix, & Hamm, 2003) and the quality of performance, both in procedural and learning tasks. Presumably, increased identified motivation yields these performance benefits because it enhances self-control and error monitoring by increasing error-processing and correction at the neural and behavioral level (Burton, Lyndon, D'Alessandro, & Koestner, 2006; Fisher, Marshall, & Nanayakkara, 2009; Legault & Inzlicht, 2013; Muraven, Gagné, & Rosman, 2008).

While prior work in these different motivational traditions has focused on the perceived utility value and self-relevance of learning tasks as such, herein we address the question whether the instructions themselves are perceived to be useful. Indeed, it is doubtful that all astronauts find following elaborate instructions for simple routine maintenance or assembly tasks to be very useful, let alone interesting or enjoyable. Yet, the degree to which they can value the importance and meaningfulness of instructions, will determine their motivation to abide by them, and their subsequent well-being and performance. It is possible that astronauts find these long instructions for simple task to be tedious, redundant and useless, which may help to explain why they experience irritation and negative affect and they begin to neglect instructions, with performance deficits as an unfortunate outcome. Therefore, the degree to which astronauts endorse instructions as personally useful, needs to be considered to understand why long and detailed instructions, especially for simple tasks, may negatively impact on individuals' well-being and performance.

4. The Present Research

The primary objective of the present experimental study was to examine the effects of length of instructions on a variety of cognitive (i.e., identified motivation), affective (i.e., experienced irritation) and behavioral (i.e., productivity, accuracy) outcomes. We investigated three issues, that is, whether the benefits or costs associated with long instructions would, first, depend on the type of task being given (i.e., *when*-question) and, second, on participants' level of achievement motivation (i.e., *whom*-question). Third, we aimed to found out *why* the provision of long instructions for executing an assembly task would affect participants' level of irritation and performance, putting forward a decrease in perceived value of instructions as a potential explanation.

We tested our hypotheses in a laboratory setting, which allowed us to reproduce the task characteristics of length of instruction and task difficulty that are distinctive for the astronautical work setting, while at the same time eliminating the effects of extraneous variables. We opted for an assembly task, as these tasks are routinely performed by astronauts on the ISS, for which we used LEGO material. The LEGO task has several advantages (Novick & Morse, 2000). The order in which bricks are placed is crucial for correctly constructing the object, an important characteristic of most assembly tasks. Additionally, as LEGO constructions vary widely in difficulty, such task are ideally suited to examine whether the effectiveness of different length of instructions depends on the complexity of the assembly task.

In agreement with the reasoning above about instruction length, we expected long, relative to short, instructions to be perceived as less useful (as reflected in participants' level of identified motivation), to provoke greater negative affect (as reflected in increased irritation) and to diminish performance (as reflected in lowered productivity and accuracy; Hypothesis 1, see Figure 1).

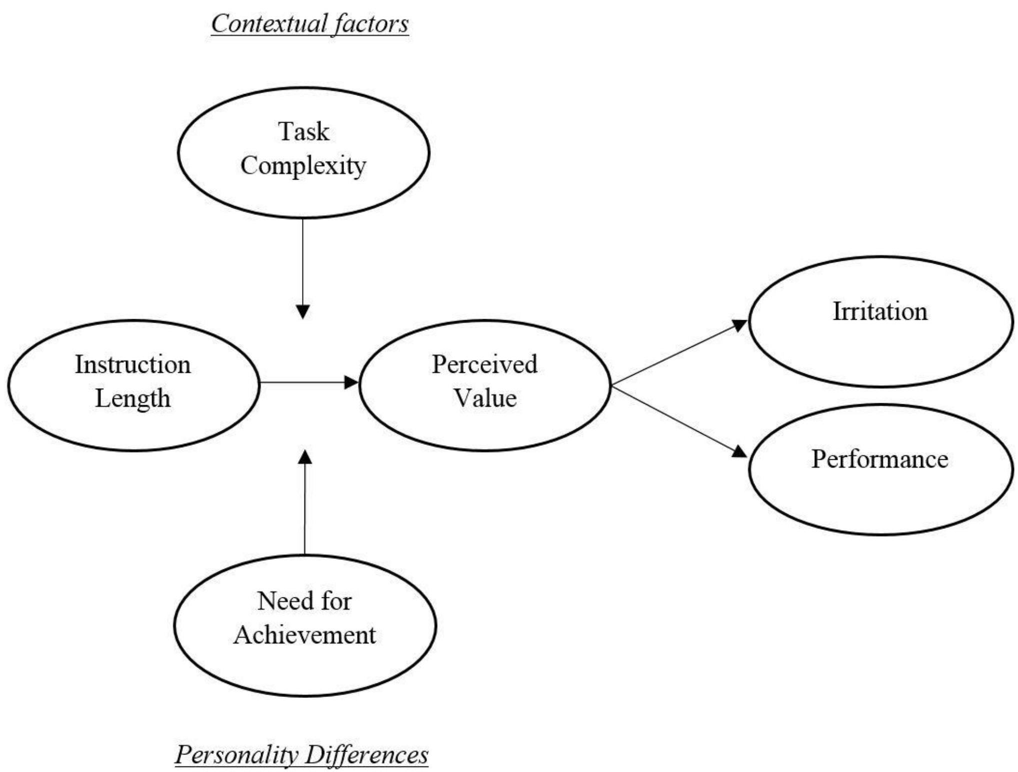

Figure 1. The hypothesized model of the associations among length of instructions, identification, irritation, performance, task difficulty and need for achievement.

The main effects of task complexity were also included in this analysis. Given that long instructions are considered more useful for difficult tasks, we examined whether the hypothesized costs of long instructions would apply when provided for simple tasks only or, alternatively, whether these costs would be less pronounced for complex tasks (*when*-question; Hypothesis 2). Additionally, we investigated the possibility of a moderation effect by need for achievement such that long instructions would come with a more pronounced cost for people who thrive on difficult challenges (*whom*-question; Hypothesis 3). Finally, in accordance with literature on perceived usefulness and performance, we tested whether identification would account for (i.e., mediate) the relationship between length of instructions and irritation and performance (*why*-question; Hypothesis 4). If long instructions are deemed less useful, one would expect the instructions to undermine motivation to abide by them, therefore causing a drop in self-regulation for error-monitoring, which would especially be reflected in poor accuracy.

5. Method

5.1 Participants

In total, 113 predominantly female (71.68%) university students (M_{age} = 18.75 years; *SD* = 2.46) participated in this experiment. Participants were randomly assigned to one of four experimental conditions.

5.2 Procedure

Prior to the experiment, students filled out an online questionnaire. At least one day later, they took part in an LEGO assembly task that lasted for 25 minutes. After completing this assembly task, they filled out a short questionnaire. The study was approved by the ethical committee of the Faculty of Psychology and Educational Sciences, Ghent University, Belgium.

Informed consent was obtained from all participants prior to their participation and participants were guaranteed confidential treatment of their responses. Participation was voluntary and students could withdraw from the experiment at any time. Immediately after the experiment, participants were informed of the broader aim of the experiment and the conducted manipulations. A more extensive debriefing followed via email about the scientific findings and implications of the study.

5.3 Experimental Design

5.3.1 LEGO Assembly Task.

Students were told that they would take part in a LEGO assembly task. Specifically, with the aid of visual instructions displayed on a computer screen, they built LEGO constructions during 25 minutes, using a self-paced working rhythm. The provided written, step-by-step instructions on the building procedure were accompanied by a picture depicting the needed LEGO material for each step. Steps were presented one at a time in a single frame, clearing the screen when the step was accomplished. The students were instructed to study the pictures and text carefully and to focus primarily on accuracy instead of the speed at which they built the constructions.

5.3.2 Manipulation.

In this experiment we adopted a 2x2 design, with length of instructions (i.e., short vs. long) and task complexity (i.e., simple versus complex) being manipulated at the between subject level. Participants were randomly assigned to one of the four experimental conditions, with the *n* per condition varying between 26 and 30. As can be noticed in Figure 2, the difficulty of the LEGO constructions was experimentally varied through varied color, symmetry and recognizability (Richardson, Jones, Torrance, & Baguley, 2006).

A. B.

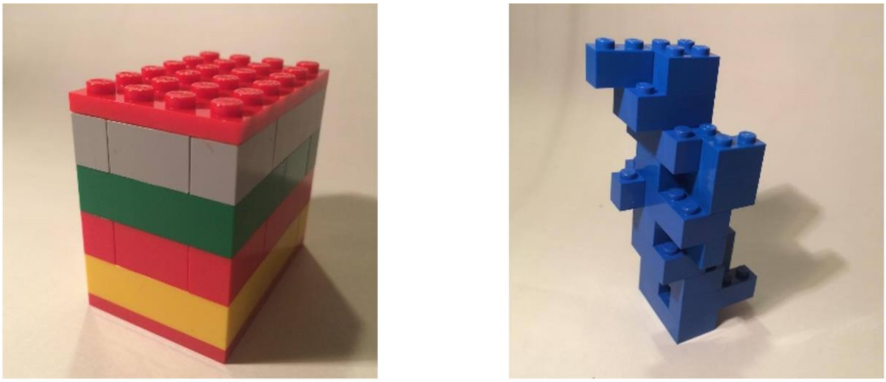

Figure 2. Example of a simple (A) and complex construction (B), respectively.

Simple constructions were made of LEGO bricks of different colors, they had a symmetrical shape and a recognizable form (i.e., cube or rectangle), whereas complex constructions were made of LEGO bricks of the same color and had an asymmetrical and amorphous shape. Length of LEGO instructions was manipulated by varying the number of intermediary steps as well as the number of LEGO brick placements per frame (see Figure 3). While long instructions contained three intermediary steps per brick (a brick selection step, a brick placement step and a verification step) and involved only one single LEGO brick per frame, short instructions had only one intermediary step per brick (a brick placement step) and involved the placement of several LEGO bricks within one single frame.

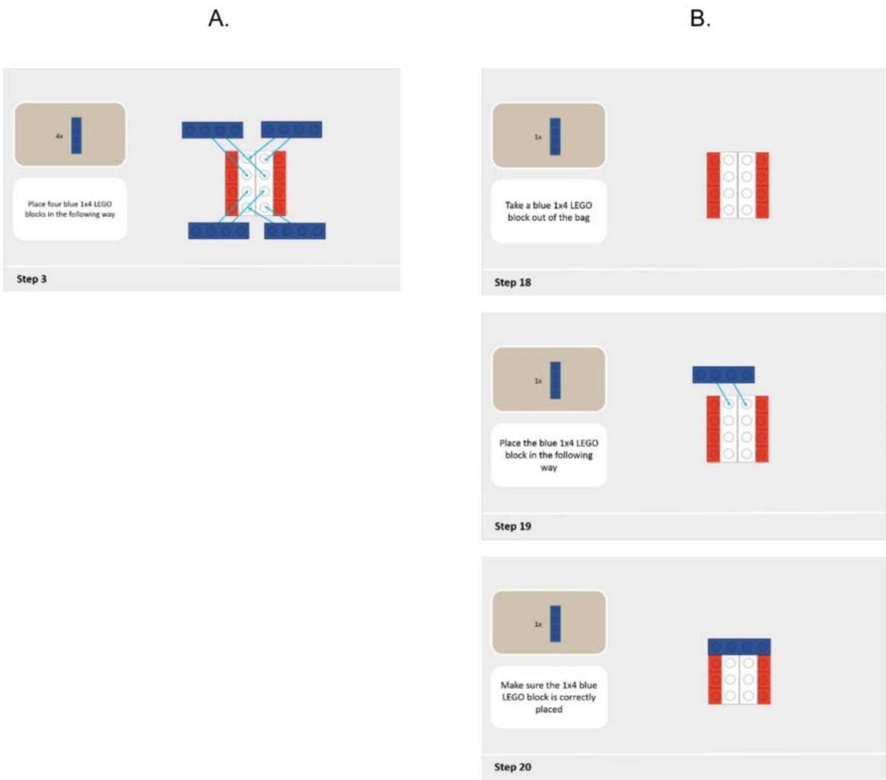

Figure 3. Example of short (A) and long instructions (B), respectively.

5.3.3 Measures.

Several existing or self-developed questionnaires were used in various parts of the study. All items in these questionnaires were scored on a 5-point Likert scale ranging from 1 ("*don't agree at all*") to 5 ("*agree completely*").

Pre-experimental Measures.

Need for achievement. Participants' need for achievement was measured using a 5-item subscale of the Achievement Motives Scale (McClelland, Atkinson, Clark, & Lowell, 1993). A sample item reads "*I like situations in which I can find out how capable I am*". Cronbach's alpha was .78.

LEGO experience and enjoyment. The degree to which participants were familiar with the LEGO material and the degree to which they enjoyed working with LEGO was assessed through four self-developed items (e.g. "*When I was younger I played with LEGO a lot*"). Cronbach's alpha for this scale was .90.

Difficulty attractiveness. To asses a potential pre-existing attraction towards the building of simple or complex constructions, participants were shown pictures of three simple and three complex constructions and were asked to rate a statement describing the constructions: "*This construction looks interesting and fun to build.*" Responses on the statements for the three simple instructions were averaged as to obtain a score for a general attractiveness of simple constructions. In the same way a general attractiveness of complex constructions was measured. Cronbach's alpha's for these scores were .89 and .86 respectively.

Post-experimental Measures.

Manipulation check. To determine the effectiveness of the difficulty and length manipulation, we measured participant's perceived task difficulty (four items; e.g., "*I thought the task was easy*"; alpha = .89), and instruction redundancy (four items; e.g. "*There were too many instructions*"). The latter scale was adapted from the questionnaire for number of steps adequacy by Nadolski et al. (2005; alpha = .66).

Irritation. Four items such as "*I felt irritated with the instructions I was given*" were used to measure how irritated participants felt with regard to the instructions. These items were based on the resentment scale of Assor, Roth, and Deci (2004). Internal consistency of this scale was .85.

Identification. Identified motivation to follow instructions was measured using six items from the adapted version of the Self-Regulation Questionnaire-Parental Rules (Soenens, Vansteenkiste, & Niemiec, 2009). As sample item reads "*I followed the instructions because I understood why they were important.*" Cronbach's alpha was .81.

Performance. Two different performance indicators were collected, that is, a quantitative and a qualitative measure. First, *productivity* was counted as the total number of constructions built during the time span of 25 minutes, regardless of accuracy. Second, *accuracy* was included to determine whether participants were following instructions attentively, which would be reflected in the quality of constructions. To measure accuracy, certain *catches* were included in some of the instructions. The vast majority (99%) of needed LEGO material consisted of conventional LEGO *blocks*. In 1% of the cases however participants needed to use an unconventional LEGO brick, such as a *bridge*. To ascertain whether a block or bridge needed to be placed, the picture representation alone did not suffice. Participants thus needed to read the written instructions accompanying the picture representation, which contained either the word 'block', or, in case of a catch, the word 'bridge' (see Figure 4). Thus, detection of these catches becomes an indicator of whether participants were paying close attention to the instructions, or whether they were browsing through the instructions by merely glancing at the picture representation alone. Accuracy was therefore measured as the percentage of detected catches, given the number of presented catches.

It should be noted that, since long instructions consisted of two more intermediary steps for the same brick (a selection and verification step, in addition to the placement step), participants in the long instruction condition could detect the catches three instead of a single time.

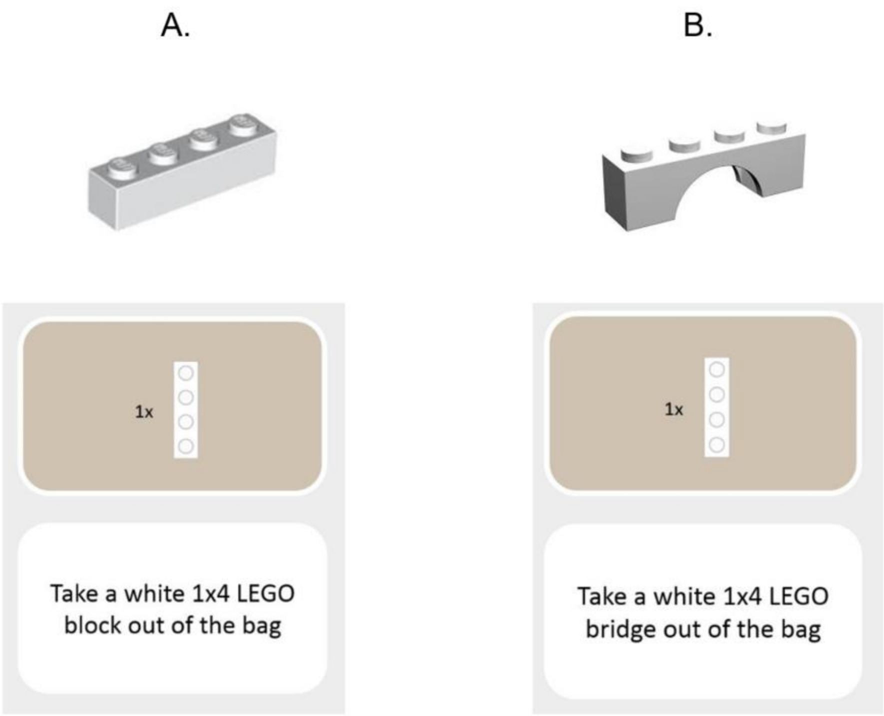

Figure 4. Example of instructions for a conventional LEGO brick (A) versus an unconventional LEGO brick, a so-called *catch* (B).

6. Results

6.1 Preliminary Analyses

For the manipulation check, a MANOVA was performed with length of instruction and task complexity as independent variables and perceived task difficulty and instruction redundancy as dependent variables. Results indicated significant multivariate (Wilks' Lambda) main effects of task complexity ($F(2,108) = 31.98$; $p < .001$; $\eta^2 = .37$) and length of instructions ($F(2,108) = 43.87$; $p < .001$; $\eta^2 = .45$), with the interaction effect being non-significant ($F < 1$). Univariate analyses revealed strong effects of task complexity on perceived task difficulty ($F(1,109) = 59.33$; $p < .001$; $\eta^2 = .35$) and on redundancy of instructions ($F(1,109) = 23.46$; $p < .001$; $\eta^2 = .18$). Complex constructions were perceived to be more difficult ($M = 2.46$; $SD = 0.75$) and contained less redundant instructions ($M = 3.69$; $SD = 0.81$) compared to simple constructions ($M = 1.46$ and 4.24, $SD = 0.65$ and 0.78, respectively). Length of instructions was strongly related to redundancy of instructions ($F(1,109) = 86.73$; $p < .001$; $\eta^2 = .44$) and had a small effect on perceived task difficulty ($F(1,109) = 4.03$; $p < .05$; $\eta^2 = .04$). Long instructions were perceived to be slightly less difficult ($M = 1.83$, $SD = 0.92$) and much more redundant ($M = 4.49$; $SD = 0.63$) compared to short instructions ($M = 2.09$ and 3.44; $SD = 0.79$ and 0.69 respectively). These findings showed that the manipulations were successful.

Means, standard deviations, and bivariate correlations among the assessed variables can be found in Table 1. A MANCOVA was performed with age, gender, need for achievement, LEGO experience and enjoyment, attractiveness of simple constructions and attractiveness of complex constructions as covariates predicting the dependent variables in this study. Multivariate tests (Wilks' Lambda) revealed significant effects of need for achievement ($F(4,101) = 2.89$; $p < .05$; $\eta^2 = .10$), attractiveness of simple constructions ($F(4,101) = 2.48$; $p < .05$; $\eta^2 = .09$) as well as attractiveness of complex constructions ($F(4,101) = 5.15$; $p < .01$; $\eta^2 = .17$). Subsequent univariate analyses showed that need for achievement was related to less irritation ($b = -.39$; $F(6,104) = 8.15$; $p < .01$; $\eta^2 = .07$) and greater accuracy ($b = .16$; $F(6,104) = 5.55$; $p < .05$; $\eta^2 = .05$). A strong attractiveness of simple constructions was related to less accuracy ($b = -.09$; $F(6,104) = 6.32$; $p < .05$; $\eta^2 = .06$), while a strong attractiveness of complex constructions was related to more irritation ($b = .33$; $F(6,104) = 16.12$; $p < .001$; $\eta^2 = .13$) and less accuracy ($b = -.11$; $F(6,104) = 6.86$; $p < .05$; $\eta^2 = .06$). Based on this MANCOVA, need for achievement, attractiveness of simple constructions and attractiveness of complex constructions were included as control variables in subsequent analyses.

Variables	*M*	*SD*	1.	2.	3.	4.	5.	6.
Pre-experimental Measures								
1. *Need for Achievement*	3.76	0.61						
2. *Attractiveness of Simple Constructions*	3.14	1.09	.03					
3. *Attractiveness of Complex Constructions*	2.97	1.06	$.29^{**}$	-.14				
Experimental Measures								
4. *Identification*	3.17	0.81	.06	.06	-.01			
5. *Irritation*	1.81	0.86	-.15	-.05	$.27^{**}$	$-.40^{***}$		
6. *Productivity*	5.54	2.97	.02	-.15	.04	.14	$-.19^{*}$	
7. *Accuracy*	.47	.41	.14	-.17	-.13	.12	$-.30^{**}$	.07

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 1. Means, standard deviations and bivariate correlations among the variables.

6.2 Primary Analyses

A Multivariate ANCOVA was conducted to examine the main and interactive effects of length of instructions and task complexity on the measures of identification, irritation and performance. Significant multivariate main effects were found for length of instruction (Wilks' Lambda = .45, $F(4,101) = 31.06$, $p < .001$, $\eta^2 = .55$) and task complexity (Wilks' Lambda = .37; $F(4,101) = 42.43$, $p < .001$, $\eta^2 = .63$). The interaction effect was also significant (Wilks' Lambda = .68; $F(4,101) = 11.80$, $p < .001$, $\eta^2 = .32$). Means and standard deviations of the outcome variables and univariate ANCOVA results of the main effects can be found in Table 2.

		Short Instructions	Long instructions	Effects of Length of Instructions	
		M (SD)	*M (SD)*	*F* (1,104)	η^2
Simple Tasks	*Identification*	3.45 (0.70)	2.65 (0.74)	16.13***	.13
	Irritation	1.33 (0.57)	2.39 (0.90)	26.62***	.20
	Productivity	9.67 (2.17)	5.29 (1.91)	69.48***	.40
	Accuracy	0.61 (0.38)	0.23 (0.40)	15.31***	.13
		Short Instructions	**Long Instructions**	**Effects of Task Complexity**	
		M (SD)	*M (SD)*	*F* (1,104)	η^2
Complex Tasks	*Identification*	3.40 (0.76)	2.99 (0.85)	0.95	.01
	Irritation	1.63 (0.72)	2.01 (0.82)	0.07	.00
	Productivity	3.86 (0.88)	3.13 (0.75)	171.96***	.62
	Accuracy	0.60 (0.39)	0.41 (0.36)	1.40	.01

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 2. Cell means and standard deviations for the four experimental conditions (simple versus complex tasks and short versus long instructions) and ANCOVA results for task complexity and length of instructions effects.

Hypothesis 1: Effects of length of instruction and task complexity. As can be noticed in Table 2, follow-up univariate ANCOVAs concerning length of instructions indicated that participants given long, relative to short, instructions reported finding the instruction less useful, as reflected by reduced identification, and experienced more irritation. Additionally, the provision of long instructions caused a drop in productivity and accuracy, compared to short instructions. With regard to task complexity, follow-up ANCOVAs showed that participants receiving complex tasks made significantly less constructions (i.e., reduced productivity). There were no significant main effects of task complexity on identification, irritation, or accuracy.

Hypothesis 2: Interaction effect of length of instructions with task complexity. Follow-up univariate ANCOVAS revealed significant interaction effects of length of instructions with task complexity on irritation ($F(1,104) = 6.16$, $p < .05$, $\eta^2 = .06$) and productivity ($F(1,104) = 36.78$, $p < .001$, $\eta^2 = .26$), but not on identified motivation ($F(1,104) = 1.78$, $p = .19$) or accuracy ($F(1,104) = 1.94$, $p = .17$). As can be seen in Table 2 and Figures 5 and 6, these results provide evidence for the fact that increasing the length of instructions provokes more irritation and diminishes productivity. Follow-up analyses indicated that these effects were particularly pronounced for simple tasks.

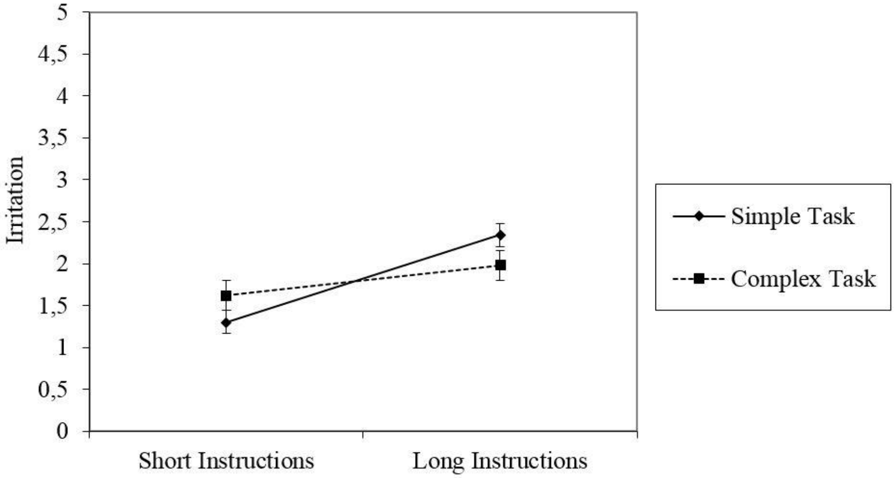

Figure 5. Significant interaction effect between task difficulty and length of instructions predicting irritation with instructions.

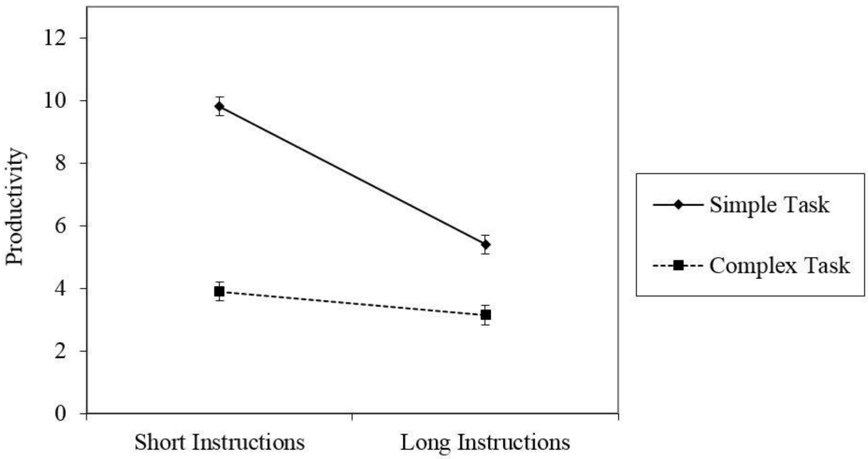

Figure 6. Significant interaction effect between task difficulty and length of instructions predicting productivity.

Hypothesis 3: Interaction effect of length with need for achievement. To investigate whether need for achievement moderated the effect of length of instructions on the outcome variables we performed four separate hierarchical regression analyses with identification, irritation, accuracy and productivity as separate outcomes, while controlling for background variables (Aiken & West, 1991; Cohen & Cohen, 1983; Jaccard & Turrisi, 2003). In the first step, we entered simultaneously the standardized scores of the control variables, need for achievement, length, complexity and the interaction term of length and complexity as predictors, while in a second step, the interaction term between length and need for achievement was added as a predictor (see Table 3).

	Identification				Irritation				Accuracy				Productivity			
	Step 1		Step 2		Step 1		Step 2		Step 1		Step 2		Step 1		Step 2	
	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*	β	*SE*
Main Effects																
Length of Instructions	$-.35^{***}$	0.07	$-.36^{***}$	0.08	$.42^{***}$	0.07	$.42^{***}$	0.07	$-.35^{***}$	0.04	$-.35^{***}$	0.04	$-.43^{***}$	0.16	$-.44^{***}$	0.16
Need for Achievement	.03	0.08	.03	0.08	$-.21^{*}$	0.07	$-.22^{*}$	0.07	.17	0.04	.17	0.04	-.05	0.15	-.05	0.16
Interaction effect																
Length x Need for Achievement			-.08	0.08			$.16^{*}$	0.07			-.06	0.04			-.04	0.16
R^2	.15		.15		.34		.36		.23		.23		.74		.74	
ΔR^2	$.15^{**}$		.01		$.34^{***}$		$.02^{*}$		$.23^{***}$		.00		$.74^{***}$		.00	

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 3. Standardized regression coefficients of a hierarchical regression analysis, with Step 1 length of instructions and need for achievement (moderator) and Step 2 their added interaction term as predictors for identification, irritation, accuracy and productivity.

In the first step, need for achievement significantly predicted irritation, but was unrelated to identification, accuracy or productivity. In the second step, the interaction term between length and need for achievement significantly predicted irritation but not identification, accuracy or productivity. The significant interaction term for irritation was further examined with the procedures proposed by Aiken and West (1991), Dawson (2014) and Dawson and Richter (2006). Follow-up analyses revealed that the provision of short instructions significantly decreased feelings of irritation, especially for participants high in need for achievement, as can be seen in Figure 7.[2]

[2] We also performed hierarchical regression analyses to test for a three-way interaction among instruction length, task complexity, and need for achievement on the four dependent variables. In the first step, we entered simultaneously the standardized scores of the control variables, need for achievement, instruction length, task complexity and the two-way interactions term between the need for achievement, instruction length and task complexity. In a second step, the three-way interaction term between complexity, length and need for achievement was added as an additional predictor. Out of four possible interactions, one significant three-way interaction effect was found for productivity ($\beta = .12$, $p < .05$), but not for identification ($\beta = .11$, $p = .25$), irritation ($\beta = .03$, $p = .72$) and accuracy ($\beta = .04$, $p = .64$). Subsequently, we examined the four separate slopes to examine which conditions were driving the three-way interaction. Yet, the Dawson and Richter test (2006) for differences in slopes indicated no significant differences, which precludes any straightforward interpretation of this three-way interaction effect.

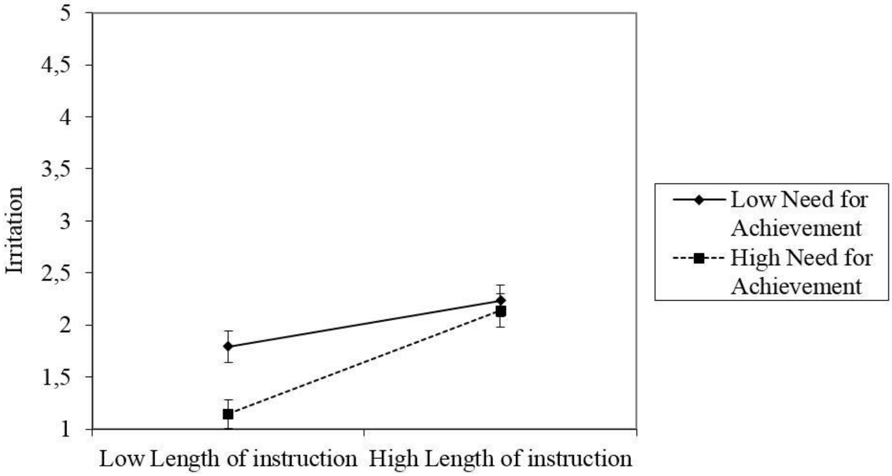

Figure 7. Significant interaction effect between need for achievement and length of instructions predicting irritation with instructions.

Hypothesis 4: Mediation effect of identification. Finally, mediation analyses were performed to test the potential mediating role of identification in the relationship between length of instructions and the outcome variables, using the Process 3.00 macro in SPSS developed by Hayes (2018). In these analyses, 5000 bootstrap samples were drawn to obtain 95% bootstrap confidence intervals. As Table 4 illustrates, the effect of length of instructions on irritation was mediated by identification. No mediation occurred for accuracy and productivity.

Outcome Variable	Direct effect	Direct effect (controlled for mediator)	X → M	M → Y	Indirect effect
Irritation	0.71*** [0.43, 0.99]	0.54*** [0.26, 0.82]	-0.58*** [-0.87, -0.28]	-0.29** [-0.46, -0.12]	0.17 [0.06, 0.30]
Accuracy	-0.29*** [-0.43, -0.14]	-0.29*** [-0.44, -0.13]	-0.60*** [-0.90 ,-0.31]	0.00 [-0.09, 0.10]	0.00 [-0.06, 0.06]
Productivity	-2.45*** [-3.51, -1.40]	-2.46*** [-3.59, -1.32]	-0.60*** [-0.90 ,-0.31]	-0.01 [-0.69, 0.68]	0.00 [-0.40, 0.37]

Note. Direct effect = effect of length of instructions on outcome variable. X → M = effect of length of instructions on identification. M → Y = effect of identification on outcome variable, controlled for length of instructions. Indirect effect = combination of two previous effects. Unstandardized estimates and [95% bootstrap confidence intervals] are provided (Hayes, 2018).

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 4. Identification as mediator between length of instructions and the outcome variables.

7. Discussion

In the present research, we sought to examine when, for whom and why the provision of long instructions for executing an assembly task would affect participants' level of irritation and performance. To do so, we assessed participants' need for achievement levels prior to placing them in one of four experimental conditions, in which they were given either long or short instructions for either simple or complex tasks. We reasoned that long instructions may especially backfire in case tasks are simple (*when*-question) and among individuals high in the need for achievement (*whom*-question), presumably because they would be less likely to identify with the self-importance and usefulness of the long instructions (*why*-question). Several interesting findings were found.

As expected, the provision of long instructions increased feelings of irritation, diminished the perceived value of the instructions, and undermined construction productivity and accuracy. These findings confirm our first hypothesis and provide experimental evidence for the downside of long instructions for assembly tasks. Previous studies (e.g., Kirschner et al., 2006) have primarily focused on the impact of dose of instructions for learning tasks, thereby examining what a minimal versus sufficient amount of instructions involves to be optimally motivating. Yet, far less attention has been paid to the question whether an overdose of instructions would backfire. Additionally, previous studies on instructions for assembly tasks have primarily focused on performance outcomes, while the present study not only included performance, but also took measures of motivation and negative affect into consideration. The current findings clearly suggest that there is a cost related to long instructions, although they are often provided in an attempt to secure higher accuracy (Kalery et al., 2010; Krikalev et al., 2010).

Next, as hypothesized, some of the negative effects of long instructions were aggravated in case participants were asked to solve simple instead of complex tasks. That is, long instructions provoked greater feelings of irritation, especially for simple tasks. These findings are consistent with anecdotic information on the reported frustration of astronauts with regard to the operation procedures for simple routine tasks on the ISS (e.g., Hendrick et al., 2009; Kanas & Manzey, 2008; Manzey, 2013).

Long instructions also caused a drop in productivity, particularly for simple tasks. For complex tasks, participants completed almost the same amount of constructions, regardless of instruction length. While long instructions did not greatly impede on production speed when participants built complex constructions, this was the case for simple constructions. Put differently, the productivity advantage for simple tasks is no longer present when participants are given long instructions. Presumably, for complex task, the time to read the long instructions roughly equals the time to figure out the correct building procedure without this extra guidance. Yet, for simple tasks, it actually takes more time to read through the long instructions than it takes time to figure out the correct procedure without the extra instructional steps, which may explain the drop in productivity. From a safety point of view, the extra reading time and reduced productivity does not necessarily constitute a problem, as long as the cost in productivity for simple tasks is compensated by an increase in accuracy. Interestingly, this was not the case, on the contrary! In fact, the provision of long, relative to short, instructions diminished accuracy, with participants being less attentive to details. These findings are remarkable, since long instructions provided three times more opportunities to detect the hidden catches than short instructions. That is, because extra steps were built into the design, the hidden catches were mentioned three times more frequently.

Apart from examining whether long instructions would backfire depending on task complexity, we also examined whether the effect of length of instructions would depend upon individuals' level of need for achievement. Our hypothesis that potential detrimental effects of long instructions would be aggravated for people scoring high on need for achievement was partially supported. We did find that individuals with a high, compared to low, need for achievement were significantly less irritated when provided with short instructions. This evidence suggest that the benefits of decreasing length of instructions are even greater for those high in need for achievement. This finding has immediate repercussions for space agencies, as astronauts are frequently given long instructions for simple assembly task and they often have a high need for achievement. To avoid such irritation to surface, the given instruction length can best be tailored to the complexity of the task and the personality of the astronaut.

Finally, as to the question of why long instructions for simple tasks have such negative repercussions on irritation and performance, mediation analyses confirmed that the effect of length of instructions on irritation could be partially accounted for by reduced identification. That is, because long instructions were perceived to be less useful and valuable, they did cause more irritation. This observation is consistent with the study of Agrawala et al. (2003), who found that instructions with information split up across too many frames were perceived as tedious, unless the information is of particular importance for the assembly task. It is also possible that the rise in irritation and the drop in performance in the case of long instructions may be accounted for by additional mouse clicking, which was required in the case of long instructions. However, since the effects on irritation and productivity were partially dependent upon task complexity, additional clicking may only partially explain for the negative effects of long instructions. Future studies may, however, avoid such a potential confound when examining the effects of length of instruction by keeping in the amount mouse clicking across length of instruction constant.

Although past research has put forward identification as a significant predictor for error monitoring and self-regulation, we did not find any evidence for the expected mediation effect of identification for accuracy. An alternative explanation for the drop in performance with long instructions, could be a potential semantic salience effect causing the catches to be more visible in the short instructions. As noted, the catches can only be detected when reading the written instructions accompanying each frame. Because long instructions consist of only one brick placement per frame, the word *bridge* appears as a single word within a shorter sentence, while for short instructions this word appears in longer sentences that also mention the conventional word *block*. Perhaps this simultaneous presentation of the words *bridge* and *block* creates a semantic salience effect, which could explain the greater detection of catches in the condition with short instructions. Another possible explanation concerns the fact that reading long instructions is more depleting than reading short instructions, which causes a drop in accuracy. The effect of depletion on self-control was previously shown by Muraven et al. (2008). Therefore measures such as attention, subjective vitality or needed effort could be better candidates to explain the effect of length of instructions on accuracy.

8. Limitations and Future Direction

To maximize the effect of length of instructions on the outcome variables, length was manipulated by varying two distinct features of instructions, namely the number of intermediate steps (a selection, placement and verification step, versus only a placement step), and the amount of information per frames (several bricks per frame versus only one brick per frame). Future studies should experimentally separate these features to study their individual influence on the outcome variables. Additionally, as long instructions employed in this study were deemed redundant even for difficult tasks, a more moderate length of instructions could be implemented in future studies, to assess optimal instructions length for tasks varying in difficulty.

Second, it should be noted that a potential semantic salience effect could have biased our results of the effect of instructions on accuracy. Therefore, future research should try to replicate our findings using non-verbal instructions to eliminate this potential contaminator. Additionally, measures of effort, vitality or attention could be included as outcome variables to explain the effect of length of instructions on accuracy. Also, differences between instructions in amount of required mouse clicking should be avoided, in order to preclude any confounding effects on irritation and performance.

Furthermore, because these results were obtained in a laboratory setting, with university students, external validity is limited, and future research should replicate these findings in more ecologically valid settings. Since data collection from actual astronauts is not always feasible, future researchers should look into space analog or space simulation missions to gather further information on the effects of instructions on well-being, motivation and performance. Alternatively, non-space related work environments can be examined that show the same task characteristics of instructions and task difficulty, typically safety functions such as air traffic controllers or health-care personnel. Finally, these results could be of value for other than procedural tasks in work settings, such as learning tasks in educational environments.

Conclusion

This experimental study confirms what anecdotic sources have suggested for some time now, namely that long instructions are perceived as less useful, and when provided for simple tasks, evoke even greater feelings of irritation. Additionally, long instructions cause a drop in productivity, without any gain in accuracy. Quite the contrary, long instructions significantly undermined accuracy, thereby invalidating the claim that increasing instructions are automatically a valid safety measure to reduce error-making. Space agencies should be particularly careful when designing operation procedures for flight missions, thereby tailoring the amount of instructions being given to the task at hand and the personality of astronauts. Indeed, evidence herein suggests that individuals high in the need for achievement, such as astronauts, benefit even more from the favorable effects of providing short instructions for simple tasks.

References

Agrawala, M., Phan, D., Heiser, J., Haymaker, J., Klinger, J., Hanrahan, P., & Tversky, B. (2003). Designing effective step-by-step assembly instructions. *ACM Transactions on Graphics, Proceedings of ACM SIGGRAPH,* 22, 828-837.

Aiken, L. S., & West, S.G. (1991). *Multiple Regression: Testing and Interpreting Interactions*. Newbury Park: Sage Publications.

Assor, A.G., Roth, G., & Deci, E.L. (2004).The emotional costs of parents' conditional regard: a Self-Determination Theory analysis. *Journal of Personality, 72,* 47-88.

Atkinson, J. W. (1957). Motivational determinants of risk-taking behavior. *Psychological Review, 64*, 359-372.

Baumann, N. & Scheffer, D. (2010). Seeing and mastering difficulty: The role of affective change in achievement flow. *Cognition and Emotion, 24*, 1304-1328.

Baumann, N. & Scheffer, D. (2011). Seeking flow in the achievement domain: The achievement flow motive behind flow experience. *Motivation and Emotion, 35,* 267-284.

Brcic, J. (2010). Motivational profile of astronauts at the International Space Station. *Acta Astronautica, 67*, 1110-1115.

Brown, E., Thoman, D. B., & Smith, J. L. (2015). From bench to bedside: A communal utility value intervention to enhance students' biomedical science motivation. *Journal of Educational Psychology, 107*, 1116-1135.

Brunyé, T. T., Taylor, H. A., & Rapp, D. N. (2008). Repetition and dual coding in procedural multimedia presentations. *Applied Cognitive Psychology, 22,* 877-895.

Burton, K. D., Lyndon, J. E., D'Alessandro, D. U., & Koestner, R. (2006). The differential effects of intrinsic and identified motivation on well-being and performance: prospective, experimental, and implicit approaches to Self-Determination Theory. *Journal of Personality and Social Psychology, 91*, 750-762.

Cerasoli, C. P., Nicklin, J. M., & Ford, M. T. (2014). Intrinsic motivation and extrinsic incentives jointly predict performance: A 40-year meta-analysis. *Psychological Bulletin, 140,* 980-1008.

Cheng, Y.-C., & Yeh, H.-T. (2009). From concepts of motivation to its application in instructional design: Reconsidering motivation from an instructional design perspective. *British Journal of Educational Technology, 40*, 597-605.

Cohen, J., & Cohen, P. (1983). *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences* (2nd ed). Hillsdale: Erlbaum.

Damnik, G., Porske, A., Narciss, S., & Körndle, H. (2013). Informal learning with technology: The effects of self-constructing externalizations. *The Journal of Educational Research, 106,* 431-440.

Dawson, J. F. (2014). Moderation in management research: What, why, when and how. *Journal of Business and Psychology, 29,* 1-19.

Dawson, J. F., & Richter, A. W. (2006). Probing three-way interactions in moderated multiple regression: Development and application of a slope difference test. *Journal of Applied Psychology, 91*, 917-926.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: the selfdetermination theory perspective. *Journal of Personality, 62*, 119-142.

Eccles, J. S. & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109-132.

Eccles, J. S. (1983). Expectancies, values, and academic behaviors, In J. T. Spence (Ed.), *Achievement and Achievement Motives: Psychological and Sociological Approaches* (pp. 75-146). San Francisco: W.H. Freemand.

Elliot, A. J. & Dweck, C. S. (2005). *Handbook of Competence and Motivation*. New York: Guilford.

Enseger, S., & Rheinberg, F. (2008). Flow, performance and moderators of challenge-skill balance. *Motivation and Emotion, 32*, 158-172.

Fisher, K. R., Marshall, P. J., & Nanayakkara, A. R. (2009). Motivational orientation, error monitoring, and academic performance in middle childhood: A behavioral and electrophysiological investigation. *Mind, Brain, and Education, 3*, 56-63.

Gagné, M., Koestner, R., & Zuckerman, M. (2000). Facilitating acceptance of organizational change: The importance of self-determination. *Journal of Applied Social Psychology, 30*, 1843-1852.

Gillet, N., Vallerand, R. J., Lafreniere, M.-A. K., & Bureau, J. S. (2013). The mediating role of positive and negative affect in the situational motivation-performance relationship. *Motivation and Emotion, 37*, 465-479.

Goemaere, S., Vansteenkiste, M., & Van Petegem, S. (2016). Gaining deeper insight into the psychological challenges of human spaceflight: The role of motivational dynamics. *Acta Astronautica, 121*, 130-143.

Hayes, A. F. (2018). Partial, conditional, and moderated mediation: Quantification, inference, and interpretation. *Communication Monographs, 85*, 4-40.

Hendricks, H., Mauroo, T., & Van Spilbeeck, B. (2009). *Het Ruimtedagboek van Frank De Winne: Dagelijks Leven in het ISS.* Leuven: Van Halewyck.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2006), Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and Clark. *Educational Psychology, 42*, 99-107.

Hulleman, C. S. & Harackiewicz, J. M. (2009). Promoting Interest and Performance in High School Science Classes. *Science, 326*, 1410-1412.

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology, 102*, 880-895.

Irrazabal, N., Saux, G., & Burin, D. (2016). Procedural multimedia presentation: the effects of working memory and task complexity on instruction time and assembly accuracy. *Applied Cognitive Psychology, 30*, 1052-1060.

Jaccard, J. J., & Turrisi, R. (2003). Interaction effects in multiple regression. *Quantitative Applications in the Social Sciences, 72*. Newbury Park: Sage Publications.

Kalery, A., Sorokin, I., & Tyurin, M. (2010). Human space exploration beyond the international space station: role of relations of human, machine and the ‘‘Earth’’. *Acta Astronautica, 67*, 925-933.

Kalyuga, S., Chandler, P., Tuovinen, J., & Sweller, J. (2001). When problem solving is superior to studying worked examples. *Journal of Educational Psychology, 93*, 579-588.

Kanas, N., & Manzey, D. (2008). *Space Psychology and Psychiatry*. Dortrecht: Kluwer.

Keller, J. M. (1979). Motivation and instructional design: A theoretical perspective. *Journal of Instructional Development, 2*, 26-34.

Keller, J. M. (2010). *Motivational Design for Learning and Performance: The ARCS Model Approach*. New York: Springer.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychology, 41*, 75-86.

Krikalev, S., Kalery, A., Sorokin, I. (2010). Crew on the ISS: creativity or determinism. *Acta Astronautica, 66*, 68-78.

Kuvaas, B., Buch, R., Gagné, M., Dysvik, A., & Forest, J. (2016). Do you get what you pay for? Sales incentives and implications for motivation and changes in turnover intention and work effort. *Motivation and Emotion, 40*, 667-680.

Legault, L., & Inzlicht, M. (2013). Self-determination, self-regulation, and the brain: autonomy improves performance by enhancing neuroaffective responsiveness to self-regulation failure. *Journal of Personality and Social Psychology, 105,* 123-138.

Manzey, D. (2013). Ruimtemoe: Het gevaar van depressieve astronauten. *Natuurwetenschap & Techniek, 3,* 20-25.

Martin, C. V., & Smith-Jackson, T. L. (2008). Evaluation of Pictorial Assembly Instructions for Young Children. *Human Factors, 50,* 652-662.

Maschke, P., Oubaid, V., & Pecena, Y. (2011). How do astronaut candidate profiles differ from airline pilot profiles? *Aviation Psychology and Applied Human Factors, 1,* 38-44.

McClelland, D. C., Atkinson, J. W., Clark, R. A., & Lowell, E. L. (1953). *The Achievement Motive*. New York: Appleton-Century-Crofts.

McClelland, D. C., Atkinson, J. W., Clark, R., & Lowell, E. (1993). A scoring manual for achievement motive. In C.P. Smith, J.W. Atkinson, D.C. McClelland, J. Veroff (Eds.), *Motivation and Personality: Handbook of Thematic Analysis* (153-178). Cambridge: Cambridge University Press.

Mittelstädt, J. M., Pecena, Y., Oubaid, V., & Maschke, P. (2016). Psychometric personality differences between candidates in astronaut selection. *Aerospace Medecine and Humand Performance, 87*, 933-939.

Morrell, R. W. & Park, D. C. (1993). The effects of age, illustrations, and task variables on the performance of procedural assembly tasks. *Psychology and Aging, 8*, 389-399.

Muraven, M., Gagné, M., & Rosman, H. (2008). Helpful self-control: Autonomy support, vitality, and depletion. *Journal of Experimental Social Psychology, 44,* 573-585.

Nadolski, R.J., Kirschner, P.A., van Merriënboer, J.J.G. (2005). Optimizing the number of steps in learning tasks for complex skills. *British Journal of Educational Psychology, 75,* 223-237.

Novick, L.R., & Morse, D.L. (2000). Folding a fish, making a mushroom: the role of diagrams in executing assembly procedures. *Memory & Cognition, 28*, 1242-1256.

P. Suedfeld (2005). Invulnerability, coping, salutogenesis, integration: four phases of space psychology. *Aviation, Space and Environmental Medicine, 7,* 61-66.

Pang, J. S. (2010). The Achievement Motive: A Review of theory and assessment of n Achievement, hope of Success, and fear of failure. In O. C. Schultheiss, & J. C. Brunstein (Eds.), *Implicit Motives* (pp. 30-70). New York: Oxford University Press.

Pekerti, A. A. (2013). Augmentation of information in educational objects: Effectiveness of arrows and pictures as information for actions in instructional objects. *Australian Journal of Educational Technology, 29*, 840-869.

Reeve, J., Nix, G., & Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *Journal of Educational Psychology, 95,* 375-392.

Reeve, J., Olson, B. C., & Cole, S. G. (1987). Intrinsic motivation in competition: the intervening role of 4 individual-differences following objective competence information. *Journal of Research in Personality, 21,* 148-170.

Richardson, M., Jones, G., Torrance, M., & Baguley, T. (2006). Identifying the task variables that predict object assembly difficult. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 48,* 511-525.

Richey, J. E., & Nokes-Malach, T. J. (2013). How much is too much? Learning and motivation effects of adding instructional explanations to worked examples. *Learning and Instruction, 25,* 104-124.

Roach, M. (2010). *Packing for Mars: The Curious Science of Life in the Void*. New York: W. W. Norton & Company.

Ryan, R. M., & Deci, E. L. (2017). *Self-Determination Theory: Basic Psychological Needs in Motivation Development and Wellness*. New York: Guilford Press.

Sandal, G. M., Bye, H. H., & van de Vijver, F. J. R. (2011). Personal values and crew compatibility: results from a 105 days simulated space mission. *Acta Astronautica, 69,* 141-149.

Savard, A., Joussemet, M., Pelletier, L. G., & Mageau, G. A. (2013). The benefits of autonomy support for adolescents with severe emotional and behavioral problems. *Motivation and Emotion, 37,* 688-700.

Schmidt-Weigand, F.,& Scheiter, K. (2011). The role of spatial descriptions in learning from multimedia. *Computers in Human Behavior, 27,* 22-28.

Schultheiss, O. C., & Brunstein, J. C. (2001). Assessment of implicit motives with a research version of the TAT: picture profiles, gender differences, and relations to other personality measures. *Journal of Personality Assessment, 77,* 71-86.

Schultheiss, O. C., Wiemers, U. T., & Wolf, O. T. (2014). Implicit need for achievement predicts attenuated cortisol responses to difficult tasks. *Journal of Research in Personality, 48,* 84-92.

Soenens, B., Vansteenkiste, M., & Niemiec, C. P. (2009). Should parental prohibition of adolescents' peer relationships be prohibited?. *Personal Relationships, 16,* 507-530.

Suedfeld, P. (2006). Space memoirs: Value hierarchies before and after missions - a pilot study. *Acta Astronautica, 58,* 583-586.

Suedfeld, P., Brcic, J. Johnson, P. J., & Gushin, V. (2012). Personal growth following long-duration spaceflight. *Acta Astronautica, 79,* 118-123.

Van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher-student interaction: a decade of research. *Educational Psychology Review, 22,* 271-296.

Van Genuchten, E., Van Hooijdonk, C., Schüler, A., & Scheiter, K. (2014). The role of working memory when 'learning how' with multimedia learning material. *Applied Cognitive Psychology, 28*, 327-335.

van Merriënboer, J. J. G., & Sweller, J. (2010). Cognitive Load Theory and complex learning: Design principle and strategies. *Medical Education, 44*, 85-93.

Vansteenkiste, M., Aelterman, N., De Muynck, G.-J., Haerens, L., Patall, E., & Reeve, J. (2018). Fostering Personal Meaning and Self-relevance: A Self-Determination Theory Perspective on Internalization. *Journal of Experimental Education, 86*, 30-49.

Wang, M.-T., & Eccles, S. E. (2013). School context, achievement motivation, and academic engagement: A longitudinal study of school engagement using a multidimensional perspective. *Learning and Instruction*, *28*, 12-23.

Yair, G. (2000). Reforming motivation: How the structure of instruction affects students' learning experiences. *British Educational Research Journal*, *26*, 191-201

CHAPTER 3

How to Buffer the Motivational and Performance Deficits of Long Instructions for Procedural Tasks? Comparing the Role of User Control Instructions, an Autonomy-Supportive Communication Style and the Use of Short Instructions[1]

[1] Goemaere, S., Vansteenkiste, M., & Beyers, W. (2018). How to buffer the motivational and performance deficits of long instructions for procedural tasks? Comparing the role of user control instructions, an autonomy-supportive communication style and the use of short instructions. *Manuscript submitted for publication.*

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Introduction

Many organizational settings with high-risk operations and high safety standards require employees to perform procedural tasks (e.g., maintenance, cleaning, monitoring), which can be varied, exceptional, and highly complex in some cases but also routine, monotonous, and simple in other cases. Usually, very elaborated and lengthy instructions are provided for these activities, even for simple routine tasks. Employees are expected to follow these instructions out of safety concerns, that is, to avoid human errors and mistakes that may have catastrophic consequences for employee health and performance. The effectiveness of such instructions has been studied in diverse professions, including railway workers (e.g., Lawton, 1994), warehouse employees (e.g., Cornelissen, van Hoof, & van Vuren, 2014), aviation pilots (e.g., Salden, Paas, & van Merriënboer, 2006), shipping (e.g., Selberg & Lundin, 2018), healthcare professionals (e.g., Chew, van Merriënboer, & Durning, 2018) or human spaceflight astronauts (e.g., Mcphee & Charles, 2009). In general, studies on instructional design tend to focus on the question of the optimal format and amount of instructions necessary for performance (e.g., see Landers & Reddock, 2017 and Van de Pol, Volman, & Beishuizen, 2010, for reviews). However, recent research suggests that an overload of instructions for routine procedural tasks requires more time and effort to process (Chew et al., 2018), elicits frustration and irritation (e.g., Mcphee & Charles, 2008), causes attention drifts, fatigue and boredom (e.g., Peldzus, Dalke, Pretlove, & Welch, 2014) and even provokes rebellious behavior (e.g., Stuster, 2010; Lawton, 1994). Goemaere, Beyers, De Muynck, and Vansteenkiste (2018) even reported that, rather paradoxically, long instructions increased the chance of subtle error making, presumably because individuals tend to read long instructions for simple tasks diagonally.

Given the pitfall of long instructions for simple procedural tasks, the present experimental study sought to investigate which countermeasures can be implemented to alleviate its adverse effects. Grounded in Self-

Determination Theory (Ryan & Deci, 2017) and research in computer-based instruction design, we examined the effectiveness of three separate countermeasures, that is, 1) the shortening of instructions, 2) the provision of long instructions through a motivating (i.e., autonomy-supportive) communication style, and 3) the implementation of adaptive instructions with user control. To get a detailed and nuanced insight in the effectiveness of these countermeasures, a broad variety of motivational (i.e., self-endorsed motivation, reactance), affective (i.e., experienced irritation, boredom and strain) and behavioral (i.e., productivity, accuracy) outcomes was included and the mechanisms underlying the effectiveness of these countermeasures were examined.

1. Self-Determination Theory: The Psychological Needs for Autonomy and Competence

Self-Determination Theory (Ryan & Deci, 2017) is an overarching motivational framework that is well suited to address the sources of employees' motivation and well-being (Deci, Olafson, & Ryan, 2017; Rigby & Ryan, 2018). SDT postulates the existence of three inherent psychological needs (i.e., autonomy, competence, and relatedness) that can be satisfied or frustrated to different degrees, depending on the supervisors' leadership style and the way jobs are designed. Specifically, employees would function most optimally when they feel *related*, that is, when they experience mutual care and warmth, thereby developing genuine authentic relations with colleagues. Equally critical for employees' thriving is their experience of *competence*, which denotes the experience of confidence to effectively execute activities and the experience of accomplishment when using and extending one's skills and expertise to overcome challenges. Finally, employee well-being will be enhanced when employees get their need for *autonomy* met, which involves experiencing volition and personal freedom when engaging in an activity. The need for autonomy is also defined as individuals' desire to behave in line with their own interests and to express their feelings freely.

Dozens of studies have shown the benefits of employee need satisfaction (see Ryan & Deci, 2017; Vansteenkiste, Niemiec, & Soenens, 2010), as indexed by its positive relation to performance (Baard, Deci, & Ryan, 2004), organizational commitment (Gagné, Chemolli, Forest, & Koestner, 2008), and job satisfaction (Van den Broeck, Vansteenkiste, De Witte, Soenens, & Lens, 2010) and its negative relation to burnout (Van den Broeck, Vansteenkiste, De Witte, & Lens, 2008) and effective turnover (Van den Broeck et al., 2010). Recently, a meta-analytic review of 99 studies with 119 samples in organizational settings revealed that satisfaction of the basic needs associates with more desired forms of motivation, positive affect, and both life and job satisfaction, while it may offset more pressuring types of regulation, negative affect, burnout and turnover intentions (Van den Broeck, Ferris, Chang, & Rosen, 2016).

Given the critical role of experiences of need satisfaction, dozens of studies have identified critical contextual antecedents of employees' need satisfaction, with autonomy-supportive management receiving primary attention (Baard et al., 2004; Deci, Connell, & Ryan, 1989). When autonomy-supportive, supervisors adopt a basic attitude of curiosity and openness, thereby trying to attune to employees' perspective. Instead, when controlling, supervisors adopt a tunnel-perspective, thereby forcing employees to act, think, and feel in prescribed ways. Supervisors can use a more autonomy-supportive or a more controlling style with respect to a variety of tasks, including delegating activities, providing instructional procedures, monitoring progress, and communicating feedback. Previous, albeit primarily correlational, research has shown that perceived autonomy-supportive management relates positively to a host of desirable outcomes, including need satisfaction, vitality, and job performance (see Deci et al., 2017, for an overview).

Herein, we sought to provide more experimental evidence for the causal impact of an autonomy-supportive management style in relation to the communication of instructional procedures in particular. Given that extensive and detailed instructions for simple procedural tasks have been found to elicit irritation and a drop in accuracy (Goemaere et al., 2018), two autonomy-supportive countermeasures were examined as potential autonomy-supportive buffers against these pitfalls, that is, an attuning and a participative approach.

2. Countermeasures 1: Attuning Long Instructions to Employee's Perspective

Recent research (Aelterman et al., in press) suggests that autonomy-supportive socialization can get segmented into a more *attuning* and a more *participative* approach, with each of these approaches involving a variety of motivating practices. When attuning, supervisors try to align themselves with the employees' perspective, thereby accustoming to their interests, preferences, and values. They can do so by empathizing with employees' perspective, providing an employee-centered meaningful rationale, fostering task interest and enjoyment, and by making use of more inviting instead of pressuring language. Alternatively, when participative, supervisors make use of practices such as offering choice and welcoming of employees' input, thus fostering a dialogue and involving employees in a joint decision process.

Deci and Eghrari (1994) examined the effectiveness of this attuning approach in an experimental study in which they varied the presence versus absence of three attuning autonomy-supportive measures, i.e., the provision of a meaningful rationale for doing a task, the acknowledgement of negative feelings towards the task, and the use of non-controlling language. Participants were asked to engage in a monotonous and, hence, uninteresting computer-based activity for which they received a minimal set of instructions. The greater the number of attuning measures were operationalized, the more participants perceived the task to be valuable and the more volitional they felt during task execution. Subsequent studies isolated some of these attuning practices, with Jang (2008) experimentally varying the provision of a meaningful rationale among students for participating in an uninteresting learning activity. Rationale provision, versus the lack thereof, prompted greater self-endorsed motivation, behavioral engagement and learning, with the rationale especially buffering against declining engagement. Overall, several studies in educational (e.g., Vansteenkiste, Simons, Lens, Soenens, & Matos, 2005; Vansteenkiste, Lens, & Deci, 2006; Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009), clinical (e.g., Savard, Joussemet, Pelletier, & Mageau, 2013; Van der Kaap-Deeder et al., 2014) and sport settings (e.g., Carpentier, Mageau, 2013; 2016; De Muynck et al. 2017) have found similar results, indicating that, when tasks are framed in a way that emphasizes their importance for self-development and growth, engagement and volitional functioning increases (see Vansteenkiste et al., 2018 for an overview). In short, although previous studies demonstrated the effectiveness of an attuning communication style, these studies made use of a learning instead of a procedural task and they all dealt with the question how boring tasks instead of instructions accompanying the tasks could be introduced in more motivating ways. Thus, it remains to be seen whether the benefits of an attuning approach generalize to procedural tasks, which are introduced with extensive instructions.

3. Countermeasure 2: Offering Choice

While autonomy-supportive supervisors may help employees to better see the relevance of long instructions and validate the elicited negative affect, another possibility is to present instructions in a more gradual fashion, thereby leaving the choice regarding the amount of desired instructions to the employees themselves. The motivational benefits of choice - a *participative* practice - have been extensively studied. A meta-analysis by Patall, Cooper, and Robinson (2008), synthesizing studies on choice across various life domains, showed that overall, choice enhances self-endorsed motivation, task performance, and a sense of competence. The benefits of choice may even radiate to participants' performance as shown by Dember, Galinsky, and Warm (1992). Offering university students the opportunity to select either a difficult or easy task increased their performance compared to a no-choice control group, even though all participants received the same task. Similarly, Legault and Inzlicht (2013) gave participants the opportunity to choose between differently labelled tasks, while in fact, unbeknownst to participants, all tasks were identical. Again, results showed increased performance, and higher task interest and task value when participants were provided with a choice in which task to perform, suggesting that the mere act of choosing suffices to produce performance benefits.

At the same time, several strands of research indicate that the effectiveness of choice as a motivational strategy can be questioned (Patall, & Hooper, 2017). First, from a SDT-perspective, for the effects of choice to be maximized, the offered choice needs to engender the experience of choice, volition, and psychological freedom. To this end, offered options need to be sufficiently attractive and match individuals' preferences (Katz & Assor, 2007). Also, *action* choices, which concern the latitude to decide *how* to perform a task were found to yield a more powerful effect compared to *option* choice, that is, the choice *which* task to perform (Reeve, Nix, & Hamm, 2003), especially if the offered options are closely related to one another in terms of (un)attractiveness (De Muyck, Soenens, De Graewe, Vande Broek, & Vansteenkiste, 2018).

Second, from a self-regulatory perspective, the act of choosing is potentially energy-depleting, which may suppress its benefits. More self-regulatory resources may get depleted, when an overload of options is provided, thereby also leading one to question one's effectiveness to choose (e.g., Iyengar & Lepper, 2000; Mozgalina, 2015; Patall, 2012), or when choosers need to make a consecutive series of choices. According to the meta-analysis of Patall et al. (2008), choice appears to be most effective when two to four repeated choices are made.

Third, in the literature on computer-based instructional design, the use of adaptive instructions, which enables individuals to alter task instructions (i.e., *user control* or, in the case of learning tasks, *learner control*), has produced inconsistent results. Based on a recent meta-analysis regarding the effectiveness of learner control instructions, the authors concluded that "*the overall effects of learner control are generally small and subtle*" (Landers & Reddock, 2017, p. 474). The heterogeneity in the observed effects of learner control may be partially due to differences in operationalization and methodology (Landers & Reddock, 2017) and several studies have sought to examine potential moderating variables such as choosers' personality (e.g., Orvis, Brusso, Wasserman, & Fisher, 2011), prior knowledge (e.g., Kopcha & Sullivan, 2008), self-regulation (e.g., Gorissen, Kaster, Brand-Gruwel, & Martens, 2013) and cognitive style (e.g., Papanikolaou, Mabbott, Bull, & Grigoriadou, 2006).

In spite of these critical observations, it remains to be seen whether the use of user control instructions may appear beneficial for procedural tasks. Different from learning tasks, which involved the acquirement of new knowledge or skills, thus, involving the extension of one's competence, procedural tasks, especially when they are monotonous and easy, come with little, if any, skill-development. Indeed, procedural tasks in high-risk and safety professions such as aviation, healthcare and shipping, consist of a combination of physical activities to attain a certain goal, guided by procedural instructions. Since employees in high-risk or safety professions have been reported to sometimes disregard procedures or limit themselves to a diagonal read of instructions, the implementation of user control is intuitively appealing. Especially the use of *supplement control* may be effective, as employees are in this case by default given a limited set of instructions, yet, additional instructions are available, if needed. This form of user control has the advantage of presenting individuals with shorter instructions, which has been shown beneficial for motivation, affect and performance in past research (Argawala et al., 2003; Goemaere et al., 2018; Irrazabal, Saux, & Burn, 2016; Novick & Morse, 2000). Additionally, adaptive instructions with supplement control allow users to repeatedly make action choices (i.e., to make use of additional instructions when needed), which was observed to have the strongest positive effect on self-endorsed motivation (Reeve et al., 2003).

4. Countermeasure 3: Shortening Instructions

While supervisors could try to motivate employees by being more attuned to workers’ perspective or implementing more participative practices, they could also consider shortening instructions in such a way as to align task challenge with employee competence. Most studies on instructional guidance have observed the detrimental effects of not providing students with sufficient help to attain learning goals (e.g., Stroet, Opdenakker, & Minnaert, 2013; Van de Pol et al., 2010). However, very little is known about the consequences of an overload of instructional information, especially for procedural tasks (Goemaere et al., 2018). Presumably, when simple tasks are accompanied by elaborate detailed instructions, they become less challenging, which could impede opportunities for employees to use their expertise and develop skills, and could harm their sense of accomplishment.

A variety of correlational studies on skill utilization in organizational settings have found that, when employees are able to make use of their expertise and capabilities, they experienced greater job satisfaction (e.g., Feldman and Bolino, 2000; Morrisson, Cordery, Girardi, & Payne, 2005) more work engagement (e.g., Feldman and Bolino, 2000; Parker, 2003; Van den Broeck, Scheurs, Günter, & van Emmerik, 2015), and less hypertension (Konno & Munakata, 2014). In contrast, when a company has employees who experience insufficient opportunities to exercise their skills, chances for collective turnover increase (Mitchell & Zatzick, 2015). Unfortunately, experimental studies on the optimal amount of instructional guidance to enhance skill utilization and sense of accomplishment in procedural tasks are lacking. However, shortening instructions for simple tasks have been reported to enhance motivation, well-being and performance. Specifically, in a laboratory, university students were asked to perform simple or complex LEGO assembly tasks, for which they were given either short or more detailed elaborate instructions with more intermediary steps (Goemaere et al., 2018). Results indicated that shortening instructions decreased frustration and enhanced productivity, with these advantages being most pronounced for simple tasks. Additionally, participants who were given short instructions found instructions to be more useful and were less inclined to discard them. They also made less mistakes, presumably because short instructions are less strenuous to follow for longer periods of time. However, the assumption that shortening instructions, especially for simple tasks, benefits employees because such task characteristics are more fitted to employees' need for competence and sense of challenge, remains to be determined.

In general, organizations are not too keen on diminishing instructional guidance for high-risk and safety professions, probably because they assume shortening instructions would increase the risk for human error making, despite experimental research (e.g., Goemaere et al., 2018) and anecdotal sources (e.g., Peldzus et al., 2014; Stuster, 2010) attesting to the contrary. In the present study, we therefore examined whether shortening instructions could be equally effective in alleviating the previously observed negative consequences of long instructions compared to the introduction of long instructions, yet, in more motivating ways (cfr. countermeasures 1 and 2).

5. The Present Study

The primary objective of the present experimental study was to examine the effects of length, adaptability and communication style of instructions on a variety of motivational (i.e., self-endorsed motivation, reactance), affective (i.e., experienced irritation, boredom and strain) and behavioral (i.e., productivity, accuracy) outcomes. We further investigated whether the effects of instructions would be mediated by changes in experiences of autonomy and competence. We tested our hypotheses in a laboratory setting, which allowed us to reproduce the task characteristics that are distinctive for high-risk organizational settings with high safety standards, while at the same time eliminating the effects of extraneous variables. In accordance with the above reasoning about instruction length, autonomy-supportive communication style and adaptability of instructions, we expected short, autonomy-supportive and user control, relative to long instructions to cause greater need satisfaction (as reflected in participants' sense of volition and accomplishment), enhance internalization (as reflected in participants' increased self-endorsed motivation and decreased reactance), provoke less negative affect (as reflected in decreased irritation, boredom and strain) and to promote performance (as reflected in more productivity and accuracy) (Hypothesis 1). Second, in accordance with SDT literature on basic psychological needs, we expect autonomy and competence to account for (i.e., mediate) the relationship between instructions and motivation, affect and performance (Hypothesis 2).

This study aims to contribute to the scientific literature in several ways. First, this study expands on the literature on computer-based instructional design by examining the effect of an overload of information through lengthy instructions and the introduction of adaptive instructions with supplement control in procedural tasks. Second, the study builds on previous research in SDT by examining whether autonomy-supportive measures proven effective in relation to learning tasks would also be beneficial for procedural tasks and by formally testing the mechanisms (i.e., autonomy and competence satisfaction) underlying their effectiveness. Finally, the study aims to contribute to research in the organizational domain by reproducing task characteristics in a laboratory setting that are typical for high-risk and safety professions such as aviation, human spaceflight and healthcare.

6. Method

6.1 Participants

In total, 123 predominantly female (83.7%) university students (M_{age} = 19 years and 3 months; *SD* = 3 years and 2 months) participated in this experiment, in exchange for a course credit. Participants were randomly assigned to one of four study conditions: three experimental conditions and one control condition.

6.2 Procedure

Prior to the experiment, students filled out an online questionnaire. At least one day later, they took part in an Excel task which lasted for 40 minutes. After completing this task, they completed a short questionnaire. The study was approved by the ethical committee of the Faculty of Psychology and Educational Sciences, Ghent University, Belgium. Informed consent was obtained from all participants prior to their participation and participants were guaranteed confidential treatment of their responses. Participation was voluntary and students could withdraw from the experiment at any time. Immediately after the experiment, participants were informed of the broader aim of the experiment and the conducted manipulations. A more extensive debriefing followed via email about the scientific findings and implications of the study.

6.3 Experimental Design

6.3.1 Excel experiment

Students were told that they would take part in an Excel task. Before the actual Excel task, they participated in a trial version of the Excel task, allowing them to get familiar with the task material (two computer screens, a keyboard and a computer mouse) and the Excel instructions. During this trial task, which lasted about five minutes, participants made a few exemplary Excel exercises and were given the opportunity to ask questions. After the trial version, the actual Excel task started. Specifically, with the aid of visual instructions displayed on the second computer screen, participants inserted numbers and formulas, made calculations, and built graphics in several Excel sheets during 40 minutes, using a self-paced working rhythm. The provided written instructions for the Excel task presented the procedure steps one at a time in a single frame, clearing the screen when the step was accomplished. The students were asked to study the instructions carefully and to focus primarily on accuracy instead of the speed at which they made the Excel exercises.

6.3.2 Manipulation

In this experiment, we adopted a 1 x 4 design, with type of instructions being manipulated at the between subject level. In the control condition, briefly referred to as *long instructions*, participants were provided with elaborate and detailed instructions, consisting of extended descriptions of every single procedure step. In contrast, participants in the first experimental condition, entitled *short instructions*, were given instructions with briefer descriptions of the procedure steps, containing fewer intermediary steps (see Figure 1 and 2).

2.0 Databars graphics.

2.1 Use the Conditional Formatting menu to make the following graphics in the following cells:

2.1.1 Cells A1 to C2: full orange databars.

2.1.2 Cells A4 to C5: full green databars.

2.1.3 Cells A7 to C8: full red databars.

Figure 1. Example of short instructions.

2.0 Databar graphics

2.1 Databars 1 and 2

2.1.1 Select the cells A1, B1, C1, A2, B2 and C2.

2.1.2 Click the Conditional Formatting menu on the 'HOME' tab.

2.1.3 Go to the option '*Data Bars*'.

2.1.4 Select the orange databar with '*Solid Fill*'.

2.2 Databars 4 and 5

2.2.1 Select the cells A4, B4, C4, A5, B5 en C5.

2.2.2 Click the Conditional Formatting menu on the 'HOME' tab.

2.2.3 Go to the option '*Data Bars*'.

2.2.4 Select the green databar with '*Solid Fill*'.

2.3 Databars 7 and 8

2.3.1 Select the cells A7, B7, C7, A8, B8 en C8.

2.3.2 Click the Conditional Formatting menu on the 'HOME' tab.

2.3.3 Go to the option '*Data Bars*'.

2.3.4 Select the red databar with '*Solid Fill*'.

Figure 2. Example of long instructions.

The third condition, entitled *need-supportive instructions*, was identical to the control condition with long instructions, except that participants had a brief interaction with a need-supportive experimenter between the trial task and the actual Excel task. Specifically, after the trial task, the experimenter entered the participant's room, holding a clipboard with a single written multiple choice question, and engaged in the following script:

"*Now that you've gotten a first taste of the Excel task, I would just quickly like to ask you a question. What did you think of these instructions? Were they* (showing the multiple choice question on the clip board):

Way too brief
A little too brief
Ok as they were
A little too elaborate
Way too elaborate"

The experimenter listened to the participants' opinion regarding the instructions, wrote down their answer, and delivered the following message:

"I am asking you this because, we've noticed that some people prefer shorter instructions, while others prefer longer, more detailed instructions like the ones you received. We've also noticed that these longer instructions have their benefits. For instance, when you give people shorter instructions, they have a tendency to go through them rather quickly, and as a consequence, they overlook some details and have to retrace their steps. However, when people are given more elaborate instructions, they often work more precisely and accurately from the start, which also makes them faster. Now, there are many factors that can influence performance on the Excel task, aside from computer skills. For instance, some people perform better because they have stronger visual capacities, others because they pay more attention to detail or

show more determination. But also aspects like task enjoyment or motivation can play a part. We want to study all these factors, and in that sense, this study could also be of use to you. By the end of the task, we'll be able to give you feedback on which factors exactly influenced your performance. This could be useful for you in the future, for instance when you need to use Excel or when you need to learn new computer software. Do you have any more questions?" The experimenter listened and replied to questions, if participants had any, before ending with: *"If you don't have any more questions, I will now start the Excel task for you."*

The experimenter then started the actual Excel task before leaving the room.

Finally, in the last condition, entitled *user control instructions*, with every procedure step, participants were given the choice between the long and short instructions. Specifically, participants received standard short instructions, but by clicking on an optional pop-up link at the bottom of each frame labelled "*More information*", they were given the choice to receive the longer set of instructions, if they deemed so necessary (see Figure 3). Participants were randomly assigned to one of the four study conditions, with the *n* per condition varying between 30 and 32.

2.0 Databars graphics.

2.1 Use the Conditional Formatting menu to make the following graphics in the following cells:

2.1.1 Cells A1 to C2: full orange databars.

2.1.2 Cells A4 to C5: full green databars.

2.1.3 Cells A7 to C8: full red databars.

More Information

3.0 Databar graphics

3.1 Databars 1 and 2

3.1.1 Select the cells A1, B1, C1, A2, B2 and C2.

3.1.2 Click the Conditional Formatting menu on the 'HOME' tab.

3.1.3 Go to the option '*Data Bars*'.

3.1.4 Select the orange databar with '*Solid Fill*'.

3.2 Databars 4 and 5

3.2.1 Select the cells A4, B4, C4, A5, B5 en C5.

3.2.2 Click the Conditional Formatting menu on the 'HOME' tab.

3.2.3 Go to the option '*Data Bars*'.

3.2.4 Select the purple databar with '*Solid Fill*'.

3.3 Databars 7 and 8

3.3.1 Select the cells A7, B7, C7, A8, B8 en C8.

3.3.2 Click the Conditional Formatting menu on the 'HOME' tab.

3.3.3 Go to the option '*Data Bars*'.

3.3.4 Select the red databar with '*Solid Fill*'.

Figure 3. Example of user control instructions, after clicking 'More Information'.

6.3.3 Measures

Several existing or self-developed questionnaires were used in various parts of the study. All items in these questionnaires were scored on a 5-point Likert scale ranging from 1 ("*don't agree at all"*) to 5 ("*agree completely"*). All measures were available in Dutch, the native language of the participants, and several of them were validated successfully in previous studies. Others were created for the purpose of this study and are available on request.

Pre-experimental measures.

***Trait reactance proneness*.** An inclination for reactive behavior was measured using the 13-item Hong Psychological Reactance Scale (Hong & Faedda, 1996). A sample item reads "*I like to contradict other people*" and internal consistency was .86.

***Trait boredom proneness*.** The Boredom Proneness Scale (Zondag, 2007) was administered to assess students' tendency to experience boredom. This scale consists of ten items, e.g. "*I can easily stay concentrated*" (alpha = .70).

Post-experimental measures.

***Manipulation check*.** To determine whether our manipulation of length, autonomy-support and adaptability of instructions was successful, we measured participants' perceived instruction redundancy (four items; e.g., "*There were too many instructions*"; alpha = .67; Goemaere et al., 2018; adapted from Nadolski, Kirschner, & van Merriënboer, 2005), and perceived autonomy-support (four self-developed items; e.g., "*I felt understood by the experimenter*"; alpha = .77; adapted from Savard et al., 2013).

Autonomy. The experience of volition and personal freedom during the Excel task, indicative of the satisfaction of participants' need for autonomy, was measured using three items from the Intrinsic Motivation Inventory (Ryan, 1982; Deci, Eghrari, Patrick, & Leone, 1994.) and the Activity-Feeling States Scale (Reeve & Sickenius, 1994), in accordance with Reeve et al. (2003). An item example reads: "*During the Excel task I experienced a relaxed sense of freedom*". Internal consistency was .61.

Competence. For the assessment of competence, we measured the experience of challenge, use of skills and overall sense of accomplishment, using a 5-item self-developed scale based on items from the Intrinsic Motivation Inventory (Ryan, 1982; Deci, Eghrari, Patrick, & Leone, 1994) and the skill variety subscale of the Work Design Questionnaire (Morgeson & Humphry, 2006). An item example reads: "*I found the Excel task challenging*". Cronbach's alpha was .61.

Motivation. In SDT, quality of motivation can be differentiated based on the reasons to engage in a certain activity, being more internalized and self-endorsed, or more pressuring. Many studies in SDT have convincingly shown that employees feel and perform better when their motivation is self-endorsed in nature, that is, when they engage in their work because they find it enjoyable, interesting or valuable, and have internalized the reasons for engagement in their work (e.g., De Cooman, Stynen, Van den Broeck, Sels, & De Witte, 2013; Baard et al., 2004; Van den Broeck, Lens, De Witte, & Van Coillie, 2013), while, in contrast, employees function less optimally when they engage in particular behavior out of inner or external pressures (Chemolli, Gagné, & Koestner, 2012; Gagné et al., 2015). In the present study, self-endorsement and acceptance of instructions for the Excel task (instead of the participation in the task) was assessed using an adapted version of the Self-Regulation Questionnaire - Parental Rules (Soenens, Vansteenkiste, Niemiec, 2009; Goemaere et al., 2018). Participants were asked for their reasons to follow instructions for the Excel task: "*During the Excel task, I followed instructions because…*" In total, 15 items were used to measure external regulation (e.g. "*this was expected of me*"; 3 items; Cronbach's alpha = .78), introjected regulation (e.g., "*I would have felt guilty otherwise*"; 6 items; Cronbach's alpha = .77) and identified regulation (e.g; "*I understood why they were important*"; 6 items; Cronbach's alpha = .85. In line with previous work, a summarizing measure was created, the relative internalization index (RII)[2] (Soenens, et al., 2009; Vallerand, Forties, & Guay, 1997; Neyrinck, Vansteenkiste, Lens, Duriez, & Hutsebaut, 2006; van der Kaap-deeder, et al., 2014). Overall, higher scores on this index indicate higher levels of ownership and internalization of instructions.

Reactance. The tendency to oppose and bluntly dismiss the Excel instructions was measured using four items adapted from Vansteenkiste, Soenens, Van Petegem, and Duriez (2014). A sample item reads "*From time to time I wanted to disregard the instructions that were set for me*". Cronbach's alpha (.85) revealed a good internal consistency.

Irritation. Four items such as "*I felt irritated with the instructions I was given*" were used to measure how irritated participants felt with regard to the instructions. These items were based on the resentment scale of Assor, Roth,

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[2] This composite score is calculated by a weighted combination of volitional and pressuring forms of motivation, wherein the volitional motives were given a positive weight and the pressuring motives were given a negative weight. Because the different kinds of regulations in SDT (i.e., identified, introjected, and external) are supposed to lie on one continuum of self-endorsement, the weights that are assigned to these regulations (i.e., +3, −1, and −2, respectively) when creating the RII are balanced. Such a weighting procedure guarantees that the sum of the assigned weights is zero and that self-endorsed and pressuring types of regulation are equally weighted in the creation of the RII (Neyrinck et al., 2006).

and Deci (2004) and were previously used by Goemaere et al. (2018). Internal consistency of this scale was .89.

Strain. Three self-developed items were used the measure the amount of strain experienced by participants to follow the instructions attentively. A sample item reads "*I found it difficult to stay focused and follow the instructions attentively*." Cronbach's alpha was .79.

Boredom. The 8-item Multidimensional State Boredom Scale (Fahlman, Mercer-Lynn, Flora, & Eastwood, 2011) was used to measure the degree to which participants felt bored during the Excel task (e.g. "*Time went by slower than usual*"; alpha = .83).

Performance. Two different performance indicators were collected, that is, a quantitative and a qualitative measure. First, *productivity* was counted as the total number of Excel tasks completed during the time span of 40 minutes, regardless of accuracy. Second, *accuracy* was included to determine whether participants were following instructions attentively, which would be reflected in the quality of the Excel exercises. To measure accuracy, certain *catches* were included in some of the instructions. For instance, during the Excel tasks, participants were repeatedly required to build graphs in the colors orange, green and red. In the case of a catch, however, instructions would unexpectedly require participants to build a purple graph. Only through continued careful consideration of the instructions could these catches be detected. Accuracy was therefore measured as the percentage of detected catches, given the number of presented catches.

7. Results

7.1 Preliminary Analyses

To check whether instructions in the experimental conditions were successfully manipulated, three ANOVAs were performed with each experimental condition contrasted with long instructions as an independent variable, and style or redundancy as a dependent variable. Results indicated a significant main effect of length ($F(1,59) = 26.09$; $p < .001$; $\eta^2 = .31$) and adaptability of instructions ($F(1,61) = 8.73$; $p < .01$; $\eta^2 = .13$) on redundancy, with short and user control instructions being perceived as less redundant than long instructions ($M = 3.22$, 3.70 and 4.13; $SD = 0.78$, 0.55. and 0.62, respectively). A need-supportive communication style was strongly related to autonomy-support ($F(1,59) = 42.90$; $p < .001$; $\eta^2 = .42$), with need-supportive instructions ($M = 4.45$, $SD = 0.55$) being experienced as more autonomy-supportive than long instructions ($M = 3.35$, $SD = 0.74$). These results suggest that our manipulations were successful.

Means, standard deviations and bivariate correlations among the assessed variables can be found in Table 1. A MANCOVA was performed with age, gender, trait reactance and trait boredom proneness as covariates predicting the dependent variables in this study. Multivariate tests (Wilks' λ) revealed a significant effect of age ($F(9,104) = 2.75$; $p < .05$; $\eta^2 = .18$). Subsequent univariate analyses revealed that age was related to less strain ($b = -.05$; $F(7,112) = 4.42$; $p < .05$; $\eta^2 = .04$) and less productivity ($b = -.12$; $F(7,112) = 13.20$; $p < .001$; $\eta^2 = .11$). Based on this MANCOVA, age was included as a control variable in subsequent analyses.

	M (SD)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
1. Age	18.77 (1.72)	-											
2. Gender	0.15 (0.36)	$.19^{*}$	-										
3. Trait reactance	2.70 (0.65)	$.26^{***}$	$.29^{***}$	-									
4. Trait boredom	2.79 (0.54)	.01	.03	-.03	-								
5. Volition	2.74 (0.71)	.04	.03	-.01	.10	-							
6. Competence	2.57 (0.64)	.17	-.09	.07	.10	$.46^{***}$	-						
7. Motivation	-0.16 (2.81)	.08	-.05	-.02	.10	$.53^{***}$	$.43^{***}$	-					
8. Reactance	2.27 (1.10)	.03	$.17^{\dagger}$	.10	-.04	$-.27^{***}$	$-.38^{***}$	$-.39^{***}$	-				
9. Irritation	2.59 (1.03)	.04	$.19^{*}$	.06	-.04	$-.45^{***}$	$-.45^{***}$	$-.47^{***}$	$.57^{***}$	-			
10. Strain	3.08 (1.10)	$-.16^{\dagger}$	.05	-.05	.01	$-.27^{***}$	$-.41^{***}$	$-.37^{***}$	$.51^{***}$	$.51^{***}$	-		
11. Boredom	2.73 (0.74)	-.03	.01	.12	-.06	$-.58^{***}$	$-.51^{***}$	$-.51^{***}$	$.39^{***}$	$.60^{***}$	$.46^{***}$	-	
12. Productivity	7.21 ((1.20)	$-.25^{**}$	.07	-.03	-.10	-.08	-.05	-.14	.07	$.17^{\dagger}$	.14	.12	-
13. Accuracy	.33 (.29)	.10	-.04	.06	-.11	.10	.09	$.19^{*}$	-.15	-.12	-.12	.01	-.04

$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 1. Means, standard deviations and correlations among the study variables.

7.2 Primary Analyses

Hypothesis 1: Main effects. To test whether the manipulation of instructions had an effect on the outcome variables, we tested for differences between the study conditions by performing a MANCOVA with the different conditions as a fixed factor, and the outcome variables as dependent variables. Results can be found in Table 2. The multivariate effect turned out significant (Wilks's λ = .54, $F(27,313) = 2.69$, $p < .001$; $\eta^2 = .18$), and follow-up univariate ANOVAs and contrast analyses revealed significant differences between each of the experimental conditions and the control group. Specifically, participants who received short instructions experienced significantly less reactance and strain compared to participants receiving long instructions. With regards to performance, they made less mistakes, but were also less productive, compared to the control condition. In the need-supportive condition, participants experienced a greater sense of volition and found the task less boring, compared to the long instructions condition. Further, need-supportive instructions elicited less reactance and irritation than long instructions. Finally, in the user control condition, participants felt significantly more autonomous and competent, experienced greater self-endorsed motivation and less reactance, found instructions to be less irritating and strenuous and the task less boring, compared to participants in the long instructions condition. Additionally, participants who were provided with user control instructions were significantly more accurate than the control group.

	Study Conditions				Univariate Effects		Contrasts-*t*		
	Long Instructions *M* (*SD*)	Short Instructions *M* (*SD*)	Need-Supportive Instructions *M* (*SD*)	User Control Instructions *M* (*SD*)	$F(3,114)$	η^2	L vs S	L vs N	L vs U
<u>Mediating mechanisms</u>									
Volition	2.55_b (0.61)	2.49_b (0.65)	2.95_a (0.76)	2.90_a (0.65)	3.64^*	.09	-0.34	2.29^*	2.00^*
Competence	2.46_b (0.58)	2.72_{ab} (0.64)	2.71_{ab} (0.68)	2.95_a (0.77)	$2.64^\dagger$	.06	1.47	1.44	2.81^{**}
<u>Outcomes</u>									
Motivation	-0.81_b (2.93)	0.62_{ab} (3.27)	0.54_{ab} (2.56)	1.83_a (3.29)	3.76^*	.09	$1.79^\dagger$	$1.71^\dagger$	3.36^{**}
Reactance	2.57_a (1.28)	1.94_b (0.94)	1.99_b (0.82)	1.66_b (0.85)	4.42^{**}	.10	-2.42^*	-2.25^*	-3.56^{**}
Irritation	2.96_a (1.03)	2.58_{ab} (0.87)	2.24_{bc} (0.92)	1.92_c (0.86)	7.03^{***}	.16	-1.57	-3.00^{**}	-4.36^{***}
Strain	3.16_a (1.13)	2.49_{bc} (0.80)	2.95_{ab} (1.07)	2.22_c (0.88)	5.73^{**}	.13	-2.62^*	-0.82	-3.74^{***}
Boredom	2.95_a (0.71)	2.81_{ab} (0.70)	2.53_{bc} (0.71)	2.35_c (0.81)	3.99^{**}	.09	-0.70	-2.20^*	-3.11^{**}
Productivity	7.27_a (1.34)	6.28_b (1.79)	7.03_a (1.04)	7.20_a (1.22)	3.46^*	.08	-2.85^{**}	-0.69	-0.19
Accuracy	$.25_b$ (.29)	$.60_a$ (.39)	$.40_b$ (.28)	$.58_a$ (.41)	6.50^{***}	.15	3.83^{***}	1.66	3.63^{***}

Note. Means not sharing subscripts are significantly different ($p < .05$) as indicated by contrasts.
$^\dagger p < .10$. $^* p < .05$. $^{**} p < .01$. $^{***} p < .001$.

Table 2. Effects of study conditions on the outcome variables.

Hypothesis 2: Explanatory role of psychological needs. To test whether volition and competence served as intervening variables in the effects of autonomy-supportive and user control instructions on the outcome variables, we relied on SEM analyses using MPlus 7 software (Muthén & Muthén, 1998-2015) in combination with dummy coding. Herein, the long instructions condition was used as a reference point. Two dummy variables were created, one comparing autonomy-supportive instructions (1) with long instructions (0) and one comparing user control instructions (1) with long instructions (0). To examine the effects of the autonomy-supportive and user control instructions, the two dummy variables, along with the age variable, were modelled as predictors of both autonomy and competence need satisfaction. Subsequently, the two dummy variables, the two mediators, and age were modelled as predictors of motivation, reactance, irritation, strain, boredom, and accuracy. Fit indices showed an excellent fit ($\chi^2_{(2)}$ = 3.65; SRMR = .03; CFI = 1.00). In a second SEM analysis, the non-significant paths between autonomy and reactance (β = -.12, p = .43), strain (β = -.17, p = .32), and accuracy (β = .03, p = .56), between competence and accuracy (β = -.01, p = .86), and between boredom and need-supportive and user control instructions (β = -.06, p = .54 and β = -.10, p = .36, respectively) were omitted from the model. Fit indices again revealed an excellent for this model ($\chi^2_{(9)}$ = 6.99; SRMR = .04; CFI = 1.00). Results of this final model are depicted in Figure 4. To test the intervening roles of autonomy and competence in a formal way, we relied on tests for indirect effects (MacKinnon, Lockwood, & Williams, 2004). The indirect effects are computed as the product of the association between an independent variable and the intervening variable (the α association) and the association between the intervening variable and the dependent variable (the β association), divided by the standard error of this product. Because the traditional methods to estimate indirect effects, such as the Sobel test, have a low power and a high probability of Type-I errors, MacKinnon et al. (2004) proposed a bias-corrected bootstrap method. This method is based on a resampling approach and involves the calculation of confidence intervals (CI) to determine the significance of an indirect effect. When zero is not included in the CI, the indirect effect is significant. When significant, such an effect indicates that an independent variable is related indirectly to a dependent variable through an intervening variable.

Results in Table 3 showed significant indirect effects of an autonomy-supportive communication style on motivation and boredom, and marginally significant indirect effect on irritation, through volition. The effect of user control instructions on motivation was significantly mediated by autonomy and almost reached significance in the case of competence, and the effect on reactance was significantly mediated by competence. Likewise, there was a significant indirect effect of user control instructions on irritation through competence, as well as a marginally significant indirect effect through autonomy. Competence also played a significant mediating role in the effect of user control instructions on strain. Finally, we found significant indirect effects of user control instructions on boredom, mediated both by autonomy and competence.

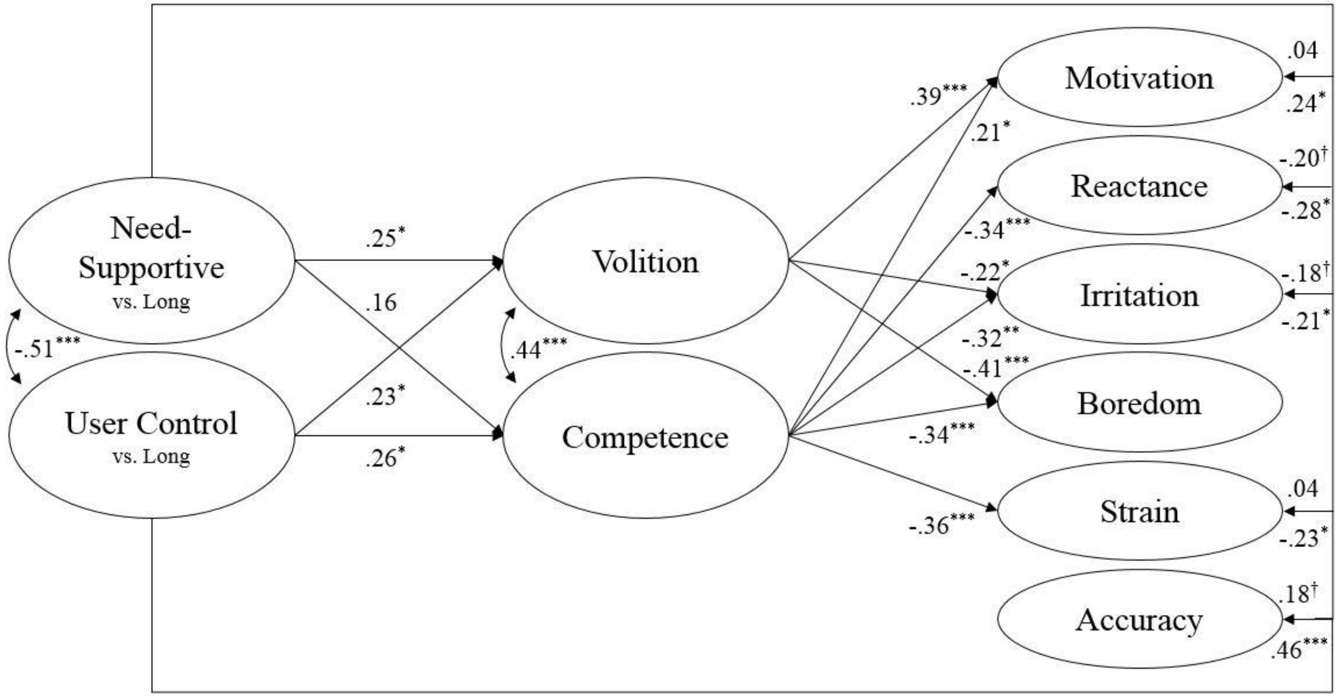

Figure 4. Graphical representation of the structural equation model of the intervening roles of volition and competence in the effects of need-supportive and user control instructions on the outcome variables.

	Autonomy-supportive instructions through volition			User control instructions through volition		
	Estimate	95% CI	90% CI	Estimate	95% CI	90% CI
Motivation	.10	[.01, .22]	[.02, .19]	.09	[.001, .17]	[.01, .16]
Irritation	-.06	[-.14, .00]	[-.12, -.01]	-.05	[-.11, .00]	[-.10, -.003]
Boredom	-.10	[-.21, -.01]	[-.19, -.02]	-.09	[-.18, -.001]	[-.16, -.01]
	Autonomy-supportive instructions through competence			User control instructions through competence		
	Estimate	95% CI	90% CI	Estimate	95% CI	90% CI
Motivation	.03	[-.02, .08]	[-.01, .07]	.05	[.00, .13]	[.01, .11]
Reactance	-.05	[-.15, .02]	[-.13, .01]	-.09	[-.20, -.01]	[-.18, -.02]
Irritation	-.05	[-.12, .02]	[-.11, .01]	-.08	[-.18, -.01]	[-.16, -.02]
Strain	-.06	[-.15, .02]	[-.13, .01]	-.09	[-.20, -.01]	[-.18, -.02]
Boredom	-.05	[-.12, .03]	[-.11, .01]	-.09	[-.18, -.01]	[-.16, -.02]

Note . Standardized estimates, [95% bootstrap confidence intervals (CI)] and [90% bootstrap confidence intervals (CI)] are provided. When zero is not in these intervals, the indirect effect is (marginally) significant.
$^{\dagger}p < .10$. $^{*}p < .05$.

Table 3. Indirect effects of autonomy-supportive and user control instructions on the outcome variables through volition and competence.

8. Discussion

In the present experimental study, we sought out to investigate which countermeasures could alleviate the downfalls of long instructions for simple procedural tasks. Specifically, we examined how length, communication style and adaptability of instructions would impact several motivational, affective and behavioral outcomes. Additionally, we wanted to find out whether changes in experiences of autonomy and competence could explain the impact of instructions on these outcomes. Results indicated user control instructions to be most beneficial, followed by need-supportive, and short instructions.

8.1 Contrasting Different Countermeasures

The current findings indicated that the shortening of instructions buffered against the emergence of reactance and strain, and the drop of accuracy when long instructions are provided. These results are in line with a previous experimental study on the shortening of instructions for assembly tasks (Goemaere et al., 2018), indicating that shorter instructions are effective in reducing reactance and enhancing self-endorsed motivation and accuracy. In contrast with previous findings however, the use of shorter instructions also yielded a downside in this study, as it caused a drop rather than an increase in productivity. At first sight, this finding is surprising as participants were expected to need less time to go through short instructions, thereby leading them to complete a greater number of Excel tasks. One explanation for this unexpected drop in productivity could be that, by shortening instructions, participants had to spend more time searching for menus and functions in the Excel software. The anticipated gain in time and subsequent boost in productivity by not having to read additional text, was therefore lost on an unexpected extra subtask, namely the location of icons and tabs, instead of the actual Excel exercises. While short instructions seem beneficial in enhancing motivation and accuracy and relieving negative affect, careful consideration is needed when developing such procedures as to make sure that the reduction of instruction length does not add to the workload, thereby diminishing productivity.

In contrast with the rather mixed set of outcomes associated with short instructions, providing long instructions in an autonomy-supportive way revealed only positive effects on the outcome variables. An autonomy-supportive style of introducing instructions enhanced participants' volition, while diminishing feelings of reactance, irritation and boredom. While autonomy-supportive instructions hardly benefit performance on the Excel task, no adverse effects were found either. It seems that the combined provision of an empathic response and meaningful rationale for instructions, together with an emphasis on the personal relevance of the task and a promise of individual feedback, was sufficient in alleviating a substantial number of negative effects attributed to lengthy procedures. These results are congruent with a number of experimental studies on the benefits of autonomy-supportive measures in other domains, such as sports (e.g., Carpentier & Magneau, 2013; 2016; De Muynck et al. 2017) and the classroom (e.g., Jang, 2008; Vansteenkiste, et al., 2005; 2006; 2009). Given that instructions in the autonomy-supportive condition were identical to the long instructions, aside from a brief and one-time intervention, these positive changes in motivational and affective outcomes are quite remarkable. Moreover, these results are interesting because, while shortening instructions is not always a feasible measure to implement, for instance in human spaceflight missions with their strict safety regulations, long instructions can quite easily be accompanied by an autonomy-supportive message.

Without a doubt, the most successful intervention turned out to be the implementation of adaptive instructions with supplement control. While both short and autonomy-supportive instructions tended to increase a sense of competence and self-endorsed motivation, only user control instructions were significantly effective in doing so. Additionally, user control instructions were perceived as the least strenuous, while being equally effective in enhancing autonomy and accuracy, and decreasing reactance, irritation and boredom, compared to the other experimental conditions. Moreover, a potential additional advantage of user control instructions lies in the fact that the driver of these benefits, i.e., the repeated provision of action choices, is continuously present throughout the total duration of the task. Therefore, it is likely that the observed benefits of user control instructions in this experiment, which were measured after 40 minutes, would also be present for longer tasks. For the autonomy-supportive instructions however, the beneficial effects of the driver, i.e., the one-time autonomy-supportive message before the start of the task, might wear off as time proceeds, something which future studies should take into consideration.

Interestingly, the positive results of user control instructions in this experiment are inconsistent with findings on adaptive instructions with supplement control in learning tasks (Landers & Reddock, 2017). Whereas supplement control tends to have only minor positive effects on learning outcomes, and even negative effects on attitude towards instructions, these results are apparently not translatable to procedural tasks. Possibly, the provision of supplement control in learning tasks, meaning that learners can choose additional study material if they want to, creates doubt whether sufficient knowledge has been gained to successfully perform on the following test. In procedural tasks however, the user immediately knows whether he or she needs additional instructions, since the task needs to be performed at that very instant, without delay or a subsequent learning test.

8.2 Understanding the Effectiveness of Different Countermeasures

A second key objective of the present study was to test whether need satisfaction, particularly a sense volition and competence, could explain the effects of instructions on the outcome variables. A SEM analysis with tests for indirect effects revealed that an autonomy-supportive communication style elicits a greater sense of willingness and personal freedom, which in turn enhances self-endorsed motivation and diminishes feelings of boredom. For user control instructions, all effects were mediated by either a higher sense of volition, or competence, or both. Providing participants with repeated action choices turns out to be beneficial for experiencing willingness and personal freedom, and feeling challenged and accomplished. Subsequently, an increased sense of volition reinforces self-endorsed motivation and diminishes boredom, while a stronger feeling of competence reduces defiant tendencies, strain, irritation and boredom. In short, while the positive effects of autonomy-supportive instructions were mediated by an increased sense of volition, user control instructions were effective through a greater experience of both volition and competence, which could explain the more beneficial main effects of user control instructions.

The enhancing effect of user control instructions on accuracy was mediated by neither volition nor competence, but rather seemed to be a direct effect of the instruction manipulation itself. Probably, a salience effect could explain this finding, since one can logically assume that novel words (e.g., "*purple*" in the case of a catch) would more easily pop out in shorter instructions. No mediation through need satisfaction could be observed for the effects of length of instructions on the outcome variables, since shortening instructions did not significantly influence experiences of volition or competence. However, creating conditions that foster people's needs for volition and competence can still be an effective measure to alleviate the detrimental impact of long and elaborate instructions on motivational and affective outcomes.

8.3 Practical Implications and Limitations

The present study yields several practical implications. Although organizational management might find additional instructional material intuitively appealing to enhance safety and performance in risky work environments, the present findings suggest these additional instructions may comes at a cost in accuracy, on top of motivational and affective disadvantages. Shortening instructions can be beneficial to enhance employee compliance and diminish boredom, but it can also cause a drop in productivity. The challenge for organizational managers is then to provide the optimal dose of instructions (neither too long, nor too short) themselves or, alternatively, leaving the decision up to the employees themselves. Fortunately, management can still opt for the more lengthy operating procedures and provide them in an autonomy-supportive way more attuned to participants' needs, by 1) allowing or even encourage employees to voice their frustration with regards to tasks and procedures, without it having any negative consequences for their future career, 2) providing them with a meaningful rationale why long operating procedures are useful, 3) increasing the personal relevance of a task by explaining how the task contributes to employee interests. Alternatively, managers could match specific tasks more closely to specific interests of employees. Also, 4) managers could consistently give employees personalized feedback on their performance, which can enhance task interest and would enable employees to gain further knowledge and develop their skills and expertise. Finally, organizations could implement more employee participation by embedding instructions with repeated action choices such as supplement control, allowing employees to choose if and when additional instructional guidance is needed. Presumably, it would require more investment from organizations to embed repeated action choices in procedural instructions. However, once those investments have been made, the process of need-support would implement itself automatically, independent of management-employee communications. Implementing user control instructions could in fact be more time- and cost-effective than an autonomy-supportive communication style from managers, since 1) managers wouldn't need additional training, and 2) the effects of user control instructions are likely more robust than an autonomy-supportive message, which would need to be repeated and varied, to remain personally relevant for employees.

This study has a number of limitations. First, the results were obtained in a laboratory setting with university students as participants, which limits the external validity of our findings. Future studies should aim to replicate these findings in more ecologically valid settings, for instance with healthcare professionals, air traffic controllers, airline pilots, astronauts or other high-risk and safety functions. Second, while several autonomy-supportive measures were administered in combination (i.e., empathy, meaningful rationale, and personal relevance), future studies should experimentally separate these features to study their individual influence on the outcome variables. Finally, it would be interesting to examine instruction manipulation on longer tasks, perhaps even spanning several days, to test for the robustness of their beneficial effects.

Conclusion

Although organizational management in high-risk domains puts forward the use of lengthy elaborate procedural instructions for safety reasons, results of this experimental study confirmed results from previous research, namely that the provision of long instructions for simple tasks can be detrimental for participants' motivation, affect and accuracy. However, while shorter instructions are effective in alleviating these deficits, they can also cause a drop in productivity. In contrast, the provision of autonomy-supportive, and especially user control instructions, was successful in alleviating all detrimental effects of lengthy procedures, and this mainly through increased experiences of willingness and sense of challenge and accomplishment. Based on these results, organizations could implement a number of need-supportive measures, both in the development and provision of procedural instructions for workers, and the training of managers in communicating instructions and interacting with employees.

References

Alterman, N.*, Vansteenkiste, M.*, Soenens, B., Fontaine, J., Haerens, L., & Reeve, J. (accepted). Toward an integrative and fine-grained insight in motivating and demotivating teaching: The merits of a circumplex approach. (*equal contributions). *Journal of Educational Psychology*.

Agrawala, M., Phan, D., Heiser, J., Haymaker, J., Klinger, J., Hanrahan, P., & Tversky, B. (2003). Designing effective step-by-step assembly instructions. *ACM Transactions on Graphics, Proceedings of ACM SIGGRAPH, 22*, 828-837.

Assor, A.G., Roth, G., & Deci, E.L. (2004).The emotional costs of parents' conditional regard: a self-determination theory analysis. *Journal of Personality, 72,* 47-88.

Baard, P. P., Deci, E. L., & Ryan, R. M. (2004). Intrinsic need satisfaction: A motivational basis of performance and well-being in two work settings. *Journal of Applied Social Psychology, 34,* 2045-2068.

Carpentier, J., & Mageau, G. A. (2013). When change-oriented feedback enhances motivation, well-being and performance: a look at autonomy-supportive feedback in sport. *Psychology of Sport Exercise, 14,* 423-435.

Carpentier, J., & Mageau, G. A. (2016). Predicting sport experience during training: The role of change-oriented feedback in athletes' motivation, self-confidence and needs satisfaction fluctuations. *Journal of Sport & Exercise Psychology, 38,* 45-58.

Chemolli, E., Gagné, M., & Koestner, R. (2012). *Recurring null results between extrinsic motivation and performance and wellbeing in the workplace: Finding meaning in the void*. Paper presented at the Institute of Work Psychology Conference, Sheffield.

Chew, K. S., van Merriënboer, J. J. G., & Durning, S. J. (2017). Investing in the use of a checklist during differential diagnoses consideration: what's the trade-off? *BMC Medical Education, 17*, 234-240.

Cornelissen, P. A., van Hoof, J. J., & van Vuren, M. (2014). Enabling employees to work safely: The influence of motivation and ability in the design of safety instructions. *Technical Communication, 61*, 232-244.

De Cooman, R., Stynen, D., Van den Broeck, A., Sels, L., & De Witte, H. (2013). How job characteristics relate to need satisfaction and autonomous motivation: Implications for work effort. *Journal of Applied Social Psychology, 43*, 1342-1352.

De Muynck, G-J., Soenens, B., Degraeuwe, L., Vande Broek, G., & Vansteenkiste, M. (2018). Towards a more refined insight in the critical motivating features of choice: An experimental study among recreational rope skippers. *Manuscript submitted for publication.*

De Muynck, G-J., Vansteenkiste, M., Delrue, J., Aelterman, N., Haerens, L., & Soenens, B. (2017). The effects of feedback valence and style on need satisfaction, self-talk, and perseverance among tennis players: An experimental study. *Journal of Sport & Exercise Psychology, 39*, 67-80.

Deci, E. L., Connell, J. P., & Ryan, R. M. (1989). Self-determination in a work organization. *Journal of Applied Psychology, 74*, 580-590.

Deci, E. L., Eghrari, H., & Patrick, B. C. (1994). Facilitating internalization: the Self-Determination Theory perspective. *Journal of Personality, 62*, 119-142.

Deci, E. L., Olafsen, A. H., & Ryan, R. M. (2017). Self-Determination Theory in work organizations: The state of a science. *Annual Review of Organizational Psychology and Organizational Behavior, 4*, 19-43.

Dember, W. N., Galinsky, T. L., & Warm, J. S. (1992). The role of choice in vigilance performance. *Bulletin of the Psychonomic Society, 30*, 201-204.

Fahlman, S. A., Mercer-Lynn, K. B., Flora, D. B., & Eastwood, J. D. (2013). Development and Validation of the Multidimensional State Boredom Scale. *Assessment, 20*, 68-85.

Feldman, D. C., & Bolino, M. C. (2000). Skill utilization of overseas interns: Antecedents and consequences. *Journal of International Management, 6*, 29-47.

Gagné, M., Chemolli, E., Forest, J., & Koestner, R. (2008). A temporal analysis of the relation between organisational commitment and work motivation. *Psychologica Belgica, 48*, 219-241.

Gagné, M., Forest, J., Vansteenkiste, M., Crevier-Braudd, L., Van den Broeck, A., Aspelif, A.K.,…Westbye, C. (2015). The Multidimensional Work Motivation Scale: Validation evidence in seven languages and nine countries. *European Journal of Work and Organizational Psychology, 24*, 178-196.

Goemaere, S., Beyers, W., De Muynck G.-J., & Vansteenkiste, M. (2018). The paradoxical effect of long instructions on negative affect and performance: When, for whom and why do they backfire? *Acta Astronautica, 147*, 421-430.

Gorissen, C. J. J., Kester, L., Brand-Gruwel, S., & Martens, R. L. (2013). Autonomy supported, learner-controlled or system-controlled learning in hypermedia environments and the influence of academic self-regulation style, *Interactive Learning Environments, 23*, 655-669.

Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2006), Scaffolding and achievement in problem-based and inquiry learning: a response to Kirschner, Sweller, and Clark. *Educational Psychology, 42*, 99-107.

Hong, S. M., & Faedda, S. (1996). Refinement of the Hong Psychological Reactance Scale. *Educational and Psychological Measurement, 56*, 173-182.

Irrazabal, N., Saux, G., & Burn, D. (2016). Procedural multimedia presentation: the effects of working memory and task complexity on instruction time and assembly accuracy. *Applied Cognitive Psychology, 30*, 1052-1060.

Iyengar, S. S., & Lepper, M. (2000). When choice is demotivating: Can one desire too much of a good thing? *Journal of Personality and Social Psychology, 79*, 995-1006.

Jang, H. (2008). Supporting students' motivation, engagement, and learning during an uninteresting activity. *Journal of Educational Psychology, 100*, 798-811.

Katz, I., & Assor, A. (2007). When choice motivates and when it does not. *Educational Research Review, 19*, 429-442.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: an analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychology, 41*, 75-86.

Konno, S., & Munakata, M. (2014). Skill underutilization is associated with higher prevalence of hypertension: the watari study. *Journal of Occupational Health, 56*, 225-228.

Kopcha, T. J., & Sullivan, H. (2008). Learner preferences and prior knowledge in learner-controlled computer-based instruction. *Educational Technology, Research and Development, 56*, 265-286.

Landers, R. N., & Reddock, C. M. (2017). A meta-analytic investigation of objective learner control in web-based instruction. *Journal of Business Psychology, 32*, 455-478.

Lawton, R. (1998). Not working to rule: Understanding procedural violations at work. *Safety Science, 28*, 77-95.

Legault, L., & Inzlicht, M. (2013). Self-determination, self-regulation, and the brain: autonomy improves performance by enhancing neuroaffective responsiveness to self-regulation failure. *Journal of Personality and Social Psychology, 105*, 123-138.

MacKinnon, D. P., Lockwood, C. M., & Williams, J. (2004). Confidence limits for the indirect effect: Distribution of the product and resampling methods. *Multivariate Behavioral Research, 39*, 99-128.

Mcphee, J. C., & Charles, J. B. (2009). *Human health and performance risks of space exploration missions* (NASA SP-2009-3405). Houston, Texas, NASA Johnson Space Center.

Mitchell, M., & Zatzick, C.D. (2015). Skill underutilization and collective turnover in a professional service firm. *Journal of Management Development, 34*, 787-802.

Morrison, D., Cordery, J., Girardi, A., & Payne, R. (2005). Job design, opportunities for skill utilization, and intrinsic job satisfaction. *European Journal of Work and Organizational Psychology, 14,* 59-79.

Mozgalina, A. (2015). More or less choice? The influence of choice on task motivation and task engagement. *System, 49*, 120-132.

Muthén, L. K., & Muthén, B. O. (1998-2015). *Mplus User's Guide*. Seventh Edition. Los Angeles, CA: Muthén & Muthén.

Nadolski, R.J., Kirschner, P.A., van Merriënboer, J.J.G. (2005). Optimizing the number of steps in learning tasks for complex skills. *British Journal of Educational Psychology, 75*, 223-237.

Neyrinck, B., Vansteenkiste, M., Lens, W., Duriez, B., & Hutsebaut, D. (2006). Cognitive, affective and behavioral correlates of internalization of regulations for religious activities. *Motivation and Emotion, 30*, 323-334.

Novick, L.R., & Morse, D.L. (2000). Folding a fish, making a mushroom: the role of diagrams in executing assembly procedures. *Memory & Cognition, 28*, 1242-1256.

Orvis, K. A., Brusso, R. C., Wasserman, M. E., & Fisher, S. L. (2011). Enabled for e-learning? The moderating role of personality in determining the optimal degree of learner control in an e-learning environment. *Human Performance, 24*, 60-78.

Papanikolaou, K. A., Mabott, A., Bull, S., & Grigoriadou, M. (2006). Designing learner-controlled educational interactions based on learning/cognitive style and learner behavior, *Interacting with computers, 18,* 356-384.

Parker, S. (2003). Longitudinal effects of lean production on employee outcomes and the mediating role of work characteristics. *Journal of Applied Psychology, 88,* 620-634.

Patall, E. A. & Hooper, S. Y. (2017). The role of choice in understanding adolescent autonomy and academic functioning. In B. Soenens, S.Van Petegem, and M. Vansteenkiste (Eds.), Autonomy in Adolescent Development: Towards Conceptual Clarity (Studies in Adolescent Development). New York, NY: Routledge.

Patall, E. A. (2012). The motivational complexity of choosing: A review of theory and research. In R. M. Ryan (Ed.), *The Oxford handbook of human motivation*. USA: Oxford University Press.

Patall, E. A., Cooper, H., & Robinson, J. C. (2008). The effects of choice on intrinsic motivation and related outcomes: a meta-analysis of research findings. *Psychological Bulletin, 134,* 270-300.

Peldszus, R., Dalke, H., Pretlove, S., & Welch, C. (2014). The perfect boring situation - Addressing the experience of monotony during crewed deep space missions through habitability design. *Acta Astronautica, 94,* 262-276.

Reeve, J., Nix, G., & Hamm, D. (2003). Testing models of the experience of self-determination in intrinsic motivation and the conundrum of choice. *Journal of Educational Psychology, 95,* 375-392.

Rigby, C. S., & Ryan, R. M. (2018). Self-Determination Theory in human resource development: New directions and practical considerations. *Advances in Developing Human Resources, 20,* 133-147.

Ryan, R. M. (1982). Control and information in the intrapersonal sphere: An extension of cognitive evaluation theory. *Journal of Personality and Social Psychology, 43,* 450-461.

Ryan, R. M., & Deci, E. L. (2017). *Self-Determination Theory: Basic psychological needs in motivation, development, and wellness*. New York: Guilford Press.

Salden, R. J. C. M., Paas, F., & van Merriënboer, J. J. G. (2006). Personalised adaptive task selection in air traffic control: Effects on training efficiency and transfer. *Learning and Instruction, 16*, 350-362.

Savard, A., Joussemet, M., Pelletier, L. G., & Mageau, G. A. (2013). The benefits of autonomy support for adolescents with severe emotional and behavioral problems. *Motivation and Emotion, 37*, 688-700.

Selberg, C., & Lundin, M. (2018). Tasks and instructions on the simulated bridge: Discourses of temporality in maritime training. *Discourse Studies, 20*, 289-305.

Soenens, B., Vansteenkiste, M., & Niemiec, C. P. (2009). Should parental prohibition of adolescents' peer relationships be prohibited?. *Personal Relationships, 16,* 507-530.

Stroet, K., Opdenakker, M.-C., & Minnaert, A. (2013). Effects of need supportive teaching on early adolescents' motivation and engagement: a review of the literature. *Educational Research review, 9*, 65-87.

Stuster, J. (2010). *Behavioral issues associated with long-duration space expeditions: Review and analysis of astronaut journals* (NASA/TM-2010-216130). Houston, Texas, NASA Johnson Space Center.

Vallerand, R.J., Fortier, M.S., & Guay, F. (1997). Self-determination and persistence in a real-life setting: Toward a motivational model of high school dropout. *Journal of Personality and Social Psychology, 72*, 1161-1176.

Van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher-student interaction: a decade of research. *Educational Psychology Review, 22,* 271-296.

Van den Broeck, A., Ferris, D. L., Chang, C.-H., & Rosen, C. C. (2016). A review of Self-Determination Theory's basic psychological needs at work. *Journal of Management, 42*, 1195-1229.

Van den Broeck, A., Vansteenkiste, M., De Witte, H., & Lens, W. (2008). Explaining the relationships between job characteristics, burnout, and engagement: The role of basic psychological need satisfaction. *Work & Stress, 22*, 277-294.

Van den Broeck, A., Vansteenkiste, M., De Witte, H., Soenens, B., & Lens, W. (2010). Capturing autonomy, competence, and relatedness at work: Construction and initial validation of the Work-Related Basic Need Satisfaction Scale. *Journal of Occupational and Organizational Psychology, 83*, 981-1002.

Van den Broeck, A. Lens, W., De Witte, H., & Van Coillie, H. (2013). Unraveling the importance of the quantity and the quality of workers' motivation for well-being: A person-centered perspective. *Journal of Vocational Behavior, 82*, 69-78.

Van den Broeck, A., Schreurs, B., Günter, H., & van Emmerik, U. H. (2015). Skill utilization and well-being: a cross-level story of day-to- day fluctuations and personal intrinsic values. *Work & Stress,* 29, 306-323.

Van der Kaap-Deeder, J., Vansteenkiste, M., Soenens, B., Verstuyf, J., Boone, L., & Smets, J. (2014). Fostering self-endorsed motivation to change in patients with an eating disorder: The role of perceived autonomy support and psychological need satisfaction. *International Journal of Eating Disorders, 47,* 585-600.

Van der Kaap-Deeder, J., Vansteenkiste, M., Soenens, B., Verstuyf, J., Boone, L., & Smets, J. (2014). Fostering self-endorsed motivation to change in patients with an eating disorder: The role of perceived autonomy support and psychological need satisfaction. *International Journal of Eating Disorders, 47*, 585-600.

Vansteenkiste, M., Aelterman, N., De Muynck, G.-J., Haerens, L., Patall, E., & Reeve, J. (2018). Fostering Personal Meaning and Self-relevance: A Self-Determination Theory Perspective on Internalization. *Journal of Experimental Education, 86*, 30-49.

Vansteenkiste, M., Lens, W., & Deci, E. L. (2006). Intrinsic versus extrinsic goal contents in self-determination theory: Another look at the quality of academic motivation. *Educational Psychologist*, *41*, 19-31.

Vansteenkiste, M., Niemiec, C. P., & Soenens, B. (2010). The development of the five mini-theories of Self-Determination Theory: A historical overview, emerging trends and future directions. In T. Urdan & S. Karabenick (Eds.), *Advances in Motivation and Achievement: Vol. 16. The decade ahead* (pp. 105-166). Bingley, United Kingdom: Emerald.

Vansteenkiste, M., Sierens, E., Soenens, B., Luyckx, K., & Lens, W. (2009). Motivational profiles from a self-determination perspective: The quality of motivation matters. *Journal of Educational Psychology, 101*, 671-688.

Vansteenkiste, M., Simons, J., Lens, W., Soenens, B., & Matos, L. (2005). Examining the impact of extrinsic versus intrinsic goal framing and internally controlling versus autonomy-supportive communication style upon early adolescents' academic achievement. *Child Development*, *76*, 483-501.

Vansteenkiste, M., Soenens, B., Van Petegem, S., & Duriez, B. (2014). Longitudinal associations between adolescent perceived degree and style of parental prohibition and internalization and defiance. *Developmental Psychology*, *50*, 229-236.

Zondag, H. (2007). Introductie van een Nederlandstalige schaal voor gevoeligheid voor verveling (NSGV). *Psychologie en Gezondheid*, *35*, 225-233.

CHAPTER 4

Do Astronauts Benefit from Autonomy? Investigating Perceived Autonomy-Supportive Communication by Mission Support, Crew Motivation and Collaboration during HI-SEAS I[1]

[1] Goemaere, S., Vansteenkiste, M., Beyers, W., Vermeulen, A.C.J., & Binsted, K. (in press). Do astronauts benefit from autonomy? Investigating perceived autonomy-supportive communication by Mission Support, astronauts' motivation and collaboration during HI-SEAS I. *Acta Astronautica*.

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Introduction

Future human space exploration will differ greatly from what astronauts have experienced thus far (Kanas & Manzey, 2008; Sgobba, Kanki, Clervoy, & Sandal, 2017). With the advent of interplanetary travel, we face major challenges at the technical, physical, financial, political, but also psychological level. One particular challenge, due to the immense distance between Earth and Mars, is the restricted crew-ground communication (Kanas, 2014; Krikalev, Kalery, & Sorokin, 2010; Manzey, 2004; McIntosh et al., 2016). Where the traditional crew-ground relationship relies heavily on Mission Support, future more limited crew-ground communication will inevitably increase the autonomous functioning of the crew, which may yield implications for astronauts' motivation and instruction adherence (e.g., Morgeson, 2015). Although space agencies may fear that their more limited impact upon astronauts may come at a cost, there are theoretical reasons to believe that the increasing crew independence, when volitional in nature, may yield a range of benefits (Goemaere, Vansteenkiste, & Van Petegem, 2016). Self-Determination Theory (SDT; Deci, Olafsen, & Ryan, 2017; Ryan & Deci, 2000a), an overarching psychological theory on human motivation and social development, underscores the importance of the experience of autonomy or volition for all individuals' well-being. Based on this theoretical framework, one way for the crew to experience greater volition in space is through an autonomy-supportive communication style by Mission Support. Previous literature in human spaceflight testifies to the importance of crew-ground interactions for astronaut functioning and mission success and abundant research in SDT convincingly shows that autonomy support enhances volition and motivation in many domains.

However, to date, most research on astronaut autonomy and motivation tends to focus primarily on their importance for crew selection (e.g., Brcic, 2010; Maschke, Oubaid, & Pecena, 2011; Vinokhodova & Gushin, 2014). Moreover, the few studies that did take into account the changing nature of astronaut autonomy and crew motivation during the course of a mission often lack a strong theoretical basis (e.g., Van Baarsen, 2013), and do not relate such fluctuations to other important outcomes, such as crew-ground interactions (e.g., Sandal & Bye, 2015; Sandal, Bye, & van de Vijver, 2011). Grounded in SDT (Ryan & Deci, 2017), the present research aims to provide evidence for the potential value of an autonomy-supportive communication style by ground support, such that crew members' experience of volition and motivation, and crew-ground collaboration get fostered (Goemaere et al., 2016). Specifically, using data collected during the last eight weeks of the first mission of the NASA-funded HI-SEAS Mars simulation, our study focused on whether week-to-week fluctuations in perceived autonomy-supportive communications between Mission Support and the crew related to week-to-week variations in crew autonomy, and whether week-to-week variations in crew autonomy related to crew motivation and crew-ground collaboration.

1. A Nuanced Perspective towards Astronaut Autonomy

The last couple of years, the notion of crew autonomy has become a popular subject among space experts (e.g., Kalery, Sorokin, & Tyurin, 2010; Krikalev et al., 2010; McIntosh et al., 2016). Traditionally, Western space agencies tend to be strongly ground-based, with a centralized control from Mission Support. For instance, planning at NASA involves a top-down, hierarchical approach, where Mission Support directs the majority of the missions (McIntosh et al., 2016). Such strong reliance on direction from upper management and planning currently occurs with minimal, if any, input from crew members (Krikalev et al., 2010; Hendricks, Mauroo, & Van Spilbeeck, 2009). Because astronauts are in some cases merely considered an "*extension of ground support*" (McIntosh et al., 2016) their autonomy has been restricted, in spite of their high intelligence and capacities for independent decision making. At least some astronauts may interpret this tendency to limit autonomy as signaling distrust, which may further reduce their motivation and even give rise to feelings of irritation and defiant behavior towards Mission

Support. This could explain why, after a couple of months into a mission, astronauts tend to rebel against their deprived autonomy (McIntosh et al., 2016). As one NASA expert characterized the astronaut mentality: "*Just give me the skeleton and let me do it my way.*" (McIntosh et al., 2016, p. 484).

From a SDT perspective, such rebellious behavior can be expected. Together with the psychological needs for competence and relatedness, autonomy is conceived as an essential nutrient for psychological health, motivation and personality integration (Ryan & Deci, 2000a; Vansteenkiste & Ryan, 2013), regardless of cultural background, age and socio-economic levels (e.g., Chirkov, Ryan, Kim, & Kaplan, 2003; Sheldon et al., 2004). When autonomy is satisfied, people experience a sense of volition, ownership and psychological freedom when carrying out a task, while frustration of autonomy involves feeling conflicted and pressured to think, act or feel in a prescribed way. Importantly, from the SDT-perspective, autonomy does not equal independence (Chen, Vansteenkiste, Beyers, Soenens, & Van Petegem, 2013; Ryan & Lynch, 1989). Whereas independence refers to making decisions without external guidance, autonomy refers to the inner experience of volition and psychological freedom when engaging in an activity (Vansteenkiste & Ryan, 2008). Such a sense of volition can be experienced when acting independently, that is, when making one's own decisions, but also in a state of dependence, that is, when relying on others for advice and guidance (Soenens, Vansteenkiste, Van Petegem, Beyers, & Ryan, 2018). Hence, even if astronauts are turning to ground control for help and counseling, they do not necessarily act non-autonomously given that they concur with the guidelines offered by the ground. Thus, it is important for space agencies to understand that both a state of dependence or independence can be experienced as volitional or pressuring. Past research among adolescents has shown that (in)dependence in the parent-child relation is not the most critical predictor of their well-being and problem behavior. Instead, more important is the ownership associated with the state of either dependence or independence (Chen et al., 2013; Van Petegem, Beyers, Vansteenkiste and

Soenens, 2012). Extrapolating from this body of work, ground control would do well to foster crew members' sense of volition to optimize their health and mission success.

Previous research has shown that the experience of autonomy as volition is critical in a variety of life domains, such as education (e.g., Vansteenkiste et al., 2004; Sheldon & Krieger, 2007), healthcare (e.g., Williams et al., 2006; Zuroff et al., 2007), sports (e.g., Bartholomew, Ntoumanis, Ryan, Bosch, Thøgersen-Ntoumani, 2011; De Muynck et al., 2017; Delrue et al., 2017) and the workplace (see Deci et al., 2017, for a review). In the work context, more specifically, research has shown that employees who experienced more autonomy satisfaction were more engaged (Deci et al., 2001; Heyns & Rothmann, 2018), performed better (Baard, Deci, & Ryan, 2004), and evidenced greater well-being (Deci et al., 2017; Gillet, Fouqeureau, Lafrenière, & Huyghebaert, 2016), while experiences of autonomy frustration related to greater exhaustion (Van den Broeck, Vansteenkiste, Lens, & De Witte, 2008). Importantly, there are not only between-person differences in autonomy need satisfaction, but a person's experienced autonomy may also fluctuate from week-to-week (Campbell, Vansteenkiste, Beyers, & Soenens, 2018) and from day to day (Ryan, Bernstein, & Brown, 2010). Furthermore, such within-person fluctuations in daily autonomy satisfaction were found to relate to within-person fluctuations in well-being (Reis, Sheldon, Gable, & Roscoe, 2000), sleep quality (Campbell et al., 2018) and bulimic eating patterns (Verstuyf, Vansteenkiste, Soenens, Boone, & Mouratidis, 2013). As such, based on previous research results, it seems important to investigate astronauts' autonomy, within-person changes in these feelings of autonomy, and the link with important study variables such as Mission Support's communication style, astronaut motivation and crew-ground collaboration.

2. Astronaut Motivation and Oppositional Defiance

Although it is typically acknowledged that astronauts are highly motivated individuals, previous research (Manzey, 2004; Van Baarsen, 2013; Sandal & Bye, 2015) and anecdotal evidence (Morgeson, 2015; Landon, Rokholt, Slack, & Pecena, 2017; De la Torre et al., 2012) testify of the changing nature of astronaut motivation during past missions. According to some NASA experts (Morgeson, 2015), astronauts tend to overestimate the ease of long-duration flights and underestimate the stressors of spaceflight. Their daily schedule consists of many tasks that are not inherently interesting or enjoyable, such as cleaning, maintenance and storage. And when crews are isolated and confined, such daily routines may become even more monotonous and boring, leading to degrading motivation (Allner & Rygalov, 2008; Peldzus, Dalke, Pretlove, & Welch, 2014). In such circumstances, it is not uncommon for insubordination issues to arise, and several experts have expressed concern with regard to astronaut instruction adherence during future Mars missions (Manzey, 2004; Morgeson, 2015). It is therefore crucial to study what motivates astronaut behavior during spaceflight, and how this motivation evolves during the course of the mission. SDT offers a thorough and differentiated vision on motivation, thereby distinguishing between different types of motivation that fall along a continuum of increasing internalization or self-endorsement. In the case of external regulation, an individual’s behavior is driven by motives outside the person, such as the gain of a reward or appreciation, or the avoidance of punishment and criticism. Typical for this type of motivation is its contingent nature, that is, the desired behavior is emitted as long as the external regulator is operative but wanes as soon as the external factors are no longer present. To illustrate, according to one NASA expert (Morgeson, 2015), this type of regulation can be characteristic for the ISS crew, who may comply with guidelines from ground control in order to make a good impression, garner appreciation and eventually increase their chances to be accepted for another mission. Interestingly, in a Mars mission, this motivator would likely not be present, as such a long-duration mission would probably be the last flight for the crew, which increases the risk of motivational problems arising. Further down the motivation continuum is introjected motivation, when an individual is driven to meet internal, rather than external pressures, such as the avoidance of guilt or shame for not adhering to work protocol, or the bolstering of one's ego and reputation by doing so. To illustrate, astronauts may comply with instructions from Mission Support to avoid feeling guilty for letting down Mission Support members or other crew members. Although the motive for instruction adherence has now been internalized to some degree, it has not yet been fully accepted. Instead, a fuller form of acceptance and self-endorsement is achieved when individuals identify with the self-importance of instructions, rules and procedures. In the case of identified regulation, one volitionally decides to engage in the activity, presumably because one fully accepts and owns one's reasons for engagement. As such, identified regulation reflects a person's abiding convictions and values and is operative when astronauts perceive the personal relevance and necessity of provided instructions and introduced rules and procedures. Congruent with the assumption that these different types of regulation reflect an ordered pattern of increasing self-endorsed motivation, a wealth of previous studies has shown that the pattern of correlates with external variables follows a similar ordered pattern. That is, in an encompassing study, comprising 3435 workers from nine different cultures, Gagné et al. (2014) observed that employees' job effort, performance, and job satisfaction yielded an increasingly positive correlation with employees' motivation as one moves along the continuum from external to identified regulation. Similarly, the pattern of correlates became decreasingly negative in the case of undesirable work outcomes, such as exhaustion and turnover intention. While autonomy need satisfaction serves as a precursor for self-endorsed motivation, when individuals need for autonomy gets frustrated, they may react by becoming passive or oppositional defiant (Van Petegem, Soenens, Vansteenkiste, & Beyers, 2015). Oppositional defiance involves the blunt rejection of external guidelines and instructions, presumably because these are perceived to be autonomy-threatening (Vansteenkiste & Ryan, 2013). Indeed, oppositional defiance is said to function as a compensatory mechanism to cope with pressure and autonomy frustration (Skinner & Edge, 2002; Vansteenkiste & Ryan, 2013). Given its antagonistic nature, oppositional defiance is said to involve a form of anti-internalization, as individuals actively go against imposed instructions or regulations.

3. Autonomy-Supportive Crew-Ground Communication

One important way to support the crew's sense of volition and subsequently minimize the risk for oppositional defiance, is via autonomy-supportive interactions between the crew and Mission Support. If Mission Support is not sensitive to the specific demands and needs of the flight crew, they run the risk of being perceived as non-supportive. Previous missions have indeed shown that crew-ground interactions are a crucial factor for the crew's well-being and performance. Since the beginning of the space age, crew-ground interaction mishaps have been recorded (e.g., Kanas, 2005; Kanas & Manzey, 2008; Kanas et al., 2009). Due to relatively small inconveniences in Mission Support interaction (e.g., change in the voice quality of a ground support member), increased frustration with Mission Support personnel and decreases in the crew's performance were observed (see Salyut mission of Cosmonaut Lebedev (Lebedev, 1988)). At one time, Cosmonaut Lebedev and his crewmate for example, deliberately chose not to report a fire onboard the station to avoid panic on the ground. During so-called Skylab 4 'space strike', the flight crew closed down communications with the ground for 24h in response to Mission Support's interventions, which were perceived as pressuring and controlling (McPhee & Charles, 2009). This often observed phenomenon, in which crew-ground tensions are reflected in symptoms as decreased communication volume, reduction in the number of issues being discussed and strong preferences in the choice of communication partners, is described in the literature as ‘psychological closing’ (Kanas et al., 2006; Gushin et al., 2012). Such crew-ground miscommunications during orbital missions are expected to occur more frequently during a Mars mission due to the longer duration of high-Earth orbit missions and the greater communication delay with ground support.

The risk for increased psychological closing has alarmed space agencies (e.g., Britt, Jennings, Goguen, & Sytine, 2016; Kanas & Manzey, 2008; McIntosh et al., 2016), and has led some space experts to develop potential countermeasures to ensure continued Mission Support control over Mars crews. For instance, it has been suggested that Mission Support could make use of computer-interactive intervention programs to assess the crew’s cognitive and emotional state (Kanas & Manzey, 2008; Kanas et al., 2009). In this context, some experts have developed wearable devices that continuously record the crew’s general behavior and health (e.g., Dunn, Huebner, Liu, Landry, & Binsted, 2017), while others want to use content analysis of audio recordings of crew interactions to secure continued monitoring (e.g., Ehmann et al., 2011). However, these measures, if not volitionally accepted by the Mars crew, again run the risk of being experienced as restrictive and controlling. What is critical from a psychological viewpoint is that, to preserve the crew’s autonomy, one not only needs to focus on the technical feasibilities of ground-based guidance and support, but also on the acceptance and endorsement of this Mission Support guidance by the crew. If this happens to be the case, crew members may be less defiant and even be highly motivated to follow ground control’s guidelines. Fortunately, Mission Support members have a variety of means from which to choose when trying to motivate the flight crew. Only a few of those, however, can positively influence the crew’s sense of willingness and self-endorsed motivation.

Within SDT (Ryan & Deci, 2000b), the way Mission Support interacts with the crew can be described as either autonomy-supportive, satisfying the crew’s need for autonomy, or controlling, thwarting their sense of volition. Mission Support members can foster volitional functioning by providing the crew with a desired amount of choice, for instance in the scheduling of tasks, or in the preferred working method to accomplish mission objectives. In situations where choice is constrained, autonomy can still be supported by giving a meaningful rationale for a request, by accepting, rather than countering frustration and anger that might arise during difficult moments, and by using inviting language (e.g., “you can”). A controlling approach, on the other hand, conveys pressure by using coercive language (e.g., “you must”), the use of pressuring deadlines, controlling rewards and manipulative strategies such as guilt-induction, shaming or conditional regard (Soenens & Vansteenkiste, 2010). Numerous experimental and correlational studies (see Deci & Ryan, 2000; 2008, for a review) have shown the benefits of an autonomy-supportive communication style to improve volition and self-endorsement, and diminish oppositional defiance in various life domains, such as sports (e.g., Carpentier & Mageau, 2013; De Muynck et al., 2017), parenting (e.g., Joussemet, Landry, & Koestner, 2008; Soenens & Vansteenkiste, 2005), education (e.g., Vansteenkiste, Simons, Lens, Soenens, & Matos, 2005; Jang, Reeve, & Deci, 2010), or work (e.g., Baard et al., 2004; Jungert, Van den Broeck, Schreurs, & Osterman, 2018). However, as previously noted by some space experts (e.g., Van Baarsen, 2013), such findings still need to be validated in the astronaut context.

4. This Study

Although the topic of crew autonomy has received increasing theoretical (Goemaere et al., 2016) and some empirical (e.g., Kanas et al., 2011; Roma et al., 2011) attention, the question whether astronauts benefit from autonomy, and how autonomy can be fostered on a day-to-day basis in space deserves further examination. The current study presents the findings of a unique dataset that was collected from the six participants during the first mission of the NASA space simulation HI-SEAS in 2013. HI-SEAS involved an experimental study, which was set up to simulate a four-month stay on Mars.

During this simulation study, participants filled out weekly questionnaires tapping into their felt autonomy, their motives for adhering or defying Mission Support guidelines, collaboration with the ground and the perceived autonomy-supportive versus controlling nature of communication by Mission Support. The repeated, weekly assessment of these constructions allowed us to address a series of unique questions at the within-person level rather than the between-person level. While the latter concerns the question how autonomy-dynamics differ between persons, at the within-person level, the question is addressed to what extent fluctuations occur within a given person in their weekly autonomy-based functioning. Our overall objective is then to examine whether weekly ups and downs in the extent to which Mission Support is perceived by the crew to be autonomy-supportive versus controlling, relates to weekly ups and downs in the crew's sense of volition, which in turn would relate to weekly fluctuations in important outcomes of motivation (i.e., internalization, lack of defiance) and collaboration (i.e., cooperation, irritation).

Grounded in SDT, the following two hypotheses will be investigated. First, we hypothesize that week-to-week variations in the crew's experienced autonomy would relate positively to week-to-week variations in self-endorsed motivation for following up instructions by Mission Support, and with week-to-week variations in Mission Support cooperation. In contrast, such weekly variations in autonomy experiences would relate negatively to week-to-week variations in rebellious and defiant reactions towards regulations and instructions by Mission Support, and to week-to-week variations in feelings of irritation towards Mission Support members (Hypothesis 1).

Secondly, we hypothesize that the weekly ups and downs in crew volition would be driven by a more autonomy-supportive versus controlling communication style from Mission Support during that week, as perceived by the crew (Hypothesis 2). Because the current study involved the weekly assessment of crew members' motivation, we examined in a more explorative way how these motives changed over time. Such changes in motivational functioning have been examined by Van Baarsen (2013), and Sandal, Bye and van de Vijver (2011) in the past, who focused on a different set of motivational factors than those addressed herein (Sandal et al., 2011; Sandal & Bye, 2015; Van Baarsen, 2013). The study was approved by the NASA Institutional Review Board and the Ghent University Ethical Commission.

5. Method

5.1 Subjects

The study comprised six volunteers, three women and three men, between 33 and 43 years of age (M= 39, SD= 4) at the beginning of the simulation. The participants were of US, Canadian and Belgian nationalities. The three men and women of this HI-SEAS crew were chosen to have a similar mix of experience and backgrounds as real NASA astronauts.

5.2 Mission

The HI-SEAS I mission simulated a four-month stay on Mars, from mid-April until mid-August 2013. The HI-SEAS habitat, an eleven-meter diameter geodesic dome connected to a container, is located in an isolated location on the flanks of the Mauna Loa Volcano on Hawaii, an area with Mars-like features, such as the absence of vegetation and animal life and a barren volcanic rock terrain. Crew members performed a variety of routine tasks on a daily, weekly, and monthly basis as well as a more limited set of unique, single time tasks. These standard tasks involved cleaning, maintenance, and reporting duties similar to ISS tasks, which were taken up in a rotating system. Additionally, as part of several ongoing scientific studies, crew members carried out several scientific tasks throughout the duration of the mission.[2] Ground support members were available at all time to assist crew members in any way they needed. Crew members and Mission Support communicated throughout the day via email, which was delayed by 20 minutes to simulate the Earth-Mars communication lag. The crew only left the module for weekly extravehicular activities, in simulated spacesuits, to explore the surrounding terrain and perform geological studies.

5.2 Procedure

For the purpose of this study, the crew filled out questionnaires on a weekly basis, on Sunday evenings, during eight consecutive weeks. Several existing or self-developed questionnaires were used in various parts of the study. All items in these questionnaires were scored on a five-point Likert scale ranging from one ("*I don't agree at all*") to five ("*I agree completely*"). To avoid question order effects, the different questionnaires were presented in a random sequence every week.

Perceived Autonomy-Support versus Control. Crew members were asked to report their perception of Mission Support being autonomy-

[2] The primary objective of HI-SEAS 1 was a food, odorant identification, and nasal patency study. The second major category of HI-SEAS 1 studies included research on sleep and lighting, food microbiology and hygiene monitoring, antimicrobial textiles, robotic companions, geological exploration, thermal analysis and evaluation of the habitat, remote-operated robotic farming, and research on personal resilience, education and public outreach. a variety of scientific tasks, activities, and assessments, such as daily intensive physical workouts, light therapy, evaluations, and recordings of meals, completing questionnaires, Extra Vehicular Activities, geological mapping and exploration, to name a few.

supportive instead of controlling during the past week. Eleven items adapted from the Work Climate Questionnaire (Baard, Deci, & Ryan, 2000) were administered to tap into autonomy-supportive (e.g., "*Mission Support members tried to understand how I would like to do things, before making any suggestions on how to accomplish my tasks*") and controlling behavior (e.g., "*Mission Support members were less friendly to me when I didn't complete tasks in the way they expected me to*"). Higher scores indicated greater perceptions of autonomy-supportive behavior. Cronbach's alpha was .73.

Autonomy. The crew's general sense of personal freedom and volitional functioning was assessed using eight adapted items from the autonomy subscale of the Basic Psychological Need Satisfaction Scale (Deci & Ryan, 2000; Gagné, 2003), e.g., "*I felt my decisions reflected what I truly wanted*". Cronbach's alpha was .90.

Motivation. Self-endorsement and acceptance of instructions for daily tasks was assessed using an adapted version of the Self-Regulation Questionnaire - Parental Rules (Goemaere, Vansteenkiste, Beyers, & De Muynck, 2018; Soenens, Vansteenkiste, & Niemiec, 2009). The crew members were asked for their reasons to follow instructions for their daily activities: "*During the past week, I followed instructions because...*". In total, 19 items were used to measure external regulation (e.g., "*this was expected of me*"; seven items; Cronbach's alpha = .72), introjected regulation (e.g., "*I would have felt guilty otherwise*"; 6 items; Cronbach's alpha = .81) and identified regulation (e.g., "*I understood why they were important*"; six items; Cronbach's alpha = .87). In line with previous work, a summarizing measure was created, the relative internalization index (RII) (Soenens et al., 2009; Neyrinck, Vansteenkiste, Lens, Duriez, & Hutsebaut, 2006; Vallerand, Fortier, & Guay, 1997; van der Kaap-Deeder et al., 2014). This composite score consists of a weighted combination of volitional and pressuring forms of motivation, wherein the volitional motives were given a positive weight and the pressuring motives were given a negative weight. Because the different kinds of regulations in SDT (i.e., identified, introjected, and external) are supposed to lie on one continuum of self-endorsement, the weights that are assigned to these regulations (i.e., +3, −1, and −2, respectively) when creating a relative internalization index in empirical research are balanced. Such a weighting procedure guarantees that the sum of the assigned weights is zero and that self-endorsed and pressuring types of regulation are equally weighted in the creation of a relative internalization index (Neyrinck et al., 2006). Overall then, higher scores on this scale indicate higher levels of acceptance and internalization of instructions.

Oppositional defiance. A tendency towards the dismissal of instructions for daily tasks was measured using four items adapted from Vansteenkiste, Soenens, Van Petegem and Duriez (2014). A sample item reads "*From time to time I wanted to disregard the instructions that were set for me*". Cronbach's alpha (.58) revealed a poor internal consistency. Deleting one item from the scale increased alpha to .74 for the three remaining items. This score was used in the analyses.

Irritation with Mission Support. Four items such as "I felt irritated with Mission Support" were used to measure the level of irritation crew members experienced during their interactions with Mission Support. These items were based on the resentment scale of Assor, Roth, and Deci (2004). Internal consistency of this scale was .92

Cooperation with Mission Support. Four self-developed items such as "*I was able to cooperate well with my Mission Support*" were used to measure the perceived cooperation crew members experienced in their interactions with Mission Support. Internal consistency of this scale was .69.

5.3 Statistical Analyses

To analyze whether variation in crew autonomy during the course of the mission could account for variation in motivation, oppositional defiance and crew-ground interactions, and whether these fluctuations in crew volition related to fluctuations in perceived autonomy-support from Mission Support, multilevel analyses, which take into account between- and within-person variation, were conducted with the statistical software package HLM7. In each of the main models, we started with a random intercepts-only model. These random intercepts-only models consist of random intercepts and a constant as the only predictor (Hox, 2010) and decompose the total variation into variation at the between-person level and at the within-person level. In a second step, we added fixed effects to these random intercepts-only models.

6. Results

6.1 Preliminary Analyses

Six random intercepts-only models were created to examine the percentage of variance in perceived weekly autonomy support versus control, autonomy satisfaction, internalization, defiance, irritation and cooperation, that is, because of within-person and between-person variation. Aggregated means and standard deviations for the measured variables can be found in Table 1, as well as correlations between the study variables on the between and within level, and week-to-week variances derived from the intra-class correlations. Figure 1 provides an example of the distribution of variance on the within- and between-person level for our assessment of autonomy.

	M (SD)	1.	2.	3.	4.	5.	6.
1. Perceived Autonomy-Support vs. Control	3.88 (0.48)	1.00	$.91^{***}$	.48	-.48	-.37	$.78^{\dagger}$
2. Autonomy	3.48 (0.80)	$.52^{**}$	1.00	$.48^{*}$	-.17	.69	.47
3. Internalization of Instructions	0.99 (1.07)	.32	$.54^{*}$	1.00	$-.66^{\dagger}$	-.07	.45
4. Oppositional Defiance towards Instructions	2.78 (0.97)	$-.29^{*}$	$-.34^{**}$	-.23	1.00	.59	$-.86^{\dagger}$
5. Irritation with Mission Support	2.94 (0.96)	$-.59^{***}$	$-.29^{*}$	$-.18^{\dagger}$	$.49^{***}$	1.00	-.27
6. Cooperation with Mission Support	3.63 (0.56)	$.45^{***}$	.11	$.26^{*}$	$-.31^{*}$	$-.61^{***}$	1.00
Week-to-week variance		87%	26%	30%	23%	92%	88%

Note. Within-subject correlations are displayed below the diagonal, and between-subject correlations above.
$p^{\dagger} < .10$. $p^{*} < .05$. $p^{**} < .01$. $p^{***} < .001$. Based on Wald test in Mplus (estimate/standard error).

Table 1. Means, standard deviations, within- and between-subject correlations, and week-to-week variances for the study variables.

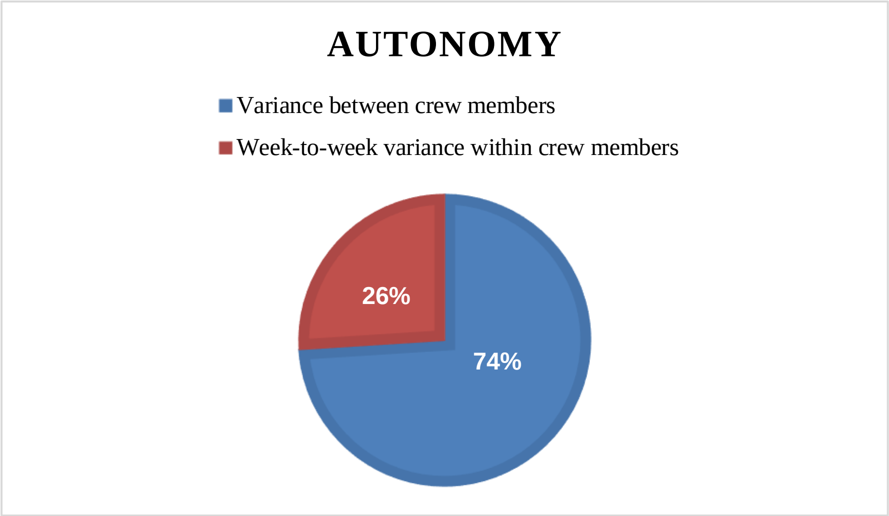

Figure 1. The distribution of variance on the between- and within-level for autonomy.

6.2 Primary Analyses

Hypothesis 1: weekly correlates of autonomy need satisfaction. Multilevel analyses indicated that week-to-week variations in autonomy were significantly related to week-to-week variations in internalization (b= .87, t(36) = 2.33, p< .05), oppositional defiance (b= -.71, t(36) = -2.73, p< .05) and irritation with Mission Support (b= -.70, t(36) = -2.56, p< .05), but not to week-to-week variation in cooperation with Mission Support (b= .11 , t(36) = 0.11, p= .48).[3] As expected, during weeks that crew members experienced more volition, they reported a higher level of self-endorsed motivation to

[3] Since variations in autonomy did not significantly predict variations in cooperation with Mission Support (hypothesis 1), we further tested whether changes in cooperation would instead relate to changes in perceived autonomy-supportive communication with Mission Support. This indeed was the case, with more perceived autonomy support from Mission Support being significantly related to greater perceptions of a fruitful cooperation with Mission Support members (b= .44, t(35) = 2.69, p< .05).

follow-up daily instructions from Mission Support, while being less likely to rebel and defy these instructions, and they experienced less irritation towards Mission Support members.

Hypothesis 2: relationship between autonomy-supportive communication and crew autonomy. A multilevel analysis indicated that fluctuations in perceived autonomy-support versus control from Mission Support significantly predicted changes in autonomy ($b = .50$, $t(35) = 2.88$, $p < .01$). As expected, the more the crew perceived Mission Support members as being autonomy-supportive, the greater their experience of volition.

6.3 Ancillary Analyses

We further tested whether the study variables increased or decreased over time and found a significant increase for internalization during the final eight weeks of the mission ($b = .13$, $t(36) = 5.67$, $p < .001$). No significant linear time effects were observed for autonomy-supportive communication ($b = -.02$, $t(35) = -.45$, $p = .66$), autonomy ($b = .03$, $t(37) = .85$, $p = .40$), defiance ($b = .04$, $t(36) = .78$, $p = .44$), irritation ($b = -.01$, t(36) = -.21, $p = .84$) or cooperation ($b = -.04$, $t(36) = -1.14$, $p = .26$).

7. Discussion

Most research on astronaut motivation has remained on a rather descriptive level, making observations on how the crew's motivation fluctuates over time, without relating these variations in motivation to variations in other important outcomes (e.g., Sandal et al., 2011; Sandal & Bye, 2015), or without including a conceptualization of motivation and autonomy that would allow to identify a more volitional and self-endorsed form of regulation (e.g., Van Baarsen, 2013). The present study's aim was to add to this body of research by introducing a) a strong theoretical framework, b) a more nuanced approach to motivation, distinguishing between more self-endorsed and more pressuring forms of motivation, c) the inclusion of measures of crew-ground collaboration, and d) the study of Mission Support's perceived communication style as a potential antecedent to crew volition and subsequent motivation and collaboration. Several interesting findings emerged.

First, our findings show a positive association between week-to-week variations in the crew's sense of volition and week-to-week fluctuations in self-endorsed motives for daily activities, while a negative relation emerged for week-to-week fluctuations in oppositional defiance. Crew members who experienced a greater sense of willingness and personal freedom, identified more with the operation procedures they were provided with, and felt less inclined to discard these task instructions. These findings suggest that instruction defiance could be avoided, and self-endorsed motivation, reflective of acceptance and ownership of behavior, could be enhanced by increasing the crew's sense of willingness and personal freedom, as has been previously observed in other domains (e.g., Joussemet, Koestner, Lekes, & Houlfort, 2004). Especially for a Mars Mission, where sustained motivation is even more at risk than in low-Earth orbit missions due to prolonged mission duration, boredom and isolation, it becomes crucial to safeguard and reinforce such volitional functioning. Weekly ups and downs in volition were also related to weekly oscillations in crew-ground interactions, with a greater sense of personal freedom being predictive of less irritation towards Mission Support members. This finding is important because, as previously mentioned, crew-ground interactions are expected to be greatly challenged during a Mars Mission, when direct communication between astronauts and Mission Support is no longer feasible. Surprisingly, a greater sense of autonomy was not related to a more fruitful cooperation with Mission Support, but rather, cooperation was associated with an autonomy-supportive communication style from Mission Support as perceived by the crew. However, it is possible for the absence of the significant relation between autonomy and cooperation to be a consequence of the small sample size and limited number of measurement moments. Apart from these statistical issues, it's very likely that crew members were trained in such a way as to comply with Mission Support's requests, regardless of feelings of frustration. A thwarted sense of autonomy might therefore more easily translate into feelings of irritation towards Mission Support, without necessarily harming the crew's cooperative intentions. Also, it is possible for other psychological needs to play a role in crew-ground cooperation, such as the need for relatedness within the crew, or between crew members and Mission Support members.

Finally, we observed that during weeks when the crew viewed Mission Support as being more autonomy-supportive, rather than controlling, they experienced a greater sense of volition and personal freedom during that week. This finding is crucial, since it suggests that the crew's sense of volition could be increased by employing autonomy-supportive measures that have already been proven effective in other domains (Deci & Ryan, 2008). From these measures, we can develop guidelines that could be implemented by space agencies when training Mission Support personnel in interacting with astronauts. For instance, Mission Support members should be particularly attentive to avoid overt control and pressuring language in interacting with the crew, such as guilt inducing criticism, negative comparisons to other crew members or even tangible rewards (Deci, Koestner, & Ryan, 1999; Soenens, Vansteenkiste, Luyten, Duriez, & Goossens, 2005). Instead, Mission Support could be trained to use communication skills such as empathic listening or even actively inquiring about and acknowledging the crew's feelings towards a particular task or problem (Deci, Eghrari, Patrick, & Leone, 1994; Koestner, Ryan, Bernieri, & Holt, 1984; Jang, 2008). Additionally, when setting up the crew's schedule or instructing astronauts in a particular task, they could try to provide different kinds of choices, especially when the task at hand is not inherently interesting or enjoyable (e.g., Patall, Cooper, & Wynn, 2010; Patall, Dent, Oyer, & Wynn, 2013). While option choices (i.e., letting the crew decide what task to perform) might not always be easy to implement in space operations, often action choices(i.e., a choice within the task, such as deciding the timing, pacing, amount of guidance or working method for a task) could be just as effective in enhancing volition (e.g., Goemaere, Vansteenkiste, & Beyers, submitted).

Alternatively, astronauts can express preferences and act upon interests more when Mission Support assigns them to tasks consistent with their preferences (e.g., Katz & Assor, 2007), thereby making the task more personally relevant. Another way for Mission Support to enhance personal relevance would be to offer a meaningful rationale for the task at hand (e.g., Reeve, Jang, Hardre, & Omura, 2002; Vansteenkiste et al., 2018), as well as to emphasize how this task could relate to the crew's personal development (Lim et al., 2010), or how it contributes to scientific advancement (Britt et al., 2016). Finally, after task completion, Mission Support could enhance volition by providing astronauts with corrective feedback through the use of inviting instead of pressuring language (Carpentier & Mageau, 2013; De Muynck et al., 2017; Lim et al., 2010).

This study has a number of limitations. As mentioned, the small sample size (N= 6) and only eight measurement times per participant limit the power of our analyses. Also, our assessments were limited to the second half of the mission, which might have impacted our results, as adaptation to mission stressors have been observed to evolve during the course of the mission (e.g., Kanas & Manzey, 2008; Kanas, 2014). Additionally, only self-report measures by crew members were used. Future research could, for instance, measure autonomy-support vs control directly with Mission Support members as informants, or make use of third-person evaluations of crew-ground interactions. Further, the relationships between the variables in this study are of a correlational nature. It would be interesting to study the effects of autonomy-support experimentally, by directly manipulating Mission Support's communication style and examining its effect on autonomy satisfaction, and subsequent motivation and crew-ground collaboration (Deci et al., 1994). In Self-Determination Theory research, dozens of studies in a variety of domains (see Ryan & Deci, 2000a; Vansteenkiste et al., 2018), for reviews) have successfully demonstrated the effectiveness of an autonomy-supportive, rather than controlling, communication style in enhancing perceived autonomy support (e.g., Halvari, Halvari, Bjørnebekk, & Deci, 2012), experiences of autonomy (e.g., Reeve et al., 2002) and self-endorsed motivation (e.g., Jang, 2008), and reducing negative affect (e.g., Savard, Joussemet, Pelletier, & Mageau, 2013). Finally, as with every simulation mission, HI-SEAS I itself has a number of limitations, such as differences in mission duration (only four months) and crew member training and selection, compared to an actual Mars mission. Future studies should aim to replicate these findings during actual spaceflight or a longer simulation mission.

Conclusion

The findings in this study attest to the central role of crew members' sense of autonomy and volition in crew motivation and crew-ground collaboration. Crew members who are more satisfied in their need for autonomy, experience greater self-endorsed motivation for daily tasks and are less likely to rebel against task procedures. Additionally, a greater sense of volition was also associated with less irritation vis-à-vis Mission Support. Since the findings also indicate that the crew's volition is associated with a more autonomy-supportive communication style from Mission Support, as perceived by the crew, space agencies could train Mission Support members to actively implement autonomy-supportive measures in their interactions with the crew, to the benefit of the crew members and the success of the mission.

References

Aelterman, N., Vansteenkiste, M., Soenens, B., & Haerens, L. (2016). A dimensional and person-centered perspective on controlled reasons for non-participation in physical education. *Psychology of Sport and Exercise, 23*, 142-154.

Allner, M. & Rygalov, V. (2008). Group dynamics in a long-term blind endeavor on Earth: An analog for space missions (Lewis & Clark expedition group dynamic analysis). *Advances in Space Research, 42*, 1957-1970.

Baard, P. P., Deci, E. L., & Ryan, R. M. (2004). Intrinsic need satisfaction: A motivational basis of performance and well-being in two work settings. *Journal of Applied Social Psychology, 34*, 2045-2068.

Bartholomew, K. J., Ntoumanis, N., Ryan, R. M., Bosch, J. A., Thøgersen-Ntoumani, C. (2011). Self-Determination Theory and diminished functioning: the role of interpersonal control and psychological need thwarting. *Personality and Social Psychology Bulletin, 37*, 1459-1503.

Brcic, J. (2010). Motivational profile of astronauts at the International Space Station. *Acta Astronautica, 67*, 1110-1115.

Britt, T. W., Jennings, K. S., Goguen, K., & Sytine, A. (2016). *The role of meaningful work in astronaut health and performance during long-duration space exploration missions* (NASA/TM-2016-219276). Houston, Texas, NASA Johnson Space Center.

Campbell, R., Vansteenkiste, M., Beyers, W., & Soenens, B. (2018). Shifts in university students' sleep during an exam period: The role of basic psychological needs and stress. *Motivation and Emotion*, Manuscript in revision.

Carpentier, J., & Mageau, G. A. (2013). When change-oriented feedback enhances motivation, well-being and performance: A look at autonomy-supportive feedback in sport. *Psychology of Sport and Exercise, 14,* 423-435.

Carpentier, J., & Mageau, G. A. (2016). Predicting sport experience during training: The role of change-oriented feedback in athletes' motivation, self-confidence and needs satisfaction fluctuations. *Journal of Sport & Exercise Psychology, 38*, 45-58.

Chen, B., Vansteenkiste, M., Beyers, W., Soenens, B., & Van Petegem, S. (2013). Autonomy in family decision making for Chinese adolescents: disentangling the dual meaning of autonomy. *Journal of Cross-Cultural Psychology, 44*, 1184-1209.

Chirkov, V., Ryan, R. M., & Kim, Y. (2003). Differentiating autonomy from individualism and independence: a Self-Determination heory perspective on internalization of cultural orientations and well-being. *Journal of Personality and Social Psychology, 84*, 97-110.

De la Torre, G. G., Van Baarsen, B., Ferlazzo, F., Kanas, N., Weiss, K., Schneider, S., & Whiteley, I. (2012). Future perspectives on space psychology: Recommendations on psychosocial and neurobehavioural aspects of human spaceflight. *Acta Astronautica, 81*, 587-599.

De Muynck, G-J., Vansteenkiste, M., Delrue, J., Aelterman, N., Haerens, L., & Soenens, B. (2017). The effects of feedback valence and style on need satisfaction, self-talk, and perseverance among tennis players: An experimental study. *Journal of Sport & Exercise Psychology, 39*, 67-80.

Deci, E. L., & Ryan, R. M. (2008). Self-Determination Theory: A macrotheory of human motivation, development, and health. *Canadian Psychology-Psychologie Canadienne, 49*, 182-185.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227-268.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: the selfdetermination theory perspective. Journal of Personality, 62, 119-142.

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin, 125*, 627-668.

Deci, E. L., Olafsen, A. H., & Ryan, R. M. (2017). Self-Determination Theory in work organizations: The state of a science. Annual Review of Organizational Psychology and Organizational Behavior, 4, 19-43.

Deci, E. L., Ryan, R. M., Gagné, M., Leone, D. R., Usunov, J., & Kornazheva, B. P. (2001). Need satisfaction, motivation, and well-being in the work organizations of a former eastern bloc country: a cross-cultural study of self-determination. *Personality and Social Psychology Bulletin, 27*, 930-942.

Delrue, J., Vansteenkiste, M., Mouratidis, A., Gevaert, K., Vande Broek, G., & Haerens, L. (2017). A game-to-game investigation of the relation between need-supportive and need-thwarting coaching and moral behavior in soccer. *Psychology of Sport and Exercise, 31*, 1-10.

Dunn, J., Huebner, E., Liu, S., Landry, S. & Binsted, K. (2017). Using consumer-grade wearables and novel measures of sleep and activity to analyze changes in behavioral health during an 8-month simulated Mars mission. *Computers in Industry, 92*, 32-42.

Ehmann, B., Balázs, L., Fülöp, E., Hargitai, R., Kabai, P., Péley, B., Pólya, T., Vargha, A., & László, J. (2011). Narrative psychological content analysis as a tool for psychological status monitoring of crews in isolated, confined and extreme settings. *Acta Astronautica, 68*, 1560-1566.

Gagné, M., Forest, J., Vansteenkiste, M., Crevier-Braudd, L., Van den Broecke, A., Aspelif, A.K.,… Westbye, C. (2015). The Multidimensional Work Motivation Scale: Validation evidence in seven languages and nine countries. *European Journal of Work and Organizational Psychology, 24*, 178-196.

Gillet, N., Fouqeureau, E., Lafrenière, M.-A., & Huyghebaert, T. (2016). Examining the roles of work autonomous and controlled motivations on satisfaction and anxiety as a function of role ambiguity. *The Journal of Psychology, 150*, 644-665.

Goemaere, S., Vansteenkiste, M., & Beyers, W. (2018). How to buffer the motivational and performance deficits of long instructions for procedural tasks? Comparing the role of user control instructions, an autonomy-supportive communication style and the use of short instructions. *Manuscript submitted for publication.*

Goemaere, S., Vansteenkiste, M., & Van Petegem, S. (2016). Gaining deeper insight into the psychological challenges of human spaceflight: The role of motivational dynamics. *Acta Astronautica, 121,* 130-143.

Gushin, V., Shved, D., Vinokhodova, A., Vasylieva, G., Nitchiporuk, I., Ehmann, B., & Balazs, L. (2012). Some psychophysiological and behavioral aspects of adaptation to simulated autonomous Mission to Mars. *Acta Astronautica, 70,* 52-57.

Halvari, E. M., Halvari, H., Bjørnebekk, G., & Deci, E. L. (2012). Motivation for dental home care: Testing a Self-Determination Theory model. *Journal of Applied Social Psychology, 42*, 1-39.

Hendricks, H., Mauroo, T., & Van Spilbeeck, B. (2009). *Het Ruimtedagboek van Frank De Winne: Dagelijks Leven in het ISS.* Leuven: Van Halewyck.

Heyns, M., & Rothmann, S. (2018). Volitional trust, autonomy satisfaction, and engagement at work. *Psychological Reports, 121*, 112-134.

Jang, H. (2008). Supporting students' motivation, engagement, and learning during an uninteresting activity. *Journal of Educational Psychology, 100*, 798-811.

Jang, H., Reeve, J., & Deci, E. L. (2010). Engaging students in learning activities: It's not autonomy support or structure, but autonomy support and structure. *Journal of Educational Psychology, 102,* 588-600.

Joussemet, M., Landry, R., & Koestner, R. (2008). A Self-Determination Theory perspective on parenting. *Canadian Psychology-Psychologie Canadienne, 49,* 194-200.

Jungert, T., Van den Broeck, A., Schreurs, B., & Osterman, U. (2018). How colleagues can support each other's needs and motivation: An intervention on employee work motivation. *Applied Psychology, 67,* 3-29.

Kalery, A., Sorokin, I., & Tyurin, M. (2010). Human space exploration beyond the international space station: role of relations of human, machine and the ‘‘Earth’’. *Acta Astronautica, 67,* 925-933.

Kanas, N. (2005). Interpersonal issues in space: Shuttle/Mir and beyond. *Aviation, Space and Environmental Medicine, 76*, 126-134.

Kanas, N. (2014). Psychosocial issues during an expedition to Mars. *Acta Astronautica, 103,* 73-80.

Kanas, N., & Manzey, D. (2008). *Space Psychology and Psychiatry*. Dortrecht: Kluwer.

Kanas, N., Sandal, G., Boyd, J., Gushin, V., Manzey, D., North, R., Leon, G., … Wang, J. (2009). Psychology and culture during long-duration space missions. *Acta Astronautica, 64,* 659-677.

Kanas, N., Saylor, S., Harris, M., Neylan, T., Boyd, J., Weiss, D., Baskin, P., Cook, C., & Marmar, C. (2011). High versus low crew member autonomy in space simulation environments, *Acta Astronautica*, *67*, 731-738.

Katz, I., & Assor, A. (2007). When choice motivates and when it does not. Educational Research Review, 19, 429-442.

Koestner, R., Ryan, R. M., Bernieri, F., & Holt, K. (1984). Setting limits on children's behavior: The differential effects of controlling versus informational styles on intrinsic motivation and creativity. *Journal of Personality*, *52*, 233-248.

Krikalev, S., Kalery, A., Sorokin, I. (2010). Crew on the ISS: creativity or determinism. *Acta Astronautica, 66*, 68-78.

Landon, L. B., Rokholt, C., Slack, K. J., & Pecena, Y. (2017). Selecting astronauts for long-duration exploration missions: Considerations for team performance and functioning. *Reviews in Human Space Exploration, 5,* 33-56.

Lebedev, V. (1988). *Diary of a Cosmonaut: 2011 Days in Space, College Station.* Texas: Phytoresource Research Information Service.

Lim, D. S. S., Warman, G. L., Gernhardt, M. L., McKay, C. P., Fong, T., Marinova, M. M., Davilaa, A. F.,… Williams, D. (2010). Scientific field training for human planetary exploration. *Planetary and Space Science, 58,* 920-930.

Manzey, D. (2004). Human mission to Mars: new psychological challenges and research issues. *Acta Astronautica, 55*, 781-790.

Maschke, P., Oubaid, V., & Pecena, Y. (2011). How do astronaut candidate profiles differ from airline pilot profiles? *Aviation Psychology and Applied Human Factors, 1,* 38-44.

McIntosh, T., Mulhearn, T., Gibson, C., Mumford, M. D., Yammarino, F. J., Connelly, S., Day, E. & Vessey, B. (2016). Planning for Long-Duration Space Exploration: Interviews with NASA Subject Matter Experts. *Acta Astronautica, 129*, 477-487.

Mcphee, J. C., & Charles, J. B. (2009). *Human health and performance risks of space exploration missions* (NASA SP-2009-3405). Houston, Texas, NASA Johnson Space Center.

Morgeson, F. P. (2015). *Issues in Maintaining Team Motivation over Long-Duration Exploration Missions*, (NASA/TM-2015-218586). Houston, Texas, NASA Johnson Space Center.

Patall, E. A., Cooper, H., & Wynn, S. R. (2010). The effectiveness and relative importance of choice in the classroom. *Journal of Educational Psychology, 102,* 896-915.

Patall, E. A., Dent, A. L., Oyer, M. & Wynn, S. R. (2013). Student autonomy and course value: The unique and cumulative roles of various teacher practices. *Motivation and Emotion, 37*, 14-32.

Peldszus, R., Dalke, H., Pretlove, S., & Welch, C. (2014). The perfect boring situation - Addressing the experience of monotony during crewed deep space missions through habitability design. *Acta Astronautica, 94*, 262-276.

Reeve, J., Jang, H., Hardre, P. & Omura, M. (2002). Providing a rationale in an autonomy-supportive way as a strategy to motivate others during an uninteresting activity. *Motivation and Emotion, 26*, 183-207.

Reis, H. T., Sheldon, K. M., Gable, S; L., & Roscoe, J. (2000). Daily well-being: The role of autonomy, competence, and relatedness. *Personality and Social Psychology Bulletin, 26*, 419-435.

Roma, P. G., Hursh, S. R., Hienz, R. D., Emurian, H. H., Gasior, E. D., Brinson, Z. S., & Brady, J. V. (2011). Behavioural and biological effects of autonomous versus scheduled mission management in simulated space-dwelling groups. *Acta Astronautica, 68,* 1581-1588.

Ryan, R. M. & Deci, E. L. (2000b). Self-Determination Theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*, 68-78.

Ryan, R. M., & Deci, E. L. (2000a). The darker and brighter sides of human existence: basic psychological needs as a unifying concept. *Psychological Inquiry, 11,* 319-338.

Ryan, R. M., & Deci, E. L. (2017). *Self-Determination Theory: Basic psychological needs in motivation, development, and wellness*. New York: Guilford Press.

Ryan, R. M., & Lynch, J. H. (1989). Emotional autonomy versus detachment: revisiting the vicissitudes of adolescence and young adulthood. *Child Development, 60,* 340-356.

Ryan, R. M., Bernstein, J. H., & Brown, K. W. (2010). Weekends, work, and well-being: Psychological need satisfaction and day of the week effects on mood, vitality, and physical symptoms. *Journal of Social and Clinical Psychology, 29,* 95-122.

Sandal, G. M., & Bye, H. H. (2015). Value diversity and crew relationships during a simulated space flight to Mars. *Acta Astronautica, 114,* 164-173.

Sandal, G. M., Bye, H. H., & van de Vijver, F. J. R. (2011). Personal values and crew compatibility: results from a 105 days simulated space mission. *Acta Astronautica, 69*, 141-149.

Savard, A., Joussemet, M., Pelletier, L. G., & Mageau, G. A. (2013). The benefits of autonomy support for adolescents with severe emotional and behavioral problems. *Motivation and Emotion, 37*, 688-700.

Sgobba, T., Kanki, B., Clervoy, J.-F., & Sandal, G. (2017). *Space Safety and Human Performance*. Oxford: Butterworth-Heinemann.

Sheldon, K. M., & Krieger, L. S. (2007). Understanding the negative effects of legal education on law students: A longitudinal test of self-determination theory. *Personality and Social Psychology Bulletin, 33*, 883-897.

Sheldon, K. M., Elliot, A. J., Ryan, R. M., Chirkov, V., Kim, Y., Wu, C., Demir, M., & Sun, Z. G. (2004). Self-concordance and subjective well-being in four cultures. *Journal of Cross-Cultural Psychology, 35*, 209-223.

Skinner, E. A., & Edge, K. (2002). Parenting, motivation, and the development of children's coping, In L. J. Crockett (Ed.), *Agency, Motivation, and the Life Course: The Nebraska Symposium on Motivation 48* (pp 77-143). Lincoln: University Of Nebraska Press.

Soenens, B., & Vansteenkiste, M. (2005). Antecedents and outcomes of self-determination in 3 life domains: The role of parents' and teachers' autonomy support. *Journal of Youth and Adolescence, 34,* 589-604.

Soenens, B., & Vansteenkiste, M. (2010). A theoretical upgrade of the concept of parental psychological control: Proposing new insights on the basis of self-determination theory. *Developmental Review 30*, 74-99.

Soenens, B., Vansteenkiste, M., Luyten, P., Duriez, B. & Goossens, B. L. (2005). Maladaptive perfectionistic self-representations: The mediational link between psychological control and adjustment. *Personality and Individual Differences, 38,* 487-498.

Soenens, B., Vansteenkiste, M., Van Petegem, S., Beyers, W., & Ryan, R. M. (2018). How to solve the conundrum of adolescent autonomy? On the importance of distinguishing between independence and volitional functioning. In: S. Soenens, M. Vansteenkiste, S. Van Petegem (Eds.), Autonomy in Adolescent Development: Towards Conceptual Clarity. Abingdon: Routledge.

Van Baarsen, B. (2013). Person autonomy and voluntariness as important factors in motivation, decision making, and astronaut safety: First results from the Mars500 LODGEAD study, *Acta Astronautica*, *87*, 139-146.

Van den Broeck, A., Vansteenkiste, M., De Witte, H., & Lens, W. (2008). Explaining the relationships between job characteristics, burnout, and engagement: The role of basic psychological need satisfaction. *Work & Stress*, *22*, 277-294.

Van Petegem, S., Beyers, W., Vansteenkiste, M., & Soenens, B. (2012). On the association between adolescent autonomy and psychosocial functioning: Examining decisional independence from a Self-Determination Theory perspective. *Developmental Psychology, 48,* 76-88.

Van Petegem, S., Soenens, B., Vansteenkiste, M., & Beyers, M. (2015). Rebels with a cause? Adolescent defiance from the perspective of reactance theory and Self-Determination Theory. *Child Development*, *86,* 903-918.

Vansteenkiste, M., & Ryan, R. M. (2013). On psychological growth and vulnerability: basic psychological need satisfaction and need frustration as a unifying principle. *Journal of Psychotherapy Integration, 23*, 263-280.

Vansteenkiste, M., Aelterman, N., De Muynck, G.-J., Haerens, L., Patall, E., & Reeve, J. (2018). Fostering personal meaning and self-relevance: A Self-Determination Theory perspective on internalization. *Journal of Experimental Education, 86*, 30-49.

Vansteenkiste, M., Ryan, R. M., & Deci, E. L. (2008). Self-Determination Theory and the explanatory role of psychological needs in human well-being. In L. Bruni, F. Comim, & M. Pugno (Eds.), Capabilities and Happiness (pp. 187-223). Oxford: Oxford University Press.

Vansteenkiste, M., Simons, J., Lens, W., Soenens, B., & Matos, L. (2005). Examining the impact of extrinsic versus intrinsic goal framing and internally controlling versus autonomy-supportive communication style upon early adolescents' academic achievement. *Child Development, 76*, 483-501.

Vansteenkiste, M., Simons, J., Soenens, B., & Lens, W. (2004). How to become a persevering exerciser? The importance of providing a clear, future intrinsic goal in an autonomy-supportive manner. *Journal of Sport and Exercise Psychology, 26*, 232-249.

Verstuyf, J., Vansteenkiste, M., Soenens, B., Boone, L., & Mouratidis, A. (2013). Daily ups and downs in women's binge eating symptoms: The role of basic psychological needs, general self-control and emotional eating. *Journal of Social and Clinical Psychology, 32*, 335-361.

Vinokhodova, A. G., & Gushin, V. I. (2014). Study of values and interpersonal perception in cosmonauts on board of international space station. *Acta Astronautica, 93*, 359-365.

Williams, G. C., McGregor, H. A., Sharp, D., Levesque, C., Kouides, R. W., Ryan, R. M., & Deci, E. L. (2006). Testing a Self-Determination

Theory intervention for motivating tobacco cessation: supporting autonomy and competence in a clinical trial. *Healthy Psychology*, *25*, 91-101.

Zuroff, D. C., Koestner, R., Moskowitz, D. S., McBride, C., Marshal, M., & Bagby, R. M. (2007). Autonomous motivation for therapy: A new non-specific predictor of outcome in the brief treatment of depression. *Psychotherapy Research*, *17*, 137-148.

CHAPTER 5

Life on Mars from a Self-Determination Theory Perspective: How Astronauts' Needs for Autonomy, Competence and Relatedness Go Hand in Hand with Crew Health and Mission Success - Results from HI-SEAS IV[1]

[1] Goemaere, S., Van Caelenberg, T., Beyers, W., Binsted, K., & Vansteenkiste, M. (2018). Life on Mars from a Self-Determination Theory perspective: How astronauts' needs for autonomy, competence and relatedness go hand in hand with crew health and mission success - Results from HI-SEAS IV. *Manuscript in revision.*

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Introduction

There's an exciting future awaiting human space exploration, one that is certainly not without challenges. In contrast with astronauts partaking in low orbit and short term ISS missions, future deep space crews are bound to encounter stressors never observed before, making ISS missions look almost routine. Tackling the issues arising during the preparations for future interplanetary missions proves to be a massive multi-disciplinary undertaking. Technological advancements, for example, seem to hit a certain limit when messages send out to Mars at the speed of light take over 40 minutes to receive an answer. Mission duration will also pose a problem as, to date, only four people have spent 365 consecutive days in space or longer, while a future Mars mission will most likely have astronauts confined with fellow crew members over the course of several years. Space experts are facing the ambitious task of understanding how these new challenges, if not stressors, will affect astronauts, and careful consideration and understanding of those challenges will surely prove to be beneficial for both astronaut health and mission success. Moreover, there is an urgent need for more longitudinal research, which enables investigating how such challenges evolve during the course of a mission and how these evolutions relate to fluctuations in astronaut functioning. At this point, research in human spaceflight could benefit from psychological insights that help identify factors of astronaut resilience in handling the encountered challenges. To achieve this goal, an overarching theoretical framework on human motivation and development is needed.

Self-Determination Theory (SDT; Ryan & Deci, 2000a; Deci, Olafsen, & Ryan, 2017) is a viable candidate in this respect, as the theory is very clear on the critical predictors of human thriving and wellness, thereby offering a set of dynamic concepts that are susceptible for week-to-week or even day-to-day variation that enable us to predict the ups and downs of astronaut functioning. Specifically, SDT underscores the importance of the experience of three basic psychological needs for all individuals' well-being: the need for autonomy (i.e., the experience of volition and psychological freedom), the need for competence (i.e., the experience of mastery and a sense of skill-utilization and development), and the need for relatedness (i.e., the experience of care and warm, genuine relationships). In the present study, we had the unique opportunity to track crew members' weekly variation in need-based functioning during the yearlong mars simulation mission HI-SEAS IV. This weekly assessment allowed us to examine shifts in need-based functioning across the year and to examine whether weekly variations in the satisfaction of these psychological needs related to a variety of important outcomes in crew health, Mission Support interactions, and mission success. In the following section, we first introduce the basic principles and concepts within SDT before discussing their relevance for human spaceflight.

1. Self-Determination Theory

SDT (Ryan & Deci, 2000; Vansteenkiste, Niemiec, & Soenens, 2010) postulates the existence of three basic psychological needs, the satisfaction of which is said to be essential for individuals' motivation, growth, and psychological well-being. When people's need for competence is satisfied, they experience a sense of effectiveness and mastery, for instance because they are capable to achieve desired outcomes and are developing their skills. When people's need for relatedness is satisfied, they feel connected and experience intimacy and genuine connection with others, for instance because they are involved in supportive dyadic relationships or because they experience a sense of team cohesion. Finally, people experience autonomy when they feel a sense of personal choice, volition and psychological freedom when acting, feeling or thinking, for instance because they carry out a personally valuable and interesting task. According to SDT, satisfaction of these three basic psychological needs promote well-being and engagement, while frustration of the needs leads to negative consequences, such as negative affect, passivity, or even rebellious behavior (Vansteenkiste & Ryan, 2013).

These assertions have been empirically supported across different life domains, including work (e.g., Greguras & Dieffendorff, 2009; Van den Broeck, Ferris, Chang, & Rosen, 2016), healthcare (e.g., Van-der-Kaap-Deeder et al., 2014; Williams, Cox, Hedberg, & Deci, 2000), education (e.g., Tian, Chen, & Huebner, 2014), sports (e.g., Curran, Hill, Ntoumanis, Hall, & Jowett, 2016; Gagné, 2003) and parenting (e.g., Brenning, Mabbe, Vansteenkiste, & Soenens, 2018; Mabbe, Soenens, Vansteenkiste, van der Kaap-Deeder, & Mouratidis, 2018). The benefits associated with psychological need satisfaction were obtained irrespective of participants' age (Rodriguez-Meirinhos, Antolin-Suarez, Brenning, & Vansteenkiste), their experienced financial insecurity (Chen et al., 2015), or cultural background (Chirkov, Ryan, Kim, & Kaplan, 2003; Sheldon et al., 2004) and also emerged among individuals who do not desire getting these needs met (Chen, Van Assche, Vansteenkiste, Soenens, & Beyers, 2015; Van Assche, van-der-Kaap-Deeder, Audenaert, De Schryver, & Vansteenkiste, 2018). More specifically, in the work domain, research has shown that employees who experience more need satisfaction also report greater well-being (Gillet, Fouquereau, Forest, Brunault, & Colombat, 2012; Vanderelst, Van den Broeck, De Witte, & De Cuyper, 2012; Baard, Deci, & Ryan, 2004; Vansteenkiste et al., 2007), more work enjoyment (Andreassen, Hetland, & Pallesen, 2010), more self-endorsed motivation (De Cooman et al., 2013; Olafsen, Deci, & Halvari, 2018), greater commitment and performance (Greguras & Dieffendorff, 2009), less exhaustion (Fernet, Austin, Trépanier, & Dussault, 2013; Olafsen, 2017; Van den Broeck, Vansteenkiste, DeWitte, & Lens, 2008), and less organizational deviance (Andreassen, Hetland, & Pallesen, 2010). A recent meta-analysis on need satisfaction in the work place, including data from 99 studies and over 45 000 subjects, indicated significant positive relations between the basic needs, and well-being, job satisfaction, performance measures, and more self-endorsed forms of motivation (Van den Broeck et al., 2016).

Importantly, there are not only between-person differences in the experience of psychological needs, but a person's needs may also fluctuate over time, with need-based functioning being characterized by weekly (Campbell, Vansteenkiste, Beyers, & Soenens, 2018) or even daily ups and downs (Patrick, Knee, Canevello, & Lonsbary, 2007; Ryan, Bernstein, & Brown, 2010; Verstuyf, Vansteenkiste, Soenens, Boone, & Mouratidis, 2013). Furthermore, studies have found such within-person variations in the experience of autonomy, competence and relatedness to relate to within-person variations in well-being (e.g., Tian, Chen, & Huebner, 2014; Reis, Sheldon, Gable, & Roscoe, 2000; Wang, Liu, Jiang, & Song, 2017), sleep quality (Campbell et al., 2018), performance (Greguras & Dieffendorff, 2009) and work motivation (Olafsen et al., 2018). In light of these findings, we sought to document astronauts' weekly variation in their need-based functioning and to examine the association between week-to-week oscillations in astronauts' need satisfactions and week-to-week variations in important outcomes in astronaut well-being and mission success.

1.1 Autonomy

"*Happy it is the holiday and we get to drive our own schedule. That feels a little like we have some control over our lives. I think that is why it feels good."* (entree from an astronaut journal; Stuster, 2010, p. 19)

Although space agencies have voiced increasing concerns with crew autonomy, their view on autonomy seems to be related, yet different, from the notion of autonomy as defined in SDT. Specifically, crew agencies are concerned with the implementation of a desired and feasible level of crew independence (e.g., Hall, 2003; Palinkas, 2016). Yet, the notion of independence, which denotes astronauts' control over decision making with little, if any, external guidance, should be differentiated from SDT's notion of autonomy, i.e., the need to experience a sense of volition and the absence of pressure and conflict (Ryan & Lynch, 1989; Van Petegem, Beyers, Vansteenkiste, & Soenens, 2012). According to SDT, astronauts can either feel volitional or pressured in situations of both dependence and independence (Goemaere, Vansteenkiste, & Van Petegem, 2016; Goemaere, Beyers, De Muynck, & Vansteenkiste, 2018). That is, astronauts can feel comfortable and hence, volitionally take decisions independently, but they can also willingly concur with guidelines from Mission Support, with decisions being made for them. Yet, astronauts may also feel pressured to act independently while lacking the confidence and skills to do so; alternatively, they could feel pressured to stick closely to the guidelines offered by Mission Support. The latter seems to be a recurrent problem on present-day ISS missions, as astronauts regularly complain about the state of dependency they find themselves working in. Indeed, NASA has a strong tradition of bureaucratic and hierarchical control. Ground support is responsible for virtually all scheduling and decision-making onboard, while astronauts mainly have an executive function (Hendricks, Mauroo, & Van Spilbeeck, 2009; Kalery, Sorokin, & Tyurin, 2010; Krikalev, Kalery, & Sorokin, 2010; Hendricks, Mauroo, & Van Spilbeeck, 2009; McIntosh et al., 2016; Mulhearn et al., 2016). Previous analyses of astronaut reports and journals sometimes testify of the frustration arising from this so-called "*schedule enslavement*" and the at times ridiculously detailed operating procedures for relatively simple tasks (Stuster, 2010, p. 19). This suggests that the ISS crew's state of dependency is not always volitionally accepted, but that the crew often feels compelled to follow the rigid schedule and guidelines set up by ground control. In reaction to such rigid controls, people can become defiant, thereby refusing to engage in the requested behavior (Van Petegem, Soenens, Vansteenkiste, & Beyers, 2015; Vansteenkiste & Ryan, 2004). Such signs of rebellious behavior have been reported with astronauts, for instance, ignoring operating procedures or being less communicative with Mission Support members, which may have consequences for mission success (e.g., McIntosh et al., 2016; McPhee & Charles, 2009; Hendricks et al., 2009; Stuster, 2010;).

Some space experts argue that the communication lag associated with interplanetary travel and the subsequent loss of ground control's grip on astronaut functioning necessitates technical solutions for extended control on astronaut functioning, such as continuous recording and monitoring of crew interactions and behavior (e.g., Dunn et al., 2017; Ehmann, et al., 2011; Johannes, 2018). However, a few studies have found that astronauts tend to respond positively to increased independence in scheduling and decision-making. For instance, Sandal, Bye, and van de Vijver (Sandal, Bye, & Van de Vijver, 2011) found that astronauts tended to be less stressed and experience less frustration with Mission Support when they were granted more control in a 105-day Mars simulation. Roma et al. (2011) found crew members of a planetary exploration simulation to experience less negative affect, less stress, more positive affect, better performance and more crew cohesion when they were given more autonomous management of their work. In general, increasing independence in space simulation studies was seen to have mainly positive effects on the crew's mood (Roma et al., 2011). Overall then, evidence suggest that astronauts could thrive in a state of increased independence, in particular when such independence is more volitional in nature, that is, congruent with the astronauts' desire and preference to take more independent decisions.

A variety of studies in SDT literature has found evidence for the benefits of autonomy satisfaction. In organizational settings for instance, greater autonomy satisfaction was found to predict better employee performance (Chiniara, & Bentein, 2016) and greater creativity (Hon, 2012), while autonomy frustration predicted a higher risk of burnout (Trépanier, Fernet, & Austin, 2013). Evidence for the benefits of the experience of autonomy for astronauts was found for the crew of the Mars simulation HI-SEAS I mission (Goemaere, Vansteenkiste, Beyers, Vermeulen, & Binsted, in press). During the last eight weeks of the mission, weekly variations in crew's sense of autonomy were found to relate positively to weekly variations in motivation and negatively to defiant behavior and irritation with Mission Support. These results suggest that the experience of volition and willingness in carrying out daily tasks is just as vital for astronauts as for people on Earth.

1.2 Relatedness

"*All the conditions necessary for murder are met if you shut two men in a cabin measuring 18 feet by 20 and leave them together for two months*."
(Cosmonaut Valery Ryumin; Stuster, 2010, p. 21)

When it comes to interpersonal relations in space, far less emphasis has been put on its importance compared to astronauts' individual characteristics, such as their level of resilience (Landon & Barrett, 2018). That is, astronaut selection is mainly focused on personal features to identify candidates best suited for the job, such as cognitive, motivational, and technical skills. Less attention is paid to interpersonal skills, presumably because they are more difficult to tap into. Further, negative social interactions in space are less publicized than tragic mechanical failures, and their impact on astronauts' future lives has been less documented than the impact of some physiological changes with medical consequences. However, tense interactions have significantly damaged the comfort and morale of some crew members, disrupted the team cohesion, and even detracted from the success of missions (Suedfeld, Brcic, Johnson, & Gushin, 2015). On the plus side, astronaut journals often highlight the perhaps surprisingly ordinary day-to-day interactions that positively influence team functioning and mission success (De La Torre et al., 2012; Landon, & Barret, 2018). For instance, when the Russian cosmonaut Mikhail Kornienko returned to Earth after spending almost a year at the ISS, he declared that the companionship with his American crewmate Scott Kelly had been the most important single factor contributing to his successful adaptation (Landon & Barrett, 2018, p. 213). In interviews with NASA experts, Mulhearn et al. (2016) identified teamwork skills as the most important factor to safeguard team functioning in space mission. While cooperation and solid team functioning are important in every work organization, their role may even be more pronounced in isolated environments. While employees can physically disengage in common situations when facing conflicts, this is often not possible in space stations. Also, ISS crew must tolerate the constant scrutiny of others while attempting to solve encountered issues (Stuster, 2010). Finally, in case of long-duration interplanetary missions, the psychological guidance offered by ground support will be limited due to the time lag in communications, which may exacerbate interpersonal stressors even more than nominal space missions such as ISS missions (Landon & Barrett, 2018; Noe, Dachner, Saxton, & Keeton, 2011). For all of these reasons, good crew functioning and interpersonal relations are of utmost importance.

Several empirical studies have examined crew cohesion during actual space missions (e.g., Suedfeld & Brcic, 2011) or analogues and simulations (e.g., Sandal et al., 2011). Some studies have found crew cohesion to increase during the course of a mission (e.g., Solcova, Gushin, Vinokhodova, & Lukavski, 2013; Wu & Wang, 2015), whereas others reported evidence for a decrease in crew cohesion over time (e.g., Sandal, 2001; Sandal et al., 2011; Sandal & Bye, 2015; Stuster, 2010). However, despite the fact that some empirical studies have examined the evolution of crew cohesion during the course of a mission, two notable shortcomings in past research on intra-crew relationships still remain: first, very few studies have tracked crew cohesion longer than a few days or weeks (Salas et al., 2015), while future space missions are expected to last several years, and second, very few studies have examined how fluctuations in crew cohesion relate to fluctuations in other important outcomes, such as astronaut well-being or performance (McPhee & Charles, 2009; Solcova et al., 2013). For instance, one study by Suedfeld et al. (2015), in which the authors interviewed 20 retired cosmonauts, focused on the most common coping strategies employed by cosmonauts to reduce negative effects of stress. Results indicated that, much to the surprise of the authors, seeking social support (defined as 'the effort to obtain sympathy, help or emotional support from another person') was the most frequently reported coping strategy. The authors conclude that "*Coping in space appears to be much more of an interactive, mutually helpful enterprise than a demonstration* *of individual achievement.*" (Suedfeld, Brcic, Johnson, & Gushin, 2015, p. 48). The same results were found in the study by Brcic (2009) with 46 astronauts. The most frequently used coping strategy in space was social support, such as looking for someone to talk to, share experiences, and looking for expression of positive affect from someone. Brcic (2010) also found astronauts to score high on the need for affiliation, defined as "*establishing, maintaining, or restoring friendships encompassing affiliative and nurturant acts towards other*s" (p. 1110). In fact, astronauts' scores on their need for affiliation were almost as high as their notoriously high need for achievement (Brcic, 2010; Maschke, Oubaid, & Pecena, 2011; Mittelstädt, Pecena, Oubaid, & Maschke, 2016).

In contrast to scholars working in the tradition of Motive Disposition Theory, who focus on interpersonal differences in people's needs, such as the need for affiliation or achievement (e.g., Schultheiss & Brunstein, 2001), within SDT, the emphasis is on the extent to which one is capable of forming strong and stable interpersonal bonds, which are indicative of the satisfaction of the need for relatedness (Baumeister & Leary, 1995; Ryan & Deci, 2000b). Relatedness not only involves feeling cared for in non-contingent ways, but also being able to care for others. That is, relatedness concerns people's tendency to get involved with, show interest in, and direct energy towards the person, and convey that the person is significant and cared for non-contingently (Ryan & Deci, 2000a; 2000b; 2001). A sense of relatedness may be experienced at different hierarchical levels, ranging from dyadic relationships to group functioning. Several studies grounded in SDT have found relatedness satisfaction to relate to a variety of positive outcomes. For instance, Baard, Deci, and Ryan (Baard et al., 2004) found, aside from autonomy and competence, relatedness in particular to be predictive of higher performance evaluation ratings in employees. In sports, relatedness satisfaction was predictive of more fair play and more pro-social behavior (Rutten et al., 2011). In a longitudinal study, fluctuations in students' experience of relatedness with parents, teachers and peers were found to relate positively to fluctuating levels of engagement in school, school satisfaction, academic success, and positive affect, and to associate negatively with negative affect (King, 2015; Tian, Chen & Huebner, 2014).

Based on these results, we expect relatedness amongst crew members to be a crucial factor in astronaut health and performance. However, several anecdotal sources have attested to the importance astronaut attach to entertain close and warm relationships with loved-ones at home, be it through phone calls, emails, video recordings, or care packages (see Johnson, 2010, for a review). As these relationships are expected to also have a strong buffering effect against the stressors of spaceflight, it seems important to also take relatedness with home into account.

1.3 Competence

"*The work and the sense of accomplishment helps you get through the isolation."*(Astronaut Jerry Linenger; Sandal & Smith, 2018, p. 210).

Anecdotal evidence and astronaut journals often testify to the importance astronauts attach to feeling competent and adequate in their daily tasks (Brcic, 2010; Britt, Jennings, Goguen, & Sytine, 2016; Hendricks et al., 2009; Sandal & Smith, 2018; Stuster, 2010; 2016) . For instance, in a study using thematic content analysis in narratives of 46 ISS astronauts, Brcic (2010) found that astronauts were mainly motivated by the need for achievement, defined as a concern for excellence and unique accomplishments (McClelland, 1987). However, astronauts also testify about the frustration arising from a lack of accomplishment (Stuster, 2010; 2016). An absence of informative, corrective feedback, as well as a so-called "*praise inflation*" (i.e., profuse praise, even when undeserved, and a general avoidance of criticizing astronauts for mistakes) have often been cited as a source of competence frustration for astronauts (Stuster, 2010, p. 14). In interviews with astronauts and ground personnel, Britt et al. (2016) identified a lack of challenge as a major source of demotivation for astronauts, as social withdrawal, insomnia, and slips in performance are sometimes reported by ground personnel as signs of astronauts experiencing prolonged states of boredom (Britt et al., 2016; Sandal & Smith, 2018).

While space can be a very exciting work environment, many daily tasks in space missions consist of jobs that are not inherently exciting, challenging or interesting, and that can even be tedious or boring (e.g., cleaning or maintenance). In contrast, there are many testimonies of astronauts thriving when challenges or unforeseen situations come up (Sandal & Smith, 2018). Specifically, astronauts have been known to particularly enjoy 1) novel tasks, 2) tasks that require the use of a variety of skills, and 3) tasks they deem important because they contribute to humanity, the mission or space exploration, presumably because these tasks enhance their individual self-esteem and sense of accomplishment. Indeed, a high sense of competence and self-worth are likely to result when astronauts can use their specific skills to work on a task and feel like they are able to contribute uniquely to the mission. However, despite the fact that the importance of a sense of accomplishment for astronauts has been noted by other authors (e.g., Brcic, 2010; Peldszus, Dalke, Pretlove, & Welch, 2014; Stuster, 2010; Vanhove, Herian, Harms, & Luthans, 2014), it has received little empirical attention before in the astronautical context (Britt et al., 2016).

In SDT, competence is defined as the experience of effectiveness and mastery, which provides individuals' with a sense of confidence in their capacity to achieve desired outcomes and to develop their skills (Deci et al., 2017). Studies have found employees who experience competence satisfaction to show better work adjustment, report less anxiety and depression (Baard et al., 2004) and perform better at work (Greguras & Dieffendorff, 2009). Since competence has been observed as a key variable to positive outcomes in other domains, the relationship between weekly fluctuations in astronauts' experience of competence, and weekly variations in astronaut well-being and mission success will be examined in this study.

1.4 Autonomy-Support versus Control

"*Interesting, how you can be on top of the world one moment (literally) and then be completely demoralized the next, because of what is said on the ground."* (entree from an astronaut journal; Stuster, 2010, p. 14)

Given the hypothesized prominent role of astronauts' psychological need satisfaction, a key question is how these needs can be nurtured with the aim of enhancing crew wellness and mission success. Astronaut reports from previous missions often testify how crew-ground interactions are essential for the crew's well-being and performance. According to some experts (Stuster, 2010). Mission Support does not always see things from an astronaut perspective and even ignores the crew's viewpoint when making decisions and taking action. As a consequence, ground control is often viewed by crews as 'outsiders making unrealistic demands' (Noe, Dachner, Saxton, & Keeton, 2011, p. 13). At the same time, it is delicate for an astronaut to criticize the ground since such criticism may be interpreted as a form of insubordination, with possible repercussions for participation in future spaceflights. "*It's difficult to put up with what I see as tasks that waste my time, while other things that I want to do fall off as lower priority. I am in a difficult position, in that if I want to discuss these issues with the ground, I may be perceived as grumpy or complaining.*" (entree from an astronaut journal; Stuster, 2010, p. 31). Such crew-ground mishaps during orbital missions are expected to occur more frequently during a Mars mission, due to the longer duration of interplanetary missions and the greater communication delay with ground control. This increased risk for 'crew-ground disconnect' has alarmed space agencies (e.g., Kanas & Manzey, 2008; McIntosh et al., 2016; Sandal & Smith, 2018).

From an SDT perspective, the way Mission Support interacts with the crew can be described in terms of its level of provided autonomy-support or control. In the case of autonomy support, ground control would provide astronauts with a certain amount of choice, give a meaningful rationale in case choice is constrained, empathize with the astronauts' perspective, and make use of informational language (see Deci et al., 2017, for a review). In contrast, Mission Support could be described as controlling when showing little concern for requests or preferences in task scheduling, by preventing the crew from expressing feelings of frustration in difficult times, or by using pressuring language and making use of guilt trips, shaming or stressful interpersonal comparisons.

Interestingly, when leaders or supervisors adopt an autonomy-supportive instructional style, they are not just promoting employees' autonomy need satisfaction, but, in many cases, the satisfaction of all three needs. Presumably, under conditions of autonomy support, employees feel better understood and connected to their supervisor and they may also be assigned or given a choice surrounding tasks they feel effective in doing. In this context, Baard et al. (2004) reported that employees' experienced autonomy support by their supervisors related cross-sectionally to greater satisfaction of all three needs. In a longitudinal study, Olafsen et al. (2018) found that managerial autonomy support related to an increase in employee's general basic psychological need satisfaction over a ten-month period. Notably, the need-conducive contribution of managerial autonomy support has been found to stand cross-culturally, with both American and Bulgarian employees reporting greater need satisfaction when they perceived their supervisors to be autonomy-supportive, with psychological need satisfaction accounting for the work engagement and well-being benefits associated with managerial autonomy support (Deci et al., 2001). Initial evidence for the potential benefits of autonomy-support in space missions was also found during HI-SEAS I (Goemaere, et al., in press). In this longitudinal study, weekly variations in an autonomy-supportive communication style from Mission Support related positively to weekly variations in the crew's sense of autonomy, suggesting that the weekly ups and downs in Mission Support's communication style covary with the ups and downs in astronauts' volition. In the present study, we built on the results from HI-SEAS I, by examining the relationship between autonomy-supportive and controlling communications from Mission Support, and how they relate to all three needs.

2. The Present Study

During HI-SEAS IV, we had the unique possibility to collect weekly measures of crew members' need-based functioning, a variety of health, motivation, and performance related outcomes as well as the perceived communication style by ground control. Importantly, the crew not only filled out a battery of self-report measures, but also provided more concrete, written examples of their weekly need-based experiences and we also asked the commander of the team of six crew members to provide weekly ratings of crew members' performance, stress and happiness, to overcome the well-known problem of shared method-variance. This rich dataset allowed pursuing two critical objectives, that is, first, to investigate whether and how astronaut's need satisfaction evolve across the duration of the mission and second, to examine whether weekly ups and downs in the crew's need-based experiences relate to weekly variation in crew member functioning and interactions with Mission Support. We included a broad variety of indicators representing both crew members' adjustment as well as their maladjustment, including rated performance, crew member well-being (happiness vs. stress), collaboration with the ground (irritation vs. cooperation with Mission Support members) and their work motivation (internalization vs. oppositional defiance). Specifically, congruent with SDT, we measure crew members' reasons for abiding to instructions and regulations from ground control for more controlled reasons (e.g., to avoid repercussions or disappointment) or more autonomous reasons (e.g., the perceived fit with their own values and working method). While there are weeks during which astronauts volitionally follow-up instructions, presumably because they have fully endorsed and internalized them, there are also weeks during which astronauts bluntly defy imposed regulations, with their oppositional defiance involving a form of anti-internalization (Aelterman, Vansteenkiste, Soenens, & Haerens, 2016) .

While the three needs are distinguishable conceptually, quite a few empirical studies have modeled the needs as an overall construct (e.g., Lian et al., 2012), because thwarting any of the needs produces similar negative outcomes (Deci & Ryan, 2000), and the three needs easily go hand in hand in naturalistic settings (e.g., Baard et al., 2004; Sheldon & Niemiec, 2006; Uysal, Lin, & Knee, 2010). However, a recent meta-analysis (Van den Broeck et al., 2016) indicated that, when each need is analyzed separately, they predicted unique variance in motivation and well-being. We therefore made a distinction between the three needs to examine whether they predicted significant outcomes in crew health, motivation and performance.

We put forward the following research question and two hypotheses in the present study. First, in a more explorative manner, we examined how the astronauts' experience of autonomy, competence and relatedness would evolve over time, thereby considering the possibility of linear and curvilinear changes. We refrained from formulating directional hypotheses given that we are not aware of any preceding study that addressed this issue. Second, we predicted that weekly variations in crew members' experienced need satisfactions would relate to weekly variations in both the adjustment (i.e., self-endorsed motivation, cooperation, rated happiness and performance) and maladjustment (i.e., oppositional defiance, irritation and rated stress) of crew members (Hypothesis 1). Third, weekly variations in Mission Support's autonomy-supportive and controlling communication style were hypothesized to relate to weekly variations in the crew's experience of the needs for autonomy, competence and relatedness (Hypothesis 2).

3. Method

To investigate these hypotheses, we used diary data collected from all six participants to the fourth mission of the NASA space simulation HI-SEAS conducted in 2015-2016, an experimental study created to simulate a yearlong stay on Mars in order to address several unsolved questions concerning life and work on the red planet. The study was approved by the NASA Institutional Review Board and the Ghent University Ethical Commission.

3.1 Subjects

The study comprised the six participants of the HI-SEAS IV crew. The six volunteers, three women and three men, were between 25 and 36 years of age ($M = 30$, $SD = 4$) at the beginning of the mission. The participants were of US, UK, German and French nationalities. All had a university academic degree and were paid to take part in the experiment. All crew members met the basic requirements of the NASA astronaut program and were selected because they had similar experience and background to real NASA astronauts.

The HI-SEAS IV mission simulates a yearlong stay on Mars, from August 29, 2015 to August 28, 2016, and is the longest NASA funded space simulation in history to date (Gifford, 2016). The HI-SEAS IV habitat was located in an isolated place on the flanks of the Mauna Loa Volcano on Hawaii, an area with Mars-like features, such as the absence of vegetation and animal life and a barren volcanic rock terrain. For the whole duration of the experiment, participants were confined with their fellow crew members in the habitat module; a geodesic dome with a diameter of eleven meters enclosing a volume of 384 m^3, severely limiting privacy. The crew only left the module for weekly extra vehicular activities (EVA) in simulated spacesuits to explore the surrounding terrain and perform geological studies. In addition, to simulate the operational challenges a future deep space exploration mission will face, the crew members were largely cut off from the outside world. Their communications were limited to email and each message was delayed by 20 minutes before being sent, simulating the lag for communications travelling the 400 million kilometers from Mars to Earth and vice versa. Further in-depth information on the experiment can be found online, on hi-seas.org.

3.2 Procedure

The crew filled out questionnaires on a weekly basis on Sunday evenings, during 48 consecutive weeks. Additionally, the crew commander filled out a second questionnaire on a weekly basis. Several existing or self-developed questionnaires were used in various parts of the study. All items in these questionnaires were scored on a 5-point Likert scale ranging from 1 (“don’t agree at all”) to 5 (“agree completely”). This resulted in several measures:

Autonomy Support versus Control. Crew members were asked to report their perception of Mission Support being autonomy-supportive instead of controlling during the past week. Eleven items adapted from the Work Climate Questionnaire (Baard et al., 2004) were administered to tap into autonomy-supportive (e.g., “*Mission Support members tried to understand how I would like to do things, before making any suggestions on how to accomplish my tasks*”) and controlling behavior (e.g., “*Mission Support members were less friendly to me when I didn’t complete tasks in the way they expected me to*”). Cronbach’s alpha was .99 for autonomy-support and .92 for control (Geldhof, Preacher, & Zyphur, 2014).

Need-based experiences. The crew’s general sense of volition and personal freedom was assessed using eight adapted items from the autonomy subscale of the Basic Psychological Need Satisfaction Scale (Gagné, 2003; Deci & Ryan, 2000; Aelterman et al., 2018). This subscale includes four items for autonomy satisfaction, such as “*I felt that what I had done is far is truly interesting to me*” and four items for autonomy frustration, e.g. “*Most things*

I did felt obligatory." After reverse scoring the autonomy frustration items, Cronbach's alpha for this scale was .94. Likewise, the crew's sense of efficacy was measured using eight items adapted from the competence subscale of the Basic Psychological Need Satisfaction Scale. A sample competence satisfaction item reads "*I had faith in the fact that I did things right*", while a sample frustration item reads "*I felt insecure about my capabilities*" (Cronbach's alpha = .97). Relatedness experiences between crew members and relatedness with loved-ones at home were assessed with four items each, adapted from the Basic Psychological Need Satisfaction Scale, e.g. "*I felt connected to my fellow crew members, who likewise cared about me*", for satisfaction, or "*I felt excluded from my fellow crew members*", for frustration. The same four items were asked with regards to friends and family members at home. Cronbach's alpha was .93 for relatedness crew, and .96 for relatedness home.

Motivation. Self-endorsement and acceptance of instructions for daily tasks was assessed using an adapted version of the Self-Regulation Questionnaire - Parental Rules (Aelterman et al., 2018; Goemaere et al., in press; Goemaere et al., 2018; Soenens, Vansteenkiste, & Niemiec, 2009). As previously noted, astronauts' reason to abide by rules and operating procedures can vary in internalization and self-endorsement over time. For instance, astronauts could follow rules out of fear of not getting another mission (i.e., external regulation), a type of motivation which can be typical of ISS astronauts (Morgeson, 2015). Astronauts could also follow procedures to avoid feelings of shame due to negative comparison to others, or to gain feelings of pride and ego-enhancement (i.e., introjected regulation). In contrast, astronauts who intrinsically enjoy growing plants in space or who participate to scientific studies because they find it personally relevant or important to contribute to scientific knowledge (i.e., identified motivation), can be said to be self-endorsed for these activities. To capture varying internalization during the course of the mission, the crew members were asked for their reasons to follow instructions for their daily activities: "*During the past week, I followed instructions because…*" In total, 19 items were used to measure external regulation (e.g., "*this was expected of me*"; seven items; Cronbach's alpha = .99), introjected regulation (e.g., "*I would have felt guilty otherwise*"; 6 items; Cronbach's alpha = .96) and identified regulation (e.g., "*I understood why they were important*"; six items; Cronbach's alpha = .72). In line with previous work, a summarizing measure was created, the relative internalization index (RII) (Neyrinck, Vansteenkiste, Lens, Duriez, & Hutsebaut, 2006; Soenens et al., 2009; Vallerand, Fortier, & Guay, 1997; van-der-kaap-Deeder, 2014). This composite score consists of a weighted combination of volitional and pressuring forms of motivation, wherein the volitional motives were given a positive weight and the pressuring motives were given a negative weight. Because the different kinds of regulations in SDT (i.e., identified, introjected, and external) are supposed to lie on one continuum of self-endorsement, the weights that are assigned to these regulations (i.e., +3, −1, and −2, respectively) when creating a relative internalization index in empirical research are balanced. Such a weighting procedure guarantees that the sum of the assigned weights is zero and that self-endorsed and pressuring types of regulation are equally weighted in the creation of a relative internalization index (Neyrinck et al., 2006). Overall, higher scores on this scale indicate higher levels of ownership and internalization of instructions.

Oppositional defiance. A tendency towards the dismissal of instructions for daily tasks was measured using four items adapted from Vansteenkiste, Soenens and Van Petegem (Vansteenkiste, Soenens, Van Petegem, & Duriez, 2014). A sample item reads "*From time to time I wanted to disregard the instructions that were set for me*". Cronbach's alpha (.90) revealed a good internal consistency.

Irritation with Mission Support. Four items such as “*I felt irritated with Mission Support*” were used to measure the level of irritation crew members experienced in their interactions with Mission Support. These items were based on the resentment scale of Assor, Roth, and Deci (Assor, Roth, & Deci, 2004). Internal consistency of this scale was .80.

Cooperation with Mission Support. Four self-developed items such as “*I got along well with Mission Support*” were used to measure the perceived cooperation crew members experienced in their interactions with Mission Support. Internal consistency of this scale was .95.

Happiness. Happiness was measured by asking the commander to what degree they agreed with the following statement for each crew member: “*My fellow crew member seemed happy or satisfied this week*”. The commander did not rate their own level of happiness.

Stress. Stress was measured by asking the commander to what degree they agreed with the following statement for each crew member: “*My fellow crew member seemed stressed-out or frustrated this week*”. The commander did not rate their own level of stress.

Performance. Performance was measured by asking the commander to what degree they agreed with the following statement for each crew member: “*My fellow crew member performed well in the fulfillment of his or her duties this week*”. The commander did not rate their own level of performance.

Qualitative data. Finally, we also encouraged subjects to further explain their experiences in written word. This was explored by asking each individual crew member to report particularly frustrating or particularly pleasant experiences during the past week. They could write freely about these experiences, but were not obliged to report anything if they did not want to.

Results were used to enrich the quantitative findings, that is, to better understand which concrete need satisfying and need frustrating experiences astronauts encountered.

3.3 Statistical Analyses

To address our research question and two hypotheses, we conducted multilevel analyses with the statistical software package HLM7, which deconstructs the total variance into between-person (i.e., differences between astronauts) and within-person (i.e., week-to-week differences) variation. In each of the main models, we started with a random intercepts-only model. These random intercepts-only models consist of random intercepts and a constant as the only predictor (Hox, 2010). Afterwards, we added fixed effects to these random intercepts-only models. For the research question, we performed separate multilevel analyses with a time variable (ranging from week 1 to 48) and a squared time variable (ranging from 1 to 2304) to calculate linear and quadratic time effects for each need.

For the first hypothesis, we performed two sets of multilevel analyses. In a first step, we tested how fluctuations in each need related to fluctuations in each outcome by introducing the needs as separate predictors. When more than one need predicted an outcome, in a second set of analyses, we introduced those needs simultaneously to shed light on their unique contribution in the weekly variation in outcomes. Finally, we tested whether the weekly variation in astronauts' need-based functioning could be predicted by the variation in the perceived autonomy-supportive or controlling communication style from Mission Support. In every analysis, age and gender were entered as control variables.

3.3.1 Preliminary Analyses

Aggregated means and standard deviations for the measured variables can be found in Table 1, as well as correlations between the study variables at the between and within level, and week-to-week variances.

	M (SD)	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
1. Perceived control	1.57 (0.59)	-	.20	-.73***	-.67**	-.42	-.16	-.55*	-.65	.31	-.38*	-.17	.20	-.20
2. Perceived autonomy-support	3.20 (0.93)	-.38***	-	-.49**	.27	.17	-.50**	-.86***	.28	-.23	.67*	.84***	-.78***	.85***
3. Competence	4.29 (0.46)	-.19***	-.08	-	.31	.15	.34	.80***	.28	-.04	.22	-.28†	.29	-.33†
4. Autonomy	3.73 (0.60)	-.23**	.32***	.21**	-	.93***	.22	.19	.68***	.17	.75***	.71***	-.69***	.65**
5. Relatedness Crew	3.48 (0.96)	-.21***	.49**	-.03	.39**	-	.38	.22	.48**	.49	.60***	.62***	-.59***	.53**
6. Relatedness Home	3.59 (0.98)	-.06	.01	.19	.17*	.15	-	.68**	-.48	.76***	-.21	-.36	.45*	-.44**
7. Motivation	5.50 (2.42)	-.22***	.34***	.15*	.37***	.42***	.13	-	-.03	.33*	-.23	-.56*	.55*	-.60**
8. Oppositional defiance	1.34 (0.51)	.16**	-.19**	-.08**	-.12*	-.03	.19	-.26***	-	-.46†	.68***	.65***	-.73***	.66***
9. Irritation	2.08 (0.84)	.42***	-.37***	-.08†	-.12	-.22**	-.11	-.26***	.39***	-	-.08	-.12	.20	-.25
10. Cooperation	3.63 (0.77)	-.45***	.62***	.01	.27**	.42**	.05	.38***	-.33***	-.65***	-	.83***	-.78***	.77**
11. Happiness	3.67 (0.82)	-.13†	.44***	-.07	.25*	.39**	.10	.17**	.17	-.21*	.30**	-	-.99***	.99***
12. Stress	2.55 (0.97)	.06	-.19†	.04	-.19***	-.30***	-.21**	-.21**	-.02	.14	-.19**	-.54***	-	-.98***
13. Performance	3.93 (0.63)	-.04	.36***	-.15	.07†	.38***	.00	.00	-.05	-.17***	.26***	.52***	-.29***	-
Week-to-week variance		65%	39%	40%	21%	27%	28%	31%	70%	91%	49%	48%	50%	93%

Note. Within-subject correlations are displayed below the diagonal, and between-subject correlations above.
$^{\dagger}p < .10$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$. Based on Wald test in Mplus (estimate/standard error).

Table 1. Means, standard deviations, within- and between-subject correlations, and week-to-week variances for all variables.

3.3.2 Primary Analyses

Research Question: Mean level changes in study variables across mission. Table 2 contains the linear and quadratic time effects for the needs. We found a significant linear and curvilinear decrease for the composite score of autonomy. This pattern of mean level change was especially driven by a linear and curvilinear increase in autonomy frustration, as can be seen in Figure 1. No significant time effects were observed for competence, as competence satisfaction and frustration remained relatively stable during the course of the mission (see Figure 2). Finally, we observed significant linear and curvilinear decreases in relatedness crew and home over time, which were mainly driven by both a linear and curvilinear decrease in satisfaction for relatedness crew, and a curvilinear decrease in satisfaction for relatedness home. The evolution in relatedness satisfaction and frustration scores are depicted in Figures 3 and 4.

Furthermore, our qualitative data indicated a similar evolution of the experiences of the needs and was often able to indicate peaks and valleys in the week-to-week variances. To enrich the quantitative results in Table 2, we added exemplary diary statements from crew members in Table 3, concerning satisfying or frustrating experiences of autonomy, competence and relatedness satisfaction and frustration.

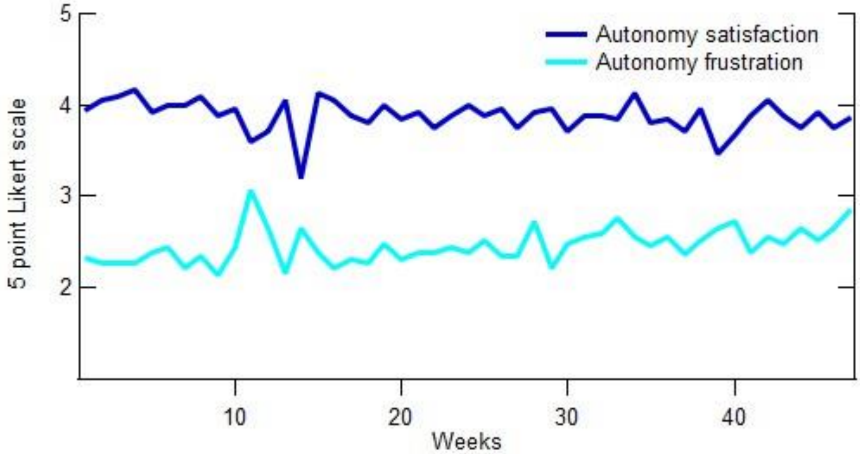


Figure 1. Evolution of autonomy satisfaction and frustration during the course of the mission.

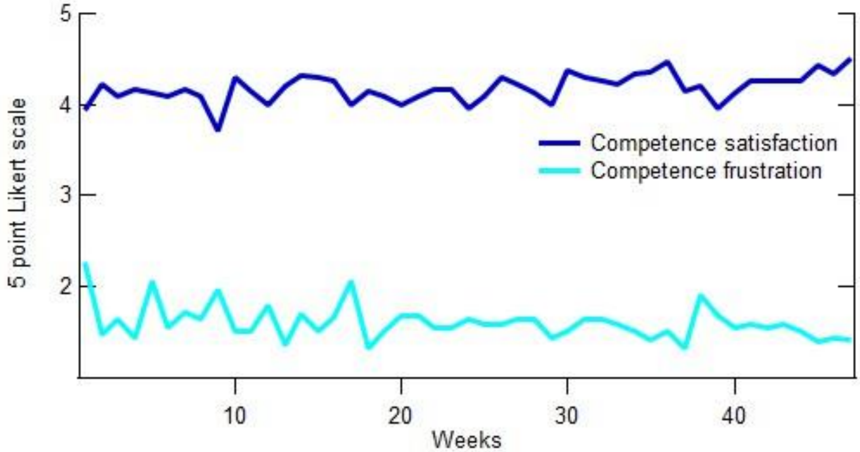


Figure 2. Evolution of competence satisfaction and frustration during the course of the mission.

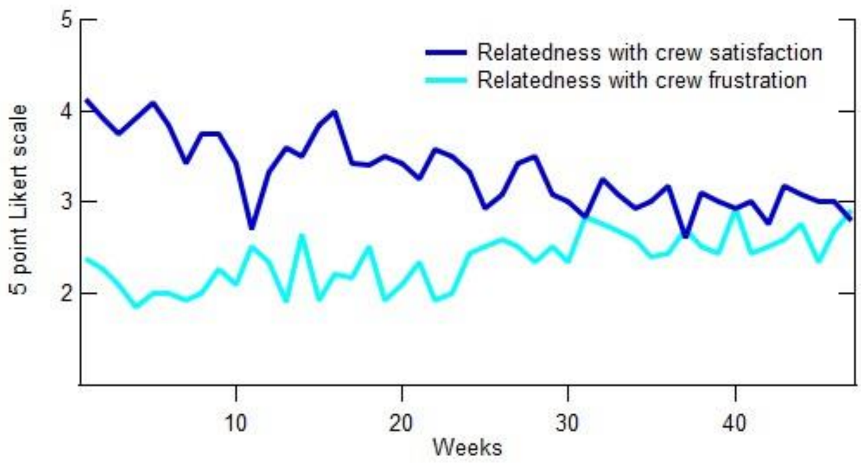


Figure 3. Evolution of relatedness crew satisfaction and frustration during the course of the mission.

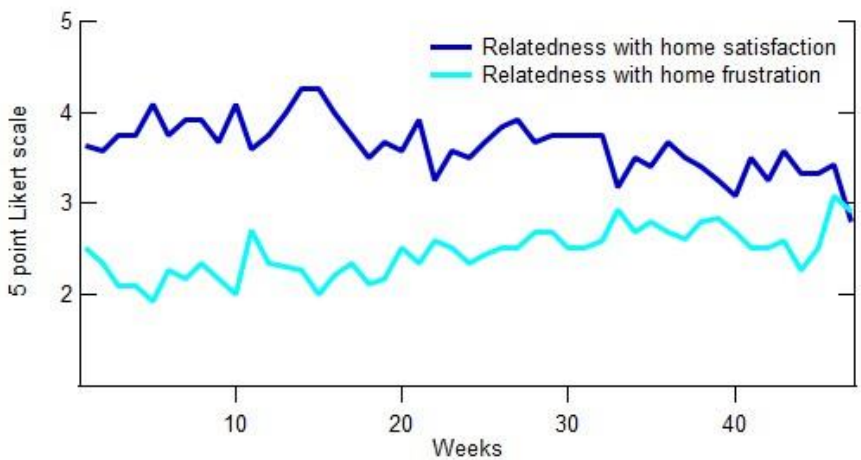


Figure 4. Evolution of relatedness home satisfaction and frustration during the course of the mission.

	M	*SD*	Linear *b*	Linear *t(267)*	Quadratic *b*	Quadratic *t(267)*
Autonomy	3.73	0.60	-5e-3	-2.46*	-1e-4	-2.61*
Autonomy satisfaction	3.90	0.56	-4e-3	-1.29	-7e-5	-1.20
Autonomy frustration	2.44	0.80	0.01	3.73***	1e-4	3.42***
Competence	4.29	0.46	4e-3	1.51	9e-5	1.73†
Competence satisfaction	4.18	0.47	5e-3	1.47	1e-4	1.82†
Competence frustration	1.59	0.56	-4e-3	-1.25	-8e-5	-1.37†
Relatedness crew	3.48	0.96	-0.02	-2.30*	-3e-4	-2.33*
Relatedness crew satisfaction	3.31	0.99	-0.02	-3.06**	-4e-4	-2.82**
Relatedness crew frustration	2.34	1.13	0.01	1.42	2e-4	1.53
Relatedness home	3.59	0.98	-0.01	-2.00*	-3e-4	-2.03*
Relatedness home satisfaction	3.63	0.93	-0.01	-1.73†	-3e-4	-1.80*
Relatedness home frustration	2.45	1.16	0.02	1.83†	-3e-4	1.81†

Note. †$p < .10$, *$p < .05$, **$p < .01$, ***$p < .001$.

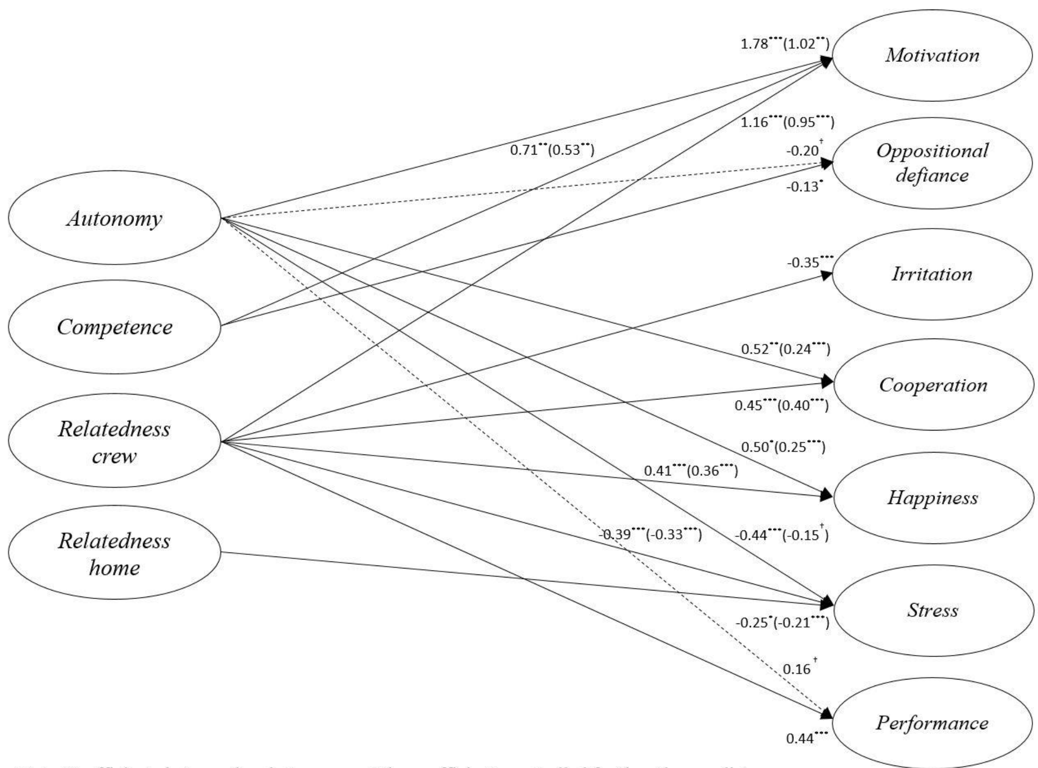
Table 2. Descriptive statistics, linear and quadratic time effects for the needs' composite score, and satisfaction and frustration scores.

Need	Satisfaction	Frustration
Autonomy	*"Some folks on [Mission Support] went out of their way to help."* (week 9) *"Just having Mission Support ask what's up or see how we're doing."* (week 39)	*"I have yet to really have any direct experiences with [Mission Support], I have only made two requests and they were both pretty much ignored."* (week 1) *"Ground not listening or acknowledging crew concerns, ground not providing adequate notice of actions that impact crew lives."* (week 22)
Competence	*"Some constructive email exchanges with Mission Support."* (week 24) *"I received indirect compliments about my work."* (week 25)	*"[Mission support] found a way to get us a big new task, but not a way to get us any experimental equipment, or the correct building materials."* (week 10) *"Spending too much time on the computer emailing, for too little outcome"* (week 20)
Relatedness crew	*"Getting reassurance from a certain person."* (week 37) *"Friendly interactions with co-workers."* (week 43)	*"The most annoying person is inside the dome, not outside."* (week 30) *"Anything that happened [this week] was outweighed by a certain crewmember being the most obnoxious person on the planet ... Earth."* (week 37)
Relatedness home	*"Received many supportive emails about terrorist attacks."* (week 8) *"I received a Merry Christmas video, including contributions from family."* (week 16)	*"Not hearing back for weeks from some people"* (week 2) *"Bad news from home"* (week 37)

Table 3. Exemplary crew member statements related to particularly pleasant or frustrating experiences, categorized into their potential impact on need satisfaction and frustration.

Hypothesis 1: Weekly variation in need-based functioning and outcomes. In three sets of independent multi-level analyses, we considered the role of the three needs separately. These results are depicted in Figure 5. Multilevel analyses on the gathered data indicated that week-to-week variations in the experience of autonomy were significantly and positively predictive of weekly variations in motivation (b = 1.78, $t(267)$ = 3.80, p < .001), cooperation (b = 0.52, $t(267)$ = 3.17, p < .01) and happiness (b = 0.50, $t(213)$ = 2.29, p < .05) and negatively predictive of weekly variations in stress (b = -0.44, $t(213)$ = 2.29, p < .001). Autonomy was also marginally significantly predictive of weekly variations in oppositional defiance (b = -0.20, $t(267)$ = -1.80, p = .07) and performance (b = 0.16, $t(213)$ = 1.69, p = .09), but was unrelated to irritation (b = -0.36, $t(267)$ = -1.35, p = .18). For competence, we found significant positive associations with weekly ups and downs in motivation (b = 0.71, $t(267)$ = 0.16, p = < .01) and negative associations with oppositional defiance (b = -0.13, $t(267)$ = -2.08, p < .05), but no associations with irritation (b = -0.24, $t(267)$ = -1.63, p = .11), cooperation (b = 0.02, $t(267)$ = 0.07, p = .95), happiness (b = -0.15, $t(213)$ = -3.96, p = .11), stress (b = 0.10, $t(213)$ = 0.97, p = .33) or performance (b = -0.33, $t(213)$ = -1.65, p = .10). While fluctuations in relatedness with crew members were significantly associated with fluctuations in motivation (b = 1.16, $t(267)$ = 7.79, p < .001), irritation (b = -0.35, $t(267)$ = -6.44, p < .001), cooperation (b = 0.45, $t(267)$ = 5.07, p < .001), happiness crew (b = 0.41, $t(213)$ = 3.52, p < .001), stress (b = -0.39, $t(213)$ = -5.72, p < .001), and performance (b = 0.44, $t(213)$ = 10.47, p < .001), no significant association was found with fluctuations in oppositional defiance (b = -0.03, $t(267)$ = -0.95, p = .34). Finally, relatedness with home was only significantly and negatively predictive of stress (b = -0.25, $t(213)$ = -2.43, p < .005), while unrelated to motivation (b = 0.34, $t(267)$ = 1.06, p = .29), oppositional defiance (b = 0.16, $t(267)$ = 1.32, p = .19), irritation (b = -0.18, $t(267)$ = -1.42, p = .16), cooperation (b = 0.06, $t(267)$ = 0.35, p = 0.73), happiness (b = 0.09, $t(213)$ = 0.73, p = 0.47) or performance (b = -0.01, $t(213)$ = -0.05, p = 0.96).

We further analyzed the prior significant associations between variations in needs and variations in outcome variables, by introducing the needs simultaneously as predictors, in order to test for their unique predictive value. When introducing the needs for autonomy, competence and relatedness crew simultaneously as predictors, all three needs remained significantly and thus uniquely related to motivation ($b = 1.02$, $t(265) = 2.89$, $p < .01$; $b = 0.53$, $t(265) = 3.14$, $p = < .01$; $b = 0.95$, $t(265) = 3.68$, $p < .001$, respectively). Likewise, when introducing autonomy and relatedness crew simultaneously as predictors, they both remained significantly and positively predictive of cooperation (($b = 0.24$, $t(266) = 4.15$, $p < .001$) and ($b = 0.40$, $t(266) = 5.09$, $p < .001$), respectively) and happiness (($b = 0.25$, $t(212) = 3.57$, $p < .001$) and ($b = 0.36$, $t(212) = 3.86$, $p < .001$), respectively). As for the negative associations between stress and relatedness crew and home, they remained significant ($b = -0.33$, $t(211) = -7.59$, $p < .001$; $b = -0.21$, $t(212) = -4.67$, $p < .001$, respectively), but the previously significant relation with autonomy became marginally significant ($b = -0.15$, $t(212) = -1.86$, $p = .06$).



Note. Coefficients between brackets represent the coefficients controlled for the other predictors.

Figure 5. Graphical representation of the multilevel analyses with the needs as predictors to the outcome measures.

Hypothesis 2: weekly variations in autonomy-support and control, and need satisfaction and frustration. Multilevel analyses on the gathered data, in which perceived autonomy-support and perceived control from Mission Support were introduced as predictors simultaneously, indicated that week-to-week variations in autonomy were significantly and positively predicted by weekly variations in perceived autonomy-support (b = 0.13, t(266) = 3.57, p < .001), and marginally significantly and negatively predicted by variations in control (b = -0.07, t(266) = -1.56, p = .08). Competence was negatively related to control (b = -0.15, t(266) = -5.40, p < .001) and unrelated to autonomy-support (b = -0.09, t(266) = -1.04, p = .30), while relatedness crew was positively related to autonomy-support (b = 0.41, t(266) = 2.24, p < .05), but not to control (b = -0.04, t(266) = -0.49, p = .63). Finally, relatedness home was unrelated to autonomy-support (b = -0.07, t(266) = -0.70, p = .49) or control (b = -0.02, t(266) = -0.10, p = .92). These results are depicted in Figure 6.

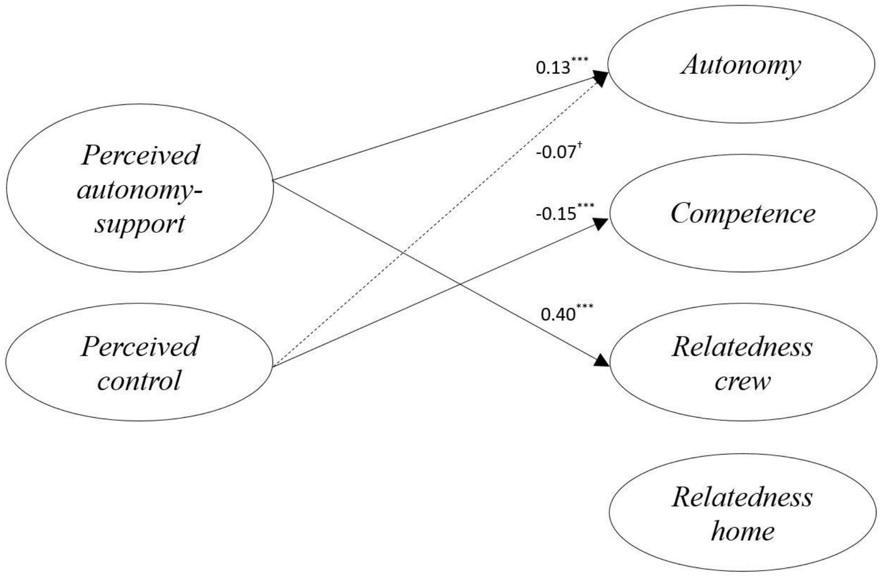


Figure 6. Graphical representation of the multilevel analyses with an autonomy-supportive and controlling communication style as predictors to the needs.

4. Discussion

In this yearlong simulation study, we measured the crew's psychological needs, motivation, well-being, performance and collaboration with Mission Support members on a weekly basis, in order to shed light on changes in need-based functioning across the mission and to understand how fluctuations in the needs relate to important outcomes in crew health and mission success, and how the needs relate to interactions with Mission Support members.

4.1 Mean level changes

First, we sought to find out how astronaut's basic psychological needs evolved as the mission progressed. We found evidence that the experience of three needs changed over time. Overall, our results show a tendency of increased autonomy frustration and decreased relatedness satisfaction (both with home and crew members) over the course of the mission, which seemed to exacerbate as the mission progressed. A significant decrease in experienced relatedness with home is far from surprising, since the prolonged lack of direct contact is bound to hinder astronauts in seeking social support with loved-ones on Earth. Instead, one would expect astronauts to search and find more and more social support from their fellow-crew members. However, the drop in experience of autonomy and relatedness with crew members over the course of the mission suggests that astronauts on Mars could become increasingly at risk of not having their needs met.

4.2 Weekly Variation in Need-based Functioning

In our first hypothesis, we sought out to investigate how weekly variations in the three psychological needs relate to weekly variations in crew members' motivation, social functioning, personal well-being and performance. Our findings show that the weekly variation in the crew's experience of autonomy covaries with the weekly variation in a variety of outcomes. Specifically, in the weeks crew members experienced a peak in their volition and personal freedom, they self-endorsed the importance of instructions more fully. This benefit also radiated to their well-being, as in weeks with greater autonomy, crew members were rated by their commander to be happier and to be less stressed. Interestingly, in the weeks astronauts felt more autonomous, they also experienced the cooperation with Mission support to be more fruitful, which may help to explain why they were rated as performing slightly better by their commander as well. These findings may prove to be important for space agencies, since one of their majors concerns for future long-distance space travels is to maintain a strong crew-ground collaboration. As previously mentioned, space experts try to negate the risk of crew-ground disconnect by developing new technologies for continuous crew monitoring, as is the case on current ISS missions. However, if these monitoring interventions are not volitionally accepted by the crew, astronauts might feel controlled and restricted in their sense of autonomy, which may have important negative repercussions for crew-ground collaborations.

Further, we found a positive association between weekly ups and downs in the crew's sense of competence and weekly variations in self-endorsed motivation, and a negative association with weekly variations in oppositional defiance. These results indicate that during weeks astronauts felt more competent, for instance after receiving positive feedback on their work (see Table 3), they were less likely to discard instructions, instead even being more motivated to follow them out of full dedication and perceived self-importance. Surprisingly, we did not find more significant associations between variations in competence and other outcome variables. A potential explanation for this more limited role of competence may have to do with its operationalization in the present study. The items tap into astronauts' sense of confidence to achieve certain outcomes. With a daily schedule consisting of numerous tedious, repetitious and monotonous tasks, crew members are unlikely to lack the required confidence and mastery, as also exemplified by the highest mean-level scores for this need of all three needs across the entire mission. Indeed, the ISS has been called 'a space station assembly line' by highly trained astronauts (Kalery et al., 2010, p. 926). Although astronauts may feel effective to take up the assigned tasks, they may not have the feeling to fully exercise their skills, let alone develop them during the mission. For this aspect of competence to be nurtured, astronauts would need more challenging and meaningful work. Hence, the execution of rather monotonous tasks, in combination with elaborate detailed operating instructions, may explain both astronauts' prior reports of frustration and boredom as well as the limited predictive validity of competence satisfaction in the current study (Britt et al., 2016; Sandal & Smith, 2018). In a laboratory study with college students (Goemaere et al., 2018), we found that the provision of long, detailed instructions were generally perceived as less useful and, when provided for simple tasks, evoked greater feelings of irritations and oppositional defiance, with a greater cost in performance. A more nuanced assessment of competence, tapping into this particular issue of feeling insufficiently challenged, could have resulted in more significant associations with motivation, well-being and performance.

With regards to the need for relatedness, our results indicated an important distinction in astronauts' perceived relatedness with their friends and family at home, and with their fellow crew members. Weekly ups and downs in relatedness with home were significantly related to weekly fluctuations in stress, but unrelated to other outcome measures. Sharply in contrast with this pattern, weekly variations in relatedness with crew members were significantly associated with weekly variations in nearly all outcome measures. We found relatedness with crew members to be positively related to self-endorsed motivation, happiness, performance, and cooperation with Mission Support, and negatively related to stress and irritation with Mission Support. Several conclusions can be drawn from these results. First, it seems that, when socially isolated and confined to small living quarters for a prolonged period of time, warm and supportive relationships with loved-ones at home become less crucial for astronaut well-being and functioning, than warm and supportive relationships with fellow crew members. Given the lack of physical proximity and direct communication with Earth, one would indeed expect astronauts to find more solace and relief, and likewise, be more perturbed by frictions, in their relationships with immediate crewmates. Congruent with this reasoning, crew members reported relatively few, and rather general, positive or negative statements about friends and family at home. For crew members however, more intense conflicts and negative emotions were reported (see Table 3). Second, our results also show some support for the construct of displacement. In previous work (e.g., Gushin, Efimov, Smirmova, Vinokhodova, & Kanas, 1998), displacement was described as a situation where intra-crew tensions that could not openly be discussed or dealt with, were projected towards more distant groups such as Mission Support. Our results are consistent with these findings, since low relatedness with crew members, potentially reflecting high intra-crew tensions, were associated with more irritation and less cooperation with Mission Support. Of course, the nature of this association cannot be defined at this point, as struggles with Mission Support could have also influenced crew cohesion, rather than the other way around. At this point, it's important to note that the concept of relatedness with crew members differs from the traditional operationalization of crew cohesion in human spaceflight literature. Crew cohesion in space missions has often been assessed as a mutual positive identification with group members, or perceived similarity to others (e.g., Gushin et al., 1998; Salas et al., 2015; Sandal et al., 2011; Solcova et al., 2013). The problem with this operationalization of crew cohesion is that a high positive identification with the group may also increase in-group favoritism and conforming behavior in the group, and the risk for out-group aggression and groupthink (Vinokhodova & Gushin, 2014). While a positive identification and higher perceived similarity with fellow crew members might result from a sense of relatedness, more pressuring forms of identification, such as conformism and groupthink, are unlikely to result from a higher sense of relatedness with the group. The notion of relatedness might therefore be more suited to grasp the positive mutual support that astronauts use to alleviate the negative stressors of spaceflight.

This brings us to our third hypothesis, for which we investigated how weekly variations in autonomy-supportive and controlling interactions with Mission Support were related to weekly variations in the crew's experience of autonomy, competence and relatedness. In weeks when crew members perceived Mission Support to be more autonomy-supportive, crew members experienced a greater sense of autonomy and relatedness with fellow crew members. The same was true for a controlling communication style, which was negatively related to autonomy and competence. These findings suggest that, not only are the crew's psychological needs related to higher well-being and functioning, but these needs could potentially be influenced by Mission Support's communication style towards the crew. The exemplary crew statements in Table 3 illustrate how crew-ground interactions could have influenced the crew’s sense of autonomy and competence. From the qualitative data, we found that crew members particularly enjoyed crew-ground interactions when Mission Support expressed a general concern for the crew’s well-being, and a genuine interest in their preferences and activities. Ground control members going the extra mile in an effort to provide a crew member with material or help outside of what was expected, was also frequently reported. In contrast, the most frustrating experiences where reported when Mission Support would show little concern for crew members, for instance by overburdening them with work, or ignoring requests and being generally unresponsive.

The fact that crew-ground interactions were found to relate to the crew’s needs opens up the possibility for space agencies to borrow from SDT research in other domains, and develop new guidelines for Mission Support inspired by evidence-based autonomy-supportive measures. Numerous studies have demonstrated the benefits of autonomy-supportive, rather than controlling, measures in sustaining people’s psychological needs (e.g., Ryan & Deci, 2000a; Joussemet, Landry, & Koestner, 2008; Soenens & Vansteenkiste, 2010). For instance, Mission Support could 1) try to provide astronauts with some option (e.g., choice in which task to perform) or action choices (e.g., choice in how or when to perform an assigned task), instead of setting up a strict work schedule without any crew input. 2) When choices are restricted, as is often the case in space operations, Mission Support could still be autonomy-supportive by explaining why the choice was restricted, by means of assigning tasks according to an astronauts preferences or interests, or highlighting the personal relevance and necessity of an assigned task by, for instance, explaining how the task relates to relevant scientific progress and the further exploration of outer space. 3) Finally, Mission Support members, and space agencies in general, should be encouraged to use inviting language in crew-ground interactions instead of pressuring language, and show empathy and allow astronauts to vent their frustrations, without it having any repercussions for the astronaut's career. These measures are expected to not only enhance the crew's sense of autonomy and competence, but relatedness with fellow crew members as well, which was proven crucial in its relations with crew motivation, well-being, performance and Mission Support collaboration. Overall, given the substantial number of significant associations between the needs, particularly the needs for relatedness with crew members and autonomy, and our outcome measures, space agencies would do well to pay considerable attention to safeguard and enhance the crew's psychological needs. Since the needs were also found to be generally positively associated with an autonomy-supportive communication style from Mission Support, and negatively with controlling interactions, the above-mentioned evidence-based autonomy-supportive and controlling measures provide an excellent starting point to develop guidelines and training for Mission Support members to achieve this objective.

This study has a number of limitations. Because of the mission duration and the setup of the experimental habitat, this study had a very high ecological validity. However, as for most research in the space domain, the results were based on a small number of subjects. Therefore, researchers need to replicate these results during other simulation and analogue missions, and preferably actual spaceflights. Furthermore, research should aim to include measures from Mission Support staff as well. For instance, Mission Support members could be asked to report on their experiences in interactions with the crew, to gain a more objective measure of cooperation with Mission Support. A more objective assessment of performance, beyond the opinion of the crew commander, would also be beneficial. We chose to focus on the commander's evaluation to reduce the effects of social desirability and shared method variance known to arise in the case of exclusive reliance on self-reports. Yet, since the commander was also a crew member actively participating in the experiment, the commander may also have been influenced by the relationship with fellow crew members. The data also showed little variance in the commander's answers for some outcome variables. It is possible that the commander felt unsure about how well crew members performed, and whether they felt happy or stressed. Therefore, a wider array of assessment methods needs to be implemented in future research. Since our results indicate surprisingly few effects of the need for competence, based on our previous reasoning, a newly developed assessment might be needed with a more nuanced take on competence, assessing whether crew members feel satisfied in the use of their capacities and development of skills. Lastly, since we did not manipulate our variables directly, we cannot draw causal conclusions about the observed associations. However, since we have found further correlational evidence indicating that astronauts' basic psychological needs are indeed related to astronaut well-being and mission success, and evidence suggesting that astronaut needs relate to the interaction style with Mission Support, future research should try to replicate these results in an experimental design.

Conclusion

In the words of one of the crew members, the HI-SEAS IV medical officer (Gifford, 2016): "*A crucial lesson from [the experiment] is that technology is the lowest common denominator. Mechanical solutions for getting a crew there and back alive will take shape as time and money allow. What cannot be engineered is people.*" For sure, people cannot be programmed or engineered. However, through careful study, we can aim to better understand astronauts' psychological functioning in general and the role of their psychological needs in particular in order to create a need-nurturing environment that fosters astronaut well-being, performance and social functioning. The findings in this study demonstrate the importance of the psychological needs of autonomy, competence and relatedness for astronaut functioning and mission success. Overall, results from this study indicate that astronauts who feel more satisfied in their psychological needs, especially in their needs for autonomy and relatedness with fellow crew members, experience more self-endorsed motivation, are less inclined to rebel against instructions, and feel happier and less stressed. They also perform better and have a more fruitful collaboration with Mission Support members. Moreover, findings from this study also suggest that an autonomy-supportive, instead of a controlling communication style from Mission Support could enhance astronauts' needs for autonomy, competence, and even relatedness with crew members. Therefore, space agencies could benefit from autonomy-supportive measures proven effective in other domains, and start developing measures to sustain and foster astronaut well-being and functioning.

References

Aelterman, N.*, Vansteenkiste, M.*, Soenens, B., Fontaine, J., Haerens, L., & Reeve, J. (accepted). Toward an integrative and fine-grained insight in motivating and demotivating teaching: The merits of a circumplex approach. (*equal contributions). *Journal of Educational Psychology*.

Aelterman, N., Vansteenkiste, M., Soenens, B., & Haerens, L. (2016). A dimensional and person-centered perspective on controlled reasons for non-participation in physical education. *Psychology of Sport and Exercise, 23*, 142-154.

Andreassen, C. S., Hetland, J., & Pallesen, S. (2010). The relationship between 'workaholism', basic needs satisfaction at work and personality. *European Journal of Personality, 24*, 3-17.

Assor, A.G., Roth, G., & Deci, E.L. (2004).The emotional costs of parents' conditional regard: a self-determination theory analysis. *Journal of Personality, 72*, 47-88.

Baard, P. P., Deci, E. L., & Ryan, R. M. (2004). Intrinsic need satisfaction: A motivational basis of performance and well-being in two work settings. *Journal of Applied Social Psychology*, *34*, 2045-2068.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, *117*, 497-529.

Brcic, J. (2009). *Universal values, coping strategies, and motive images of astronauts at the international space station*. Retrieved from the University of British Columbia Open Library.

Brcic, J. (2010). Motivational profile of astronauts at the International Space Station. *Acta Astronautica, 67*, 1110-1115.

Brenning, K., Mabbe, E., Vansteenkiste, M., & Soenens, B. (2018). Ups and downs in the joy of motherhood: Maternal well-being as a function of psychological needs, personality, and infant temperament. *Journal of Happiness Studies, manuscript in press.*

Britt, T. W., Jennings, K. S., Goguen, K., & Sytine, A. (2016). *The role of meaningful work in astronaut health and performance during long-duration space exploration missions* (NASA/TM-2016-219276). Houston, Texas, NASA Johnson Space Center.

Campbell, R., Vansteenkiste, M., Beyers, W., & Soenens, B. (2018). Shifts in university students' sleep during an exam period: The role of basic psychological needs and stress. *Motivation and Emotion, manuscript in revision.*

Chen, B., Van Assche, J., Vansteenkiste, M., Soenens, B., & Beyers, W. (2015b). Does psychological need satisfaction matter when environmental or financial safety are at risk? *Journal of Happiness Studies*, *16*, 745-766.

Chen, B., Vansteekiste, M., Beyers, W., Boone, L., Deci, E. L., Duriez, B., Lens, W., Matos, L., Mouratidis, A., Ryan, R. M., Sheldon, K., Soenens, B., van der Kaap-Deeder, J., Van Petegem, S., & Verstuyf, J. (2015). Basic psychological need satisfaction, need frustration, and need strength across four cultures. *Motivation & Emotion, 39*, 216-236.

Chiniara, M., & Bentein, K. (2016). Linking servant leadership to individual performance: Differentiating the mediating role of autonomy, competence and relatedness need satisfaction. *The Leadership Quarterly*, *27*, 124-141.

Chirkov, V., Ryan, R. M., & Kim, Y. (2003). Differentiating autonomy from individualism and independence: a Self-Determination Theory perspective on internalization of cultural orientations and well-being. *Journal of Personality and Social Psychology*, *84*, 97-110.

De Cooman, R., Stynen, D., Van den Broeck, A., Sels, L., & DeWitte, H. (2013). How job characteristics relate to need satisfaction and autonomous motivation: Implications for work effort. *Journal of Applied Social Psychology, 43*(6), 1342-1352.

De la Torre, G. G., Van Baarsen, B., Ferlazzo, F., Kanas, N., Weiss, K., Schneider, S., & Whiteley, I. (2012). Future perspectives on space psychology: Recommendations on psychosocial and neurobehavioural aspects of human spaceflight. *Acta Astronautica, 81*, 587-599.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227-268.

Deci, E. L., Olafsen, A. H., & Ryan, R. M. (2017). Self-Determination Theory in work organizations: The state of a science. Annual Review of Organizational Psychology and Organizational Behavior, 4, 19-43.

Deci, E. L., Ryan, R. M., Gagné, M., Leone, D. R., Usunov, J., & Kornazheva, B. P. (2001). Need satisfaction, motivation, and well-being in the work organizations of a former eastern bloc country: a cross-cultural study of self-determination. *Personality and Social Psychology Bulletin, 27*, 930-942.

Dunn, J., Huebner, E., Liu, S., Landry, S. & Binsted, K. (2017). Using consumer-grade wearables and novel measures of sleep and activity to analyze changes in behavioral health during an 8-month simulated Mars mission. *Computers in Industry, 92*, 32-42.

Ehmann, B., Balázs, L., Fülöp, E., Hargitai, R., Kabai, P., Péley, B., Pólya, T., Vargha, A., & László, J. (2011). Narrative psychological content analysis as a tool for psychological status monitoring of crews in isolated, confined and extreme settings. *Acta Astronautica, 68*, 1560-1566.

Fernet, C., Austin, S., Trépanier, S. G., & Dussault, M. (2013). How do job characteristics contribute to burnout? Exploring the distinct mediating roles of perceived autonomy, competence, and relatedness. *European Journal of Work and Organizational Psychology, 22,* 123-137.

Gagné, M. (2003). The role of autonomy support and autonomy orientation in prosocial behavior engagement. *Motivation and Emotion, 27,* 199-223.

Geldhof, J. G., Preacher, K. J., & Zyphur, M. J. (2014). Reliability estimation in a multilevel confirmatory factor analysis framework. *Psychological Methods, 19,* 72-91.

Gifford, S. (2016). *Life on Mars*. Retrieved on 31.05.2018 from: https://aeon.co/essays/what-i-ve-learned-so-far-from-living-in-a-mars-simulation?src=longreads.

Gillet, N., Fouquereau, E., Forest, J., Brunault, P., & Colombat, P. (2012). The impact of organizational factors on psychological needs and their relations with well-being. Journal of Business Psychology, 27, 437-450.

Goemaere, S., Beyers, W., De Muynck G.-J., & Vansteenkiste, M. (2018). The paradoxical effect of long instructions on negative affect and performance: When, for whom and why do they backfire? *Acta Astronautica, 147,* 421-430.

Goemaere, S., Vansteenkiste, M., & Van Petegem, S. (2016). Gaining deeper insight into the psychological challenges of human spaceflight: The role of motivational dynamics. *Acta Astronautica, 121,* 130-143.

Goemaere, S., Vansteenkiste, M., Beyers, W., Vermeulen, A.C.J., & Binsted, K. (in press). Do astronauts benefit from autonomy? Investigating perceived autonomy-supportive communication by Mission Support, astronauts' motivation and collaboration during HI-SEAS I. *Acta Astronautica.*

Greguras, G. J., & Dieffendorff, J. M. (2009). Different fits satisfy different needs: Linking person-environment fit to employee commitment and performance using Self-Determination Theory. *Journal of Applied Psychology, 94,* 465-477.

Gushin, V., Efimov, V. A., Smirmova, T. M., Vinokhodova, A. G., & Kanas, N. (1998). Subjects' perceptions of the crew interaction dynamics under prolonged isolation. *Aviation and Space Environmental Medicine,* 69, 556–561.

Hall, J. L. (2003). Columbia and Challenger: organizational failure at NASA. *Space Policy, 19*, 239-247.

Hendricks, H., Mauroo, T., & Van Spilbeeck, B. (2009). *Het Ruimtedagboek van Frank De Winne: Dagelijks Leven in het ISS.* Leuven: Van Halewyck.

Hon, A. H. N. (2012). When competency-based pay relates to creative performance: The moderating role of employee psychological need. *International Journal of Hospitality Management, 31*, 130-138.

Hox, J. J. (2010). *Multilevel Analysis: Techniques and Applications, Quantitative Methodology Series*. New York: Routledge.

Johannes, B. (2018). Voice stress analysis, In T. Sgobba, B. Kanki, J.-F. Clervoy, G. Sandal (Eds.), *Space Safety and Human Performance*. Oxford: Butterworth-Heinemann.

Johnson, P. (2010). The roles of NASA, U.S. astronauts and their families in long-duration missions. *Acta Astronautica, 67,* 561-571.

Joussemet, M., Landry, R., & Koestner, R. (2008). A Self-Determination Theory perspective on parenting. *Canadian Psychology-Psychologie Canadienne, 49*, 194-200.

Kalery, A., Sorokin, I., & Tyurin, M. (2010). Human space exploration beyond the international space station: role of relations of human, machine and the ‘‘Earth’’. *Acta Astronautica, 67,* 925-933.

Kanas, N. (2014). Psychosocial issues during an expedition to Mars. *Acta Astronautica, 103*, 73-80.

Kanas, N., & Manzey, D. (2008). *Space Psychology and Psychiatry*. Dortrecht: Kluwer.

Kanas, N., Saylor, S., Harris, M., Neylan, T., Boyd, J., Weiss, D., Baskin, P., Cook, C., & Marmar, C. (2010). High versus low crew member autonomy in space simulation environments, *Acta Astronautica, 67*, 731-738.

King, R. B. (2015). Sense of relatedness boosts engagement, achievement, and well-being: A latent growth model study. *Contemporary Educational Psychology, 42*, 26-38.

Krikalev, S., Kalery, A., Sorokin, I. (2010). Crew on the ISS: creativity or determinism. *Acta Astronautica, 66*, 68-78.

L. Tian, L., Chen, H., & Huebner, E. S. (2014). The Longitudinal relationships between basic psychological needs satisfaction at school and school-related subjective well-being in adolescents. *Social Indicators Research, 119*, 353-372.

Landon, L. B., & Barrett, J. D. (2018). Team resilience, In T. Sgobba, B. Kanki, J.-F. Clervoy, G. Sandal (Eds.), *Space Safety and Human Performance*. Oxford: Butterworth-Heinemann.

Lian, H., Ferris, D. L., & Brown, D. J. (2012). Does taking the good with the bad make things worse? How abusive supervision and leader-member exchange interact to impact need satisfaction and organizational deviance. *Organizational Behavior and Human Decision Processes, 117*, 41-52.

Mabbe, E., Soenens, B., Vansteenkiste, M., van der Kaap-Deeder, J., & Mouratidis, A. (2018). Day-to-day variation in autonomy-supportive and psychologically controlling parenting: The role of parents' daily experiences of need satisfaction and need frustration. *Parenting Science and Practice, 18*, 86-109.

Maschke, P., Oubaid, V., & Pecena, Y. (2011). How do astronaut candidate profiles differ from airline pilot profiles? *Aviation Psychology and Applied Human Factors, 1*, 38-44.

McClelland, D. C. (1987). *Human motivation*. Cambridge: Cambridge University Press.

McIntosh, T., Mulhearn, T., Gibson, C., Mumford, M. D., Yammarino, F. J., Connelly, S., Day, E. & Vessey, B. (2016). Planning for Long-

Duration Space Exploration: Interviews with NASA Subject Matter Experts. *Acta Astronautica, 129*, 477-487.

Mcphee, J. C., & Charles, J. B. (2009). *Human health and performance risks of space exploration missions* (NASA SP-2009-3405). Houston, Texas, NASA Johnson Space Center.

Mittelstädt, J. M., Pecena, Y., Oubaid, V., & Maschke, P. (2016). Psychometric personality differences between candidates in astronaut selection. *Aerospace Medecine and Humand Performance, 87*, 933-939.

Morgeson, F. P. (2015). *Issues in Maintaining Team Motivation over Long-Duration Exploration Missions,* (NASA/TM-2015-218586). Houston, Texas, NASA Johnson Space Center.

Mulhearn, T., McIntosh, T., Gibson, C., Mumford, M. D., Yammarino, F. J., Connelly, S., Day, E. A., & Vessey, B. (2016). Leadership for long-duration space missions: A shift toward a collective approach. *Acta Astronautica, 129,* 466-476.

Neyrinck, B., Vansteenkiste, M., Lens, W., Duriez, B., & Hutsebaut, D. (2006). Cognitive, affective and behavioral correlates of internalization of regulations for religious activities. Motivation and Emotion, 30, 323-334.

Noe, R., Dachner, A. M., Saxton, B., & Keeton, K. E. (2011). *Team training for long-duration missions in isolated and confined environments: A literature review, an operational assessment, and recommendations for practice and research* (NASA/TM-2011-216162). Houston, Texas, NASA Johnson Space Center.

Olafsen, A. H. (2017). The implications of need-satisfying work climates on state mindfulness in a longitudinal analysis of work outcomes. *Motivation and Emotion, 41,* 22-37.

Olafsen, A. H., Deci, E. L., & Halvari, H. (2018). Basic psychological needs and work motivation: A longitudinal test of directionality. *Motivation and Emotion, 42,* 178-189.

Palinkas, L. A. (2016). Impact of communication delays to and from the International Space Station on self-reported individual and team behavior and performance: mixed-methods study. *Acta Astronautica, 129*, 193-200.

Patrick, H., Knee, C. R., Canevello, A., & Lonsbary, C. (2007). The role of need satisfaction in relationship functioning and well-being: A self-determination theory perspective. *Journal of Personality and Social Psychology, 92,* 434-457.

Peldszus, R., Dalke, H., Pretlove, S., & Welch, C. (2014). The perfect boring situation - Addressing the experience of monotony during crewed deep space missions through habitability design. *Acta Astronautica, 94*, 262-276.

Reis, H. T., Sheldon, K. M., Gable, S; L., & Roscoe, J. (2000). Daily well-being: The role of autonomy, competence, and relatedness. *Personality and Social Psychology Bulletin, 26*, 419-435.

Rodriguez-Meirinhos, A., Antolin-Suarez, L., Brenning, K., Vansteenkiste, M., & Olivia, A. (2018). A bright and a dark path to adolescents (mal)adjustment: The role of need satisfaction and need frustration across gender, age, and socioeconomic background. *Manuscript submitted for publication.*

Roma, P. G., Hursh, S. R., Hienz, R. D., Emurian, H. H., Gasior, E. D., Brinson, Z. S., & Brady, J. V. (2011). Behavioural and biological effects of autonomous versus scheduled mission management in simulated space-dwelling groups. *Acta Astronautica, 68*, 1581-1588.

Rutten, E., Schuengel, C., Dirks, E., Stams, G., Biesta, G., & Hoeksma, J. (2011). Predictors of antisocial and prosocial behavior in an adolescent sports context. *Social Development, 20,* 294-315.

Ryan, R. M. & Deci, E. L. (2000a). Self-Determination Theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*, 68-78.

Ryan, R. M., & Deci, E. L. (2000b). The darker and brighter sides of human existence: basic psychological needs as a unifying concept. *Psychological Inquiry, 11*, 319-338.

Ryan, R. M., & Deci, E. L. (2001). On happiness and human potentials: A review of research on hedonic and eudaimonic well-being. *Annual Review of Psychology, 52*, 141-166.

Ryan, R. M., & Lynch, J. H. (1989). Emotional autonomy versus detachment: revisiting the vicissitudes of adolescence and young adulthood. *Child Development, 60*, 340-356.

Ryan, R. M., Bernstein, J. H., & Brown, K. W. (2010). Weekends, work, and well-being: Psychological need satisfaction and day of the week effects on mood, vitality, and physical symptoms. *Journal of Social and Clinical Psychology, 29*, 95-122.

Salas, E., Tannenbaum, S. I., Kozlowski, S. W. J., Miller, C. A., Mathieu, J. E., & Vessey, W. B. (2015). Teams in space exploration: A new frontier for the science of team effectiveness. *Current Directions in Psychological Science, 43*, 200-207.

Sandal, G. & Smith, N. (2016). Psychological resilience. In T. Sgobba, B. Kanki, J.-F. Clervoy, G. Sandal (Eds.), *Space Safety and Human Performance*. Oxford: Butterworth-Heinemann.

Sandal, G. (2001). Crew tension during a space station simulation. *Environment and Behavior, 33*, 134-150.

Sandal, G. M., & Bye, H. H. (2015). Value diversity and crew relationships during a simulated space flight to Mars. *Acta Astronautica, 114*, 164-173.

Sandal, G. M., Bye, H. H., & van de Vijver, F. J. R. (2011). Personal values and crew compatibility: results from a 105 days simulated space mission. *Acta Astronautica, 69*, 141-149.

Schultheiss, O. C., & Brunstein, J. C. (2001). Assessment of implicit motives with a research version of the TAT: picture profiles, gender differences, and relations to other personality measures. *Journal of Personality Assessment, 77*, 71-86.

Sheldon, K. M., & Niemiec, C. P. (2006). It's not just the amount that counts: Balanced need satisfaction also affects well-being. *Journal of Personality and Social Psychology, 91*, 331-341.

Sheldon, K. M., Elliot, A. J., Ryan, R. M., Chirkov, V.,Kim, Y., Wu, C., Demir, M., & Sun, Z. G. (2004). Self-concordance and subjective well-being in four cultures. *Journal of Cross-Cultural Psychology, 35*, 209-223.

Soenens, B., & Vansteenkiste, M. (2010). A theoretical upgrade of the concept of parental psychological control: Proposing new insights on the basis of self-determination theory. *Developmental Review 30*, 74-99.

Soenens, B., Vansteenkiste, M., & Niemiec, C. P. (2009). Should parental prohibition of adolescents' peer relationships be prohibited? *Personal Relationships, 16*, 507-530.

Solcova, I., Gushin, V., Vinokhodova, A., & Lukavski, J. (2013). Emotional energy, work self-efficacy, and perceived similarity during the Mars 520 study. *Aviation, Space, and Environmental Medicine, 84*, 1186-1190.

Stuster, J. (2010). *Behavioral issues associated with long-duration space expeditions: Review and analysis of astronaut journals* (NASA/TM-2010-216130). Houston, Texas, NASA Johnson Space Center.

Suedfeld, P., & Brcic, J. (2011). Resolution of psychosocial crises associated with flying in space. *Acta Astronautica, 69,* 24-29.

Suedfeld, P., Brcic, J. Johnson, P. J., & Gushin, V. (2012). Personal growth following long-duration spaceflight. *Acta Astronautica, 79*, 118-123.

Curran, T., Hill, A. P., Ntoumanis, N., Hall, H. K., & Jowett, G. E. (2016). A three-wave longitudinal test of Self-Determination Theory's mediation model of engagement and disaffection in youth sport. *Journal of Sport & Exercise Psychology, 38*, 15-29.

Britt, T. W., Jennings, K. S., Goguen, K., & Sytine, A. (2016). *The role of meaningful work in astronaut health and performance during long-duration space exploration missions* (NASA/TM-2016-219276). Houston, Texas, NASA Johnson Space Center.

Trépanier, S.-G., Fernet, C., & Austin, S. (2013). Workplace psychological harassment in Canadian nurses: A descriptive study. *Journal of Health Psychology, 18*, 384-397.

Uysal, A., Lin, H. L., & Knee, C. R. (2010). The role of need satisfaction in self- concealment and well-being. *Personality and Social Psychology Bulletin, 36*, 187-199.

Vallerand, R.J., Fortier, M.S., & Guay, F. (1997). Self-determination and persistence in a reallife setting: Toward a motivational model of high school dropout. *Journal of Personality and Social Psychology, 72*, 1161-1176.

Van Assche, J., van der Kaap-Deeder, J., Audenaert, E., De Schryver, M., & Vansteenkiste, M. (2018). Are the benefits of autonomy satisfaction and the costs of autonomy frustration dependent on individuals' autonomy strength? *Journal of Personality, manuscript in press.*

Van den Broeck, A., Ferris, D. L., Chang, C.-H., & Rosen, C. C. (2016). A review of Self-Determination Theory’s basic psychological needs at work. *Journal of Management, 42*, 1195-1229.

Van den Broeck, A., Vansteenkiste, M., DeWitte, H., & Lens, W. (2008). Explaining the relationships between job characteristics, burnout, and engagement: The role of basic psychological need satisfaction. *Work & Stress, 22*, 277-294.

Van der Kaap-Deeder, J., Vansteenkiste, M., Soenens, B., Verstuyf, J., Boone, L., & Smets, J. (2014). Fostering self-endorsed motivation to change in patients with an eating disorder: The role of perceived autonomy support and psychological need satisfaction. *International Journal of Eating Disorders, 47,* 585-600.

Van Petegem, S., Beyers, W., Vansteenkiste, M., & Soenens, B. (2012). On the association between adolescent autonomy and psychosocial functioning: Examining decisional independence from a Self-Determination Theory perspective. *Developmental Psychology, 48(*1), 76-88. https://doi.org/10.1037/a0025307.

Van Petegem, S., Soenens, B., Vansteenkiste, M., & Beyers, M. (2015). Rebels with a cause? Adolescent defiance from the perspective of reactance theory and Self-Determination Theory. *Child Development, 86,* 903-918.

Vanderelst, T., Van den Broeck, A., DeWitte, H., & De Cuyper, N. (2012). The mediating role of frustration of psychological needs in the relationship between job insecurity and work-related well-being. *Work and Stress*, *26*, 252-271.

Vanhove, A., Herian, M., Harms, P., & Luthans, E. (2014). *Resilience and growth in long- duration isolated, confined and extreme (ICE) missions: A literature review and selection, training and countermeasure recommendations* (NASA TM-218566). Houston, Texas, NASA Johnson Space Center.

Vansteenkiste, M., & Ryan, R. M. (2013). On psychological growth and vulnerability: basic psychological need satisfaction and need frustration as a unifying principle. *Journal of Psychotherapy Integration, 23,* 263-280.

Vansteenkiste, M., Niemiec, C. P., & Soenens, B. (2010). The development of the five mini- theories of Self-Determination Theory: A historical overview, emerging trends and future directions. In T. Urdan & S. Karabenick (Eds.). *Advances in Motivation and Achievement: Vol. 16. The decade ahead* (pp. 105-166). Bingley, United Kingdom: Emerald.

Vansteenkiste, M., Soenens, B., Van Petegem, S., & Duriez, B. (2014). Longitudinal associations between adolescent perceived degree and style of parental prohibition and internalization and defiance. *Developmental Psychology, 50,* 229-236.

Vansteenkiste, M., Neyrinck, B., Niemiec, C. P., Soenens, B., DeWitte, H., & Van den Broeck, A. (2007). On the relations among work value orientations, psychological need satisfaction and job outcomes: A self-determination theory approach. *Journal of Occupational and Organizational Psychology, 80*, 251-277.

Verstuyf, J., Vansteenkiste, M., Soenens, B., Boone, L., & Mouratidis, A. (2013). Daily ups and downs in women's binge eating symptoms: The role of basic psychological needs, general self-control and emotional eating. *Journal of Social and Clinical Psychology, 32*, 335-361.

Vinokhodova, A. G., & Gushin, V. I. (2014). Study of values and interpersonal perception in cosmonauts on board of international space station. *Acta Astronautica, 93,* 359-365.

Wang, R., Liu, H., Jiang, J., & Song, Y. (2017). Will materialism lead to happiness? A longitudinal analysis of the mediating role of psychological needs satisfaction. *Personality and Individual Differences, 105*, 312-317.

Williams, G. C., Cox, E. M., Hedberg, V. A., & Deci, E. L. (2000). Extrinsic life goals and health-risk behaviours in adolescents. *Journal of Applied Social Psychology, 30,* 1756-1771.

Wu, R. & Wang, Y. (2015). Psychosocial interaction during a 105-day isolated mission in Lunar Palace 1. *Acta Astronautica, 113*, 1-7.

GENERAL DISCUSSION

Human Space Exploration from a Self-Determination Theory Perspective: A General Discussion

TABLE OF CONTENTS

At the core of this dissertation were the work circumstances that astronauts face, and the type of tasks they engage in on a daily basis. Specifically, astronauts spend a substantial part of their days performing relatively simple routine tasks under strict and elaborate surveillance of ground control. Although empirical evidence is lacking, anecdotal sources have illustrated the sense of frustration and demotivation, and the performance deficits that can arise from such an overload of instructional guidance and close monitoring (e.g., Hendricks, Mauroo, & Van Spilbeeck, 2009; Kanas & Manzey, 2008; Mcphee & Charles, 2009; McIntosh et al., 2016; Stuster, 2010, 2016). To better understand the motivational, affective, and behavioral deficits associated with such an environment, and to study potential countermeasures, we relied on Self-Determination Theory, a broad theory on human motivation (SDT; Deci & Ryan, 2000). In light of SDT's claim that the needs for autonomy, competence, and relatedness are critical nutrients for motivation, growth, and well-being, the following three objectives were pursued. The first research goal of the dissertation involved finding empirical evidence for the consequences of providing long instructions for simple tasks, while the second goal focused on the development of potential countermeasures to alleviate the presumed detrimental effects of long instructions on motivation, well-being, and performance. The third and final research goal involved collecting evidence for the effectiveness of countermeasures in a naturalistic, more ecologically valid setting. The findings regarding these three general objectives are discussed topic-wise, and are graphically represented in Figure 1, thereby referencing several chapters and addressing the different objectives along the way. This final chapter also offers a number of reflections by situating the findings in the broader literature and identifying potential pitfalls of countermeasures, as well as avenues for future research. Finally, limitations and practical implications are discussed before ending with a general conclusion.

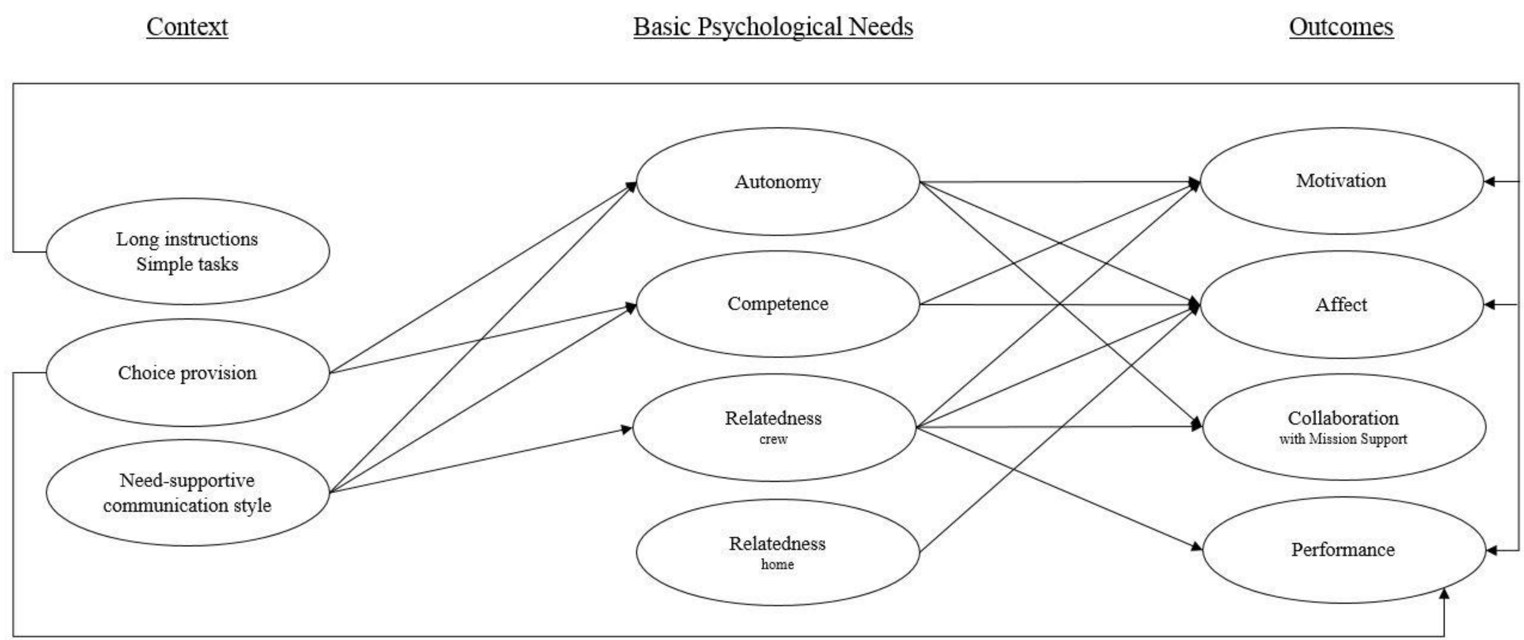


Figure 1. Graphical overview of the significant associations between the variables of this dissertation.

1. A Topic-Wise Description of the Findings and their Theoretical Implications

1.1 Long vs. Short Instructions

1.1.1 The Effects of Adding Instructional Guidance for Simple Tasks

Findings. The LEGO and Excel experiments presented in Chapters 2 and 3 have demonstrated the adverse impact of providing overly long instructions for simple tasks, in comparison to more concise instructions (research goal 1). Specifically, lengthening instructions for a simple assembly task diminished individuals' perceived usefulness of the instructions, caused a rise in feelings of irritation, and a drop in attention to detail (Figure 1). Although not reported in Chapter 2, lengthening instructions for simple tasks also increased reactance, i.e. the tendency to discard instruction[1]. These results were partially replicated in the Excel experiment, where shortening instructions significantly alleviated the tendency to ignore instructions, and increased participants' attention to detail, as well as their internalization or self-endorsement of instructions, although the latter effect was only marginally significant. Additionally, short instructions were found to be less strenuous to follow. These results are congruent with anecdotal sources testifying of the ISS crew's sense of frustration, and performance slips that occur when having to follow elaborate operating procedures for relatively simple routine tasks.

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[1] $F(1,104) = 12.46$; $p < .001$; $\eta^2 = .11$; $M = 2.34$ and 1.55, $SD = .95$ and .78, for long and short instructions, respectively. Reactance was not included as an outcome variable in the publication of Chapter 2 (Goemaere, Vansteenkiste, Beyers, & De Muynck, 2018), since the correlational pattern of reactance and other outcomes, and the effects of instruction length and task difficulty on reactance, were quasi identical to those of irritation, a closely related measure. Due to space constrains, reactance was omitted as an outcome variable.

Expertise reversal effect. Results of both experiments are reminiscent of the *expertise reversal effect* (Kalyuga, 2009; Sweller, Ayres, Kalyuga, & Chandler, 2003), a phenomenon sometimes encountered in research on Cognitive Load Theory (Swellers, 2011; Swellers, Ayres & Kalyuaga, 2011; see also van Merriënboer & Sweller 2005, for an overview). Cognitive load is defined as the demand for the working memory of a specific person to achieve goals of a particular learning task. The expertise reversal effect concerns the moderation effect of the learner's prior knowledge on the effectiveness of different instructional techniques and procedures on cognitive load. Basically, from a cognitive load perspective, there could be two major causes for unwanted cognitive load. First, in a situation where insufficient guidance is provided for a particularly challenging learning task that exceeds the available knowledge of the learner, the task could cause a cognitive load. Second, if guidance is provided to learners who have sufficient knowledge for dealing with the task, learners would have to relate and reconcile this existing knowledge with the externally provided guidance, which may possibly impose an additional cognitive load, and reduce resources available for learning. "*Presenting knowledgeable learners with detailed external guidance may hinder their learning and performance relative to the levels they could achieve with minimal instructional support*" (Kalyuga, 2007, p. 512). This expertise reversal effect has been empirically supported (see Kalyuga, 2007, for a review), for instance by McNamara, Kintsch, Songer, and Kintsch (1996). These authors reported that lengthening original instructional text in high school biology with the aim of increasing text coherence, was beneficial only for low-knowledge readers. High-knowledge readers benefitted most from using the original, minimally coherent format text rather than the enhanced text. Similarly, Kalyuga et al. (2000) found that detailed explanations of how to use a specific type of diagrams in mechanical engineering were effective for novices, but became redundant and reduced relative learning outcomes for more knowledgeable learners.

Procedural tasks. Although the experimental studies presented in Chapters 2 and 3 show some overlap with experimental research on the expertise reversal effect, they also differ in two important ways. First, research in Cognitive Load Theory and on the expertise reversal effect are mainly concerned with instructional design for learning tasks and learning outcomes. Different from the procedural tasks used in this dissertation, learning tasks consist of 1) a learning phase, in which participants gather knowledge with the help of instructions, and 2) a follow-up learning test *without* instructional guidance, to assess whether knowledge was properly acquired. In contrast, the assembly and Excel tasks consist of only procedural tasks, aimed at the execution of physical activities to be carried out on the spot, with the help of instructions, without a follow-up test. Procedural tasks therefore relate to different outcomes than a learning task. Much like putting together an IKEA chair with the accompanying instructions, learning may occur as an unintentional *by-product* of carrying out such a procedural task (learning how to put an IKEA chair together without instructions). However, learning is not considered as a primary outcome, since instructional guidance will always be available. Instead, more important outcomes are targeted, such as accuracy and productivity in the short run (Is the chair put together correctly, and how long did it take?), and psychological well-being and motivation in the long run (Is putting together IKEA chairs irritating or boring, and does one still feel like following the instructions?).

Task difficulty. Second, while the negative effects of extensive instructional guidance for simple procedural tasks are congruent with the documented expertise reversal effect for learning tasks, the latter effect is observed through a moderation effect of prior knowledge. In contrast, the negative effects of long instructions in procedural tasks reported in the LEGO experiment are mainly demonstrated through a moderation effect of task complexity, which impacts perceived task difficulty (see Chapter 2). Of course, what determines the perceived difficulty of a task is likely dependent upon a variety of task and personal characteristics, such as prior knowledge (e.g. experience; Orvis, Horn, & Belanich, 2008), task complexity (e.g., simple or complex task; Richardson, Jones, Torrance, & Baguley, 2006), and the amount of instructional guidance (e.g., number of instructional steps; Novick & Morse, 2000). For the LEGO task, moderation analyses showed no significant interactions between LEGO experience and instruction length or task complexity in the prediction of outcome variables. Presumably, this is due to the fact that, considering the relatively elementary nature of the LEGO material, mere basic skills suffice to perform successfully on the LEGO task. As such, task performance would not depend as much on expertise or prior experience with LEGO material. Instead, participants' performance would vary more as a function of task complexity, with the costs of adding instructional guidance for productivity being particularly pronounced for simple tasks. Similarly, the rise in irritation and reactance evoked by lengthening instructions, was observed only for simple tasks ($F(1,106) = 12.74$, $p < .01$; $\eta^2 = .11$, see Figure 2).

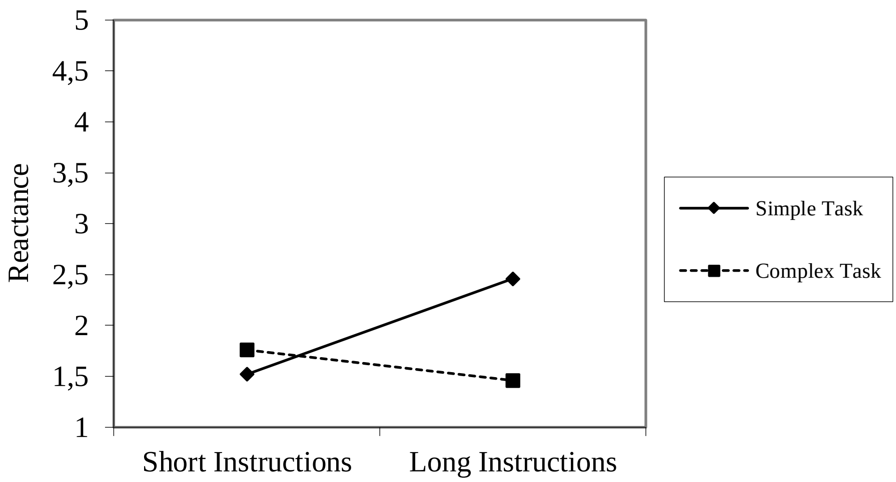

Figure 2. Significant interaction effect between task difficulty and length of instructions predicting reactance.

For the Excel study, task difficulty was not experimentally manipulated. Instead, we opted for a relatively simple Excel task ($M_{task\ difficulty}$ = 1.81, compared to $M_{task\ difficulty}$ = 1.45 and 2.47, for the simple and complex LEGO tasks, respectively). In line with the expertise reversal effect, and because of the less intuitive and user-friendly nature of the Excel software, we expected Excel knowledge and expertise to moderate the effects of type of instruction on performance. Indeed, one could easily imagine long instructions being particularly demotivating and annoying for experienced, compared to novice Excel users. However, no significant interaction effects were found between our manipulations of length, communication style or adaptability of instructions, and any of the outcome variables. In fact, rather surprisingly, Excel expertise did not significantly correlate with any of the measured variables, including performance indicators. Possibly, the lack of significant effects for Excel expertise is related to our assessment method itself, namely with three self-developed items (e.g., "*I use Excel regularly*"). Such a self-report questionnaire might not be reliable to capture actual Excel capabilities. Instead, a more objective measure, for instance by requiring participants to take an Excel test prior to the Excel task, might have resulted in a more accurate assessment.

1.1.2. The Pitfalls of Shortening Instructions

Although long instructions were found to yield a number of costs across the LEGO and EXCEL task, there was one notable exception on this pattern. In the Excel tasks, short instructions did not increase productivity, on the contrary. How can this unexpected drop in productivity be explained? Again, task difficulty plays an important part in this regard. Since instructional length was found to influence task difficulty, short instructions may have inadvertently *increased* task difficulty, thereby hindering productivity. Specifically, it is possible that participants who received short instructions had to spend more time figuring out the correct procedure to accomplish certain exercises, for instance when searching for menus and functions in the Excel software. Thus, the potential gain in time that caused productivity benefits by not having to read long instructions, may have been lost on unexpected new demands, which may both take extra time and cause unwanted cognitive load. This would correspond to the above-mentioned first type of instructional load, where insufficient guidance is provided for a particularly challenging task that exceeds the available knowledge and skills of the individual. To test this hypothesis, we measured the increase in task difficulty caused by shortening instructions for the LEGO and Excel tasks. Results indicated an increase in task difficulty of 0.12 points, on a Likert-scale of 1 to 5, for simple LEGO tasks, 0.40 for complex LEGO tasks, and 0.80 for the Excel task. Next, we merged the results of the LEGO and Excel experiments in a single dataset, and transformed actual productivity scores into relative productivity scores (a percentage score)[2]. Finally, a hierarchical regression analysis (Aiken & West, 1991; Cohen & Cohen, 1983; Jaccard & Turrisi, 2003) and the procedures proposed by Dawson (2014) and Dawson and Richter (2006), showed a significant interaction effect of increase in task difficulty and instruction length on productivity ($\beta = .29$, $p < .001$, see Figure 3). Specifically, when shortening instructions causes just a small increase in task difficulty, productivity is enhanced. However, when shortening instructions makes the task substantially more difficult, productivity is diminished.

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[2] Percentage scores were measured by dividing the productivity scores of each participant, by the highest measured productivity score for each task, i.e., 15 for the simple LEGO task, 5 for the complex LEGO task, and 9 for the Excel task.

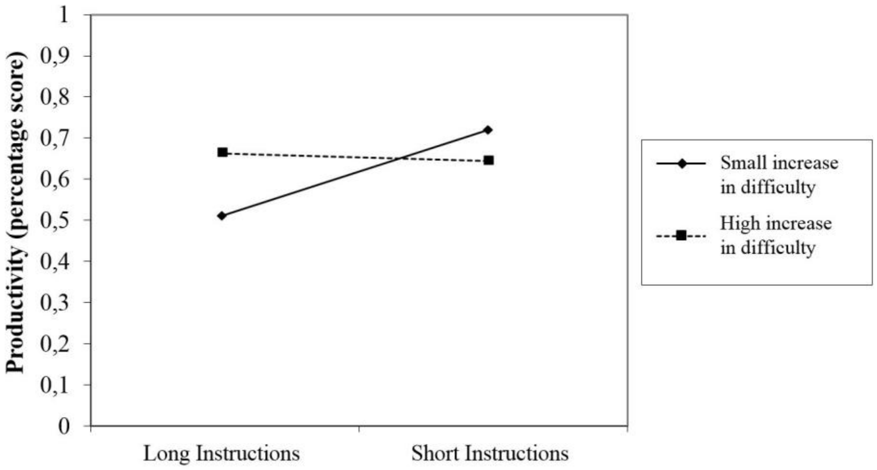

Figure 3. Significant interaction effect between the increase in task difficulty due to shortening instructions, and length of instructions, predicting productivity.

To conclude, while evidence supports shortening instructions for simple tasks as an effective strategy to enhance motivation, to alleviate negative affect, and to improve accuracy, careful consideration is needed to tailor instructions in such a way as to find the optimal dose of instructions to generate motivational and performance benefits.

1.2 A Need-supportive Communication Style

1.2.1 The Effectiveness of a Need-supportive Message

Findings. While shortening instructions might in some cases result in performance deficits, no adverse effects were observed when long instructions were provided in a need-supportive communication style (research goal 2). The need-supportive measure preceding the Excel task turned out successful in relieving a sense of pressure, which in turn enhanced internalization of instructions and diminished task boredom (Figure 1). In addition, when using this style, feelings of irritation and the tendency to rebel against the instructions did not emerge. Interestingly, a need-supportive message did not diminish the strain required to follow instructions attentively, meaning that, although it remained equally hard to concentrate on following instructions, long instructions accompanied by a need-supportive message did not elicit the same experience of frustration and demotivation as long instructions without a need-supportive message. Additionally, while this communication style did not significantly foster performance, the SEM analysis indicated a small, marginally significant increase in attention to detail. Presumably, making participants attentive to the usefulness of instructions might indeed have slightly motivated them to read instructions more carefully. Overall, these results add to the already existing research on the effectiveness of a need-supportive communication style, in particular the beneficial impact of showing empathy (e.g., Deci, Eghrari, Patrick, & Leone, 1994), providing a meaningful rationale for a particular request (e.g., Vansteenkiste, Aelterman, De Muynck, Haerens, Patall, & Reeve, 2018) and augmenting the personal relevance of a task by explaining how the task related to personal values and interests (e.g., Savard, Joussemet, Pelletier, & Mageau, 2013). They are also consistent with qualitative research with astronauts and other space experts, conducted to uncover the issues of frustration and boredom arising from not finding daily activities meaningful. Several entrees into astronaut journals illustrate this point (Stuster, 2010, p. 11):

"I had to laugh to myself at the procedures today. To replace a light bulb, I had to have safety glasses and a vacuum cleaner handy. This was in case the bulb broke. However, the actual bulb is encased in a plastic enclosure, so even if the glass bulb did break, the shards would be completely contained. Also, I had to take a photo of the installed bulb, before turning it on. Why? I have no idea! It's just the way NASA does things."

"Busy work also causes me to miss home more. I think I feel less of a sense of purpose if I don't believe in the tasks that I am doing. Of course, I will continue to do them and to press on. But, it does make the days go longer."

"Yesterday was painful - trash gathering. Theoretically, this should not hurt, but when they want the trash items listed off by serial number it can get a bit ridiculous."

Alternatively, many entrees in astronaut journal express genuine pleasure and gratification when accomplishing meaningful tasks (Stuster, 2010, p. 12):

"*It is also great to be getting some real science done... There have been several problems along the way toward getting this experiment operational, so it is wonderful to be getting results now*."

"*Another great day on orbit! Conducted some very interesting experiments this afternoon…"*

In interviews with space experts, Britt, Jennings, Goguen, and Sytine (2016) uncovered that crew members found their work most meaningful when they contributed to humanity, the mission and space exploration, and when they overcame challenges and used their skills and abilities. When asked about the characteristics of tasks that contributed to meaningful work, the most frequent responses were the tasks using a variety of skills, not being monotonous, feeling personal control over their schedule and autonomy in the execution of tasks, and understanding the importance of the experiments that were conducted. Concerning the factors that decreased engagement in meaningful work, the experts indicated having to do tasks with no explanation of why, not understanding the purpose of a task or experiment, and a lack of communication regarding the experiments. They also pointed towards misperceptions between the crew and the ground, and a decrease in novelty and time away from family, wondering whether the time away from family was justified by the increasingly monotonous tasks being performed. Others noted that engaging in tasks or experiments that contributed to the mission or general exploration goals was meaningful to them, particularly when they could contribute through tasks they were personally interested in or knowledgeable about. Although these findings have never been experimentally tested in an astronautical setting, results from the laboratory study in Chapter 3 suggest that manipulating personal relevance and task rationale could indeed be effective to enhance crew motivation and well-being.

Ecological validity. Aside from the experimental study of Chapter 3, a need-supportive communication style was also examined in a more ecologically valid setting, namely the HI-SEAS Mars simulations. Results of the diary studies conducted during HI-SEAS I (Chapter 4) and IV (Chapter 5) show that weekly variations in the way the HI-SEAS crews perceived Mission Support members as being more autonomy-supportive or controlling, related significantly to weekly variations in their experience of need satisfaction. That is, during the weeks the HI-SEAS I crew saw Mission Support members as being more autonomy-supportive, rather than controlling, they also experience a greater sense of volition and personal freedom during that same week. Similarly, when the HI-SEAS IV crew found Mission Support members to be more autonomy-supportive, for instance by listening to crew members' opinion, or by trying to understand how crew members would like to fulfil their duties, the crew's sense of autonomy, and even relatedness with fellow crew members, increased. Qualitative data from HI-SEAS IV also revealed the particular appreciation of the crew for Mission Support members who simply inquired how they were doing, something that has also been observed in other astronaut journals (Stuster, 2010, p. 16):

"*I appreciate the good will expressed by [NASA senior managers] giving their time [making a social call to see how we are doing]. The content of the calls is not the point.*"

In contrast, when crewmembers found Mission Support to communicate in a more controlling way, for instance by pressuring them to live up to their expectations, crew members felt less competent, and they may even have experienced less volition (a marginally significant association). Although Mission Support members are extensively trained to communicate in a kind, polite, and efficient manner, they too can become tired and stressed-out (e.g., Suedfeld, 2005), which can sometimes translate into a more controlling attitude towards the crew (Stuster, 2010, p. 15):

"*The ground seems to treat almost every request we make a little defensively, as if a crew request implies irritation or dissatisfaction. I will need to work on that.*"

In the diary study of HI-SEAS IV, we found no complaints of the ground being particularly controlling. Instead, qualitative date indicated that frustration with Mission Support members usually arose when they were being non-responsive, or generally absent.

Moreover, a need-supportive communication style from Mission Support also predicted increased relatedness among crew members. Although it might come as a surprise that an autonomy-supportive attitude from Mission Support would also be associated with more relatedness among crew members, from a Self-Determination Theory perspective, this finding is not necessarily unexpected. In fact, managerial autonomy-support has been found to relate to experiences of autonomy, competence, and even relatedness with co-workers in previous studies (e.g., Baard, Deci, & Ryan, 2004). Of course, whether managerial autonomy-support creates work circumstances that facilitate a sense of belonging among co-workers, or whether employees who feel closely connected to colleagues tend to perceive management as more autonomy-supportive, remains to be seen, as the direction of this association cannot be determined due to the correlational nature of the data.

Generally speaking, the findings of HI-SEAS I and IV are very encouraging, since they suggest that in-flight support through a need-supportive attitude from Mission Support can be successful in enhancing the crew's need satisfaction, even when contact is relatively restricted. Given the current psychological hassles and stressors of spaceflight, and the predicted and unforeseeable challenges of future interplanetary travel, astronauts need all the help they can get.

1.2.2 The Pitfalls of a Need-supportive Communication Style

When trying to be autonomy-supportive in particular, and need-supportive in general, in one's communication towards others, careful consideration is needed to make sure that the message is indeed perceived as truly need-supportive. This point was perfectly illustrated by the results of a pilot study we conducted in an attempt to develop a successful need-supportive message that could accompany the long instructions in Chapter 3.

Pilot study. Specifically, we provided participants (N = 32) with long instructions for a simple assembly task, but this time, we incorporated need-supportive strategies proven effective in previous studies, namely 1) taking someone's perspective and showing empathy (e.g., Deci et al., 1994) and 2) offering a meaningful rationale (e.g., Mageau & Vallerand, 2003). In particular, before the task, an experimenter engaged in the following script with the participants:

"*You'll see that the task instructions can be rather extensive. They will show you step-by-step where to put which brick. We've noticed that some participants can find this a bit tedious or annoying, and that it isn't always very pleasant to keep following instruction attentively* (perspective taking and empathic response). *However, we have noticed from previous studies that these step-by-step instructions can be useful. Participants who follow them attentively, have a tendency to be more precise and make less mistake* (meaningful rationale). *We would therefore like to ask you to try and follow these instructions as best you can.*"

Afterwards, participants got started on the actual assembly task with long instructions. The experimenter did not engage in the above-mentioned script with participants in the control group. Again, results were unexpected, and rather disappointing, with no significant differences between participants in terms of competence, motivation, affect or performance. There was, however, a marginally significant difference in volition, with participants in the supposedly need-supportive condition experiencing *less* volition than the control group[3]. Several reasons can be put forward for the ineffectiveness, or possibly even controlling impact of this intervention.

First, it is possible that the wording used in the description of long instructions unintentionally influenced participants' attitude towards those instructions, and by extension the task itself. For instance, several experiments conducted by Kurdi and Banaji (2017) to investigate the effects of evaluative statements, indicated that negative statements about unpleasant stimuli aggravated the negative implicit attitudes towards those stimuli. In this particular pilot study, in an effort to sound empathic and take participants' perspective, we indeed used negative statements to characterize the instructions, calling them *tedious*, *annoying* and *unpleasant*.

Second, aside from wording, one could also question the empathic quality of the message itself. After all, its underlying tone could easily come across as more judging ("*You will probably want to skip instructions*"), possibly even threatening ("*You better not make any mistakes*"). In SDT research, several

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[3] $F(1,63) = 3.49$; $p = .07$; $\eta^2 = .05$, with $M = 2.81$ and 3.16, $SD = .73$ and $.78$, for the need-supportive and control condition, respectively.

studies have convincingly demonstrated the adverse effects of controlling language (e.g., Hooyman, Wullf, & Lawthwaite, 2014; Reeve & Tseng, 2010; Vansteenkiste, Simons, Lens, Soenens, & Matos, 2005).

Additionally, the timing of the message was possibly quite awkward, since participants hadn't even started the task yet, and hadn't yet gotten the opportunity to get acquainted with the instructions, and their demotivating effects.

Finally, the *personal relevance* of the message needs to be highlighted, since the presumed need-supportive measures are likely ineffective in situations that lack any meaning or merit for the individual. The provided rationale ("*You will perform better on the task if you follow instructions*") itself might not be meaningful for participants, who probably don't see the added value of performing well on this particular assembly task. That is, for a rationale to foster the process of internalization, the provided explanation needs to be *personally relevant.* The personal relevance of a task can be highlighted if it is made clear how the instructions or task are congruent with individuals personal values, preferences, and interests (Vansteenkiste et al., 2018). Along similar lines, also from an Expectancy-Value Theory perspective, the notion of *utility value* denotes the subjective belief that engaging in an activity will be useful for achieving a short- or long-term outcome (Eccles & Wigfield, 2002). Several experimental studies in this theoretical tradition indicated that the experimental enhancement of the utility value of a task promotes greater commitment and better performance, provided that the personal usefulness of the task is highlighted (e.g., Harackiewicz, Cannings, Tibbetts, Priniski, & Hyde, 2016; Hulleman, Godes, Hendricks, & Harackiewicz, 2010).

Taking these concerns into consideration, the need-supportive message tested in Chapter 3 was adapted accordingly, with the following changes:

(1) Timing: students participated in a trial version of the Excel task, to first get a sense of the instructions by themselves. Only afterwards did

the experimenter intervene with a need-supportive message. By first experimenting with the task themselves, the conveyed message may come across as less evaluative and steering.

(2) Empathy: after a trial period, the experimenter inquired about participants' initial opinion with regards to instructions, before introducing the rationale:

"*Now that you've gotten a first taste of the Excel task, I would just quickly like to ask you a question. What did you think of these instructions?"*

(3) Wording: instructions were positively (instead of negatively) framed, and their benefits were described in comparison to short instructions.

"We've also noticed that these longer instructions have their benefits. For instance, when you give people shorter instructions, they have a tendency to go through them rather quickly, and as a consequence, they overlook some details and have to retrace their steps. However, when people are given more elaborate instructions, they often work more precisely and accurately from the start, which also makes them faster."

(4) Relevance: the personal relevance of the task was experimentally manipulated by explaining how the task, and knowledge regarding one's performance, could be personally relevant in the future, with the promise of personal feedback.

"Now, there are many factors that can influence performance on the Excel task, aside from computer skills. For instance, some people perform better because they have stronger visual capacities, others

> *because they pay more attention to detail or show more determination. But also aspects like task enjoyment or motivation can play a part. We want to study all these factors, and in that sense, this study could also be of use to you. By the end of the task, we'll be able to give you feedback on which factors exactly influenced your performance. This could be useful for you in the future, for instance when you need to use Excel or when you need to learn new computer software."*

As it turns out in Chapter 3, these seemingly small differences in timing and wording can have big repercussions.

Calibration. A final note concerns a specific aspect of motivating individuals for simple tasks through a need-supportive communication style, as presented in Chapter 3. Specifically, we believe it is unlikely that a one-time need-supportive message would continue to enhance or sustain motivation and well-being for longer lasting tasks. As with the user control instructions, where the need-satisfying driver, i.e. choice provision, is continually present throughout the task, a repeated driver would likewise have to be present for the need-supportive message to remain efficient. While being genuinely empathic towards people, and actively inquiring about their well-being and opinion is surely appreciated in most situations, it is doubtful that being repeatedly provided with information on the usefulness of instructions and personal task relevance for the same routine tasks would be anything less than innerving in the long run. Moreover, there are wide individual differences in people's values and interests, and some space experts have warned for the varying interests and preferences of astronauts with regards to what they find meaningful (Britt et al., 2016).

Overall, these results underscore the need to carefully calibrate a presumably need-supportive message to individuals' personal preferences and to particular tasks, for such a message to be perceived as truly need-supportive.

1.3 Choice Provision

1.3.1 The Effectiveness of User Control Instructions

Findings. From the three countermeasures tested in Chapter 3 (research goal 2), the implementation of choice through user control instructions turned out the most successful in enhancing motivational and affective outcomes. In fact, participants who were given the repeated option to choose between short or long instructions, benefitted from this intervention on *all* motivational and affective outcomes (Figure 1). By the end of the task, the reasons to follow instructions were more internalized, participants were less likely to discard instructions, they experienced less irritation and less boredom, and found following instructions less strenuous. Moreover, they were able to pay more attention to detail and made less mistakes, while being equally productive.

While space agencies seem generally somewhat reluctant to grant astronauts more independence, these results suggest that a little freedom to chose, such as being able to opt for different doses of instructions, can have a significant impact on well-being and performance. Similar findings were reported by other space researchers (Kanas et al., 2011; Roma et al., 2011), and these results were also expected from a Self-Determination Theory perspective, since several studies found action choices to be advantageous for motivation, affect, and performance (e.g., Legault and Inzlicht, 2013; Patall and colleagues, 2010, Patall et al., 2014), especially when they are provided repeatedly (Patall et al., 2008).

Repeated choices. Analysis of clicking behavior of participants in the user control condition indicates that, on average, participants were provided 42 times with the option to receive long instructions, and they chose this option in 9% of the cases (M = 4.26, SD = 3.18). Only three participants stuck with the short instructions, without opting for more information. The maximum number of clicks for longer instructions was 11 times, by one participant. Although previous studies have found the optimal amount of repeated or serial choice opportunities to range between two and four (Patall et al., 2008), this amount was largely exceeded in the Excel experiment. One can wonder why these many sequential choice opportunities weren't perceived as more difficult or energy depleting (e.g., Mozgalina, 2015). One potential explanation has to do with the fact that, in the majority of cases, participants didn't *actively* have to choose between short or long instructions. Clearly, participants found short instructions sufficiently informative for most of the Excel exercises. And since short instructions were presented by default, participants weren't actually required to make a choice between these two options. Instead, only when the short instructions didn't suffice, did they have to make an active choice, which, on average, was four times. The effects of sequential choice making could have been different in case both the short and long instructions had been provided simultaneously, with participants first having to indicate which option they prefer in every single step. Because participants would then need to repeatedly indicate their preference, the act of choosing itself could be experienced as more energy-depleting, possibly attenuating some of the benefits observed for choice herein.

Complex Tasks. Continuing this reasoning, one could also wonder what the effect would be of implementing this type of user control for complex tasks. If task complexity or chooser's capabilities are such that the task becomes very difficult, one might not necessarily benefit from being presented with short instructions by default, since one would likely have to choose long instructions in most of the cases. This would require a great amount of actively choosing, which could be experienced as exhausting, with potentially disastrous consequences for well-being and performance. This idea is somewhat supported in a study by De Bruyne et al. (2018), who found that, when students were required to click on additional information to understand a difficult text, learning was impeded. In such situations, choosers might benefit more from being presented with long instructions by default, or would benefit more from another type of choice (e.g., choosing when to receive feedback; Hummel, Paas, & Koper, 2006) or another type of adaptive instructions, (e.g., just-in-time information, where additional instructions are automatically shown precisely, and only, when they are needed during task performance; van Merriënboer, Kirschner, & Kester, 2003).

1.3.2. The Pitfalls of Choice Provision

Similar to the implementation of a need-supportive communication style, it's dangerous tot assume that any form of choice provision would automatically be equally successful in every situation. Again, this was illustrated by the results of a pilot experiment conducted in preparation of the Excel experiment.

Pilot Study. For this pilot study, we asked psychology students (N = 31) to partake in a simple 40 minutes assembly task, and gave them a choice in instruction length. After a short try-out period with both short and long instructions, participants could choose to continue using either long or short instructions for the remainder of the task (i.e., a one-time action choice). In the control groups, participants were simply assigned to a condition with either short or long instructions, without the possibility to chose, and without being aware of the other option. Results indicated that, rather unsurprisingly, the majority of participants in the choice condition (81%) opted for the short instructions. However, contrary to our expectations, choice provision did not benefit any of the measured outcomes. Multivariate tests (Wilks' Lambda) revealed no significant effects of choice between participants who opted for short instructions, compared to a control group ($F(8,50) = 0.67$; $p = .72$; $\eta^2 = .01$). Specifically, participants who chose short instructions did not differ significantly from to participants who were simply given short instructions, with regards to need satisfaction, motivation, affect or performance. Moreover, evidence suggests that the few participants who opted for long instructions, might have actually suffered from this choice ($F(8,31) = 3.11$; $p = .01$; $\eta^2 = .45$). Participants who picked long instructions showed significantly less identification with instructions ($F(1,38) = 5.49$; $p < .05$; $\eta^2 =$

.13; *M* = 3.12 and 3.54, *SD* = .53) than participants in a control group who were simply provided with long instructions.

Regret. How can such unexpected results be understood? Let us first take a look at the few participants who chose long instructions. A binary logistic regression analysis indicated that those participants were significantly more field dependent than participants who opted for short instructions ($\beta = -.88$, $p < .05$). Field dependence is a cognitive style first introduced by Witkin (1962). In general, people who exhibit field dependence tend to rely on information provided by the background, the field or frame of a situation. As such, for individuals high in field dependence, instructional information segmented over several frames is often less overwhelming than having the same amount of information presented in one single frame. We therefore anticipated that participants high in field dependence would be more likely to choose long instructions, which was indeed the case. However, given the low complexity nature of the assembly task, those participants might have come to *regret* their initial choice after some time. With increased task duration, they might have realized that short instructions would have been amply sufficient for successful task completion. But since participants were offered just a one-time choice opportunity at the beginning of the task, without the possibility to change their minds, they had to continue using the long instructions during the remainder of the assembly task. In contrast, participants who were never given the option to choose between long or short instructions, simply performed the task as instructed, without the possibility to experience regret.

Contrast. Yet, such a sense of regret would likely not explain the ineffectiveness of choice provision for participants following short instructions. To better grasp the effects of choice provision, it’s important to understand the circumstances in which choice becomes meaningful. For an objectively offered choice to be truly advantageous, it needs to translate into the subjective perception of volition and psychological freedom, which may be dependent upon the type of choice being offered (see De Muynck et al., 2018, for a review). For instance, researchers have found two to four consecutive choices to be optimally motivating (Patall, Steingut, Vasquez, Trimble, Pituch, & Freeman, 2018), ideally between three to five alternatives (Patall et al., 2008), an amount neither too restricted, nor too overwhelming (e.g., Botti & Iyengar, 2006) or too energy-depleting (e.g., Vohs et al., 2008). Further, action choices (i.e. choosing how to perform a task; e.g., Mouratidis, Vansteenkiste, Sideris, & Lens, 2011; Jang, Reeve, & Halusic, 2016) are generally more successful in enhancing volition and engagement than option choices. Finally, another crucial choice characteristic concerns the *contrast*, i.e. the difference in attractiveness, between the offered options. For instance, when choosers need to pick a dish from a menu of equally attractive (Luce, 1998) or unattractive meals (Higgins, 1998), thereby choosing between low-contrast choices, decision-making becomes more difficult. In case of a high contrast between options, the act of choosing will likely be less complicated, but potentially also less *meaningful*. If one option is substantially more attractive than the other, the choice might not actually be experienced as a *true* choice, i.e., a choice that is personally relevant (Vansteenkiste, Aelterman, De Muynck, Haerens, & Reeve, 2018) and entails opportunities for self-realization (e.g., Katz & Assor, 2007). In this particular pilot study, we believe that the high contrast between the offered options, namely the long instructions and the clearly more appealing short instructions, didn't translate into an actual experience of choice. This potential explanation is supported by the overall low mean scores for perceived choice, which differed only marginally between choosers and non-choosers ($F(1,47) = 3.44$; $p = .07$; $\eta^2 = .06$; $M = 2.51$ and 2.11, $SD = .91$ and .74, respectively).

The choice provision implemented in the Excel experiment presented in Chapter 3 takes into account these concerns, by providing repeated action choices, between options of a more moderate contrast. To sum up, results of these pilot studies again point towards the crucial task of carefully tailoring presumed need-supportive interventions to characteristics of participants, task, and the situation at hand (see Vansteenkiste, Aelterman, Haerens, & Soenens, 2018, for a review).

1.4 Need Satisfaction in the Astronautical Work Place

Experimental findings. While need satisfaction from a Self-Determination Theory Perspective has been extensively researched in a variety of life domains, it had never before been studied in the context of human space exploration, or in the context of instructional design for procedural tasks. The experimental study presented in Chapter 3 investigated the effects of shortening instructions, providing instructions with a need-supportive message, or implementing user control, on experiences of competence and autonomy. A need-supportive message was effective in enhancing a sense of volition when carrying out the Excel task, while user control instructions enhanced feelings of both competence and volition. In fact, mediation analyses indicated that increased need satisfaction could explain the majority of significant effects of need-supportive and adaptive instructions. The week-to-week studies conducted during the final eight weeks of the HI-SEAS I mission (Chapter 4), and the yearlong HI-SEAS IV mission (Chapter 5), further underscore the ecological validity of the lab-based findings as they confirm the significance of need satisfaction, and an autonomy-supportive attitude towards astronauts (research goal 3).

Autonomy. When crew members experienced more volition or psychological freedom in performing daily activities, they simultaneously reported enhanced motivation, better collaboration with Mission Support, more positive affect and less negative affect. From a Self-Determination Theory perspective, these results are not surprising, since many diary studies have uncovered the importance of autonomy satisfaction in other domains. However, to this point, it hadn’t been confirmed for human spaceflight. Despite the extraordinariness of being in outer space, the actual work circumstances of astronauts can be quite restrictive, and several studies have demonstrated the importance of autonomy satisfaction, particularly in more restrictive environments, such as nursing homes (e.g., Kasser & Ryan, 1999) or prisons (e.g., van der Kaap-Deeder, 2017).

Relatedness. Interestingly, relatedness with crew members turned out to have the most and strongest associations with crew well-being and functioning. Crew members reported more self-endorsed motivation, reported feeling more happy, irritation- and stress-free, and they performed and collaborated better with the ground, during weeks when they also experienced a greater sense of belonging and connection with fellow crew members. The central role of crew relatedness is concordant with other studies on need satisfaction within groups, which, for instance, found interpersonal relatedness to be more predictive of positive affect and commitment than personal autonomy (e.g., Sheldon & Bettencourt, 2002). In comparison, relatedness with friends and family at home was only significantly associated with less stress. Several explanations can be put forward for the more limited contribution of relatedness with loved-ones. First, due to the delay of 20 minutes, direct communication like phone conversations or video chats with home were no longer feasible. In contrast, crew members spent a substantial amount of time directly interacting in close proximity with their colleagues, with whom they lived, and often worked together. Second, qualitative data from HI-SEAS IV also revealed some conflicts among crew members, which could have caused in-crew relatedness satisfaction and frustration to take a more prominent place within every day life, thus having a greater impact on fluctuations in crew well-being and performance.

Competence. Contrary to our expectations, the contribution of competence satisfaction was more limited, as it was significantly related to variations in self-endorsed motivation and reactance only. The lack of significant associations with other outcomes is unexpected. Yet, upon further reflection, these null-findings could possibly be due to the particular operationalization of competence in the diary study. Specifically, competence was measured with the Basic Psychological Need Satisfaction Scale (Aelterman et al., 2018; Deci & Ryan, 2000; Gagné, 2003). This more traditional operationalization of competence focusses exclusively on the experience of confidence and self-efficacy in carrying out certain activities, with items such as "*I felt capable to achieve my goals*" and "*I had serious doubts whether I did things right or not.*" Of course, a high workload and tight scheduling are common stressors on the work floor, and they can easily result in task difficulty being misaligned (i.e. too high) with astronaut capacities and resources, thereby eliciting feelings of incompetence (see Stuster, 2010, 2016). However, given the high abilities of astronauts, their extensive training, and the detailed procedural instructions, crew members are also likely to experience competence frustration when task requirements are too low in comparison to their skills and expertise level. As previously mentioned, this problem can be exacerbated when crew members no longer find their duties meaningful. If the competence measure had tapped more into aspects of crew members' experience of being insignificantly challenged, being unable to use, demonstrate, or extend one's skills, this could have resulted in stronger findings for the HI-SEAS IV study. Such a new assessment of competence was introduced in the Excel experiment. In particular, the need for competence was measured with items addressing the experience of challenge and skill utilization, with such items like "*I found the Excel task challenging*" and "*After the task I felt more confident about my Excel skills*". Although the HI-SEAS studies and the Excel experiment differed in many ways, this competence measure showed greater predictive validity for the experience of self-endorsed motivation and the avoidance of negative affect.

This underexposed facet of the need for competence, reflecting a desire to experience challenge, and use or even develop skills and talents, is somewhat reflected in a newly proposed psychological need. Recently, authors considered the existence of a so-called *need for novelty*, aside from the three traditional psychological needs within SDT (González-Cutre, Sicilia, Sierra, Ferriz, & Hagger, 2016). This need for novelty is defined as the need to experience something that was not previously experienced or that deviates from everyday routine (González-Cutre, Sicilia, Sierra, Ferriz, & Hagger, 2016). Such experiences can be familiar, but not overly repetitive or routine (Bagheri & Milyavskaya, 2018). The authors argue that, while this need is surely related to the traditional needs for competence and autonomy, it seems a source of motivation on its own. In fact, they believe that, even when people in the workplace feel related to colleagues, psychologically free, and confident in their capabilities, if they do not seek out novel activities, they will likely experience boredom and maladaptive outcomes like low self-worth, negative affect, low life satisfaction and psychological well-being. Preliminary research provides some empirical support for the need for novelty co-existing alongside the needs for competence, autonomy and relatedness, and that novelty satisfaction uniquely relates to self-endorsed motivation and well-being (González-Cutre, Romero-Elias, Jiménez-Loaisa, Beltrán-Carrillo, Hagger, 2018), while frustration relates to boredom and ill-being (Bagheri & Milyavskaya, 2018; González-Cutre et al., 2018). The newly developed items to asses need for novelty proposed in the above-mentioned research do not completely overlap with the operationalization of competence used in this study, which tapped into feeling challenged, and feeling one is actively using and developing skills. Instead, one could assume a sense of challenge and a sense of satisfaction from skill development, to be a direct consequence of seeking out and engaging in new activities, as defined by the need for novelty. Novelty would therefore not necessarily be considered as a basic psychological need, but rather as a favourable condition to experience challenge and to use or enhance one's capabilities.

Finally, the results of HI-SEAS IV revealed that, while their sense of effectiveness remained stable, crew members experienced less and less relatedness and autonomy over the course of their yearlong mission. These results are crucial to keep in mind, as they highlight the risk of growing need frustration for future Mars crews, and therefore the necessity for more and repeated need-supportive interventions.

To sum up, the findings from this dissertation clearly underscore the merits of need satisfaction for the crew, particularly a sense of autonomy and relatedness with crew members, as defined by Self-Determination Theory.

Evidence also supports the value of operationalizing competence as a sense of challenge and accomplishment, instead of control and mastery.

1.5 The Moderating Role of Need for Achievement

Astronauts have been described as action-oriented individuals who have a high achievement motivation, characterized by actively seeking involvement in challenging tasks and enjoying the process of mastering these challenges. (Baumann & Scheffer, 2010; Brcic, 2010; Maschke, Oubaid, & Pecena, 2011). Previous research has indicated that the provision of challenge and meaningful work is particularly important for individuals high in need for achievement (Enseger & Rheinberg, 2008; Baumann & Scheffer, 2010, 2011). Astronauts who are involved in meaningful work will not only be less likely to experience negative outcomes associated with the demands of spaceflight (e.g. boredom, performance errors; Britt et al., 2016, p. 2), but will also experience positive consequences from successfully mastering the challenges in executing mission-relevant tasks under difficult operational conditions, as reported in previous studies (e.g., Ritsher, Kanas, Ihle, & Saylor, 2007; Suedfeld & Brcic, 2011). As part of our first research goal, we therefore expected achievement motivation to moderate the effects of instructional length on well-being and performance. In Chapter 2, we could not find evidence for the negative effects of long instructions being more pronounced for participants high in need for achievement. However, we did find that those participants particularly benefitted from shortening instructions, since shortening instructions diminished irritation even more for participants with a high achievement motivation. A similar pattern of findings was observed in the Excel experiment (see Figure 4), although the moderation effect was only marginally significant ($\beta = .24$, $p = .07$).[4]

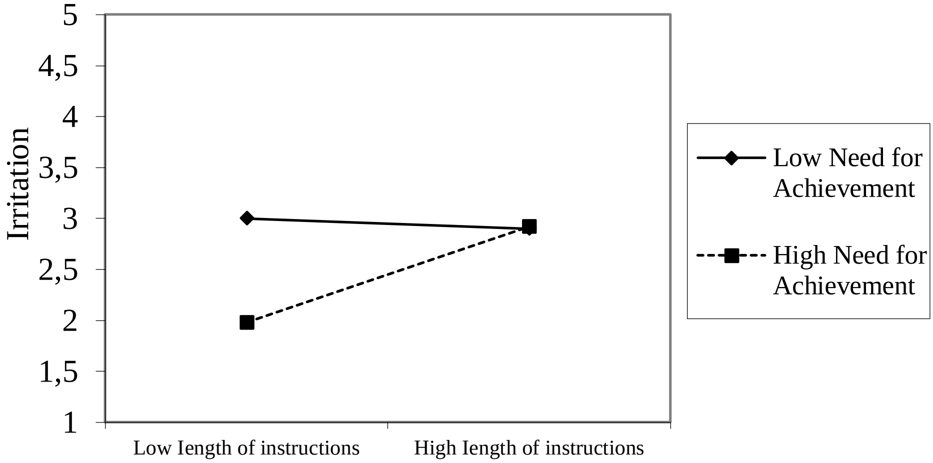

Figure 4. Marginally significant interaction effect between need for achievement and length of instructions predicting irritation with instructions.

Presumably, individuals high, compared to low, in need for achievement, benefit even more from shortening instructions, because reduced instructional guidance increases task difficulty.

A similar interaction effect for accuracy was found when providing user control instructions, with the advantages of user control instructions for attention to detail being more pronounced for participants high in need for achievement (see Figure 5).

[4] Results of moderation analyses for achievement motivation were not included in the publication of Chapter 3 (Goemaere, Vansteenkiste, & Beyers, 2018), due to space limitations.

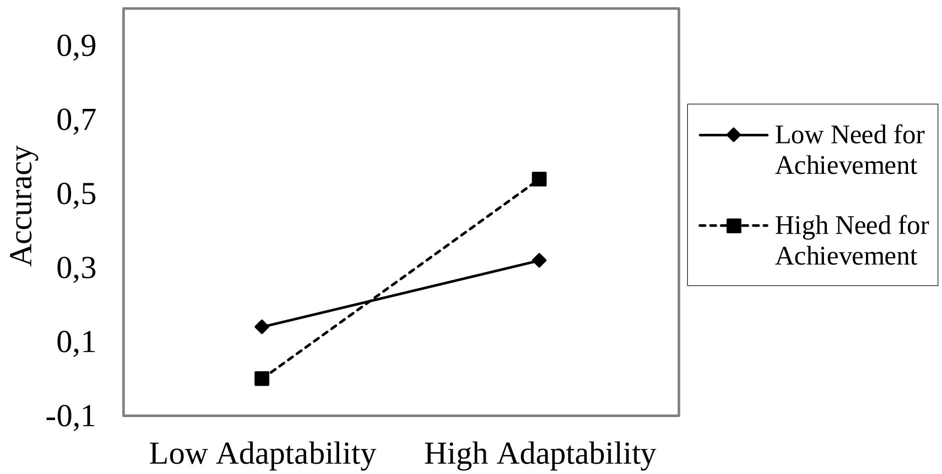

Figure 5. Significant interaction effect between need for achievement and the provision of user contrrol instructions predicting accuracy.

To sum up, while we couldn't find evidence for the negative effects of long instructions being particularly notable for individuals high in need for achievement, we did find some evidence that those individuals might gain even more from short or user control instructions. These results are important, since they imply that astronauts might thrive even more under conditions of lessened instructional guidance and more opportunities to choose how to perform their duties.

2. Limitations and Directions for Future Research

While the results of this dissertation are encouraging, there are reasons to be cautious when interpreting the findings, as the presented studies are subject to a number of limitations.

Measures. First, all but the objective performance indicators in Chapters 2 and 3, and the commander-rated performance and well-being measures in Chapters 4 and 5, are self-report measures. Commander ratings were introduced to limit the burden put upon other crew members, by restricting the length of weekly questionnaires. Also, in-depth interviews with the HI-SEAS I commander convinced us of the high probability that the crew commander would be particularly attentive to his or her fellow crew members' well-being and performance. However, while such third-person ratings have the benefit of reducing the effects of social desirability and shared method variance typical of self-reports, they also remain somewhat limited in their ability to reliably assess more subjective outcomes, such as stress and happiness.

In the future, more objective behavioral and physiological measures could be used to assess a variety of adaptive psychological and biological outcomes in space research. For instance, higher need satisfaction has been shown to relate to less elevated peaks in cortisol secretion (Quested, Bosch, Burns, Cumming, Ntoumanis, & Duda, 2001), while control and pressure were found to relate to higher levels in cortisol secretion (Reeve & Tseng, 2011). Roma et al. (2011) for instance, found salivary cortisol to be reduced when crew members were granted more independence during a simulated planetary geological exploration task. Other physiological measures include heart rate variability (HRV; Berntson, 1997), and galvanic skin conductance (GSR; Katkin, 1965), which was found to increase in response to a controlling tone of voice (Paulmann, Zougkou, Weinstein, 2018). Future studies could also include more behavioural measures, such as free choice persistence (e.g., Deci, Koestner, & Ryan, 1999), an assessment technique where self-endorsed motivation is reflective of the degree to which participants return to and persist in a particular activity after an experimental phase (Deci, 1971). Finally, Mission Support members could have been more actively included in the HI-SEAS studies, for instance by gathering ratings from Mission Support members themselves with regards to crew-ground communication and collaboration.

Generalizability. A second important limitation of the dissertation concerns the generalizability of the findings. Unfortunately, data collection from actual astronauts is extremely hard to come by, and crews from simulation or analogue studies tend to be really small (e.g., NEEMO, $N = 4$, Kanas et al., 2011; geological exploration, $N = 9$, Roma et al., 2011; MARS 500, $N = 6$; Tafforin, 2013). It is therefore difficult to conduct research with a large enough sample of participants for sufficient statistical power that is also representative of the astronaut population. While the samples of psychology students in Chapters 2 and 3 allowed us to conduct strong experimental research, they likely differed greatly from astronauts on a variety of individual characteristics such as age, personality, multiculturalism, capabilities, educational background, and training, which limits the generalizability of our findings. Fortunately, we also had the opportunity to test our findings with a more representative sample of participants in Chapters 4 and 5. However, while selection procedures where such that HI-SEAS crew members had a similar mix of experience and backgrounds as real NASA astronauts, differences remain inevitable, particularly in terms of prior training.

Ecological validity. A final important limitation of this dissertation involves the ecological validity of the presented studies. While the manipulated task characteristics of task difficulty and instruction length were conducted in accordance with the anecdotal sources from astronauts and space experts, the overall laboratory setting was not altered to simulate an astronautical work floor. We specifically chose a rather generic assembly task, since astronauts have to assemble and manipulate a lot of hardware on the ISS. However, it is likely that participants found the use of LEGO material rather enjoyable, which could have limited the findings of our study. Additionally, task duration was very short, ranging from 25 minutes for the LEGO tasks to 40 minutes for the Excel tasks. In all likelihood, effects would have been more pronounced with longer tasks, or participants having to repeat similar tasks for several consecutive days. While the HI-SEAS simulations were a far more ecologically valid setting than the laboratory settings in Chapters 2 and 3, the analogy with an actual space mission is not perfect. It is true that ground-based simulations offer many advantages compared to space studies: they are cheaper, safer, less complicated, and variables can be more easily controlled. But even when simulations are successful in replicating the organizational and functional possibilities and constraints of a space mission (Manzey, 2004), the extent to which extrapolation from such studies to space capsules might be valid, remains heavily debated. For instance, Earth-based simulations cannot reproduce all of the stressors found in space, such as microgravity, increased radiation and potential danger without little hope of rescue (Kanas, 1998). The actual experience that corresponds to a situation of potential danger beyond the point-of-no-return is something that simply cannot be duplicated in a simulation study. No research ethics board would approve a confinement experiment that was conducted under the rule "*Once you're in, you cannot get out until the study is finished*" (Suedfeld, 2010). This was demonstrated recently with the evacuation of a HI-SEAS VI crew member who needed to be rushed to the hospital after suffering an electric shock. Alternatively, space simulations also fail to reproduce the more exciting experiences of space missions, such as the thrill of actually being in space, the feeling of floating, and the views of Earth. Since these positive experiences are also more limited, they cannot buffer against other psychological stressors.

Now that correlational and experimental (albeit in a laboratory setting) evidence has been found to support the significance of a need-nurturing communication style and choice provision for crew members, future studies should look into the experimental manipulation of Mission Support's interactions with the crew. For instance, weeks of more autonomy-support, where Mission Support allow crew members to express negative affect, inquire about their preferences in how to perform a task, and provide them with action or even option choices, could be alternated with weeks of *support-as-usual* (e.g., Mouratidis Vansteenkiste, Lens, & Sideridis, 2011), with stricter schedules and guidelines. This would result in stronger evidence for the causal association between autonomy-support and need satisfaction in the astronautical work place. Future studies could also include relatedness with Mission Support as a possible source of need satisfaction, since anecdotal sources (e.g., Johnson, 2010; Stuster, 2016) have illustrated the importance astronauts attach to familiar voices from the ground, and kind messages from Mission Support members, as also demonstrated by the qualitative data gathered during HI-SEAS IV.

3. Implications for Practice

The current dissertation provides insight into the importance of need satisfaction for astronauts, how need satisfaction affects a variety of crucial outcomes in crew well-being and mission success, and how need satisfaction is influenced by procedural instructions and interactions with Mission Support. Based on the findings, some recommendations are made, which space agencies could take into account when designing procedures or training Mission Support members and astronauts.

Crew autonomy versus independence. Although an increase in crew independence will be unavoidable for future interplanetary travels, and some studies have provided preliminary evidence for the benefits of increased self-management for astronaut well-being, space agencies seem generally unwilling to grant space crews with more decision-making authority. Presumably, space agencies' primary concern is that an increase in crew independence would add to the workload and pressure for astronauts, who might feel they have to fend off the challenges of high-risk and complex space operations on their own, without sufficient support from the ground. At this point, space agencies need to start making the distinction between independence, and Self-Determination Theory's notion of autonomy, as these are not mutually exclusive. While more crew *independence* could go either way, being an opportunity for the crew to act more volitional, or in contrast, causing them to feel pressured by the increase in responsibility, more crew *autonomy* will always have its merits. Results from this dissertation suggest that astronauts' sense of volition and accomplishment when carrying out a task can be enhanced through need-supportive measures. Specifically, the manner in which Mission Support members communicate with crew members can be autonomy-supportive, but space agencies could also try to uphold a more autonomy-supportive attitude in several other ways.

Freedom of Expression. First, crew members should be allowed, if not encouraged, to express deviating opinions or even negative affect with regards to typically frustrating situations, for instance when having to follow elaborate procedures, having to perform tasks without understanding why, or being monitored by the ground for no apparent reason. While it is unlikely that space agencies explicitly forbid astronauts to complain, the fact remains that crew members often sense it is not appropriate to do so, since it could be frowned upon by the ground, or negatively affect the mood onboard. However, uttering frustration is likely an efficient way to alleviate stress, since being able to act in accordance with one's values and beliefs is part of experiencing volition and psychological freedom. In fact, Mission Support members, and space agencies in general, could go as far as to proactively inquire about astronaut experiences and preferences.

Choice. Second, astronauts would have more opportunities to act according to their own values and preferences, if provided with a choice in how to perform certain tasks. While the provision of choice might be particularly challenging for ISS missions, due to the high complexity and inter-connectivity of space systems and operations that take hundreds, if not thousands of people on the ground to function properly, certain types of choice might still be feasible. For instance, when the situation allows for it, astronauts could get a say in when to perform certain tasks, or in what order, or in the amount of instructional guidance accompanying the task. Setting up user control instructions would require more time and effort to design, but once implemented, they become a cost-effective way to grant crew members more autonomy in everyday activities, since choice provision would occur quasi-automatically, without interference from Mission Support. Additionally, the crew's sense of challenge and use of skill would get boosted, experiences which can easily be affected by repeatedly having to conduct simple routine tasks.

Astronauts could also be consulted about potentially controlling actions that are not always necessary, such as ground monitoring. In cases when video surveillance is not essential, astronauts could opt to carry out their duties with or without the watchful eye of the ground, dependent upon whether they experience it as controlling, evaluative and signaling distrust, or as reassuring and helpful. The same is true for other monitoring interventions proposed by space experts, such as continuous recordings of astronaut conversations onboard (Ehmann et al., 2011), computerized psychological assessments (Kanas et al., 2009), and wearable physiological monitors (Dunn, Huebner, Liu, Landry, & Binsted, 2017). Whether such measures are perceived as guiding and helpful, or controlling and evaluative (Deci & Ryan, 1985), is likely dependent upon several factors, such as personal preferences (some crew members prefer the extra help, others don't), mood (some days crew members might not mind video surveillance, some days they might), timing (monitoring for dangerous operations will probably be more accepted than monitoring during leisure time) and reason (astronauts who understand why monitoring is important, are more likely to accept it willingly).

Task relevance. In cases where choice provision is highly restricted, astronauts' sense of autonomy can still be sustained, even enhanced, by providing a meaningful rationale for why choice is restricted, or why it's important to carry out a particular task. For astronauts in particular, understanding how a task adds to scientific knowledge, the mission or space exploration, can be very motivating, since astronauts are generally exceptionally driven to contribute to these areas (Britt et al., 2016). Moreover, tasks can also be framed in such a way as to connect with astronauts' personal interests. In fact, space agencies would do well to keep a very close record of individual crew members' existing preferences, and *changes* in preferences, as to match up crew tasks to astronaut preferences, when possible.

Feedback. Although feedback was not experimentally manipulated in this dissertation, the promise of feedback was a strategic part of the need-supportive communication style in Chapter 3, which was successful in enhancing volition. Moreover, several studies have found feedback to be crucial to enhance one' sense of competence (e.g., Deci, Koestner, & Ryan, 1999; Mouratidis et al., 2008). Unfortunately, receiving negative feedback on one's performance can be demotivating (e.g., Vansteenkiste & Deci, 2003; De Muynck et al., 2017), and affect people's self-confidence (e.g., Brewer, Van Raalte, Linder, & Van Raalte, 1991). As such, providing negative feedback to astronauts onboard is a delicate affair, particularly when so much ground personnel is listening in on the conversation. This could explain why astronauts sometimes complain of the so-called *praise inflation* on the ISS, where positive feedback is perceived as not genuine (Stuster, 2010, 2016). Other studies have empirically demonstrated the adverse effects of exaggerated praise (e.g., Brummelman, Thomaes, Orobio de Castro, Overbeek, & Bushman, 2014). Several studies have indicated that individuals' competence can be maintained, if negative feedback is communicated in a need-supportive way (Carpentier & Mageau, 2013; De Muynck et al., 2017; Lim et al., 2010; Mouratidis et al., 2010). For instance, Mission Support could 1) ask astronauts whether they would like to receive feedback on their performance, 2) inquire about astronauts' own opinion concerning their performance, 3) use inviting language, and 4) focus on the way astronauts can improve task performance, instead of focusing on the failed end results.

Pre-flight training. Although this dissertation mainly focuses on potential sources of autonomy and competence frustration, and ways in which these needs could be nurtured, relatedness with crew members made off with a capital role in Chapter 5. Opportunities for crew members to get to know each other, feel connected, and provide emotional support should therefore be encouraged, particularly amongst a multicultural crew. Extensive group training pre-flight, as is already the case today, is likely very effective in this regard, granting crew members the possibility to get acquainted with fellow crew members' values and beliefs. The longer crew members train together, the better they get to know each other, the more they will be able to satisfy each others' need for relatedness. Ideally, most pre-launch training will involve people from the ground who will provide in-flight support during the mission, to the benefit of crew-ground interactions, which was found to also predict crew relatedness. That way, both Mission Support and flight crew get accustomed to both each other's personalities, and to the stressors and limitations of each other's work environments. Being more aware of the way decisions are taken by the ground, astronauts might feel less controlled when having to follow their working schedules. Similarly, knowing the stresses astronauts go through every day, Mission Support might feel less violated when an astronaut is having a bad day.

The Positive Effects of Spaceflight. One of the objectives of these studies was to uncover the demotivational effects of some particularly frustrating task characteristics of the astronautical work environment. As such, need frustration and the negative effects of certain procedures were featured prominently in this dissertation. However, it's important to remember that, overall, ISS missions have a profoundly beneficial effect on astronauts, who come back from such an enriching experience with enhanced personal strength and increased appreciation for the Earth and its inhabitants (Ihle, Ritsher, & Kanas, 2006; Suedfeld, Legkaia, & Brcic, 2010). As pointed out in Chapter 1, one could question the benefits of dwelling on the stressors of spaceflight, instead of concentrating on the facets of spaceflight that enhance astronauts' positive experiences in space. However, everyday hassles that might seem minor on the surface, have the potential to gradually contribute to a more chronic sense of frustration, as exemplified by the lack of autonomy and sense of meaningful accomplishment that can arise several weeks into a mission (Britt et al., 2016.; Peldzus et al., 2014; Stuster, 2016,). Additionally, the studies presented in this dissertation demonstrated the potential of relatively small interventions to diminish feelings of need frustration, with increased chances for growth and a sense of accomplishment. We therefore recommend space agencies to always keep an eye on all possible ways in which astronaut experiences can be improved, even they might seem trivial at first sight.

"I am convinced that human relations, human virtue, human attention is of the utmost importance for the exploration of the universe. We take our human values with us as we go into space, in our attempt to spread them while building on our human presence beyond the borders of our planet Earth. I would like to encourage anyone who is involved in the exploration of space to always keep this human aspect in their minds."

Frank De Winne, Star City, 2009

4. General Conclusion

The multiple challenges and thrills of human space exploration can give rise to a variety of psychological issues, and life changing positive effects. Therefore, it is important to pay careful attention to provide astronauts with a need-nurturing work and living environment to support their psychological needs in order to allow astronauts to fully meet their potential, which functions as a buffer against stressors, and enhances their salutogenic experiences. The aim of this dissertation was to examine a particularly frustrating facet of the astronautical work floor, namely the provision of elaborate instructional guidance for relatively simple tasks. Results of these studies have found that adding instructions negatively influenced motivation, affect and performance, particularly for simple tasks. Several countermeasures were proposed to diminish these disadvantageous effects, and to enhance need satisfaction, well-being, and performance. The success of shortening instructions depended upon the subsequent increase in task difficulty following reduction of instructional guidance. In contrast, providing long instructions in a need-supportive way, and implementing repeated action choices through user control instructions, turned out to have only positive effects on need satisfaction, motivation, well-being and performance. User control instructions are particularly promising, since the active driver of need support, i.e., the repeated action choice, is continually and automatically provided throughout the task. Moreover, shortening instructions and providing choice turned out even more beneficial for participants high in need for achievement, a typical personality trait of astronauts. Further, the experience of volition, and a sense of challenge and accomplishment, had important roles as explanatory mechanisms for the effectiveness of a need-supportive communication style and user control instructions. The potential effectiveness of a need-supportive communication style was also demonstrated during two ecologically valid studies conducted during two different Mars simulation missions, which found, aside from autonomy and competence, the need for relatedness with fellow crew members to be particularly predictive of several crucial outcomes in crew well-being and functioning. Overall, the findings of this dissertation testify of the importance of need satisfaction for crew members, and of the effectiveness of need-supportive countermeasures to enhance crew motivation, well-being and performance. It is my sincere hope that at least some of these findings may be taken to heart by space agencies, such that some of the proposed practical countermeasures get implemented, to the benefit of the crew members, and the success of human space exploration more generally.

References

Aelterman, N.*, Vansteenkiste, M.*, Soenens, B., Fontaine, J., Haerens, L., & Reeve, J. (2018). Toward an integrative and fine-grained insight in motivating and demotivating teaching: The merits of a circumplex approach. (*equal contributions). *Journal of Educational Psychology*.

Aiken, L. S., & West, S.G. (1991). *Multiple Regression: Testing and Interpreting Interactions*. Newbury Park: Sage Publications.

Baard, P. P., Deci, E. L., & Ryan, R. M. (2004). Intrinsic need satisfaction: A motivational basis of performance and well-being in two work settings. *Journal of Applied Social Psychology, 34*, 2045-2068.

Bagheri, L., & Milyavskaya, M. (2018). Novelty-variety as a basic psychological need : New evidence across three studies. *Manuscript submitted for publication*.

Berntson, G. G., et al. (1997). Heart rate variability: origins, methods, and interpretive caveats. *Psychophysiology*, *34*, 623-648.

Botti, S., & Iyengar, S. S. (2006). The dark size of choice: when choice impairs social welfare. *Journal of Public Policy and Marketing*, 25, 24-38.

Britt, T. W., Jennings, K. S., Goguen, K., & Sytine, A. (2016). *The role of meaningful work in astronaut health and performance during long-duration space exploration missions* (NASA/TM-2016-219276). Houston, Texas, NASA Johnson Space Center.

Brummelman, E., Thomaes, S., Orobio de Castro, B., Overbeek, G., & Bushman, B. J. (2014). “That’s not just beautiful—that’s incredibly beautiful!” The adverse impact of inflated praise on children with low self-esteem. *Psychological Science*, *25*, 728-735.

Carpentier, J., & Mageau, G. A. (2013). When change-oriented feedback enhances motivation, well-being and performance: A look at autonomy-supportive feedback in sport. *Psychology of Sport and Exercise, 14,* 423-435.

Cohen, J., & Cohen, P. (1983). *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences* (2nd ed). Hillsdale: Erlbaum.

Dawson, J. F. (2014). Moderation in management research: What, why, when and how. *Journal of Business and Psychology, 29,* 1-19.

Dawson, J. F., & Richter, A. W. (2006). Probing three-way interactions in moderated multiple regression: Development and application of a slope difference test. *Journal of Applied Psychology, 91*, 917-926.

De Bruyne, E., Bourgonjon, J., Kremer, M. & Valcke, M. (2018). Improving students' reading for academic purposes through vocabulary support in texts. *Manuscript in preparation.*

De Muynck, G-J., Soenens, B., Degraeuwe, L., Vande Broek, G., & Vansteenkiste, M. (2018). Towards a more refined insight in the critical motivating features of choice: An experimental study among recreational rope skippers. *Manuscript submitted for publication.*

De Muynck, G-J., Vansteenkiste, M., Delrue, J., Aelterman, N., Haerens, L., & Soenens, B. (2017). The effects of feedback valence and style on need satisfaction, self-talk, and perseverance among tennis players: An experimental study. *Journal of Sport & Exercise Psychology, 39,* 67-80.

Deci, E. L. (1971). Effects of externally mediated rewards on intrinsic motivation. *Journal of Personality and Social Psychology, 18,* 105-15.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry, 11,* 227-268.

Deci, E. L., Eghrari, H., Patrick, B. C., & Leone, D. R. (1994). Facilitating internalization: the Self-Determination Theory perspective. *Journal of Personality, 62,* 119-142.

Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin, 125*, 627-668.

Dunn, J., Huebner, E., Liu, S., Landry, S. & Binsted, K. (2017). Using consumer-grade wearables and novel measures of sleep and activity to analyze changes in behavioral health during an 8-month simulated Mars mission. *Computers in Industry, 92*, 32-42.

Eccles, J. S. & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109-132.

Ehmann, B., Balázs, L., Fülöp, E., Hargitai, R., Kabai, P., Péley, B., Pólya, T., Vargha, A., & László, J. (2011). Narrative psychological content analysis as a tool for psychological status monitoring of crews in isolated, confined and extreme settings. *Acta Astronautica, 68*, 1560-1566.

Gagné, M. (2003). The role of autonomy support and autonomy orientation in prosocial behavior engagement. *Motivation and Emotion, 27*, 199-223.

Goemaere, S., Beyers, W., De Muynck G.-J., & Vansteenkiste, M. (2018). The paradoxical effect of long instructions on negative affect and performance: When, for whom and why do they backfire?. *Acta Astronautica, 147*, 421-430.

Goemaere, S., Vansteenkiste, M., & Beyers, W. (2018). How to buffer the motivational and performance deficits of long instructions for procedural tasks? Comparing the role of user control instructions, an autonomy-supportive communication style and the use of short instructions. *Manuscript submitted for publication.*

González-Cutre, D., Romero-Elias, M., Jiménez-Loaisa, A., Beltrán-Carrillo, V., Hagger, M. S. (2018). Testing the need for novelty as an additional candidate need in Self-Determination Theory. *Manuscript submitted for publication.*

González-Cutre, D., Sicilia, A., Sierra, A. C., Ferriz, R., & Hagger, M. S. (2016). Understanding the need for novelty from the perspective of Self-Determination Theory. *Personality and Individual Differences, 102,* 159-169.

Harackiewicz, J. M., Canning, E. A., Tibbetts, Y., Priniski, S. J., & Hyde, J. S. (2016). Closing achievement gaps with a utility-value intervention: Disentangling race and social class. *Journal of Personality and Social Psychology, 111*, 745-765.

Hendricks, H., Mauroo, T., & Van Spilbeeck, B. (2009). *Het Ruimtedagboek van Frank De Winne: Dagelijks Leven in het ISS.* Leuven: Van Halewyck.

Higgins, E. T. (1998). Promotion and prevention: Regulatory focus as a motivational principle. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (Vol. 30, pp. 1-46). San Diego, CA: Academic Press

Hooyman, A., Wulf, G., & Lewthwaite, R. (2014). Impacts of autonomy-supportive versus controlling instructional language on motor. learning. *Human Movement Science, 36*, 190-198.

Hulleman, C. S., Godes, O., Hendricks, B. L., & Harackiewicz, J. M. (2010). Enhancing interest and performance with a utility value intervention. *Journal of Educational Psychology, 102*, 880-895.

Hummel, H. G. K., Paas, F, Koper, E. J. R. (2006). Timing of cueing in complex problem-solving tasks: Learner versus system control. *Computers in Human Behavior, 22*, 191-205.

Ihle, E., Ritsher, J., & Kanas, N. (2006). Positive psychological outcomes of spaceflight: an empirical study. *Aviation, Space, and Environmental Medicine, 77*, 93-102.

Jaccard, J. J., & Turrisi, R. (2003). Interaction effects in multiple regression. *Quantitative Applications in the Social Sciences, 72*. Newsbury Park: Sage Publications.

Jang, H. (2008). Supporting students' motivation, engagement, and learning during an uninteresting activity. *Journal of Educational Psychology, 100*, 798-811.

Jang, H., Reeve, J., & Halusic, M. (2016). A new autonomy-supportive way of teaching that increases conceptual learning: Teaching in students' preferred ways. *Journal of Experimental Education*, *84*, 686-701.

Kalyuga, S. (2007). Expertise Reversal effect and its implications for learner-tailored instruction. *Educational Psychology Review*, *19*, 509-539.

Kalyuga, S. (2009). Knowledge elaboration: A cognitive load perspective. *Learning and Instruction, 19*, 402-410.

Kalyuga, S., Chandler, P., & Sweller, J. (2000). Incorporating learner experience into the design of multimedia instruction. *Journal of Educational Psychology, 92,* 126-136.

Kanas, N. (1998). Psychosocial issues affecting crews during long-duration international space missions. *Acta Astronautica, 42*, 339-361.

Kanas, N., Saylor, S., Harris, M., Neylan, T., Boyd, J., Weiss, D., Baskin, P., Cook, C., & Marmar, C. (2010). High versus low crewmember autonomy in space simulation environments, *Acta Astronautica*, *67*, 731-738.

Kanas, N., & Manzey, D. (2008). *Space Psychology and Psychiatry*. Dortrecht: Kluwer.

Kasser, V. G., & Ryan, R. M. (1999). The relation of psychological needs for autonomy and relatedness to vitality, well-being, and mortality in a nursing home. *Journal of Applied Social Psychology, 29*, 935-954.

Katkin, E. S. (1965). Relationship between manifest anxiety and two indices of autonomic response to stress. *Journal of Personality and Social Psychology, 2*, 324-333.

Katz, I., & Assor, A. (2007). When choice motivates and when it does not. *Educational Research Review*, *19*, 429-442.

Kurdi, B., & Banaji, M. R. (2017). Repeated evaluative pairings and evaluative statements: How effectively do they shift implicit attitudes? *Journal of Experimental Psychology, 146*, 194-213.

Legault, L., & Inzlicht, M. (2013). Self-determination, self-regulation, and the brain: autonomy improves performance by enhancing neuroaffective responsiveness to self-regulation failure. *Journal of Personality and Social Psychology, 105*, 123-138.

Lim, D. S. S., Warman, G. L., Gernhardt, M. L., McKay, C. P., Fong, T., Marinova, M. M., Davilaa, A. F., … Williams, D. (2010). Scientific field training for human planetary exploration. *Planetary and Space Science, 58,* 920-930.

Luce, M. F. (1998). Choosing to avoid: Coping with negatively emotion-laden consumer decisions. *Journal of Consumer Research, 24,* 409-433.

Mageau, G. A., & Vallerand, R. J. (2003). The coach-athlete relationship: A motivational model. *Journal of Sports Sciences, 21*(11), 883-904.

McIntosh, T., Mulhearn, T., Gibson, C., Mumford, M. D., Yammarino, F. J., Connelly, S., Day, E. & Vessey, B. (2016). Planning for Long-Duration Space Exploration: Interviews with NASA Subject Matter Experts. *Acta Astronautica, 129*, 477-487.

McNamara, D., Kintsch, E., Songer, N. B., and Kintsch, W. (1996). Are good texts always bet- ter? Interactions of text coherence, background knowledge, and levels of understanding in learning from text. *Cognitive Instructions, 14*, 1-43.

Mcphee, J. C., & Charles, J. B. (2009). *Human health and performance risks of space exploration missions* (NASA SP-2009-3405). Houston, Texas, NASA Johnson Space Center.

Mouratidis, A. A., Vansteenkiste, M., Sideridis, G., & Lens, W. (2011). Vitality and interest-enjoyment as a function of class-to-class variation in need-supportive teaching and pupils' autonomous motivation. *Journal of Educational Psychology, 103,* 353-366.

Mouratidis, A., Lens, W., & Vansteenkiste, M. (2010). How you provide corrective feedback makes a difference: The motivating role of communicating in an autonomy-supporting way. *Journal of Sport & Exercise Psychology, 32*, 619-637.

Mouratidis, A., Vansteenkiste, M., Lens, W., & Sideridis, G. (2008). The motivating role of positive feedback in sport and physical education: evidence for a motivational model. *Journal of Sport & Exercise Psychology, 30*, 240-268.

Mouratidis, A., Vansteenkiste, M., Lens, W., & Sideridis, G. (2011). Variation in vitality and interest-enjoyment as a function of class-to-class need-supportive teaching and pupils' autonomous motivation. *Journal of Educational Psychology, 103*, 353-366.

Novick, L.R., & Morse, D.L. (2000). Folding a fish, making a mushroom: the role of diagrams in executing assembly procedures. *Memory & Cognition*, *28*, 1242-1256.

Orvis, K. A., Horn, D. B., & Belanich, J. (2008). The roles of task difficulty and prior videogame experience on performance and motivation in instructional videogames. *Computers in Human Behavior*, 24, 2415-2433.

Patall, E. A., Cooper, H., & Robinson, J. C. (2008). The effects of choice on intrinsic motivation and related outcomes: a meta-analysis of research findings. *Psychological Bulletin, 134,* 270-300.

Patall, E. A., Cooper, H., & Wynn, S. R. (2010). The effectiveness and relative importance of choice in the classroom. *Journal of Educational Psychology, 102*, 896-915.

Patall, E. A., Steingut, R. R., Vasquez, A. C., Trimble, S. S., Pituch, K. A., & Freeman, J. L. (2018). Daily autonomy supporting or thwarting and students' motivation and engagement in the high school science classroom. *Journal of Educational Psychology*, *110*(2), 269-288.

Patall, E. A., Sylvester, B. J., & Han, C. (2014). The role of competence in the effects of choice on motivation. *Journal of Experimental Social Psychology, 50,* 27-44.

Paulmann, S., Zougkou, K., Weinstein, N. (2018). *How motivational prosody impacts on listeners' physiological response*. Manuscript in preparation.

Peldszus, R., Dalke, H., Pretlove, S., & Welch, C. (2014). The perfect boring situation - Addressing the experience of monotony during crewed deep space missions through habitability design. *Acta Astronautica, 94*, 262-276.

Quested, E., Bosch, J. A., Burns, V. E., Cumming, J., Ntoumanis, N., & Duda, J. L. (2011). Basic psychological need satisfaction, stress-related appraisals, and dancers' cortisol and anxiety responses. *Journal of Sport & Exercise Psychology, 33,* 828-846.

Reeve, J., & Tseng, C. M. (2011). Cortisol reactivity to a teacher's motivating style: The biology of being controlled versus supporting autonomy. *Motivation and Emotion, 35*, 63-74.

Richardson, M., & Jones, G. (2006). Identifying the task variables that predict object assembly difficult. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 48*, 511-525.

Roma, P. G., Hursh, S. R., Hienz, R. D., Emurian, H. H., Gasior, E. D., Brinson, Z. S., & Brady, J. V. (2011). Behavioural and biological effects of autonomous versus scheduled mission management in simulated space-dwelling groups. *Acta Astronautica, 68*, 1581-1588.

Deci, E. L., & Ryan, R. M. (1985). The General Causality Orientations Scale: Self-Determination in Personality. *Journal of Research in Personality, 19,* 109-134.

Ryan, R. M., & Deci, E. L. (2000). Self-Determination Theory and the facilitation of intrinsic motivation, social development, and well-being. American Psychologist, 55, 68-78.

Savard, A., Joussemet, M., Pelletier, L. G., & Mageau, G. A. (2013). The benefits of autonomy support for adolescents with severe emotional and behavioral problems. *Motivation and Emotion, 37*, 688-700.

Sheldon, K. M., & Bettencourt, B. A. (2002). Psychological need-satisfaction and subjective well-being within social groups. *British Journal of Social Psychology, 41*, 25-38.

Soenens, B., Vansteenkiste, M., & Niemiec, C. P. (2009). Should parental prohibition of adolescents' peer relationships be prohibited? *Personal Relationships, 16*, 507-530.

Stuster, J. (2010). *Behavioral issues associated with long-duration space expeditions: Review and analysis of astronaut journals* (NASA/TM-2010-216130). Houston, Texas, NASA Johnson Space Center.

Stuster, J. (2016). *Behavioral Issues Associated With Long Duration Space Expeditions: Review and Analysis of Astronaut Journals Experiment*. (NASA/TM-2016-218603). Houston, Texas, NASA Johnson Space Center.

Suedfeld, P. (2005). Invulnerability, coping, salutogenesis, integration: four phases of space psychology. *Aviation, Space and Environmental Medicine, 7*, 61-66.

Suedfeld, P. (2010). Historical space psychology: Early terrestrial explorations as Mars analogues. *Planetary and Space Science,* 58, 639-645.

Suedfeld, P., Legkaia, K., & Brcic, J. (2010). Changes in the hierarchy of value references associated with flying in space. Journal of Personality, 78, 1411-1436.

Sweller, J. (2011). Cognitive Load Theory. In *The psychology of learning and motivation* (Vol. 55, pp. 37-76). Elsevier Inc.

Sweller, J., Ayres, P. L., Kalyuga, S., & Chandler, P. (2003). The expertise reversal effect. *Educational Psychologist, 38*, 23-31.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive Load Theory*. New York: Springer.

Tafforin, C., 2013. The Mars-500 crew in daily life activities: an ethological study. *Acta Astronautica, 91*, 69-76.

Van der Kaap-Deeder, J., Audenaert, E., Mabbe, E., Soenens, B., Vandevelde, S., & Vansteenkiste, M. (2017). Choosing when choices are limited: *The role of perceived afforded choice and autonomy in prisoners. Law and Human Behavior, 41*, 567-578.

van Merriënboer, J & Sweller, J (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review, 17*, 147-177.

van Merriënboer, J. J. G., Kirschner, P. A., & Kester, L. (2003). Taking the load off a learner's mind: Instructional design for complex learning. *Educational Psychologist, 38*, 5-13.

Vansteenkiste, M., & Deci, E. L. (2003). Competitively contingent rewards and intrinsic motivation: Can losers remain motivated? *Motivation and Emotion, 27*, 273-299.

Vansteenkiste, M., Aelterman, N., De Muynck, G.-J., Haerens, L., Patall, E., & Reeve, J. (2018). Fostering Personal Meaning and Self-relevance: A Self-Determination Theory Perspective on Internalization. *Journal of Experimental Education, 86,* 30-49.

Vansteenkiste, M., Aelterman, N., Haerens, L., & Soenens, B. (2018). *Seeking stability in stormy educational times: A need-based perspective on (de)motivating teaching grounded in Self-Determination Theory*. Manuscript in preparation.

Vansteenkiste, M., Simons, J., Lens, W., Soenens, B., & Matos, L. (2005). Examining the impact of extrinsic versus intrinsic goal framing and internally controlling versus autonomy-supportive communication style upon early adolescents' academic achievement. *Child Development, 76,* 483-501.

Vohs, K. D., Schmeichel, B. J., Nelson, N. M., Baumeister, R. F., Twenge, J. M., Tice, D. M. (2008). Making choices impairs subsequent self-control: A limited-resource account of decision making, self-regulation, and active initiative. *Journal of Personality and Social Psychology, 94*, 883-898.

Witkin, H. A., Dyk, R. B., Faterson, H. F., Goodenough, D. R., & Karp. S. A. (1962). *Psychological Differentiation*. New York: John Wiley & Sons Inc.

SUMMARY

Human Space Exploration from a Self-Determination Theory Perspective: A Diary and Experimental Investigation

Introduction

Human Space Exploration has always captivated people's imagination, with astronauts performing fascinating operations like spacewalks and spacecraft docking. However, contrary to popular belief, a majority of astronaut duties on the International Space Station consist of relatively simple routine tasks, such as maintenance, cleaning, and storage. Moreover, astronauts do not have the decision-making authority to deviate from the many rules and guidelines introduced by Mission Support (Kalery, Sorokin, & Tyurin, 2010; Krikalev, Kalery, & Sorokin, 2010). Instead, for every space operation, they need to stick to the very extensive visual instructions provided to them. In case of contingencies, astronauts need to alert Mission Support members, who then decide on the appropriate action by which to proceed, to be strictly followed by the astronaut. Therefore, in spite of the wonder and excitement of being in outer space, and the many salutogenic experiences reported by astronauts (Ihle, Ritsher, & Kanas, 2006; Suedfeld, Legkaia, & Brcic, 2010), the astronautical work floor can also be perceived as a rather restrictive environment. Although astronauts rarely overtly rebel against these organizational circumstances, anecdotal sources show that deviant behavior and so-called insubordination issues (Morgeson, 2015) do sometimes occur, for instance when astronauts fail to inform Mission Support of a particular contingency (e.g., Hendricks, Mauroo, & Van Spilbeeck, 2009), ignore certain requests made by the ground (e.g., Morgeson, 2015), or discard instructional procedures (e.g., Mcphee & Charles, 2009). As a consequence, performance slips are known to occur, and boredom sets in, when tasks become increasingly routine (e.g., Britt, Jennings, Goguen, & Sytine, 2016; Peldszus, Dalke, Pretlove, & Welch, 2014).

From a psychological viewpoint, such affective, motivational, and behavioral responses of astronauts do not come as a surprise. In this dissertation, we approach these issues from a Self-Determination Theory perspective (Ryan & Deci, 2000), a broad theory on human motivation and optimal functioning that offers an encompassing theoretical framework to examine the effects of certain organizational characteristics (Deci, Olafson, & Ryan, 2017). Specifically, within SDT, the satisfaction of three basic psychological needs for autonomy (i.e., feeling volitional), competence (i.e., experiencing a sense of mastery or challenge) and relatedness (i.e., feeling cared for) are said to represent the critical nutrients for astronauts' optimal functioning. In contrast, the frustration of these basic psychological needs is deemed detrimental. As such, space agencies, and Mission Support in particular, face the challenge to create a need-supportive work environment, while equally avoiding a need-thwarting one, characterized by high control and a lack of challenge or sense of accomplishment.

Although abundant research has demonstrated the benefits associated with need satisfaction and need-supportive management in traditional organizational settings (Deci, Olafson, & Ryan, 2017) and other life domains (Deci & Ryan, 2008; Vansteenkiste, Niemiec, & Soenens, 2010), Self-Determination Theory has never been studied in the astronautical setting before. Moreover, few studies have implemented diary studies of within-person fluctuations in employee need satisfaction and functioning in authentic work environments. (e.g., De Gieter, Hofman, & Bakker, 2018; Olafsen, Deci, & Halvari, 2018, as exceptions). Finally, very little is known about the consequences of providing an overload of instructional guidance for relatively simple and uninteresting activities. In general, research on instructional design tends to primarily focus on the provision of the optimal amount and format of instructions to present learners with sufficient guidance to accomplish certain learning goals (see Van de Pol, Volman, & Beishuizen, 2010 and Landers & Reddock, 2017, for reviews). Congruent with these lacunae in the literature, the present dissertation pursued three general research goals in four empirical studies involving 248 participants in both laboratory and more ecologically valid settings. That is, (1) the examination of the adverse impact of long instructions for simple tasks, (2) the development and implementation of need-supportive countermeasures to alleviate the negative effects of long instructions and, (3) gaining deeper insight into the dynamics of astronaut behavior by studying weekly variations in crew members' perception of Mission Support's need-supportive interactions, and weekly variations in crew members' need satisfaction and functioning, in an ecologically valid setting.

Results and Discussion

The Effects of Long Instructions for Simple Tasks

Findings. Two experimental studies with 113 and 123 participants (M_{age} = 18.75, Chapter 2; and M_{age} = 19.25, Chapter 3, respectively) demonstrated the negative effects of providing long instructions for simple tasks. Taken together, these experiments found long instructions to diminish self-endorsed motivation to follow instructions, to increase the tendency to discard instructions, to elicit more feelings of irritation, boredom and strain, and to decrease accuracy. Moreover, in cases when tasks were fairly simple, long instructions also diminished productivity. The majority of these negative effects were less pronounced or absent, for complex tasks. Overall, these findings suggest that the provision of long instructions have detrimental effects on individuals' motivation, affect, and performance, particularly for simple tasks, thereby confirming anecdotal sources testifying of astronauts' sense of frustration and demotivation arising from detailed procedural instructions for simple routine activities.

Practical Implications. The findings of Chapters 2 and 3 provide valuable insight into the negative effects of adding instructional guidance for relatively simple tasks. Of course, space agencies are primarily concerned with providing astronauts with ample support and guidance for their daily activities. However, space agencies would do well to distinguish between complex operations and more routine simple tasks. While more extensive instructions are likely to be perceived as useful and helpful for complex operations, astronauts might benefit from less instructional guidance for simple tasks, as to avoid the demotivational and performance deficits of long instructions.

Need-Supportive countermeasures

Findings. While shortening procedural instructions might not always be feasible, for instance when instructions need to be evaluated and approved by strict safety boards, space agencies could also consider providing long instructions in a more need-supportive way. In an experimental study with 123 participants (M_{age} = 19.25, Chapter 3), we examined whether accompanying instructions with a need-supportive message, and embedding instructions with repeated action choices, could alleviate the negative effects of long instructions for simple tasks. Results indicated that a need-supportive communication style was effective in diminishing reactance, reducing feelings of irritation and boredom, while having no adverse side-effects on performance. Alternatively, choice provision through adaptive instructions demonstrated beneficial effects on all motivational and affective outcomes, in addition to a boost in accuracy. Mediation analyses also indicated that an increase in volition or sense of challenge, or both, could explain the majority of significant effects of need-supportive and adaptive instructions.

Practical Implications. Results from this study suggest that astronauts' sense of volition and experience of challenge when carrying out a task could be enhanced through in-flight need-supportive measures. Specifically, the manner in which Mission Support members communicate with crew members can be autonomy-supportive, or Mission Support could give astronauts a choice in the amount of instructional guidance through adaptive instructions. However, space agencies could also try to uphold a more need-supportive attitude in other ways, for instance by encouraging freedom of expression, providing autonomy-supportive corrective feedback, and allocating tasks in accordance with crew members' interests and preferences, to name a few.

Need Satisfaction and Support in an Ecologically Valid Setting

Findings. Although the experimental studies discussed above provided useful insight in the causal impact of long instructions and possible countermeasures, the question whether the observed benefits of need-supportive communication would also be noticed in naturalistic settings remains unclear. To address this issue, during the final eight weeks of the Mars simulation mission HI-SEAS I (Chapter 4) and the yearlong mission HI-SEAS IV (Chapter 5), we measured twelve crew members' (M_{age} = 39 and 30, respectively) weekly variations in perceived autonomy-supportive communications from Mission Support, need satisfaction, well-being, collaboration with the ground, and performance. Taken together, results demonstrated that, while crew members' sense of effectiveness remained stable, they experienced a decreasing degree of relatedness and autonomy over the course of the mission. Further, while the contributions of weekly variation in crew members' sense of effectiveness and relatedness with friends and family at home in the prediction of weekly outcomes were more limited, weekly variation in a sense of autonomy, and particularly relatedness with crew members, yielded strong and significant associations with crew motivation, well-being, performance, and collaboration with Mission Support. Finally, findings also indicated that, in weeks when crew members perceived Mission Support as more autonomy-supportive in their communications, they simultaneously experienced more need satisfaction.

Practical Implications. The week-to-week studies conducted during HI-SEAS I and IV further underscore the need for space agencies to implement need-supportive measures, as crew members might be increasingly at risk of not having their needs met as missions last for a longer period of time. The findings also underscore the ecological validity of the lab-based findings, as they confirmed the significance of need satisfaction, and an autonomy-supportive attitude towards crew members. The limited significance of competence, operationalized in these studies as *mastery* or *effectiveness*, suggests that competence frustration for astronauts is more likely to originate from a lack of challenge, use of skill, and sense of accomplishment. Further research is needed to gain insight into this somewhat understudied facet of the need for competence.

Conclusion

The multiple challenges and thrills of human space exploration can give rise to a variety of psychological issues, and life changing positive effects. Therefore, it is important to pay careful attention to provide astronauts with a need-nurturing work and living environment to support their psychological needs in order to allow them to fully actualize their potential, which functions as a buffer against stressors, and enhances their salutogenic experiences. The aim of this dissertation was to examine a particularly frustrating facet of the astronautical work floor, namely the provision of elaborate instructional guidance for relatively simple tasks. Results of these studies have found that providing long instructions negatively influenced motivation, affect and performance, particularly for simple tasks, compared to short instructions. Several countermeasures were proposed to diminish these disadvantageous effects, and to enhance need satisfaction, well-being, and performance. Providing long instructions in a need-supportive way, and implementing repeated action choices through adaptive instructions, turned out to have positive effects on need satisfaction, motivation, well-being and performance. Further, the experience of volition, and a sense of challenge and accomplishment, had important roles as explanatory mechanisms for the effectiveness of a need-supportive communication style and adaptive instructions. The potential effectiveness of a need-supportive communication style was also demonstrated during two ecologically valid studies conducted during two different Mars simulation missions, which found, aside from autonomy, and to a lesser extent competence, the need for relatedness with

fellow crew members to be particularly predictive of several crucial outcomes in crew well-being and functioning. Overall, the findings of this dissertation testify of the importance of need satisfaction for crew members, and of the effectiveness of need-supportive countermeasures to enhance crew motivation, well-being and performance. Based on these findings, several practical countermeasures are proposed that may be taken to heart by space agencies, to the benefit of the crew members, and the success of human space exploration more generally.

References

Britt, T. W., Jennings, K. S., Goguen, K., & Sytine, A. (2016). *The role of meaningful work in astronaut health and performance during long-duration space exploration missions* (NASA/TM-2016-219276). Houston, Texas, NASA Johnson Space Center.

De Gieter, S., Hofmans, J., Bakker, A. B. (2018). Need satisfaction at work, job strain, and performance: A diary study. *Journal of Occupational Health Psychology*, *23*, 361-372.

Deci, E. L., & Ryan, R. M. (2008). Self-Determination Theory: A macrotheory of human motivation, development, and health. *Canadian Psychology-Psychologie Canadienne, 49*, 182-185.

Deci, E. L., Olafsen, A. H., & Ryan, R. M. (2017). Self-Determination Theory in work organizations: The state of a science. *Annual Review of Organizational Psychology and Organizational Behavior, 4*, 19-43.

Hendricks, H., Mauroo, T., & Van Spilbeeck, B. (2009). *Het Ruimtedagboek van Frank De Winne: Dagelijks Leven in het ISS*. Leuven: Van Halewyck.

Ihle, E., Ritsher, J., & Kanas, N. (2006). Positive psychological outcomes of spaceflight: An empirical study. *Aviation, Space, and Environmental Medicine, 77*, 93-102.

Kalery, A., Sorokin, I., & Tyurin, M. (2010). Human space exploration beyond the international space station: role of relations of human, machine and the ‘‘Earth’’. *Acta Astronautica, 67*, 925-933.

Krikalev, S., Kalery, A., Sorokin, I. (2010). Crew on the ISS: creativity or determinism. *Acta Astronautica*, *66*, 68-78.

Landers, R. N., & Reddock, C. M. (2017). A meta-analytic investigation of objective learner control in web-based instruction. *Journal of Business Psychology*, *32*, 455-478.

Lawton, R. (1998). Not working to rule: Understanding procedural violations at work. *Safety Science, 28*, 77-95.

Mcphee, J. C., & Charles, J. B. (2009). *Human health and performance risks of space exploration missions* (NASA SP-2009-3405). Houston, Texas, NASA Johnson Space Center.

Morgeson, F. P. (2015). *Issues in Maintaining Team Motivation over Long-Duration Exploration Missions*, (NASA/TM-2015-218586). Houston, Texas, NASA Johnson Space Center.

Olafsen, A. H., Deci, E. L., & Halvari, H. (2018). Basic psychological needs and work motivation: A longitudinal test of directionality. *Motivation and Emotion, 42*, 178-189.

Peldszus, R., Dalke, H., Pretlove, S., & Welch, C. (2014). The perfect boring situation - Addressing the experience of monotony during crewed deep space missions through habitability design. *Acta Astronautica, 94*, 262-276.

Ryan, R. M., & Deci, E. L. (2000). The darker and brighter sides of human existence: basic psychological needs as a unifying concept. *Psychological Inquiry, 11*, 319-338.

Suedfeld, P., Legkaia, K., & Brcic, J. (2010). Changes in the hierarchy of value references associated with flying in space. *Journal of Personality, 78*, 1411-1436.

Van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher-student interaction: A decade of research. *Educational Psychology Review, 22*, 271-296.

Vansteenkiste, M., Niemiec, C. P., & Soenens, B. (2010). The development of the five mini- theories of Self-Determination Theory: A historical overview, emerging trends and future directions. In T. Urdan & S. Karabenick (Eds.). *Advances in Motivation and Achievement: Vol. 16. The decade ahead* (pp. 105-166). Bingley, United Kingdom: Emerald.

SAMENVATTING

Bemande Ruimtevaart vanuit een Zelf-Determinatie Theorie Perspectief: een Dagboek- en Experimenteel Onderzoek

Introductie

Bemande ruimtevaart heeft altijd tot de verbeelding gesproken, met astronauten die fascinerende operaties uitvoeren, zoals ruimtewandelingen en het aanleggen van ruimtevaartuigen. Maar in tegenstelling tot wat veel mensen denken, bestaat het merendeel van de taken van astronauten op het Internationale Ruimtestation uit relatief eenvoudige routinetaken, zoals onderhoud, schoonmaak en opslag. Bovendien beschikken astronauten niet over de beslissingsbevoegdheid om af te wijken van de vele regels en richtlijnen die door Mission Support zijn geïntroduceerd (Kalery, Sorokin, & Tyurin, 2010; Krikalev, Kalery, & Sorokin, 2010). Voor elke ruimtevaartoperatie moeten astronauten zich houden aan zeer uitgebreide visuele instructies, waarvan ze niet mogen afwijken. In geval van onvoorziene omstandigheden moeten astronauten Mission Support waarschuwen, die vervolgens beslist welke actie astronauten moeten ondernemen. Ondanks de wonderlijke en vervoerende ervaring van in de ruimte te zijn, en de vele salutogenetische ervaringen die door astronauten zijn gemeld (Ihle, Ritsher, & Kanas, 2006; Suedfeld, Legkaia, & Brcic, 2010), kan de astronautische werkvloer ook ervaren worden als een restrictieve omgeving. Hoewel astronauten zelden openlijk rebelleren tegen deze organisatorische omstandigheden, tonen anekdotische bronnen aan dat afwijkend gedrag en zogenaamde insubordinatieproblemen (Morgeson, 2015) soms voorkomen, bijvoorbeeld wanneer astronauten Mission Support niet op de hoogte brengen van een bepaalde situatie (vb., Hendricks, Mauroo , & Van Spilbeeck, 2009), bepaalde verzoeken van de grond negeren (vb., Morgeson, 2015) of instructieprocedures in de wind slaan (vb., Mcphee & Charles, 2009). Bijgevolg kunnen er performantiefouten en verveling optreden, zeker wanneer taken meer routineus worden (vb., Britt, Jennings, Goguen, & Sytine, 2016; Peldszus, Dalke, Pretlove, & Welch, 2014).

Vanuit psychologisch oogpunt zijn zulke affectieve, motivationele en gedragsmatige reacties van astronauten weinig verrassend. In dit proefschrift benaderen we deze kwesties vanuit het perspectief van de Zelf-Determinatie Theorie (ZDT; Ryan & Deci, 2000), een brede theorie over menselijke motivatie en optimaal functioneren die een omvattend theoretisch raamwerk biedt om het effect van bepaalde organisatorische kenmerken te onderzoeken (Deci, Olafson, & Ryan, 2017). Specifiek binnen ZDT wordt beweerd dat de bevrediging van drie psychologische basisbehoeften voor autonomie (i.e., welwillendheid en psychologische vrijheid), competentie (i.e., een gevoel van effectiviteit en uitdaging ervaren) en verbondenheid (i.e., warme en hechte banden met belangrijke anderen ervaren) de kritische voedingsstoffen vertegenwoordigen voor het optimaal functioneren van astronauten. Daarentegen wordt de frustratie van deze psychologische basisbehoeften als nadelig beschouwd. Daarom staan ruimtevaartorganisaties, en vooral Mission Support, voor de uitdaging om een werkomgeving te creëren die deze behoeften ondersteunt, en tegelijkertijd een omgeving te vermijden waarin deze behoeftes worden gedwarsboomd, gekenmerkt door controle en een gebrek aan uitdaging.

Hoewel overvloedig onderzoek het nut geassocieerd met behoeftebevrediging en behoefte-ondersteunend management in traditionele organisatorische omgevingen (Deci, Olafson, & Ryan, 2017) en andere levensdomeinen (Deci & Ryan, 2008; Vansteenkiste, Niemiec, & Soenens, 2010) heeft aangetoond, is ZDT nooit bestudeerd in de astronautische setting. Bovendien hebben weinig onderzoekers dagboekstudies uitgevoerd rond de binnen-persoon fluctuaties in behoeftesatisfactie en het functioneren van werknemers in authentieke werkomgevingen. (e.g., De Gieter, Hofman, & Bakker, 2018; Olafsen, Deci, & Halvari, 2018, als uitzonderingen). Ten slotte is er weinig bekend over de gevolgen van het bieden van een teveel aan instructies voor relatief eenvoudige en oninteressante procedurele activiteiten. In het algemeen richt onderzoek rond Instructional design zich voornamelijk op het bieden van de optimale hoeveelheid en vorm van instructies om leerlingen voldoende begeleiding te bieden om bepaalde leerdoelen te bereiken (zie Van de Pol, Volman, & Beishuizen, 2010 en Landers &

Reddock, 2017, voor beoordelingen). Conform deze lacunes in de literatuur, heeft dit proefschrift drie algemene onderzoeksdoelen nagestreefd in vier empirische onderzoeken met 248 deelnemers in zowel laboratorium- als meer ecologisch valide omgevingen. Meer specifiek, (1) het onderzoeken van de nadelige gevolgen van lange instructies voor eenvoudige taken, (2) de ontwikkeling en implementatie van maatregelen om de negatieve effecten van lange instructies te verminderen en, (3) meer inzicht te krijgen in de dynamiek van het gedrag van astronauten, door wekelijkse variaties te bestuderen in de perceptie door bemanningsleden van behoefte-ondersteunende interacties van Mission Support en wekelijkse variaties in behoeftesatisfactie en het algemeen functioneren van de bemanning in een ecologisch valide omgeving.

Resultaten en Discussie

De Effecten van Lange Instructies voor Eenvoudige Taken

Resultaten. Twee experimentele studies met 113 en 123 deelnemers ($M_{leeftijd}$ = 18.75, Hoofdstuk 2 en $M_{leeftijd}$ = 19.25, Hoofdstuk 3, respectievelijk) toonden de negatieve effecten aan van het verstrekken van lange instructies voor eenvoudige taken. Samenvattend vonden deze experimenten dat lange instructies de autonome motivatie om instructies te volgen verminderen, de neiging om instructies te negeren versterkten, meer gevoelens van irritatie, verveling en inspanning opwekten, en taakaccuraatheid negatief beïnvloedden. Bovendien, wanneer taken relatief eenvoudig waren, verminderden lange instructies ook de productiviteit. Het merendeel van deze negatieve effecten was minder uitgesproken of afwezig, voor complexe taken. Al bij al suggereren deze bevindingen dat het aanbieden van lange instructies nadelige gevolgen heeft voor de motivatie, het affect en de performantie van individuen, in het bijzonder voor eenvoudige taken. Hiermee bevestigen deze studies anekdotische bronnen die getuigen van de frustraties en gevoelens van demotivatie voor astronauten, voortvloeiend uit gedetailleerde procedurele instructies voor eenvoudige routineactiviteiten.

Praktische implicaties. De bevindingen in Hoofdstuk 2 en 3 bieden een waardevol inzicht in de negatieve gevolgen van het toevoegen van instructies voor relatief eenvoudige taken. Uiteraard houden ruimtevaartagentschappen zich voornamelijk bezig met het bieden van voldoende ondersteuning en begeleiding aan astronauten voor hun dagelijkse activiteiten. Ruimtevaartagentschappen moeten echter overwegen om een onderscheid te maken tussen complexe operaties en meer routineuze eenvoudige taken. Hoewel uitgebreidere instructies waarschijnlijk als nuttig en behulpzaam worden ervaren voor complexe operaties, kunnen astronauten meer baat hebben bij minder begeleiding voor eenvoudige taken, om de demotiverende gevolgen van lange instructies te vermijden.

Behoefte-ondersteunende maatregelen

Resultaten. Hoewel het verkorten van procedurele instructies misschien niet altijd haalbaar is, bijvoorbeeld wanneer instructies worden geëvalueerd en goedgekeurd door strikte veiligheidsraden, kunnen ruimtevaartorganisaties ook overwegen om lange instructies op een meer behoefte-ondersteunende manier aan te bieden. In een experimenteel onderzoek met 123 deelnemers ($M_{leeftijd}$ = 19.25, Hoofdstuk 3), onderzochten we of instructies met een behoefte-ondersteunende boodschap, en instructies met herhaalde actiekeuzes, de negatieve effecten van lange instructies voor eenvoudige taken kunnen verlichten. De resultaten toonden aan dat een behoefte-ondersteunende communicatiestijl effectief was in het verminderen van gevoelens van verzet, irritatie en verveling, zonder nadelige effecten op de performantie. Keuzevoorziening via adaptieve instructies leverde gunstige effecten op voor alle motivationele en affectieve uitkomsten, naast een toename in accuraatheid. Mediatie-analyses toonden ook aan dat een toename in autonomie of gevoel van uitdaging, of beide, de meerderheid van de significante effecten van behoefte-ondersteunende en adaptieve instructies kon verklaren.

Praktische implicaties. De resultaten van deze studie suggereren dat de ervaring van autonomie en uitdaging bij astronauten tijdens het uitvoeren van een taak kan bevredigd worden door behoefte-ondersteunende maatregelen tijdens de missie. In het bijzonder kunnen Mission Support-leden meer autonomie-ondersteunend communiceren met bemanningsleden, of ze kunnen astronauten een keuze aanbieden in de hoeveelheid instructieve begeleiding, door middel van adaptieve instructies. Ruimtevaartorganisaties zouden echter ook op andere manieren een meer behoefte-ondersteunende houding kunnen handhaven, bijvoorbeeld door bemanningsleden meer uitingsvrijheid te gunnen, autonomie-ondersteunende corrigerende feedback te geven, en taken toe te wijzen in overeenstemming met de interesses en voorkeuren van bemanningsleden.

Behoefte-ondersteuning en -satisfactie in een Ecologisch Valide Setting

Resultaten. Hoewel de hierboven besproken experimentele studies nuttig inzicht verlenen in de causale impact van lange instructies en mogelijke tegenmaatregelen, blijft de vraag onduidelijk of de waargenomen voordelen van een behoefte-ondersteunende communicatiestijl ook worden opgemerkt in naturalistische omgevingen. Om dit probleem aan te pakken hebben we, tijdens de laatste acht weken van de Mars simulatiemissie HI-SEAS I (Hoofdstuk 4) en de jaarlange missie HI-SEAS IV (Hoofdstuk 5), de twaalf bemanningsleden (respectievelijk ($M_{leeftijd}$ = 39 en 30) wekelijkse variaties gemeten in gepercipieerde autonomie-ondersteunende communicatie van Mission Support, noodsatisfactie, welzijn, collaboratie met de grond, en performantie. Alles bij elkaar tonen de resultaten aan dat, hoewel hun gevoel van effectiviteit stabiel bleef, de bemanningsleden tijdens de missie steeds minder verbondenheid en autonomie ervoeren. Hoewel de bijdragen van wekelijkse variaties in hun gevoel van effectiviteit, en verbondenheid met vrienden en familie thuis, beperkt waren in hun voorspelling van wekelijkse uitkomsten, leverden wekelijkse variaties in hun ervaring van autonomie, en vooral verbondenheid met de bemanningsleden, sterke en significante associaties op met motivatie, welzijn, performantie, en collaboratie met Mission Support. Tot slot toonden de bevindingen ook aan dat, in de weken waarin bemanningsleden Mission Support als meer autonomie-ondersteunend ervoeren, zij gelijktijdig meer behoeftesatisfactie voelden.

Praktische implicaties. De week-tot-week studies uitgevoerd tijdens HI-SEAS I en IV onderstrepen de noodzaak voor ruimtevaartorganisaties om behoefte-ondersteunende maatregelen te implementeren, aangezien bemanningsleden mogelijk steeds meer het risico lopen op behoeftefrustratie naargelang missies langer duren. De bevindingen onderstrepen ook de ecologische validiteit van de experimentele bevindingen, door het belang van behoeftesatisfactie en een autonomie-ondersteunende houding tegenover bemanningsleden te bevestigen in een meer naturalistische setting. De beperkte voorspellende waarde van competentie, geoperationaliseerd in deze studies als meesterschap of effectiviteit, suggereert dat competentiefrustratie voor astronauten eerder voortvloeit uit een gebrek aan uitdaging, gebruik van vaardigheden en gevoel van voldoening. Verder onderzoek is nodig om inzicht te krijgen in dit enigszins onderbelicht facet van de behoefte aan competentie.

Conclusie

De vele uitdagingen en sensaties van bemande ruimtevaart kunnen aanleiding geven tot een verscheidenheid aan psychologische problemen en ingrijpende positieve effecten. Het is daarom cruciaal om astronauten te voorzien van een behoefte-ondersteunende werk- en leefomgeving, die hun psychologische behoeftes kan bevredigen, zodat ze hun potentieel volledig kunnen actualiseren, dat als buffer tegen stressoren fungeert en hun salutogenetische ervaringen versterkt. Het doel van dit proefschrift was om een bijzonder frustrerend facet van de astronautische werkvloer te onderzoeken, namelijk het aanbieden van uitgebreide instructies voor relatief eenvoudige taken. Uit de resultaten van dit onderzoek is gebleken dat het verstrekken van lange instructies een negatieve invloed heeft op motivatie, affect en performantie, vooral voor eenvoudige taken, in vergelijking met korte instructies. Er werden verschillende maatregelen voorgesteld om deze nadelige effecten te verminderen en noodsatisfactie, welzijn en performantie te verbeteren. Lange instructies op een behoefte-ondersteunende wijze aanbieden, en herhaalde keuzemogelijkheden via adaptieve instructies implementeren, bleken positieve effecten te hebben op noodsatisfactie, motivatie, welzijn en performantie. Verder hadden de ervaring van autonomie en een gevoel van uitdaging en voldoening, belangrijke rollen als verklarende mechanismen voor de effectiviteit van een behoefte-ondersteunende communicatiestijl en adaptieve instructies. De potentiële effectiviteit van een behoefte-ondersteunende communicatiestijl werd ook aangetoond tijdens twee ecologisch valide studies die werden uitgevoerd tijdens twee verschillende Mars simulatiemissies. Afgezien van de behoefte aan autonomie, en in mindere mate competentie, bleek verbondenheid met medebemanningsleden bijzonder voorspellend te zijn voor verschillende cruciale uitkomsten in het welzijn en functioneren van de bemanning. Samenvattend getuigen de bevindingen van dit proefschrift van het belang van behoeftebevrediging voor bemanningsleden, en van de effectiviteit van behoefte-ondersteunende maatregelen om de motivatie, het welzijn en de performantie van de bemanning te bevorderen. Op basis van deze bevindingen worden verschillende praktische tegenmaatregelen voorgesteld die ter harte kunnen worden genomen door ruimtevaartorganisaties, ten behoeve van de bemanningsleden, en het succes van bemande ruimtevaart in het algemeen.

Referenties

Britt, T. W., Jennings, K. S., Goguen, K., & Sytine, A. (2016). *The role of meaningful work in astronaut health and performance during long-duration space exploration missions* (NASA/TM-2016-219276). Houston, Texas, NASA Johnson Space Center.

De Gieter, S., Hofmans, J., Bakker, A. B. (2018). Need satisfaction at work, job strain, and performance: A diary study. *Journal of Occupational Health Psychology*, *23*, 361-372.

Deci, E. L., & Ryan, R. M. (2008). Self-Determination Theory: A macrotheory of human motivation, development, and health. *Canadian Psychology-Psychologie Canadienne, 49*, 182-185.

Deci, E. L., Olafsen, A. H., & Ryan, R. M. (2017). Self-Determination Theory in work organizations: The state of a science. *Annual Review of Organizational Psychology and Organizational Behavior, 4*, 19-43.

Hendricks, H., Mauroo, T., & Van Spilbeeck, B. (2009). *Het Ruimtedagboek van Frank De Winne: Dagelijks Leven in het ISS.* Leuven: Van Halewyck.

Ihle, E., Ritsher, J., & Kanas, N. (2006). Positive psychological outcomes of spaceflight: an empirical study. *Aviation, Space, and Environmental Medicine, 77*, 93-102.

Kalery, A., Sorokin, I., & Tyurin, M. (2010). Human space exploration beyond the international space station: role of relations of human, machine and the ‘‘Earth’’. *Acta Astronautica, 67*, 925-933.

Krikalev, S., Kalery, A., Sorokin, I. (2010). Crew on the ISS: creativity or determinism. *Acta Astronautica*, *66*, 68-78.

Landers, R. N., & Reddock, C. M. (2017). A meta-analytic investigation of objective learner control in web-based instruction. Journal of Business Psychology, 32, 455-478. Lawton, R. (1998). Not working to rule: Understanding procedural violations at work. *Safety Science, 28*, 77-95.

Mcphee, J. C., & Charles, J. B. (2009). *Human health and performance risks of space exploration missions* (NASA SP-2009-3405). Houston, Texas, NASA Johnson Space Center.

Morgeson, F. P. (2015). *Issues in Maintaining Team Motivation over Long-Duration Exploration Missions*, (NASA/TM-2015-218586). Houston, Texas, NASA Johnson Space Center.

Olafsen, A. H., Deci, E. L., & Halvari, H. (2018). Basic psychological needs and work motivation: A longitudinal test of directionality. *Motivation and Emotion, 42*, 178-189.

Peldszus, R., Dalke, H., Pretlove, S., & Welch, C. (2014). The perfect boring situation - Addressing the experience of monotony during crewed deep space missions through habitability design. *Acta Astronautica, 94*, 262-276.

Review, 22, 271-296.

Ryan, R. M., & Deci, E. L. (2000). The darker and brighter sides of human existence: basic psychological needs as a unifying concept. *Psychological Inquiry, 11*, 319-338.

Suedfeld, P., Legkaia, K., & Brcic, J. (2010). Changes in the hierarchy of value references associated with flying in space. *Journal of Personality*, *78*, 1411-1436.

Van de Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in teacher-student interaction: a decade of research. *Educational Psychology Review, 22*, 271-296.

Vansteenkiste, M., Niemiec, C. P., & Soenens, B. (2010). The development of the five mini- theories of Self-Determination Theory: A historical overview, emerging trends and future directions. In T. Urdan & S. Karabenick (Eds.). *Advances in Motivation and Achievement: Vol. 16. The decade ahead* (pp. 105-166). Bingley, United Kingdom: Emerald.

APPENDIX

Data Storage Fact Sheet

Name/identifier study: Sophie Goemaere Chapter 2

Author: Sophie Goemaere

Date: 28/09/2018

1. Contact details

===

1a. Main researcher

- name: Sophie Goemaere
- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: sophie.goemaere@UGent.be

1b. Responsible Staff Member (ZAP)

- name: Prof. Dr. Maarten Vansteenkiste
- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: maarten.vansteenkiste@ugent.be

If a response is not received when using the above contact details, please send an email to data-ppw@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the datasets to which this sheet applies

===

* Reference of the publication in which the datasets are reported:

Goemaere, S., Beyers, W., De Muynck G.-J., & Vansteenkiste, M. (2018). The paradoxical effect of long instructions on negative affect and performance: When, for whom and why do they backfire? *Acta Astronautica*, *147*, 421-430.

* Which datasets in that publication does this sheet apply to?: LEGO. Information about the files that have been stored

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3a. Raw data

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* Have the raw data been stored by the main researcher? [X] YES / [ ] NO

If NO, please justify:

* On which platform are the raw data stored?

- [X] researcher PC

- [X] research group file server

- [ ] other (specify): ...

* Who has direct access to the raw data (i.e., without intervention of another person)?

- [X] main researcher
- [X] responsible ZAP
- [X] all members of the research group
- [ ] all members of UGent
- [ ] other (specify): ...

3b. Other files

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* Which other files have been stored?

- [X] file(s) describing the transition from raw data to reported results. Specify: SPSS syntax file describing the transformation of raw data into the used variables.
- [X] file(s) containing processed data.
- [X] file(s) containing analyses. Specify: SPSS syntax file for the conducted analyses
- [ ] files(s) containing information about informed consent. Specify: ...
- [ ] a file specifying legal and ethical provisions. Specify: ...
- [ ] file(s) that describe the content of the stored files and how this content should be interpreted. Specify: ...
- [ ] other files. Specify: ...

* On which platform are these other files stored?

[X] individual PC

- [X] research group file server

- [ ] other: ...

* Who has direct access to these other files (i.e., without intervention of another person)?

- [X] main researcher

- [X] responsible ZAP

- [X] all members of the research group

- [ ] all members of UGent

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Data Storage Fact Sheet

Name/identifier study: Sophie Goemaere Chapter 3

Author: Sophie Goemaere

Date: 28/09/2018

1. Contact details

===

1a. Main researcher

- name: Sophie Goemaere

- address: Henri Dunantlaan 2, 9000 Ghent, Belgium

- e-mail: sophie.goemaere@UGent.be

1b. Responsible Staff Member (ZAP)

- name: Prof. Dr. Maarten Vansteenkiste

- address: Henri Dunantlaan 2, 9000 Ghent, Belgium

- e-mail: maarten.vansteenkiste@ugent.be

If a response is not received when using the above contact details, please send an email to data-ppw@ugent.be or contact Data Management, Faculty of Psychology and Educational Sciences, Henri Dunantlaan 2, 9000 Ghent, Belgium.

2. Information about the datasets to which this sheet applies

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* Reference of the publication in which the datasets are reported:

Goemaere, S., Vansteenkiste, M., & Beyers, W. (2018). How to buffer the motivational and performance deficits of long instructions for procedural tasks? Comparing the role of user control instructions, an autonomy-supportive communication style and the use of short instructions. *Manuscript submitted for publication*.

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3a. Raw data

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* Have the raw data been stored by the main researcher? [X] YES / [ ] NO

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* On which platform are the raw data stored?

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- [X] responsible ZAP

- [X] all members of the research group

- [ ] all members of UGent

- [ ] other (specify): ...

3b. Other files

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Data Storage Fact Sheet

Name/identifier study: Sophie Goemaere Chapter 4

Author: Sophie Goemaere

Date: 28/09/2018

1. Contact details

===

1a. Main researcher

- name: Sophie Goemaere

- address: Henri Dunantlaan 2, 9000 Ghent, Belgium

- e-mail: sophie.goemaere@UGent.be

1b. Responsible Staff Member (ZAP)

- name: Prof. Dr. Maarten Vansteenkiste

- address: Henri Dunantlaan 2, 9000 Ghent, Belgium

- e-mail: maarten.vansteenkiste@ugent.be

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2. Information about the datasets to which this sheet applies

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* Reference of the publication in which the datasets are reported:

Goemaere, S., Vansteenkiste, M., Beyers, W. , Vermeulen, A.C.J., & Binsted, K. (2018). Do astronauts benefit from autonomy? Investigating perceived autonomy-supportive communication by Mission Support, astronauts' motivation and collaboration during HI-SEAS I. *Manuscript in revision*.

* Which datasets in that publication does this sheet apply to?: EXCEL. Information about the files that have been stored

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3a. Raw data

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* Have the raw data been stored by the main researcher? [X] YES / [ ] NO

If NO, please justify:

* On which platform are the raw data stored?

- [X] researcher PC

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- [X] main researcher

- [X] responsible ZAP

- [X] all members of the research group

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- [ ] other (specify): ...

3b. Other files

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Data Storage Fact Sheet

Name/identifier study: Sophie Goemaere Chapter 5

Author: Sophie Goemaere

Date: 28/09/2018

1. Contact details

===

1a. Main researcher

- name: Sophie Goemaere
- address: Henri Dunantlaan 2, 9000 Ghent, Belgium
- e-mail: sophie.goemaere@UGent.be

1b. Responsible Staff Member (ZAP)

- name: Prof. Dr. Maarten Vansteenkiste
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Goemaere, S., Van Caelenberg, T., Beyers, W., Binsted, K., & Vansteenkiste, M. (2018). Life on Mars from a Self-Determination Theory perspective: How astronauts' needs for autonomy, competence and relatedness go hand in hand with crew health and mission success - Results from HI-SEAS IV. *Manuscript in revision.*

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- [ ] all members of UGent
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3b. Other files

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