

Supplementary information for: Aesthetic flourishing: Scientists' experiences of beauty, wonder, and awe as indicators of higher wellbeing

Peter J. Varga · Chelsea Rae Kelly · Christopher J. Jacobi

Supplementary tables

Supplementary Table S1. *Robustness tests: Interaction models of country, gender, position and age with the three focal variables*

Predictors	Flourishing			
	Interaction Model 1	Interaction Model 2	Interaction Model 3	Interaction Model 4
	Gender	Country	Position	Age
Gender: Women (ref. Men)	0.06+ (-0.00 - 0.11)	0.07* (0.01 - 0.12)	0.06* (0.00 - 0.12)	0.06* (0.00 - 0.11)
Country (ref. USA)				
UK	0.06 (-0.02 - 0.15)	0.08+ (-0.01 - 0.16)	0.05 (-0.03 - 0.13)	0.05 (-0.03 - 0.13)
India	-0.02 (-0.07 - 0.04)	0.01 (-0.05 - 0.07)	-0.02 (-0.08 - 0.04)	-0.02 (-0.08 - 0.04)
Italy	0.19*** (0.12 - 0.26)	0.20*** (0.13 - 0.26)	0.19*** (0.13 - 0.25)	0.18*** (0.11 - 0.25)
Age	0.18*** (0.11 - 0.26)	0.18*** (0.10 - 0.27)	0.18*** (0.10 - 0.26)	0.19*** (0.11 - 0.27)
Age squared	-0.04 (-0.09 - 0.01)	-0.03 (-0.09 - 0.02)	-0.03 (-0.08 - 0.01)	-0.03 (-0.08 - 0.02)
Position (ref. Postgraduate student)				
Postdoc	0.08 (-0.15 - 0.32)	0.07 (-0.17 - 0.30)	0.07 (-0.14 - 0.27)	0.06 (-0.17 - 0.30)
Research Scientist	-0.15 (-0.41 - 0.11)	-0.14 (-0.40 - 0.12)	-0.15 (-0.34 - 0.04)	-0.16 (-0.41 - 0.09)
Junior Faculty	-0.03 (-0.18 - 0.12)	-0.02 (-0.18 - 0.13)	0.01 (-0.13 - 0.15)	-0.05 (-0.20 - 0.11)
Mid-level Faculty	-0.06 (-0.19 - 0.08)	-0.07 (-0.21 - 0.08)	-0.07 (-0.20 - 0.06)	-0.08 (-0.23 - 0.06)
Senior Faculty	-0.13 (-0.30 - 0.04)	-0.15+ (-0.31 - 0.02)	-0.10 (-0.27 - 0.06)	-0.14 (-0.32 - 0.03)
Survey wave: Wave 2 (ref. Wave 1)	-0.02	-0.02	-0.03	-0.02

	(-0.14 - 0.09)	(-0.13 - 0.09)	(-0.13 - 0.08)	(-0.14 - 0.09)
Other stressor during the pandemic: Stressor mentioned (ref. not mentioned)	-0.06	-0.07	-0.08	-0.06
	(-0.18 - 0.07)	(-0.18 - 0.05)	(-0.20 - 0.04)	(-0.19 - 0.06)
Basic Needs Satisfaction	0.56***	0.54***	0.58***	0.54***
	(0.51 - 0.61)	(0.49 - 0.60)	(0.45 - 0.71)	(0.50 - 0.58)
Vocational Identity	0.03	0.05	0.04	0.06*
	(-0.04 - 0.10)	(-0.03 - 0.12)	(-0.03 - 0.11)	(0.00 - 0.11)
Aesthetic Frequency	0.24***	0.21***	0.14***	0.21***
	(0.19 - 0.29)	(0.17 - 0.25)	(0.07 - 0.20)	(0.17 - 0.24)
USA X Basic Needs Satisfaction		0.00		
		(0.00 - 0.00)		
UK X Basic Needs Satisfaction		-0.04		
		(-0.16 - 0.07)		
India X Basic Needs Satisfaction		0.11**		
		(0.04 - 0.17)		
Italy X Basic Needs Satisfaction		-0.15***		
		(-0.21 - -0.09)		
USA X Vocational Identity		0.00		
		(0.00 - 0.00)		
UK X Vocational Identity		-0.03		
		(-0.12 - 0.06)		
India X Vocational Identity		0.10*		
		(0.02 - 0.18)		
Italy X Vocational Identity		0.08*		
		(0.00 - 0.16)		
USA X Aesthetic Frequency		0.00		
		(0.00 - 0.00)		
UK X Aesthetic Frequency		0.08*		
		(0.01 - 0.15)		
India X Aesthetic Frequency		-0.03		
		(-0.08 - 0.02)		
Italy X Aesthetic Frequency		-0.11***		
		(-0.16 - -0.06)		
Men X Basic Needs Satisfaction	0.00			
	(0.00 - 0.00)			
Women X Basic Needs Satisfaction	-0.08*			
	(-0.14 - -0.01)			
Men X Vocational Identity	0.00			
	(0.00 - 0.00)			
Women X Vocational Identity	0.06			
	(-0.02 - 0.13)			
Men X Aesthetic Frequency	0.00			
	(0.00 - 0.00)			
Women X Aesthetic Frequency	-0.06+			
	(-0.13 - 0.01)			

Postgraduate Student X Basic Needs Satisfaction	0.00 (0.00 - 0.00)	
Postdoc X Basic Needs Satisfaction	-0.05 (-0.26 - 0.16)	
Research Scientist X Basic Needs Satisfaction	-0.08 (-0.24 - 0.08)	
Junior Faculty X Basic Needs Satisfaction	-0.00 (-0.18 - 0.18)	
Mid-level Faculty X Basic Needs Satisfaction	-0.14 (-0.33 - 0.05)	
Senior Faculty X Basic Needs Satisfaction	-0.09 (-0.35 - 0.18)	
Postgraduate Student X Vocational Identity	0.00 (0.00 - 0.00)	
Postdoc X Vocational Identity	0.15+ (-0.03 - 0.33)	
Research Scientist X Vocational Identity	0.00 (-0.12 - 0.13)	
Junior Faculty X Vocational Identity	-0.05 (-0.28 - 0.17)	
Mid-level Faculty X Vocational Identity	-0.01 (-0.15 - 0.13)	
Senior Faculty X Vocational Identity	-0.04 (-0.26 - 0.18)	
Postgraduate Student X Aesthetic Frequency	0.00 (0.00 - 0.00)	
Postdoc X Aesthetic Frequency	0.10 (-0.02 - 0.22)	
Research Scientist X Aesthetic Frequency	0.15* (0.00 - 0.29)	
Junior Faculty X Aesthetic Frequency	0.24** (0.07 - 0.41)	
Mid-level Faculty X Aesthetic Frequency	0.02 (-0.07 - 0.11)	
Senior Faculty X Aesthetic Frequency	0.14+ (-0.00 - 0.29)	
Age X Basic Needs Satisfaction		-0.02 (-0.10 - 0.06)

Age X Vocational Identity				-0.03 (-0.10 - 0.04)
Age X Aesthetic Frequency				0.03 (-0.01 - 0.07)
Observations	3,082	3,082	3,082	3,082
R-squared	0.45	0.45	0.46	0.45

Note. N = 3,082; Standardized regression coefficients (β) computed separately for each model (columns); all continuous variables have been standardized; 95% confidence intervals in brackets; ***p < .001, **p < .01, *p < .05, +p < .1.

Supplementary Table S2. Robustness tests: Further interaction models in which the positive association of position with flourishing is weakened with increasing age

Predictors	Flourishing			
	Interaction Model 2a	Interaction Model 2b	Interaction Model 2c	Interaction Model 2d
Gender: Women (ref. Men)	-0.04 (-0.14 - 0.05)	0.06 (-0.01 - 0.13)	0.07* (0.00 - 0.14)	0.06* (0.00 - 0.12)
Country (ref. USA)				
UK	-0.15** (-0.26 - -0.04)	-0.03 (-0.12 - 0.06)	-0.01 (-0.11 - 0.08)	0.06 (-0.03 - 0.14)
India	-0.14*** (-0.21 - -0.06)	0.01 (-0.04 - 0.07)	0.01 (-0.05 - 0.07)	-0.04 (-0.10 - 0.02)
Italy	0.23*** (0.14 - 0.31)	0.18*** (0.12 - 0.25)	0.18*** (0.11 - 0.25)	0.19*** (0.12 - 0.25)
Age	0.13 (-0.14 - 0.41)	0.30*** (0.14 - 0.46)	0.30*** (0.17 - 0.43)	0.35*** (0.19 - 0.52)
Position (ref. Postgraduate student)				
Postdoc	0.17 (-0.12 - 0.46)	-0.03 (-0.34 - 0.28)	-0.07 (-0.37 - 0.24)	-0.04 (-0.37 - 0.29)
Research Scientist	-0.06 (-0.34 - 0.22)	-0.33* (-0.63 - -0.03)	-0.33* (-0.63 - -0.03)	-0.27 (-0.59 - 0.06)
Junior Faculty	0.08 (-0.25 - 0.41)	-0.18* (-0.36 - -0.01)	-0.22* (-0.41 - -0.04)	-0.12 (-0.31 - 0.06)
Mid-level Faculty	0.20 (-0.11 - 0.51)	-0.18 (-0.43 - 0.07)	-0.22+ (-0.44 - 0.01)	-0.14 (-0.40 - 0.12)
Senior Faculty	0.23 (-0.09 - 0.54)	-0.19+ (-0.42 - 0.03)	-0.22+ (-0.45 - 0.02)	-0.14 (-0.37 - 0.10)
Postgraduate Student X Age	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)	0.00 (0.00 - 0.00)
Postdoc X Age	0.11 (-0.32 - 0.54)	-0.09 (-0.39 - 0.22)	-0.16 (-0.45 - 0.13)	-0.16 (-0.44 - 0.13)
Research Scientist X Age	0.14 (-0.19 - 0.47)	-0.18 (-0.50 - 0.14)	-0.22 (-0.50 - 0.07)	-0.23 (-0.53 - 0.06)
Junior Faculty X Age	0.05 (-0.31 - 0.41)	-0.26 (-0.59 - 0.07)	-0.26 (-0.57 - 0.05)	-0.30+ (-0.61 - 0.01)
Mid-level Faculty X Age	0.01 (-0.29 - 0.31)	-0.23* (-0.41 - -0.05)	-0.23* (-0.41 - -0.05)	-0.26* (-0.47 - -0.06)

Senior Faculty X Age	-0.03 (-0.37 - 0.31)	-0.23 (-0.52 - 0.06)	-0.28+ (-0.56 - 0.00)	-0.31+ (-0.63 - 0.00)
Survey wave: Wave 2 (ref. Wave 1)	-0.06 (-0.23 - 0.10)	-0.05 (-0.17 - 0.07)	-0.04 (-0.17 - 0.08)	-0.03 (-0.14 - 0.09)
Other stressor during the pandemic: Stressor mentioned (ref. not mentioned)	-0.29*** (-0.45 - -0.13)	-0.05 (-0.17 - 0.08)	-0.05 (-0.18 - 0.08)	-0.06 (-0.18 - 0.06)
Basic Needs Satisfaction		0.57*** (0.51 - 0.62)	0.55*** (0.50 - 0.59)	0.54*** (0.50 - 0.58)
Vocational Identity			0.13*** (0.09 - 0.17)	0.05* (0.00 - 0.10)
Aesthetic Frequency				0.22*** (0.19 - 0.25)
Observations	3,082	3,082	3,082	3,082
R-squared	0.11	0.39	0.41	0.45

Note. N = 3,082; Standardized regression coefficients (β) computed separately for each model (columns); all continuous variables have been standardized; 95% confidence intervals in brackets; *** $p < .001$, ** $p < .01$, * $p < .05$, + $p < .1$.

Appendix A: Examples of qualitative coding suggesting directionality of aesthetics and wellbeing

In addition to the quantitative data obtained from 3,086 scientists in physics and biology departments in the UK, USA, Italy, and India, we conducted in-depth interviews with physicists and biologists in the same four countries. 394 scientists were interviewed prior to the online survey. This sample includes qualitative data extracted for just the four countries of interest from a larger interview study conducted with physicists and biologists. 100 were conducted in the US, 137 in the UK, 81 in Italy, and 80 in India. These data were combined with interviews we conducted with an additional 24 physicists and 20 biologists in the four countries focusing specifically on questions about the aesthetic dimensions of science. These interviews were primarily used to help design the quantitative survey.

A subset of the surveyed scientists were invited to participate in a more in-depth interview after the quantitative data collection ($n = 215$). The majority of these interviewees were recruited from survey respondents who gave permission to be contacted for an interview. 24 additional scientists were recruited via “snowball sampling” techniques either from contacts of academic scientists interviewed for the study, or personal contacts from members of the project team. An additional 10 in-depth interviews were conducted with scientists who trained or worked at institutions in the four countries and left academia. These interviewees were also recruited via snowball sampling techniques. Table A1 provides a demographic overview of the main sample of follow-up interviews with scientists still working in academia.

Table A1. Demographic overview of main sample of academic scientists (N = 205)

Characteristic	N	% of Sample
Country		
USA	52	25.4
UK	51	24.9
India	50	24.4
Italy	52	25.4
Gender		
Female	97	47.3
Male	108	52.3
Discipline		
Physics	106	51.8
Biology	98	47.8
Other	1	0.5
Position		
Postgraduate Student	51	24.9
Postdoc	50	24.4
Research Scientist	13	6.3
Junior Faculty	35	17.1
Mid-Level Faculty	25	12.2
Senior Faculty	30	14.6
Other	1	0.5
Race/Ethnicity		
Caucasian, White, European	136	66.3
South Asian	55	26.3
Hispanic or Latino/a	6	2.9
Black, African	2	0.9
Other	6	3.4
Religious affiliation		
None	95	46.3
Roman Catholic	40	19.5
Hindu	33	16.1
Protestant Christian	20	9.8
Buddhist	2	1.0
Jewish	2	1.0
Muslim	3	1.5
Orthodox	2	1.0
Other	8	3.9
<i>Total</i>	205	

Note. Interviews conducted between July-December, 2021, for Work and Well-Being in Science: An International Study. Adapted from Ritz (2023).

Table A2 presents the demographic characteristics of the supplemental sample of scientists who have left academia.

Table A2. *Demographic overview of supplemental sample of scientists who left academia (N = 10)*

Characteristic	N
Country	
USA	4
UK	2
India	1
Italy	3
Gender	
Female	6
Male	4
Discipline	
Physics	4
Biology	6
<i>Total</i>	10

Note: Interviews conducted between December, 2021, and January, 2022, for Work and Well-Being in Science: An International Study. Adapted from Ritz (2023).

Further information about the interview protocol can be found in the detailed methodological report for the study (Ritz, 2023).

Directionality of scientists' claims about aesthetic experiences and wellbeing

Qualitative data from this body of interviews was used to inform the directionality of our hypotheses and is discussed separately in other papers. Representative examples from the qualitative dataset are given below to demonstrate the directionality of scientists' claims about aesthetic experiences and wellbeing.

Beauty helps to deal with stress (W_IT02_PHY):

it's easy to get frustrated, then to feel sad and to feel disappointed because things are not working but I think that if I can focus my attention on the fact that even in that part there is something positive, something nice, something beautiful, something inspiring. Dealing with this feeling may be easier, and maybe make myself progress better and yeah, and give me a stronger support. if you think of gratitude in your life, it's like if you can focus on the good part would help you dealing with the negative or the more stressful aspect.

And disappointments (W_IN07_BIO):

I think it buffers people from all the unhappiness that is inherent in day-to-day science. See, I connect on Zoom and the first thing I notice is the painting drawing, whatever it is behind you. And yesterday night I was reading something which described, you know, something very beautifully. And I was in fact thinking that if only my students, many of them come from backgrounds where they haven't ever been exposed to a book, non-textbook, they're good students, they score well but get into all the entrance exams and interviews and so on, but they have not had the

privilege of the schooling up with a book and reading for the sheer beauty of it. And I feel that those who have that access to that beauty are better buffered from the sort of ups and downs of rejections and -- actually mostly downs of rejections and failed experiments and all that. I think it's very, very important. I recommend it to students; I try to show it on them. I very actively tell people, you know, have paintings in the office and stuff like.

And the hardship of research (W_US02_PHY):

I mean, if there is a way in which beauty can be a motivating aspect to the individual scientists, I think there's a goodness to that, right? That if there's something attractive about it, then that's going to like motivate you to put forward the effort and the time needed to investigate it, then that's -- I think there's something good in that.

Wonder makes scientists happy (W_IN07_BIO):

So, I mentioned about a time in my life when money was more important than I needed the stable income. Once my basic needs, and those are like very basic needs I'm talking about, in today's currency maybe ₹30,000, ₹40,000 per month, which I could get [inaudible]. After that, on a day-to-day basis, I need something to keep me happy, and I think that sense of wonder and that sense of discovery is very necessary for me.

No, it's something that I profound eloquently onto my students. I'm feeling a little conscious to say to somebody who has probably seen a lot of science also. But anyway, for the record. So for me, I actually had it on my website for some time. That for me -- so do you know, Edwin Hubble -- I'm not good at quoting exactly, but Edwin Hubble has a quotation that -- I mean, some words he has said about how man explores the universe with five senses, and that is an adventure we call science. To me, that is what captures my feeling. When I read it, I knew, "Okay, this is what I mean about science." For me, what is your training? What is your background? How many papers you've published? How many grants you hold? How many students you have? None of these things really define -- they all make me feel good. And I've done fairly comfortable. I mean, I'm comfortable with what I have done on all those aspects, it's not a cover up for something I couldn't do. But, in spite of that even now what motivates me is that sense of wonder when I see something, it could be in tissue culture, it could be while I'm having a walk in the park, but when I feel like, "Wow, how is that happening?" That's what really makes me feel that kick. So yeah, that signs for me.

Wonder replenishes energy when it is depleted overtime (W_IT02_BIO):

Yes, it is an inspiration and also... it is a bit like if you were replenished with energy every time that... Now, I am not used to fishing, yet I guess that when you go fishing and you stay there for 10 hours without catching anything, you say to yourself, "Let's go home" and instead you hook a fish and so you are recharged for another 10 hours. I think it is some kind of similar effect.

Impact of the lack of aesthetic experiences on wellbeing

The lack of aesthetic experiences in science came up in conjunction with deficits in wellbeing and running out of motivation to continue on in the academic scientific profession. Some respondents suggested that the absence of such aesthetic elements might motivate scientists to leave academic research altogether. One American biologist (R_US01_BIO) responded this way when asked whether he experienced beauty, awe, or wonder in his scientific work:

Not personally, and that was one of the reasons why I was like, no, I am done. I have never really felt that way. Just because I didn't like where my project was going, how difficult it was, and it wasn't enough to keep me from wanting to be a teacher, which would allow me to have a family. Like being a teacher, there's more free time to raise a family whereas if I was doing academic research, then there would be less time.

Many respondents insisted that were it not for aesthetic experiences, there would be no point in doing science at all. One physicist (R_US64_BIO) told us,

Awe and wonder at nature in general—I feel like there's really no point doing science if you don't feel that. If it's just another thing, why go into this low-paying, high-stress field, academic research, if you don't think that there's something amazing about nature and that it's a fun and interesting thing to study. I would definitely say that—I can't imagine not having that feeling, I guess.

Other respondents also emphasized that aesthetic experiences added meaning and motivation to their work as well as increased wellbeing. One American physicist said that without aesthetic experiences, "it really doesn't seem worth it. Then you just feel like a technician or what you're doing is not meaningful" (G_US15_PHY).

Authors

Peter J. Varga

Department of Experimental Psychology; Christ Church, University of Oxford

<https://orcid.org/0000-0001-5124-5778>

peter.varga@psy.ox.ac.uk

Chelsea Rae Kelly

Department of Sociology, The Catholic University of America

<https://orcid.org/0000-0001-9172-3535>

Christopher J. Jacobi

Department of Sociology, The Catholic University of America

<https://orcid.org/0000-0002-0752-8428>

Funding

Data collection for this paper was funded by a grant from the Templeton Religion Trust (TRT0296, PI: Brandon Vaidyanathan).

Conflict of interest statement

The authors report no conflicts of interest.

Author contributions statement

Conceptualisation: PJV, CRK; Methodology: PJV, CRK, CJJ; Analysis: CRK, CJJ; Writing – Original Draft: PJV; Writing – Review and Editing: PJV, CRK, CJJ.

Data availability statement

Data pertaining to the variables analysed in this article are available upon request.

Acknowledgements

We are grateful for the advice and input of Brandon Vaidyanathan, who commented on the conceptualization of this article, and for the assistance of Matthew Lee, who answered our questions about the structure of the Human Flourishing Index.

Publishing Timeline

Received 31 March 2023

Revised version received 29 June 2024

Accepted 16 July 2024

Published 25 November 2024