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The ecological significance of the overview effect: Environmental attitudes and behaviours in astronauts

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ABSTRACT

The aim of this exploratory study was to investigate the previously underexplored ecological dimension of the overview effect phenomenon – the cognitive shift in awareness experienced by astronauts as a result of seeing Earth from outer space – and to identify and describe its defining features. Based on 14 semi-structured interviews with astronauts, this study applied interpretive phenomenological analysis (IPA) and utilized the Environmental Attitudes Inventory (EAI) measures to qualitatively demonstrate that the overview effect contains an unanticipated and distinguishable ecological significance that has the ability to markedly influence post-spaceflight environmental attitudes and behaviours (EABs), resulting in a new level of environmental awareness and consciousness in astronauts. This study also qualitatively mapped the breadth and depth of participants' present EABs, contributing first-time observations on attitudes towards specific ecological issues and behaviours pertaining to environmental movement activism and personal conservation practices. The potential utility of the phenomenon's ability to more broadly increase environmental awareness and concern is underexplored but promising. Further research to expand on this study's findings, as well as the purposive and strategic application of astronauts in national and international environmental communication and engagement initiatives, is suggested.

1. Introduction

Environmentalism and human space exploration share complex psychological linkages that substantiate a renewed consideration in the context of our intensifying ecological crisis (IPCC 2018). Individuals' motivation to behave in sustainable ways "constitutes a key challenge for environmental science" (Langenbach, Berger, Baumgartner, & Knoch, 2019, 1), with the need to transform the dominating anthropogenic consciousness that serves as the psychological basis of the crisis increasingly urgent (Biriukova, 2005, 34). One phenomenon in particular, produced as a result of human spaceflight, shows underexplored but promising potential for environmentalism back on Earth. The overview effect—a term coined by Frank White in 1987—is a "cognitive shift in awareness" experienced by astronauts during spaceflight that, among others, leads to "a renewed sense of responsibility for taking care of the environment" (White, 2014, 2).[1] Aside from the aforementioned line, White does not explore the qualitative or quantitative attributes of this "renewed sense" despite fragmented evidence in the source material and existing literature suggesting the phenomenon may contain much greater ecological significance than has been previously investigated. While long-term changes in astronauts' personal outlook and general attitudes towards their relationship to the Earth have been documented (Yaden et al., 2016), and while one study quantitatively demonstrated a post-spaceflight increase in astronauts' involvement with environmental causes (Ihle, Ritsher, & Kanas, 2006), these changes have not been previously explored systematically and qualitatively from an ecological perspective.

The overview effect can best be explained through a heightened feeling of awe and wonder (Yaden et al., 2016). It is related to a sense of vastness and aesthetic beauty that emphasizes perceptual and conceptual themes of awe (Shaw, 2017; Silvia, Fayn, Nusbaum, & Beaty, 2015), resulting in altered perceptions of the Earth's beauty and existential value (Ihle et al., 2006; Stuster, 2010; Yaden et al., 2016). The outer space perspective of Earth is unique; a landmark

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[1] The full definition is necessary here: "A cognitive shift in awareness reported by some astronauts and cosmonauts during spaceflight, often while viewing the Earth from orbit, in transit between Earth and the moon, or from the lunar surface. It refers to the experience of seeing first-hand the reality that the Earth is in space, a tiny, fragile ball of life, 'hanging in the void', shielded and nourished by a paper-thin atmosphere. The experience often transforms astronauts' perspective on the planet and humanity's place in the universe. Some common aspects of it are a feeling of awe for the planet, a profound understanding of the interconnection of all life, and a renewed sense of responsibility for taking care of the environment." (White, 2014, 2).

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neurophenomenological study suggests this specific view, and not merely of any other celestial body, was key to inducing enhanced awe and wonder experiences (Reinerman-Jones, Sollins, Gallagher, & Janz, 2013), while also being different from terrestrial awe-inducing experiences as "it has tremendous, perhaps absolute, conceptual vastness" (Yaden et al., 2016, 4). Despite its promising potential to lead to transformative and enduring change (Gaggioli, 2016), awe has only recently started receiving rigorous empirical attention (Chirico, Yaden, Riva, & Gaggioli, 2016). It is both an emotion that is powerful and complex and a response to a perception of vastness that challenges our mental schemas to accommodate that vastness (Keltner & Haidt, 2003). While awe and aesthetic beauty might be insufficient in explaining long-term changes in astronauts (Cohen, Gruber, & Keltner, 2010), self-transcendent experiences (STEs) can be used to explain the more transformative versions of the experience, meaning the overview effect could perhaps best be understood "as a state of awe with self-transcendent qualities, precipitated by a particularly striking visual stimulus" (Ibid.). STEs are temporary, positive feelings of unity and connection to other individuals or humankind that can even be transformative – subjects have reported such experiences to be among the most important in their lives (Griffiths, Richards, Johnson, McCann, & Jesse, 2008; Hood, Hill, & Spilka, 2009; Yaden, Haidt, Hood, Vago, & Newberg, 2017). Awe has numerous psychological benefits (Yaden et al., 2016), including influencing attitudes and beliefs (Chirico, Ferrise, Cordella, & Gaggioli, 2018; Schneider, 2009).

As such, any transformative or long-term changes resulting from the phenomenon's ecological dimension could best be investigated through environmental attitudes and behaviours (EABs). Environmental attitudes (EAs), encompassing environmental concern and its hierarchical and multidimensional nature (McIntyre & Milfont, 2016), are a latent construct and psychological tendency expressed by evaluative responses to the natural environment with some degree of favour or disfavour (Milfont & Duckitt, 2010), and can be inferred from overt responses, self-report methods or implicit measurements (Himmelfarb, 1993). EAs have preservation and utilization dimensions, fluctuate over time, and vary according to numerous demographic factors, often determining behaviour that increases or decreases environmental quality (Gifford & Sussman, 2012). Environmental behaviours (EBs), understood as individual behaviours contributing to environmental sustainability (Mesmer-Magnus et al., 2012), can be interpreted through intent-oriented or impact-oriented approaches, with criticism of the former being neglect of behaviour patterns with strong objective environmental impacts (Bamberg & Rees, 2015; Gatersleben, Steg, & Vlek, 2002). EBs can be categorized as activism, nonactivist public sphere behaviours, and private sphere environmentalism (Stern, 2000). Most studies have established a potentially strong but much debated link between pro-environmental attitudes and behaviours (EABs) (Gifford & Sussman, 2012; Hines, Hungerford, & Tomera, 1986; Kaiser, Wölfing, & Fuhrer, 1999), with the added need to also address social norms, costs and benefits, individuals' emotions, values, and morals, and contextual factors (Steg & Vlek, 2009).[2]

Demonstrating long-term changes in EABs can carry significant implications for enhancing environmental communication and messaging (Gifford & Sussman, 2012). As such, this exploratory study sought to answer: Does the overview effect's ecological dimension significantly influence astronauts' long-term EABs, and if so, why does this significance come about and what is the sequence of change? The aim was to provide rich contextual information about astronauts' feelings, emotions and perceptions in order to investigate this previously underexplored ecological significance, to identify and describe its defining features, and to explore its qualitative contribution to long-term changes in EABs.

2. Methods

Qualitative research in psychology, especially investigating aspects of awe experiences, have been successful in generating meaningful evidence in the past (Frost, 2011; Willig, 2013; Yaden et al., 2016). According to astronaut Michael Lopez-Alegria, "it is extremely hard to describe quantitatively the change in people before and after spaceflight" (White, 2014, 269). As such, semi-structured interviews utilizing a questionnaire of 8–9 open-ended and exploratory questions (Appendix I) were conducted and analysed through interpretive phenomenological analysis (IPA) (Smith & Osborn, 2003), chosen due to its synthesis of phenomenology and hermeneutics and reliance on idiography that allows for flexible bottom-up theory building (Pietkiewicz & Smith, 2014).

2.1. Data collection

Approximately 150 astronauts were contacted based on purposive sampling (Smith & Osborn, 2003) and ease of sampling due to accessibility limits,[3] and financial and temporal constraints.[4] Fourteen individuals agreed (n = 14) – 13 career astronauts and one spaceflight participant, meaning, space tourist – representing a normative sample size for IPA (Brocki & Wearden, 2006; Turpin et al., 1997). Participants were interviewed once by the author by telephone or Skype over a three-month period between May and July 2019 (Table 1), and as such, "present" in the text always refers to EABs assessed during this time period.

Potential limitations include the lack of generational, cultural and gender-based representativeness and the known limitations of astronauts' accounts, whether due to systemic incentives to only report positive experiences of spaceflight (Bimm, 2014; Harrison & Fiedler, 2011) or "too laconic" expressiveness due to their occupations (i.e. military) that are known to not display excitement during flight (White, 2014, 7). Minimization of subjects' self-selection bias was attempted through vague but non-deceptive phrasing of the participation request.[5] Local ethical approval had been secured, which determined there were no notable risks, dangers or hazards to the participants, who were offered the right to withdraw anytime during the process and full confidentiality and anonymity in both the initial email request and at the beginning of the interview to ensure informed consent to public attribution of responses.[6]

Each interview, utilizing the questionnaire (Appendix I), lasted approximately half an hour (n = 12), 45 min (n = 1) and one and a

[2] The discrepancy between measured EABs can be further explained by Rastogi's (2009) four causes, quoted in Kollmuss and Agyeman (2002, 242): (1) normative influences, such as social norms; (2) direct experiences having a stronger influence on one's behaviour than indirect experiences; (3) temporal discrepancy of one's attitudes changing over time; and (4) attitude measurement being much broader in scope than measured actions, leading to discrepancies in the results. These are important to keep in mind for this article's data analysis.

[3] Those who had publicly available contact information were contacted directly by email or social media handle.

[4] Temporal constraints meant participants were asked to recall and remember their pre-spaceflight EABs, which was employed as an imperfect – due to reliance on memory – but practicable approach to extracting meaningful past information, given the lengthy timelines of astronaut training, launches, and missions.

[5] The request stated the study was about "the intersection of environmental attitudes and space travel". Some participants asked for further details or asked to see the questionnaire before consenting to be interviewed.

[6] Since all participants were retired or a spaceflight participant, public attribution of responses was decided and confirmed by the participants themselves. Some decided at the beginning while others at the end of the interview they would like to be named, with only one requesting anonymity status at the end of his interview.

Table 1
List of interview participants – in the order of interview date, including full name, age at time of interview, gender, nationality, astronaut status, number of spaceflights, year of first (and if applicable, last) spaceflight, and total completed days in space.

	Participant name	Age	Gender	Nationality	Astronaut status	Number of spaceflights	Year of first & last spaceflight	Total completed days in space
1	Story Musgrave	83	Male	American	Retired	6	1983–1993	53
2	James "Jim" Wetherbee	66	Male	American	Retired	6	1990–2002	66
3	Richard Garriott	57	Male	American, British	Spaceflight participant	1	2008	11
4	Loren Acton	83	Male	American	Retired	1	1985	7
5	Jerome "Jay" Apt	70	Male	American	Retired	4	1991–1996	35
6	Jeffrey Hoffman	74	Male	American	Retired	5	1985–1996	50
7	Anonymous	–	Male	American	Retired	–	–	–
8	Walter Cunningham	87	Male	American	Retired	1	1968	10
9	Dorothy Metcalf-Lindenburger	44	Female	American	Retired	1	2010	15
10	Ronald "Ron" Garan	57	Male	American	Retired	2	2008–2011	177
11	Nicole Stott	56	Female	American	Retired	2	2009–2011	103
12	Franz Viehbock	58	Male	Austrian	Retired	1	1991	7
13	Albert "Al" Sacco	70	Male	American	Retired	1	1995	15
14	Robert Thirsk	65	Male	Canadian	Retired	2	1996–2009	204

half hour (n = 1). When all 14 interviews concluded – at which point the data collection had reached the point of saturation (Strauss & Corbin, 1998, pp. 101–122) – the audio recordings were transcribed for analysis utilizing the Otter Voice Notes transcription software. Once the transcription was complete, each individual interview was listened to and compared against the voice recording to ensure verbatim transcription and to gain an important 'first impression' (Elliott & Timulak, 2005, 152) of the overall data that totalled 53,313 words.

2.2. Data analysis

Employing the four-stage process of IPA (Pietkiewicz & Smith, 2014; Smith, Flowers, & Larkin, 2009; Smith & Osborn, 2003), the transcript of all participants' interviews, organized in chronological order of interview date, was given multiple readings, with the content open coded (Strauss and Corbin, 1998) using descriptive, linguistic and conceptual comments and analysed paragraph-by-paragraph by the author writing notes on the margins that faithfully represented participants' subjective experiences and insights (Smith et al., 2009, 82). These notes were then transformed into emergent themes using colour-coded labels (i.e. atmosphere) in order to formulate concise phrases at a higher level of abstraction (Pietkiewicz & Smith, 2014, 12), resulting in 57 emergent themes/labels (Appendix II).

To further cluster these 57 themes based on connections and relationships between them, the 12 measurement categories (Appendix III) of the Environmental Attitudes Inventory (EAI) of Milfont and Duckitt (2010) were employed due to conceptual similarities (Smith et al., 2009) in the EAI measures that corresponded nearly uniformly to the 57 themes identified by the researcher. The 57 themes were assigned to a conceptually equivalent EAI measure or categorized as "None" when no such equivalency was available,[7] resulting in 15 clusters (12 EAI measures and three "none"), which were then further refined into 11 subcategories using abstraction, and then finally into three superordinate categories (Appendix II) based on conceptual similarities (Pietkiewicz & Smith, 2014, 12; Smith et al., 2009, 96). The three "None" categories represented the author's interpretive analysis of participants' (1) overview effect experience intensity and level of change in (2) EAs and (3) EBs from pre-spaceflight to present. These were categorized qualitatively using four descriptive categories: high, moderate, minimal, or none (Appendix IV). For (1), participants' comments were analysed for conceptual and linguistic similarity to White's (2014) overview effect definition and self-described intensity of emotion or experience (Appendix IV – Table 4). For (2), participants' comments were descriptively and linguistically compared to self-described past and present EAs for approximating the qualitative level of change (Appendix IV – Tables 5 and 6), with the same process repeated for (3) EBs (Appendix IV – Tables 7 and 8).

Multiple levels of interpretation to further elicit meaning from the experiences were then applied by reviewing themes, using metaphors and temporal referents, and drawing on existing theory and concepts (Peat, Rodriguez, & Smith, 2019). One researcher reviewed the themes and clusters to ensure representativeness. The extracts presented hereafter represent the essence of emergent themes or provide the most powerful expressions. The findings provide a coherent narrative and analytical account grounded in pertinent participant quotes and the author's detailed interpretive commentary (Peat et al., 2019; Pietkiewicz & Smith, 2014).

3. Results

The table below (Table 2) compares the IPA results from across the three superordinate categories.

3.1. Category 1: Ecological dimensions of the overview effect

3.1.1. Overview effect

The majority of participants expressed highly intensive overview effect experiences including physical reactions: "*shudder, goosebumps*" (1, 10) and "*it sent a chill up my spine*" (2). Participants described the view as "*a very mind-altering kind of experience*" (7) and "*the most beautiful thing I've ever seen*" (6), mentioning reactions such as "*you feel like you're one with everything living*" (7); "*sense of interconnectivity […] we're all in space together already*" (5); and "*it really drives home the undeniable unity that the planet represents*" (6). The moderate experience was attributed to a "*meaningful*" overview effect reaction delayed by illness and lack of time (11), while more minimal reactions acknowledged the experience's beauty but without any transformative elements (12, 13). One participant appeared to have not experienced the effect, possibly due to lack of time and deteriorating visibility conditions (14).

3.1.2. Aesthetic beauty

Participants emphasized the unexpectedly crystal-clear view of the planet and stars resulting from the lack of atmospheric distortion experienced from the surface, saying the aesthetic view of Earth was

[7] Measures 4 and 7, as well as 9 and 10, were paired together respectively for the analysis as this better represented participants' comments and insights.

Table 2
Comparison of participants' overview effect experience and changes in EABs from pre-spaceflight to present..

Quotation attribution number	Participant last name & year of first spaceflight	Intensity of the overview effect (Category 1)	Change in EAs (Category 2)	Change in EBs (Category 3)
1	Garriott (2008)	High	High	High
2	Thirsk (1996)	High	High	High
3	Viehbock (1991)	High	High	High
4	Hoffman (1985)	High	High	High
5	Stott (2009)	High	High	Moderate
6	Garan (2008)	High	High	Moderate
7	Sacco (1995)	High	High	Moderate
8	Anonymous (–)	High	High	Moderate
9	Apt (1991)	High	Moderate	Moderate
10	Metcalf-Lindenburger (2010)	High	Moderate	Minimal
11	Acton (1985)	Moderate	Minimal	Minimal
12	Musgrave (1983)	Minimal	Minimal	Minimal
13	Wetherbee (1990)	Minimal	None	None
14	Cunningham (1968)	None	None	None

Comparison of participants' overview effect experience and changes in EABs from pre-spaceflight to present.

"*overwhelming*" (4, 5, 7), "*impressive*" (3, 5, 13), and "*beautiful*" (9, 10); "*your view is so spectacular, and the detail you can see and what you believe you're learning just by watching is so compelling, that you are glued to this slowly moving map of the Earth rotating below you*" (1). Many emphasized colours, especially blues (waters) and reds and oranges (deserts), being incomparably brilliant and intensive from space, in a way not possible to see on Earth or in photographs from space (13).

3.1.3. Atmosphere & environmental fragility

Seeing the physical thinness of the atmosphere had a prominent emotional effect on most participants; six mentioned how seeing, as opposed to just intellectually knowing, this thinness was "*startling*" (10) and "*you really appreciate the finiteness of the layer of life on the planet*" (11). One metaphorically described: "*the difference between life on Earth and no life was just this incredibly thin layer of atmosphere […] sometimes I'd imagine some hypothetical fantastic giant coming by and blowing the Earth's atmosphere away and all life on Earth would cease to exist*" (2), expressing perception of its fragility.

3.1.4. Visible anthropogenic destruction & ecocentric concern

The majority emphasized seeing visible anthropogenic changes on the surface of Earth: "*the impact of humanity is everywhere*" (1); "*the environmental impact is easily seen from space*" (2); "*the human impacts are now visible from a cosmic perspective and that's pretty scary*" (4). Many mentioned seeing deforestation, coral bleaching, ocean dead zones, topsoil erosion, retreating glaciers, air pollution, pollution plumes from oil fields, and smoke spreading from burning areas. Both participants (3, 9) who flew in 1991 cited the infamous Aral Sea as an example: "*in just the few years that I flew in space you could see how it shrank*" (9). Seeing the destruction first-hand reinforced participants' impression of the Earth "*as an interconnected system, […] you can see the scale of ecological disaster, […] and those kinds of things are emotional*" (9) and "*everything on Earth is connected, everything is one*" (2), strongly emphasizing concern from an ecocentric perspective: "*You see beautiful things on Earth and then areas where humans have destroyed the environment. This always goes very deep and affects you, and [spaceflight] of course amplifies it somehow, because you've seen it*" (3).

3.1.5. Utility

The outer space perspective of Earth was said to be moderately or significantly useful for enhancing environmental outreach, including most participants expressing it is "*the key*" to improving environmental messaging (5) and "*we need to do a lot more of that*" (2), with its utility stemming from:

1. Demonstrating visible anthropogenic changes on the surface of the planet from the grander perspective of space;
2. Driving home messages of the interconnectivity of the planet as a singular socio-ecological system;
3. Space being a conversation starter on environmental issues, with the spaceflight experience serving as "*a foundation of awe and wonder that opens the mind and makes you accepting of different perspectives and ideas […] it is a much more effective way to discuss these issues*" (6).

However, its potential utility was also questioned (4, 8) due to the continuing environmental destruction since the 1970s despite the Apollo images' effect on the broader public.

3.1.6. Recreation on earth

Spaceflight was qualitatively different enough from other awe-inducing experiences on Earth because "*you see science playing out on a grand scale that you can only possibly perceive from space*" (1) and "*space is so different from anything on Earth*" (4), with some comparing in-person versus secondary (i.e. video) experiences of the Grand Canyon to illustrate this point. Some however expressed that being an educated observer of nature increased the opportunity of having similar awe-inducing experiences on Earth (11, 13), such as scuba diving producing "*similar feelings*" though not on the "*grander scale*" of space (5) or IMAX films being "*the next best thing in creating an overview effect*" on Earth (2). However, one cited the Cassini spacecraft's image Pale Blue Dot as "*more powerful than any spaceflight I took*" (12).

3.2. Category 2: Environmental attitudes

3.2.1. Attitude change

3.2.1.1. Past. The majority expressed having relatively moderate pro-EAs pre-spaceflight. The following past-to-present comparison is representative: "*I was attuned to the environment, I knew it was a priority for humanity to address, but I didn't think it was the top priority*" versus presently "*climate change is the number one issue we should be dealing with*" (2). Most cited family upbringing – "*my parents were scientists and naturalists in a broad sense*" (1) and historical context – such as Earth Day (4, 5, 8) – as influential. A few had uncharacteristically higher past pro-EAs, citing environmental passion since middle school (10) or a "*long-standing love of nature and animals*" (12), while two had minimal, expressing "*I've always had a bit of concern about our environment, not so much environmental issues*" (14), referring to concern specifically about pollution.

3.2.1.2. Present & change. Most expressed relatively high – meaning strong – present pro-EAs. Of these, some indicated high levels of change from past to present, which they related directly to their spaceflight: "*by the time I finished the flight, I was a lot more environmentally conscious than I ever was before. We used to say, if you weren't a tree hugger before you went up, you were a tree hugger when you got back […] When I came back, I thought of it a lot more and became much more associated with the sustainability issue*" (7); and "*before there wasn't a conscious awareness of it in my daily life. Now there is. Not a day goes by that it's not in the front and the back of my mind*" (5). Others described spaceflight having an "*enriching*" (12), "*enhancing*" (11), "*sensitizing*" (3, 9), "*cementing*" (8), "*reinforcing*" (6, 7, 10), "*awareness-raising*" (3, 10), and "*amplifying*" (3) effect on pre-spaceflight EAs. The following comments are representative of the nuances: "*In the past, I was not as engaged. The awareness was not as high as afterwards, certainly spaceflight increased it*" (3); "*it was a part of who I was prior to flying in space but it did have an enhancing and reinforcing effect*" (10); "*it's one thing to be intellectually interested in ecology […] going up to space gave all of that a much more immediate and emotional impact*" (4). While the majority discussed their present EAs with language expressing strong concern, importance and urgency, two (13, 14) expressed no change and anthropogenic scepticism: "*My attitude hasn't changed, I've had that attitude my whole life, that it's bad to pollute*. […] *People think that humans are causing climate change and I think it's the sun. We can't control that one bit. […] It doesn't change my opinion that we ought to try to decrease our impact on the environment*" (13).

3.2.1.3. Future. Participants expressed optimistic and pessimistic attitudes about the future, utilizing temporal referents for both: "*I'm hopeful but I don't see any reason for being hopeful right now*" (2) and "*I think in the short term we're already in deep trouble […] but I'm more optimistic when it comes to a longer time frame*" (6). Some expressed renewed optimism due to what they perceived as increased environmental consciousness and movement in the younger generation (7) and at the local, grassroots levels of society (5).

3.2.2. Attitudes towards ecological issues

3.2.2.1. Enjoyment of nature. Those who mentioned enjoyment of nature expressed highly positive attitudes, with enjoyment due to both recreational activities and personal habitat proximity: "*When I'm in the midst of nature is probably my most fulfilling time on Earth*" (2), "*I like going to spaces that are open and untouched and more pristine*" (10), and "*We now live in a place where we have a beautiful view of the mountains […] you can go anywhere on Earth and just be astounded at the beauty of the place*" (13).

3.2.2.2. Support for interventionist conservation policies. Some brought up support for increased government regulation and international climate accords and expressed pessimism about countries' current commitment to meet such agreements, such as: "*we really have to legislative a number of these solutions*" (1) and "*the decision-makers on Earth are not adequately addressing these issues, even though the survival of society, of civilization, is not guaranteed, and you see that from space*" (2). However, one expressed negative attitudes towards government action on climate financing: "*we ought to try to decrease our impact on the environment, but we shouldn't be spending billions of dollars to do it because that will have more damaging effects*" (13).

3.2.2.3. Conservation motivated by anthropogenic concern & altering nature. The majority of participants expressed "*great concern*" (11) about climate change, pollution, biodiversity loss, single-use plastics, water usage, transportation and altering nature, and broadly expressed pro-conservation attitudes motivated by these factors. The following comments are representative: "*I like having dark skies so that people can actually see the stars and experience that without the human impact. We need to protect those*" and "*our electricity mostly comes from hydropower, but that doesn't mean it doesn't come at a cost to salmon because of how we put dams on rivers*" (10). Two expressed concern about land overuse and pollution (13, 14) but concern appeared stronger about anthropogenic overstatement: "*the only thing I'm concerned about is we're trying to blame all of this on human created carbon dioxide, it's ridiculous*" (14) and "*I disagree with the alarmism of climate change […] I still have the opinion it's bad to pump toxic material or garbage into the atmosphere because we're breathing the atmosphere […] anthropogenic change is much smaller than people attribute it. I think it's the sun that's causing the climate change and we can't control that one bit*" (13).

3.2.2.4. Confidence in science and technology. Many mentioned their scientific background as a component of their pro-EABs, thus indicating high confidence in science and technology: "*I'm a great believer, because I'm a chemical engineer, in recycling*" (7); "*you can't believe in things like climate change if you don't have the scientific background to understand how the system works […] I consider myself a reasonably well-educated environmentalist*" (11). Two (13, 14) expressed scepticism about mainstream scientific evidence on anthropogenic issues: "*I do a lot of research and reading […] I still think nobody is explaining to me what the downsides of climate change are.*" (13).

3.2.2.5. Human dominance over and utilization of nature. Some conceptualized human dominance over, and utilization of, nature in terms of needing to balance conservation with economic and developmental needs: "*it's a challenge we face, to be able to have a great economy and lives but in such a way that we're not harming the planet we live on*" (8). In implying the root problem is humanity's status quo approach to nature, another said "*maybe we'll learn to get resources from other parts of the solar system but I don't think that's going to solve our problems on Earth*" (4). One prioritized development and the economy over spending "*an exorbitant amount of money*" on sustainability (13).

3.2.2.6. Support for population policies. Few mentioned the topic and expressed support for managing population growth; they conceptualized it as a challenge of living "*within the bounds*" (12) or "*carrying capacity*" (4) of the planet given Western standards of living.

3.3. Category 3: Environmental behaviours

3.3.1. Behaviour change

Four described relatively high levels of behavioural change, which some attributed directly to spaceflight: "*Before my spaceflight, I was talking the talk, but not walking the walk. That's what really changed after*" (1); "*I was not very active in fighting for our environment […] but with the spaceflight experience, this awareness was much more increased and I'm doing much more conscious decisions now*" (3). Others demonstrated relatively moderate levels of change, with participants expressing the following attributions: spaceflight had a reinforcing effect on change they felt they were already undergoing – "*I think it reinforced what I had already been on a path to understand*" (6) – or understanding of personal environmental impact increased over time as scientific evidence became more available. Even when not directly leading to change, spaceflight appears to have indirectly made participants deepen or broaden their pro-EBs in the long-term: "*because of my spaceflight, I find it very significant to give back*" (10); "*everything I do is related to that both in a direct and indirect way. I think when I start to feel lazy about it, I say to myself, you need to be part of the solution*" (5). Two experienced no change but expressed a life-long commitment to pollution minimization (13) and "*trying to do what is right […] and keep our environment okay*" (14).

3.3.2. Environmental movement activism

Many indicated involvement with environmental businesses or organizations; teaching; personal outreach; and politics by running for office, such as "*I try to always teach my students and my family and*

everybody else how to be environmentally conscious of everything that they do. That's how I make my contribution" (7). Others also mentioned outreach to family and friends about EBs (2, 10). Eight mentioned active involvement in environmental outreach in the form of presentations to decision-makers, art, photography, and/or lectures for which they always "*include the environmental message*" (2), "*because, somehow, people are willing to listen to an astronaut talk about these things in a way that they might not attend the lecture of a university professor*" (4). Numerous participants emphasized their astronaut status making them a "*role model*" (10), allowing them to gain a wider audience on environmental issues.

3.3.3. Personal conservation behaviour

3.3.3.1. Waste disposal. All considered themselves environmentally conscious and practiced recycling and proper disposal of hazardous waste. Some also practiced composting (5, 10) or garbage picking (11), while some indicated this was still the area where they were "*the worst abuser*" (1) or a "*hypocrite*" despite instituting a recycling program at his university (7).

3.3.3.2. Transportation. Ten mentioned driving cars, of which half are electric (1, 5, 6, 8, 9). Of those driving non-electric, two expressed the desire to transition but mentioned where they live as a limitation (7, 11). Some mentioned biking (4, 5, 10) – "*I ride a bicycle to work every day. Wherever possible, we try to live ecologically*" (4) – and walking or using public transportation when possible (2, 3 10).

3.3.3.3. Energy usage. Half discussed their energy consumption, with two expressing lack of control over this factor given where they live (7, 8). Comments include: "*we to go off the grid as soon as possible*" (5), "*I'm very consciously trying to protect the environment in many ways, starting from using solar energy to produce my own electricity and heat for the water*" (3), and immediately after spaceflight, putting electric probes on every circuit, switching to LED lights, and changing the water circulation system specifically to reduce his home's energy usage (1).

3.3.3.4. Water usage. Half discussed their "*responsible*" (14) and "*low*" (6) water usage, including the negative impacts of plastic-bottled water (7). Some behaviours included tracking water consumption, using reclaimed water (5) or rainwater (3) for gardening, and turning off the tap while tooth-brushing or soaping in the shower. "*It's a consciousness*" (2).

3.3.3.5. Shopping habits. Many emphasized sustainable shopping habits and mentioned using canvas, cloth or reusable paper bags for groceries (2, 3, 4, 5, 6, 7, 8, 10). Comments include: "*we always try to do one trip that covers the whole week instead of making multiple trips*" (10), "*I buy repackaged things whenever possible*" (7), as well as not using plastic straws (6), using reusable drink containers (2, 10), beeswax wraps (10), and shopping at second-hand stores (2).

3.3.3.6. Diet. Nine participants discussed switching to more sustainable diets, these ranging from flexitarian (2, 6, 8, 10), to Mediterranean (12) and somewhat or mostly plant-based diets (1, 5). Some mentioned the importance of locally grown organic food and shopping at farmers' markets (3, 7, 10).

3.3.3.7. Voting. Some considered voting a part of their personal conservation behaviour (10, 11).

4. Discussion

4.1. Category 1: Ecological dimensions of the overview effect

As expected, most participants expressed highly intensive overview effect experiences linguistically and conceptually akin to White's (2014) definition, confirming prior observations. Most reported experiencing the cognitive shift in awareness resulting from the phenomenon, including "a renewed sense of responsibility for taking care of the planet" and feelings of interconnectedness and unity (White, 2014, 2), encompassing environmental fragility and ecocentric concern. The outer space perspective of Earth appears to satisfy the physical requirement of vastness in inducing awe and wonder experiences in astronauts (Shaw, 2017; Silvia et al., 2015; Yaden et al., 2016). While the aesthetic beauty of Earth and the atmosphere's thinness was a strong catalyst in inducing the overview effect and perceptual and conceptual themes of awe (Shaw, 2017; Yaden et al., 2016), these unexpectedly contributed to the emergence of positive environmental-themed, and not just awe and wonder-related, responses in participants.

Another key outcome is the contrast between perceptual themes of awe that emphasize positive (aesthetic beauty) and negative (visible ecological destruction) sights of Earth, the latter which was unexpectedly brought up by participants. Seeing evidence of anthropogenic destruction first-hand had a deeply emotional impact; the duality and juxtaposition of both positive and negative perceptual themes can be said to have amplified environmental responses produced by awe and wonder. This finding is significant in how visible ecological destruction from the outer space perspective, more specifically low Earth orbit (LEO), substantially amplifies environmental awareness and concern in direct observers. Combined with participants finding their spaceflight experience useful as a conversation starter on environmental issues, this is an interesting finding given pushback in the environmental community against 'planetary' language that posits the perspective masks local issues and complex realities on the ground (Collins, 2016; Garb, 1985; Strong, 2013). Findings suggest that while the outer space perspective of Earth from greater distances (i.e. Moon) may not convey humanity's impact on the planet (Boes, 2014), the LEO view is effective in conveying the scale and extent of ecological destruction. Paired with participants' perceptions that the view is qualitatively at least somewhat significantly different from awe-inducing experiences on Earth, this suggests the outer space perspective brings a unique element to environmentalism rather than just having a reinforcing effect on terrestrial elements of environmentalism. As such, participants' LEO spatial referent appears to be pivotal in triggering or amplifying environmental responses on the grander scale unique to the outer space perspective.

Studies using Virtual Reality (VR) to elicit awe and wonder (Quesnel & Riecke, 2017; Chirico et al., 2018) and to raise environmental awareness (Markowitz, Laha, Perone, Pea, & Bailenson, 2018) in participants have been successful in the past. Given the psychologically impactful nature of VR (Blascovich & Bailenson, 2011; Markowitz et al., 2018), its potential use to elicit the overview effect as a virtual experience in the general public (Stepanova, Quesnel, & Riecke, 2019), and specifically to make use of the above findings to increase environmental awareness and concern, should be further explored.

4.2. Category 2: Environmental attitudes

As expected, the majority already held predominantly moderate pro-EAs pre-spaceflight – most likely due to higher awareness of scientific issues and individual circumstances, i.e. family upbringing, historical context, and proximity to natural landscapes – that reflected preservation and utilization dimensions and evidence of fluctuation over time (Gifford & Sussman, 2012).

New findings pertain to changes in astronauts' EAs post-spaceflight, in which two distinct patterns emerged: for the majority, (1a) significant positive change directly resulting from the experience or (1b) more gradual or moderate change when the experience had a more indirect reinforcing/amplifying effect on EAs; and for the minority, (2) minimal to no detectable change connected to the experience. Two participants attributed their latter minimal change to higher-than-average levels of pre-spaceflight EAs while the two none-changers, who both expressed scepticism about anthropogenic causes of climate

change and biodiversity loss, expressed holding lifelong anti-pollution attitudes unchanged by spaceflight. Ten of 14 participants described moderate to high levels of direct or indirect change between pre-spaceflight and the present (1a, 1b), confirming that astronauts indeed experience long-term changes in personal outlook and attitudes towards their relationship to Earth (Yaden et al., 2016). However, the elevated levels of change indicate the overview effect's previously implied ecological significance goes beyond astronauts merely experiencing a "renewed sense of responsibility for taking care of the planet" (White, 2014, 2). While some indicated experiencing this "renewed sense" reinforcement of their EAs and a higher-level viewpoint "involving new awareness and consciousness" (White, 2014, 2), most participants categorically experienced an ecological version of this: a new *level* of environmental awareness and consciousness about Earth, suggesting more significant changes in EAs than implied by White and that the ability of the phenomenon to increase pro-EAs is much more significant than previously assumed.

All participants expressed various levels of concern for the environment and environmental issues, as expected (Gifford & Sussman, 2012). For most, concerns and pro-conservation attitudes were motivated by a wide range of anthropogenic issues, emphasized through first-hand accounts of temporal (i.e. disappearance of the Aral Sea) and spatial referents (i.e. retreating glaciers) and conceptualized as holistic and interconnected – "*what happens on one side of the planet affects everything else*" (6). Participants expressed both optimistic and pessimistic attitudes about the future, which is somewhat surprising as astronauts are said to possess "*an optimism that comes from going into space*" (8). Other themes included high enjoyment of nature, the need to balance conservation and economic development, and living within the 'carrying capacity' of the planet. Many supported interventionist conservation policies in the form of government action and international climate accords, confirming prior findings that the overview effect results in a recognized need for a global participatory management of the planet (Cox, 2014, xvi), and expressed very high confidence in science and technology. Unexpectedly, two participants (13, 14) indicated strong scepticism about mainstream scientific evidence on anthropogenic climate change and biodiversity loss, opposition to interventionist conservation policies involving financial costs and prioritization of economic development, thus expressing hierarchical perception of the nature-humanity relationship as opposed to the more holistic and ecocentric perceptions that emerged from other participants' responses. According to one participant, "*astronauts bring to this profession the same biases they had from before they were an astronaut*" (1), offering a possible explanation for the two participants' absence of attitude change.

4.3. Category 3: Environmental behaviours

This category encompassed the newest findings pertaining to how interactions of the spaceflight experience, intensity levels of the overview effect, and pre-existing experiences and attitudes influenced EBs, as well as findings about participants' environmental practices. As expected, all participants described some level of pre-spaceflight EBs; however, the majority expressed moderate to high levels of behavioural change from past to present, signifying the considerable breadth and depth of this development over time. Similarly to Category 2, two distinct patterns emerged in which spaceflight either (1a) directly or (1b) indirectly led or partially contributed to long-term behavioural change; or (2) resulted in minimal to no detectable change. More infrequently, the spaceflight experience had a direct impact (1a) on post-spaceflight EBs, but more commonly, it led to a direct elevation in or enhancement of EAs that subsequently contributed, among other terrestrial factors, to gradual and long-term behavioural change (1b). This is consistent with the academic literature that states EAs often determine behaviour that increases or decreases environmental quality (Gifford & Sussman, 2012, 65).

Participants expressed significant engagement in environmental movement activism and personal conservation behaviour (Milfont & Duckitt, 2010), detailing activist and nonactivist public and private sphere behaviours (Stern, 2000). Unsurprisingly, numerous participants mentioned involvement with various organizations and outreach activities, but the high extent to which these public sphere activities related to environmental issues was unexpected – especially as many indicated strong personal motivation in raising environmental awareness as part of their activism. Some (4, 7) mentioned utilizing images of visible anthropogenic destruction during their outreach, reinforcing the previously suggested (Section 4.1) utility of the LEO perspective of Earth in conveying the extent and scale of anthropogenic destruction. While many demonstrated continuous engagement in environmentalism and mentioned their unique status as astronauts providing higher credibility and visibility in the eyes of decision-makers and the public, there appears to be no collective effort to strategically utilize astronauts for increasing broader environmental awareness and engagement; this potential remains unrealized to date. This gap is even more pressing given that demonstrating long-term changes in EABs can carry significant implications for enhancing environmental communication and messaging (Gifford & Sussman, 2012). Given this and participants' self-expressed utility in environmental engagement (Section 3.1.5) and strong motivation in environmental outreach (Section 3.3.2), astronauts should be collectively and strategically applied for enhancing environmental communication and engagement effectiveness at the national and international levels.

Notable breadths and depths were detected in participants' personal conservation behaviour: while some, such as recycling and proper disposal of hazardous waste, were expected given participants' scientific backgrounds, greater depths of behaviours such as collecting rainwater for gardening and toilet flushing, turning off the shower tap, or following a nearly completely plant-based diet, were more unexpected. Participants expressed both intent- and impact-oriented approaches to their behaviours (Bamberg & Rees, 2015; Gatersleben et al., 2002), although mention of the former in terms of the environmental impact of their spaceflight or space exploration more generally – such as issues of space debris (Klinkrad, 2010) or stratospheric ozone depletion (Ross, Toohey, Peinemann, & Ross, 2009) – were not brought up. As expected, participants experienced lasting behavioural change in the context of their social norms, emotions, values, morals, and the costs and benefits of their behaviour (Steg & Vlek, 2009), articulating environmental well-being's significant personal value and the importance of conducting their public and personal life spheres accordingly, even when this was perceived as negative within their social settings. Limitations and cost-benefit analyses to greener behaviour included persistent inconveniences in the lack of more sustainable options.

5. Conclusions

This exploratory study established that the overview effect phenomenon has an unanticipated and distinguishable ecological significance that has the ability to markedly influence astronauts' EABs, resulting in a new level of environmental awareness and consciousness that, for the majority of participants, led to a direct elevation in, or enhancement of, EAs post-spaceflight that subsequently contributed, among other terrestrial factors, to gradual and long-term behavioural change; for a few, it led to direct behavioural improvement post-spaceflight. Significant and unexpected elements of the phenomenon's ecological dimension include the juxtaposition of positive and negative perceptual themes of awe, especially visible anthropogenic destruction from LEO, and the unique, grander-scale version of environmentalism that results from this perspective. Participants demonstrated considerable breadth and depth in their present EABs, which the majority discussed with language expressing importance, concern and urgency, and with two participants expressing contradiction and scepticism.

The potential to utilize findings to increase environmental awareness and concern more broadly – especially among the wider public and decision-makers – through VR (Section 4.1) and the purposive and strategic application of astronauts in national and international environmental communication and engagement initiatives (Section 4.3), is underexplored but promising. As astronaut Ron Garan suggests (Section 3.1.5), the outer space perspective of Earth has the potential to shift the basis of environmental discussions from negative emotions, such as fear, to the more positive emotions of awe and wonder, potentially enabling more productive discourse. Further research on astronauts' pre- and post-spaceflight EABs is suggested to expand upon this exploratory study's findings.

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Appendix A. Supplementary data

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