**Individual differences in adapting to temperature in French students are only
related to attachment avoidance and loneliness**

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Abstract

Among animals, natural selection has resulted in a broad array of behavioral strategies to maintain core body temperature in a relatively narrow range. One important temperature regulation strategy is *social thermoregulation*, which is often done by warming the body together with conspecifics. The literature suggests that the same selection pressures that apply to other animals also apply to humans, producing individual differences in the tendency to socially thermoregulate. We wanted to investigate whether differences in social thermoregulation desires extend to other personality factors in a sample of French students. We conducted an exploratory, hypothesis-generating *cross-sectional* project to examine associations between thermoregulation and personality. We used conditional random forests in a training segment of our dataset to identify clusters of variables most likely to be shaped by individual differences to thermoregulate. We used the resulting clusters to fit hypothesis-generating mediation models. After we replicated the relationships in two datasets, personality was not related to social thermoregulation desires, with the exception of attachment avoidance. Attachment avoidance in turn predicted loneliness. This mediation proved robust across all three datasets. As our cross-sectional studies allow limited causal inferences, we suggest investing into prospective studies to understand whether and how social thermoregulation shapes attachment avoidance early in life and loneliness later in life. We also recommend replication of the current relationships in other climates, countries, and age groups.

Keywords: Personality, Social Thermoregulation, Attachment, Machine Learning

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In the animal kingdom, successfully managing core body temperature strongly influences the probability of survival. For this reason, animal species have evolved a broad array of evolutionary strategies for managing their core body temperature – including behavioral strategies. Prime among these behavioral strategies, and a strategy on which human and non-human animals alike rely, is leveraging the body heat of conspecifics through huddling and hugging (Ebensperger, 2001; Gilbert et al., 2007; Nuñez-Villegas, Bozinovic, & Sabat, 2014). This *social thermoregulation* has been particularly important in humans to adapt to the cold throughout evolution. Yet some succeed in coping with the environment better than others. As a logical consequence, individual differences should exist in adapting to climate through the individuals’ preferences to manage cold socially.

We conducted an exploratory, hypothesis-generating study to investigate whether preferences for social strategies to cope with temperature – that likely differ between individuals – relate to how people differ in their personalities. The idea behind this work is that the influence of social thermoregulation on personality would be transmitted by people’s past histories with close relationships (their *attachment style*; Fraley & Shaver, 2000), because this past history will determine whether people feel that relying on others for temperature regulation is a safe strategy.

Although they are grounded in sensible theories of evolution and relationships, our ideas are admittedly speculative. Thus, we relied on an exploratory analysis strategy enabled by a machine learning technique known as conditional random forests to generate plausible hypothesis-generating mediation models from a training dataset. We then test the replicability of these models using a testing dataset and a second replication dataset after review with this journal.

Social Thermoregulation to Adapt to the Environment

Across the animal kingdom, relying on others to regulate core body temperature is often privileged over internal methods, such as shivering (IJzerman & Hogerzeil, 2017). This is because methods such as shivering, while effective at producing heat, rely on the body's internal (and expensive) metabolic processes, whereas social methods of temperature regulation do not. Emperor penguins, for example, huddle for warmth, reducing the surface area exposed to cold and allowing colder penguins to rely on the heat from warmer conspecifics. The result is that thermoregulation via huddling requires ~38% less energy to warm their bodies than when penguins do it when alone (Gilbert et al., 2007).

This same evolutionary logic, that social methods of regulating core body temperature are much more efficient than internal processes, applies just as strongly to humans as it does to penguins (IJzerman et al., 2015). Human behavior should therefore bear the imprint of adaptations to maintain core body temperature through the behavioral use of conspecifics. Even though modern technology has made the regulation of ambient temperature an everyday convenience for many people, these technologies have existed for too short a timeframe to eliminate these behavioral adaptations.

Some evidence does indeed suggest that humans use others to help regulate their core body temperature. For example, common brain regions are involved in the regulation of social interactions and core body temperature (Satinoff, 1978, 1982). The concepts of temperature and sociality also appear cognitively linked: social proximity and distance influence our perceptions related to temperature (Hu, Li, Jia, & Xie, 2016; Zhong & Leonardelli, 2008) and people tend to think more about their loved ones when they are physically cold (IJzerman, Neyroud, et al., 2018).¹ In the latter project, people with a

¹ Notably, we recognize that the psychological sciences are facing a replication crisis. This means that – like most of the psychological literature, the social thermoregulation literature has been confronted with conflicting findings: some effects were successfully replicated (IJzerman et al., 2016b; Schilder, IJzerman, &

secure outlook on relationships were more likely to think of loved ones when cold, whereas those with an avoidant outlook were less likely.

Individual Differences in Dealing with the Environment across the Animal Kingdom

Even in the animal kingdom, individual animals of a particular species differ in their strategies for coping with the environment, including regulating their temperature. In animals, these individual differences are known as life-history strategies (Dall, Houston, & McNamara, 2004; Wolf, van Doorn, Leimar, & Weissing, 2007); such strategies generally manifest as stable differences in resource gathering, reproduction, and the avoidance of predators (Dall et al., 2004). Life history strategies generally fall into two broad clusters, or temperaments, one of which involves proactive strategies and one of which involves reactive strategies. Proactive animals engage in more aggressive, competitive, and risk-taking behaviors, whereas reactive animals engage in more passive, cooperative, risk-averse behaviors. The proactive trait usually emerges in more stable environments, whereas the reactive trait tends to be favored in unpredictable environments (Koolhaas et al., 1999; Tops, IJzerman, & Quirin, 2020).

Clusters of individual differences similar to animal temperaments also manifest in humans. According to Predictive And Reactive Control Systems (PARCS) theory, people differ in their tendency to rely on predictive versus reactive control – two systems that resemble proactive and reactive animal temperaments depending on the predictability of

Denissen, 2014), whereas others were not (Donnellan, Lucas, & Cesario, 2015; Lynott et al., 2014). Some effects relied on sufficiently large samples (Hong & Sun, 2012; IJzerman, Lindenberg, et al., 2018; IJzerman, Neyroud, et al., 2018; Van Acker, Kerselaers, Pantophlet, & IJzerman, 2016), while others were tested using underpowered designs (IJzerman & Semin, 2009, 2010; Williams & Bargh, 2008). An in-progress meta-analysis that corrects as well as possible for bias in the literature suggests however that the effects in this literature are likely not due to selective reporting alone (IJzerman, Hadi, et al., 2020).

the environment (Tops, Boksem, Quirin, & Koole, 2014; Tops et al., 2020). An environment is thought to be predictable when it is not threatening or when threats are manageable (possibly including, for example, bodily harm, harsh climates, or limited economic means). People engage more in predictive control when processing familiar stimuli and tend to engage more if they are raised in predictable environments. People engage more in reactive control when processing novel information and if they are raised in more unpredictable environments. Predictive control is considered more metabolically efficient than reactive control because it allows people to schedule more in advance (Tops et al., 2020).

The strong resemblance between the major clusters of non-human individual differences and the major clusters of human personality suggests that stable individual differences in human and non-human animals may be clustered to solve similar adaptive problems. Thus, just as animal temperaments are shaped by and adapted for particular environments, human personality may be shaped by and adapted for particular environments. This suggests that similar forces may shape human and non-human personality. It follows that strategies increasing the environment's predictability may come into play in personality processes.

Individual Differences in Coping Socially with Environmental Demands

Understanding how the predictability of the environment affects human personality processes requires identifying the parameters of predictability. The first of these is how people can cope with the environment. A primary feature of the environment's predictability is the availability of reliable conspecifics. Bowlby (1969) postulated in his *Attachment Theory* that early relationships are essential for managing the environment, as early relationships promote survival. Caregivers fulfill a number of functions toward the child, notably protection against environmental threats, nurturing and warming up when cold. These first experiences turn into individual differences predicting others' behaviors, and, according to how people think that others are reliable, into more general personality

differences (e.g., Ainsworth & Bell, 1970).

A second parameter of predictability concerns *which* threat the environment poses. Temperature is only second in importance next to oxygen regulation for survival. Yet little attention has been devoted to directly measuring how humans deal with temperature, and even less so how they deal socially with the environment, with the exception of one tool giving a first impulse in this direction: the *Social Thermoregulation and Risk Avoidance Questionnaire* (STRAQ-1; Vergara et al., 2018). The STRAQ-1 has for example a subscale that reliably assesses individual differences in terms of desires to socially thermoregulate. The STRAQ-1 was created and validated to investigate whether people's strategies to thermoregulate relate to their feelings of reliability and safety in relationships. And indeed, Vergara et al. (2018) found that people's desires to socially and solitarily thermoregulate respectively relate to avoidance and anxiety in relationships. The STRAQ-1 thus provides not only a valid measurement tool, but also shows that people's ways of coping with the environment relate to their attachment styles. This is thus a first indication that the way people cope with the environment could potentially shape their personality.

How Personality Could Help Adapt to the Environment

More commonly speaking, personality refers to an enduring pattern of thoughts feelings and behaviors displayed by an individual across a variety of situations, which is supposed to be stable over time (Ashton, 2013). The most robust and famous personality tool used to understand personality is the *Big Five* factor model. The Big Five is a dimensional approach that assumes that personality may be understood in terms of five dimensions, where individuals score relatively high or low on a continuum on each dimension (McCrae & Costa, 1999). The five dimensions consist of Openness (referring to the propensity of an individual to be open to new experiences and creative), Conscientiousness (referring to discipline and drive toward achievement), Extraversion (referring to assertiveness and gregariousness), Agreeableness (referring to kindness and

compliance), and Neuroticism (referring to individuals' tendency to feel depressed or anxious; McCrae & Costa, 1999).

Only in the last twenty years, a consensus emerged that personality in humans also may have an adaptive function and that it may be understood as life-history behavioral strategies (Buss & Penke, 2015; Dall et al., 2004; Wolf et al., 2007). In line with this postulate, personality has been shown to be influenced by the “socioecological” environment to ensure better payoffs (Smaldino, Lukaszewski, von Rueden, & Gurven, 2019), raising the question of whether temperature could have similar influences. Only in the last few years, a group of researchers found temperatures to be associated with personality. More specifically, Wei and colleagues (2017) found that people are more agreeable, extraverted, conscientious, open to experience, and less neurotic if they grew up in clement climates (closer to the psychophysiological comfort optimum of 22°C). This tentatively suggests that climate influences personality. To the extent that personality is a type of life-history behavioral strategy, personality should also be influenced by the strategies that people adopt to cope with fluctuations in local temperature.

The Big Five captures only one aspect of personality. If individual differences in temperature-coping strategies are related to personality at a broad level, these strategies may be linked to personality aspects not captured by the Big Five. Some have argued, for example, that the five factor personality model can be captured in two higher order factors (stability and plasticity; DeYoung, 2006). Other researchers have favored a six factor model (the HEXACO; Lee & Ashton, 2004). In Forager-Farmers in the Bolivian Amazon, only three instead of five factors emerged (Gurven, von Rueden, Massenkoff, Kaplan, & Vie, 2013). In yet another (dictionary-based) study in Farsi, a Big Two or Big Three structure emerged (Farahani, Farzad, & Fotouhi, 2004). In a dictionary study of the French personality lexicon, six factors emerged (albeit, not the same as the HEXACO; Boies, Ashton, Pascal, & Nicol, 2001). Only one 2015 study in a French sample did detect a five-factor structure of a personality inventory for the DSM (Roskam et al., 2015).

Altogether this meant that some uncertainty exists as to which model is the most the most likely to emerge from our sample of French students.

As well, we remain quite uncertain how temperature may have shaped human life-history strategies for the mere reason that, unlike ecologists, psychologists haven't paid as much attention to the influence of temperature. Also, we don't know exactly how to measure "life-history strategies" in humans, thus supplying the need to step back and explore when testing our general ideas in a French sample. Taking all these arguments into account, prior to moving on to our main exploratory-confirmatory analysis in which desires to (socially) thermoregulate are related to attachment and personality, we took an explicit, exploratory approach with few a priori assumptions. This meant that we first selected a large number of items in our training dataset and conducted an exploratory factor analysis to create new personality variables (Cronbach & Meehl, 1955; Guilford, 1948). At the end of our analyses section we do however test similar mediation models with the traditional factor structures of the assessed scales.

Research Overview

Overall, we suspected that individual differences in personality variables could be related to individual differences in the way people deal with temperature constraints. We also suspected that people are more likely to use social strategies to regulate their temperature in predictable social environments. We assumed that attachment mediates the relation between the regulation of temperature and personality.

In our work, we only provide starting points for a process of guided exploration by conducting hypothesis-generating research in two cross-sectional datasets. We used conditional random forests, a machine learning technique specialized for exploratory research, to identify robust relationships in our dataset and fit a series of mediation models.

These mediation models cannot be taken as evidence of causal mechanisms given that our data are cross-sectional and that mediational processes we assumed imply changes over

time. For example, Maxwell and Cole (2007; Maxwell, Cole, & Mitchell, 2011) demonstrated mathematically that the conditions under which cross-sectional designs may capture the true parameters of the mediation are rarely (if not never) met. Yet, despite the fact that our meditation does not reflect the causal processes we predict, they can indicate that some relations exist, particularly if replicated with the precision we predicted. Then still, a finding of statistical mediation in cross-sectional data does not imply the presence of causal relationships unless the analyst is willing to make strong, and unlikely unsupportable (Maxwell & Cole, 2007; Maxwell et al., 2011), causal assumptions. This project thus aims to identify mediated relationships that *could* exist rather than relationships that *do* exist. The relationships that we identify can then be investigated in longitudinal and experimental studies that support stronger causal inference, in which some predictions may pan out and others will fail.

Altogether, this study aimed to explore the potential mediation pathways through which individual differences to thermoregulate might impact personality through individual differences in attachment. In all our models, social thermoregulation (as measured by the STRAQ-1) served as the ultimate cause, attachment (as measured by ECR-R) served as the mediator, and some aspect of personality served as the dependent variable personality. The analysis strategy follows three phases (see **Figure 1**): 1) Exploratory phase, in the training dataset of Study 1 we used conditional random forests to select relevant variables for the mediation models, and we tested the models; 2) Prediction phase, based on the parameters of the mediation models we then formalized predictions; 3) Confirmatory phase, we tested the replicability of our models in the testing dataset of Study 1, and in the full dataset of Study 2. As per the guidelines for Registered Reports, we have not yet analyzed the confirmatory set of Study 1. These analyses and the replication results of the full dataset of Study 2 and our discussion will be added after review. The analysis workflow is graphically depicted in **Figure 1**.

Figure 1. Analysis Strategy of our study including the initial split of the dataset, the exploratory phase, and then the confirmatory phase.

Study 1

This manuscript was generated via papaja (Aust & Barth, 2020) and was conducted in line with the CO-RE Lab Lab Philosophy v4 (Klein et al., 2020).

Participants and Procedure

For our first study, we relied on a convenience sample of already collected data. For this sample, participants ($N = 510$) were recruited from Université Grenoble Alpes in France in 2018 and answered multiple online questionnaires on Qualtrics. Participants were psychology students (69 men, 435 women, and 6 others): 134 in L1, 192 in L2, 132 in L3 and 50 in M1 (3 missing). The M_{age} was 20.89 ($SD_{\text{age}} = 6.08$), $M_{\text{self-reported height}}$ was 166.35 cm ($SD_{\text{self-reported height}} = 8.14$ cm)² and the $M_{\text{self-reported weight}}$ was 59.71 kg ($SD_{\text{self-reported weight}} = 11.46$ kg). Within participants, 123 were smokers and 382 were not (4 missing). Also, 281 were in a relationship, 213 were not, and 16 preferred not to answer.

² We removed observations under 100cm for the calculation of the $M_{\text{self-reported height}}$ and $SD_{\text{self-reported height}}$, given the high unlikelihood of these scores (and were probably in our data due to typing errors).

Power Analysis

To ensure we had sufficient power to run mediations in either half of our sample, before we conducted our analyses, we ran an a priori power analysis for mediation based on the Sobel test with the *powerMediation* package (Qiu, 2017). It first requires to estimate the standard deviation of the independent variable and of the mediator. It also requires to estimate the effect size of the relations between the independent variable and the relations between the mediator and the dependent variable. Finally, it requires to compute the standard deviation of the error term of the relation between the independent variable and the dependent variable controlling for the mediator based on the effect size of the three paths of the mediation (for more information, see Perugini, Gallucci, & Costantini, 2018). Based on a minimum effect size of interest of $\beta = .25$ for all relations in the mediation and a statistical power of .80, we found that 231 participants were needed to detect a mediation. We thus concluded that our number of participants was sufficient to be able to split our data in two equal parts (for our script and other details, see <https://osf.io/74fr3/>).

Measures

Our measures were chosen by researchers who participated in the so-called “testweek” at Université Grenoble Alpes. Department members nominated questionnaires for inclusion (as these were thus not chosen by us, it constrained what we could find in our sample). The department then posted Qualtrics links with the full battery of questionnaires to student Facebook groups. Students could then participate in a battery of questions in exchange for course credits. Before moving onto our Exploratory Factor Analyses, we report the scales in their usual form together with their reliability from the training set (see **Table 1**; these will be updated to include the test set after review).

Table 1
Scales in their usual form with their reliabilities from the training set.

Scales	Subscales	Items	alpha	Omega	<i>M</i>	<i>SD</i>	Example item	Minimum	Maximum	References
Big Five Personality Traits										
IPIP-NEO	Openness	24	.79	.83	3.65	1.12	I prefer variety to routine	1 (Very inaccurate)	5 (Very accurate)	Johnson, 2014
	Conscientiousness	24	.88	.90	3.46	1.10	I carry out my plans	1 (Very inaccurate)	5 (Very accurate)	
	Extraversion	24	.84	.88	3.23	1.17	I feel comfortable around people	1 (Very inaccurate)	5 (Very accurate)	
	Agreeableness	24	.83	.87	3.93	1.00	I am concerned about others	1 (Very inaccurate)	5 (Very accurate)	
	Neuroticism	24	.88	.90	3.07	1.22	I worry about things	1 (Very inaccurate)	5 (Very accurate)	
Intergroup Orientation Variables										
The Speciesism scale		6	.73	.77	2.10	1.32	Morally, animals always count for less than humans	1 (strongly disagree)	7 (strongly agree)	Caviola et al., 2019
Prejudice toward North Africans		15	.91	.93	3.06	1.54	Northern Africans have a culture too different from that of the French to be perfectly integrated in France	1 (No, strongly disagree)	7 (Yes, strongly agree)	Dambrun & Guimond, 2001
The Social Dominance Orientation		16	.89	.92	5.71	1.33	The lower groups should stay in their place	1 (strongly disagree)	7 (strongly agree)	Duarte et al., 2004
The Right-Wing Authoritarianism		20	.87	.90	2.50	1.43	Our country needs a powerful leader, in order to destroy the radical and immoral currents prevailing in society today	-4 (Strongly Agree)	4 (Strongly Agree)	Altemeyer et al., 1988
Individual Differences Concerning the Self										
The Rosenberg Self-Esteem		10	.90	.92	2.22	0.79	On the whole, I am satisfied with myself	1 (Strongly agree)	5 (Strongly disagree)	Robins et al., 2001
The Self-Control Scale		13	.81	.85	2.86	1.13	I am good at resisting temptation	1 (Not at all)	5 (Very much)	Tangney et al., 2004
The Repetitive Thinking Mode Questionnaire		18	.62	.77	2.62	0.86	Once I started thinking about the situation, I couldn't stop	1 (Not true at all)	to 5 (Very true)	McEvoy et al., 2010
The Depression Anxiety Stress Scale		21	.93	.94	2.01	0.94	I couldn't seem to experience any positive feeling at all	0 (Did not apply to me at all)	3 (Applied to me very much, or most of the time)	Lovibond & Lovibond, 1995
The Warwick-Edinburgh Mental Well-Being Scale		14	.89	.92	3.43	0.89	I've been feeling optimistic about the future	1 (none of the time)	5 (all of the time)	Tennant et al., 2007
The Self-Reported Stress questionnaire		14	.89	.91	2.90	1.03	In the last month, how often have you felt nervous and "stressed"?	1 (Never)	4 (Very often)	Cohen et al., 1983
Individual Differences Related to Social Functioning										
The Experiences in Close Relationships (ECR)	Anxiety	18	.90	.91	3.75	1.77	I'm afraid that this person may abandon me	1 (Strongly agree)	7 (Strongly disagree)	Fraley et al., 2011
	Avoidance	18	.94	.95	2.83	1.65	I usually discuss my problems and concerns with this person	1 (Strongly agree)	7 (Strongly disagree)	
The Social Thermoregulation and Risk Avoidance Questionnaire (STRAQ-1)	High temperature sensitivity	7	.85	.9	3.09	1.24	I am sensitive to heat	1 (Strongly Agree)	5 (Strongly disagree)	Vergara et al., 2019
	Socialt thermoregulation	5	.79	.83	3.05	1.25	When I feel cold I seek someone to cuddle with	1 (Strongly Agree)	5 (Strongly disagree)	
	Solitary thermoregulation	8	.73	.81	3.37	1.20	When it is cold, I wear more clothing than others	1 (Strongly Agree)	5 (Strongly disagree)	
	Risk avoidance	3	.54	.59	3.52	1.14	I try to maintain myself in familiar places	1 (Strongly Agree)	5 (Strongly disagree)	
The UCLA Loneliness Scale		20	.92	.93	3.06	0.89	I feel isolated from others	1 (Never)	4 (Often)	Russel et al., 1980

¹ alpha are Cronbach's alpha.
² Omega are McDonald's omega total.

Data Preparation: Exploratory Factor Analysis

Personality variables. Because of the relative uncertainty of the factor structure for our sample, we formed new aggregate measures using exploratory factor analysis. This method allowed to create scales that are more valid in terms of construct validity and provide explanations that are more economical (Cronbach & Meehl, 1955; Guilford, 1948). Admittedly, this is based on a convenience sampling, as we did not select these items a priori. But by grouping items sharing the highest amount of variance between scales, the constructs measured are more likely to measure a single trait that does not overlap with other constructs.

From our dataset we inserted items from the following variables into our Exploratory Factor Analysis: Attachment Anxiety, Attachment Avoidance (Fraley, Heffernan, Vicary, & Brumbaugh, 2011), Repetitive Thinking Mode (McEvoy, Mahoney, & Moulds, 2010), the Big Five factors Openness, Agreeableness, Conscientiousness, Extraversion, and Neuroticism (Johnson, 2014), Speciesism (Caviola, Everett, & Faber, 2019), Self-esteem (Robins, Hendin, & Trzesniewski, 2001), Self-control (Tangney, Baumeister, & Boone, 2004), Self-Reported Stress (Cohen, Kamarck, & Mermelstein, 1983), Prejudice Toward North Africans (Dambrun & Guimond, 2001), the UCLA Loneliness scale (Russell, Peplau, & Cutrona, 1980), Right Wing Authoritarianism (Altemeyer, 1988), Social Dominance Orientation (Duarte, Dambrun, & Guimond, 2004), DASS Depression, Anxiety, and Stress (Lovibond & Lovibond, 1995), and Well-being (Tennant et al., 2007).

In order to determine the number of factors from our items, we both used Parallel Analysis (Costello & Osborne, 2005; Hayton, Allen, & Scarpello, 2004) and Velicer's (1976) MAP test. Our Parallel Analysis suggested a 17 factor-solution whereas the Velicer's MAP provided similar average squared partial correlation values for 17, 18, and 19 factors and higher for 16 factors. Based on the results of both tests (and choosing the least amount of factors for reasons of parsimony), we extracted 17 factors for our further analyses.

To create each of the 17 scales, we first examined factor loading of each individual

item as we only included items if the factor load was superior to .30. In addition, we inspected each item to understand how applicable the item was to the construct (for example, we left out “I love life” for the self-esteem measure). Finally, we removed any items that cross-loaded onto multiple factors in order to reduce overlap between the created scales (Tabachnick & Fidell, 2001). All the excluded items with rational for exclusion are presented in **Appendix 1**. With the final list, we averaged items to 17 different scale averages.

Our 17 new scales we titled Attachment Anxiety “Modified” (which dropped two items of the original scale), Attachment Avoidance “Modified” (exact same scale as the original), Anxiousness, Wellbeing, Self-esteem, Self-discipline, Loneliness “Modified”, Social Dominance Orientation “Modified”, Right-Wing Prejudice, Impulsiveness, Reflection, Trust, Right-Wing Authoritarianism Modified, Stimulation, Sociability, Leadership, and Empathy. All new scales with their reliabilities and their composing items with their factor loadings are provided in **Appendix 2**. All the details of our factor analysis with all items and loads onto the 17 factors can be found on our OSF page: <https://osf.io/f6qun/>.

Analysis Strategy Overview

Our analytic strategy consisted in an exploratory phase and a confirmatory phase. Prior to analyzing our data, we randomly split our dataset into a training and testing dataset. In the first phase of the exploratory analyses, we ran an exploratory factor analysis with all the variables in our dataset, except for the STRAQ-1. Based on factor loading, we created new personality variables, thus composed of items that loaded onto the same factors.³

Once we defined our new factors, we explored existing relations in our data to

³ Notably, we are conscious of the discussion of the contribution of states and traits to psychological measurements. For the sake of simplicity at this initial stage, we included them as equivalent in the factor analyses (without any decomposition into traits or states; Hamaker, Nesselroade, & Molenaar, 2007).

generate mediation model hypotheses through a powerful supervised machine learning method called conditional random forests. In supervised machine learning more generally, the algorithm infers a pattern from the data derived from a “signal” (or dependent variable). The method relies on “out-of-bag estimates”, which involves repeated sampling from a training dataset (e.g., Breiman, 2001). Multiple “trees” are formed by assessing whether each variable influences the “signal”. The “trees” (votes on whether variables matter for the outcome variable or not) are then assembled into a “forest”. Each “tree” receives a “vote” into an ensembled model that then summarizes all information from the trees. The outcome in the case of conditional random forests is a variable importance list. The importance list allows us to identify which are the best predictors of the variable of interest and which of the computed variables differ from random noise when predicting the variable of interest (see also IJzerman et al., 2016a). In our case the random forest allows us to select the variables to be included in the mediation analyses in the exploratory phase. In the first stage of our exploratory analyses, we ran three sets of conditional random forests, one for each of the three mediation paths (the a , b , and c path).

In each set of analyses, we specified an outcome variable and derived the best predictor for the given outcome variable. To identify the mediators between thermoregulation (independent variables) and personality (dependent variables), we ran conditional random forests on the attachment variables (mediators) with thermoregulation variables as predictors to examine relations between the mediators and the independent variables (a path in the model). Then, we ran conditional random forests on personality variables with attachment variables to select only personality variables that were related to attachment (b path in model). After that we refined our personality variables selection by running conditional random forests on personality variables with thermoregulation variables as predictors to determine which personality variables were related to thermoregulation variables (c path in the model) and thus to select only personality variables that were related to both attachment and thermoregulation variables. This funnel-like strategy

enabled us to select the most relevant personality variables for the mediation analyses that followed and thus to generate the strongest mediation models to test, in a data-driven way. In the second stage of the exploratory phase, we tested the significance of these mediation models through more common, confirmatory, mediation analyses.

Main Analysis Plan: Approach for the Conditional Random Forests

All our analysis scripts, auxiliary results, and data can be found on our OSF project page: <https://osf.io/74fr3/>. In the exploratory phase, we first explored relations between the thermoregulation scales of the STRAQ-1 (social thermoregulation, temperature sensitivity, and solitary thermoregulation), attachment, and various personality factors via conditional random forests along the line of a mediation logic. As there were a large number of potential mediation models we could run (i.e., 2 independent variables $\times$ 2 mediator $\times$ 17 dependent variables = 68 potential models), conditional random forests helped us to determine which ones would be potentially relevant based on the three paths of the mediation (see **Figure 2**).

Figure 2. Mediation model and paths for thermoregulation, attachment, and personality.

We chose conditional random forests over a regression for three reasons. First, linear

regression is a parametric approach that requires a priori predictions of relationships between variables and also requires hypotheses regarding potential nonlinearities and interactions (Grömping, 2012). As we were interested in exploring our data, we relied on a non-parametric type of machine learning, which relies on a flexible number of parameters, where the number of parameters can grow as the algorithm learns more data (Russell & Norvig, 2002). Overall, they are therefore well-suited for situations in which researchers have no a priori predictions such as exploratory research. Second, random forests are less prone to overfitting in relatively small samples with multiple variables (Grömping, 2012). Third and finally, random forests have a smaller chance for collinearity when including multiple predictors, as is the case in the current situation (Matsuki, Kuperman, & Van Dyke, 2016).

In order to understand which mediation models were most likely to be accurate representations of reality, we went through three sets of conditional random forests following the three steps of the expected mediation: 1) thermoregulation-related variables predicting attachment variables, 2) attachment variables predicting personality variables, 3) the thermoregulation variables predicting the personality variables. In each set of the conditional random forests, we added all the created personality variables as predictors of “non-interest” for the main reason that the random noise is better estimated with an increased number of variables.

Exploratory Results

STRAQ-1 Predicting Attachment (mediation path a). To understand what predicted attachment, we ran one set of 100 conditional random forests for the newly created Attachment Anxiety “Modified” as “signal” and one set of 100 conditional random forests for the newly created Attachment Avoidance “Modified” as “signal” with the

STRAQ-1 variables (excluding the Risk Avoidance scale)⁴ as predictors. In order to be able to separate relevant predictors from noise, we added other personality variables that we were not interested in as variables of non-interest. In both of these sets of analyses, we also added in the other attachment variable that was not of main interest to be predicted (i.e., Attachment Avoidance “Modified” when predicting Anxiety “Modified” et vice versa) as they usually share considerable variance. By adding them, we could capture their unique variance predicted by the STRAQ-1.

Here, we only summarize the predictors that differed from random noise. Results of the conditional random forests predicting the two newly formed attachment variables are displayed in the first section of **Table 2**. In this table, we only report the extracted variables. The full variable importance can be found on our OSF page (<https://osf.io/fchyd/>). From the average of our first 100 conditional random forests predicting Attachment Anxiety “Modified”, we found that the 8th most potent predictor (after, amongst others, Loneliness “Modified”, Attachment Avoidance “Modified”, and Impulsiveness) of Attachment Anxiety “Modified” was Solitary Thermoregulation. The most potent predictor from our second set of 100 conditional random forests predicting Attachment Avoidance “Modified” was Social Thermoregulation (before amongst others, Loneliness “Modified”, Attachment Anxiety, and Self-Esteem). Furthermore, Solitary Thermoregulation did not predict Attachment Avoidance and Social Thermoregulation did not predicted Attachment Anxiety. Thus, when using Attachment Anxiety as mediator Solitary (and not Social) Thermoregulation should be used as predictor. When Attachment Avoidance is used as a mediator, Social (and not Solitary) Thermoregulation should be used as predictor.

Attachment Predicting Personality (mediation path *b*). For the dependent variables/signals (the different personality factors we identified in our Exploratory Factor

⁴ We omitted the Risk Avoidance scale because the scale reliability was questionable in its original version (for a discussion see also Vergara et al. (2018)).

Analysis), we ran 100 conditional random forests per variable with the newly created attachment variables. We again inserted the personality variables we were not predicting as variables of non-interest, but excluded the STRAQ-1 variables (as they were potential predictors of attachment in our mediation models).

We again only summarize the results here. The extracted variables for each of our 100 conditional random forests are displayed in the second section of **Table 2**. For Wellbeing, Anxiousness, and Impulsiveness the only attachment variable predicting these personality factors beyond random noise was Attachment Anxiety “Modified”. In other words, when trying to predict these three variables one should utilize Attachment Anxiety as mediator.

For Self-esteem, Loneliness “Modified”, Trust, Sociability, and Leadership the variables predicting beyond random noise were Attachment Anxiety “Modified” followed by Attachment Avoidance “Modified”. Both Attachment Anxiety “Modified” and Avoidance “Modified” can thus be used as mediator when predicting these variables. For Right Prejudice, Right Wing Authoritarianism “Modified”, and Empathy the only attachment variable predicting beyond random noise was Attachment Avoidance “Modified”. Only Attachment Avoidance “Modified” should thus be used as a predictor in the mediation analyses. For the other personality variables, none of the attachment variables were predictors beyond random noise.

STRAQ-1 Predicting Personality (mediation path c). For the dependent variables (personality), we ran 100 conditional random forests per personality outcome variable with the STRAQ-1 variables (excluding the Risk Avoidance scale) as predictors. We again inserted other personality variables as predictors of non-interest. We summarize the main findings here; the extracted variables for each of our 100 conditional random forests are again displayed in the third section of **Table 2**.

For Anxiousness and Social Dominance Orientation “Modified” the only thermoregulation variable predicting these personality factors beyond random noise was Solitary Thermoregulation. Solitary Thermoregulation should thus be used as a predictor

for these two variables. For Loneliness and Sociability, the only thermoregulation variable predicting these personality factors beyond random noise was Social Thermoregulation. Social Thermoregulation should thus be used as predictor for these two variables. For Trust and Empathy, the thermoregulation variables predicting these personality factors beyond random noise were Social Thermoregulation first and Solitary Thermoregulation second. Both Social and Solitary Thermoregulation should thus be used as predictors for Trust and Empathy. For the other personality variables, none of the thermoregulation variables were predictors beyond the random noise.

We have now established some (seemingly robust) relationships for the different paths of the mediation. However, our conditional random forests also presented some surprises, as not all relationships between (social) thermoregulation and personality were mediated by attachment. In our next step, we selected the personality factor that were candidates for prediction for our thermoregulated-related variables (with corresponding mediators, if applicable). We display a summary of the conditional random forest results and consistent mediation models in **Table 3**.

Relationships between the Personality Factors and their Predictors.

Relationships between all the variables of the mediation models displayed in **Table 3**. More specifically, we examined the relationships between the thermoregulation variables and their attachment mediators, the relationships between the attachment mediators the selected personality factors, and the relationships between the thermoregulation variables and the selected personality factors. To examine whether these were linear or not, we compared the traditional regression lines to the locally estimated scatterplot smoothing (LOESS) curves by calculating as many local least squares regression functions as there are data segments. All scatter plots are available on our OSF page (<https://osf.io/74fr3/>). By comparing the LOESS curves to the regression lines, we found that none of the relations between the variables of our mediation models were non-linear. We thus further proceeded with traditional mediation analyses using linear regression.

Table 2

This table displays extracted predictors differing from random noise for the A, B, C Path of the mediation Thermoregulation -> Attachment -> Personality models. Full table including full Conditional Random Forests results is posted on our OSF page.

	Variables to be predicted	Extracted thermoregulation predictors (which likely differ from random noise)	Extracted attachment predictors (which likely differ from random noise)
Mediators	Anxiety "Modified"	Solitary Thermoregulation	
	Avoidance "Modified"	Social Thermoregulation	
Dependant Variables	Wellbeing	None	Anxiety "Modified"
	Anxiousness	Solitary Thermoregulation	Anxiety "Modified"
	Self-esteem	None	Anxiety "Modified" & Avoidance "Modified"
	Self-discipline	None	None
	Loneliness "Modified"	Social Thermoregulation	Anxiety "Modified" & Avoidance "Modified"
	Social Dominance Orientation	Solitary Thermoregulation	None
	"Modified"		
	Right Prejudice	None	Avoidance "Modified"
	Impulsiveness	None	Anxiety "Modified"
	Reflection	None	None
	Trust	Solitary Thermoregulation & Social Thermoregulation	Anxiety "Modified" & Avoidance "Modified"
	Right Wing Authoritarianism	None	Avoidance "Modified"
	"Modified"		
	Stimulation	None	None
	Sociability	Social Thermoregulation	Anxiety "Modified" & Avoidance "Modified"
	Leadership	None	Anxiety "Modified" & Avoidance "Modified"
	Empathy	Social Thermoregulation & Solitary Thermoregulation	Avoidance "Modified"

Table 3

Summary of exploratory results and projected models for regression analyses.

Dependant variable	Mediator	Predictor(s)	Resulting model
Wellbeing	Not Applicable	Anxiety "Modified"	Correlation
Anxiousness	Anxiety "Modified"	Solitary Thermoregulation	Mediation (Solitary Thermoregulation -> Anxiety -> Anxiousness)
Self-esteem	Not Applicable	Anxiety "Modified" and Avoidance "Modified"	Correlation
Self-discipline	Not applicable	Not applicable	None
Loneliness "Modified"	Anxiety "Modified"; Avoidance "Modified"	Social Thermoregulation	Mediation (Social Thermoregulation -> Avoidance -> Loneliness "Modified")
Social Dominance Orientation "Modified"	Not applicable	Solitary Thermoregulation	Correlation
Right Prejudice	Not applicable	Avoidance "Modified"	Correlation
Impulsiveness	Not applicable	Anxiety "Modified"	Correlation
Reflection	Not applicable	Not applicable	None
Trust	Anxiety "Modified"; Avoidance "Modified"	Solitary Thermoregulation and Social Thermoregulation	Mediation (Solitary Thermoregulation -> Anxiety -> Trust and Social Thermoregulation -> Avoidance -> Trust)
Right Wing Authoritarianism "Modified"	Not applicable	Avoidance "Modified"	Correlation
Stimulation	Not applicable	Not applicable	None
Sociability	Anxiety "Modified"; Avoidance "Modified"	Social Thermoregulation	Mediation (Social Thermoregulation -> Avoidance -> Sociability)
Leadership	Not applicable	Anxiety "Modified" and Avoidance "Modified"	Correlation
Empathy	Avoidance "Modified"	Social Thermoregulation	Mediation (Social Thermoregulation -> Avoidance -> Empathy)

Regression Analyses

Based on our conditional random forest results, we continued to explore more traditional regression analyses. This included a hypothesis-generating mediation model. Conducting these analyses will also allow us to write down the prediction for our confirmatory study, as well as better understand the relationships between variables (in addition, our conditional random forests included variables of non-interest and may thus not have represented the most optimal relationship between variables). We will split these up into mediation analyses first and simple correlations second.

Mediation models

To test the indirect effect in the mediations, we relied on the joint significance approach. This approach consists of testing the significance of the two components constituting the indirect effect, which is the relation between the independent variable and the mediator (a path) and the relation between the mediator and the dependent variable (b path) controlling for the independent variable (see **Figure 1**). The indirect effect is the product of those two coefficients and is significant only when both the a path and the b path are significant. This method has a lower Type 1 error rate than methods that rely on bootstrapping (Yzerbyt, Muller, Batailler, & Judd, 2018).

We also used the Monte Carlo method as a complementary approach to estimate the significance of the indirect effect and the confidence interval. The Monte Carlo method first estimates the standard error distributions for a and b for the sample and then computes 5000 random samples based on the product of those two distributions estimates. We report the results of the joint significance test and the Monte Carlo method in **Table 4**.

For all mediation models, we decided to include the sex as control variable as per the recommendation by IJzerman et al. (2020). They found that participants' sex may have an influence on the effect size of variables related to social thermoregulation (we did not make

any further inferences about sex, because our sample was not representative of men versus women). We include the analyses without sex as control variable on our OSF page (<https://osf.io/f6qun/>).⁵

We found that the effect of Solitary Thermoregulation on Anxiousness was mediated by Attachment Anxiety “Modified” and that the effect of Solitary Thermoregulation on Trust was mediated by Attachment Anxiety “Modified”. We also found that the effect of Social Thermoregulation on Trust, Loneliness “Modified”, and Empathy was mediated by Attachment Avoidance “Modified” and that the effect of Social Thermoregulation on Sociability was mediated by Attachment Avoidance “Modified”. The results of mediation analyses are displayed in **Table 4**.

We then proceeded with correlational analyses between the identified personality factors and thermoregulation variables. Indeed, based on CRF results, not all relationships seemed to be mediated by attachment. In this additional set of analyses, we found that Social Dominance Orientation “Modified” and Empathy was predicted by Solitary Thermoregulation and that Sociability was predicted by Social Thermoregulation (note that Attachment Avoidance was very close to random noise when predicting Sociability in our conditional random forests, so we did not presume mediation). Note that the relationship between Solitary Thermoregulation and Social Dominance Orientation “Modified” is weak, unlikely to replicate, and must be interpreted with caution. Pearson’s correlations and their p-values are displayed in **Table 5**.

⁵ In half of our sample, the correlation between solitary thermoregulation and sex was $r = .31$, $p < .001$ and the correlation between social thermoregulation and sex was $r = .04$, $p = .44$. Furthermore, Vergara et al. (2018) found a link between thermoregulation variables and the relationship status and we might expect similar relation in our sample as well. In half of our sample, the correlation between solitary thermoregulation and the relationship status was $r = -.11$, $p = .09$ and the correlation between social thermoregulation and the relationship status was $r = .22$, $p < .001$.

Table 4

Exploratory mediation analyses for the Thermoregulation → Attachment → Personality models.

Variables			a path			b path			c path			c' path			Indirect effect
Independent variable	Mediator	Dependent Variable	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	Monte Carlo 95% CI
Solitary	Anxiety	Anxiousness	0.30**	<i>t</i> (242) = 2.79	< .01	0.27***	<i>t</i> (238) = 7.65	< .01	0.19**	<i>t</i> (244) = 2.87	< .01	0.13*	<i>t</i> (238) = 2.24	.03	[0.02; 0.15]
Thermoregulation	"Modified"	Trust	0.30**	<i>t</i> (242) = 2.79	< .01	-0.23***	<i>t</i> (239) = 5.35	< .01	-0.16*	<i>t</i> (245) = 2.18	.03	-0.13	<i>t</i> (239) = 1.74	.08	[-0.13; -0.02]
Social	Avoidance	Trust	-0.56***	<i>t</i> (240) = 7.42	< .01	-0.17***	<i>t</i> (237) = 3.50	< .01	0.20***	<i>t</i> (247) = 3.73	< .01	0.10	<i>t</i> (237) = 1.58	.12	[0.04; 0.16]
Thermoregulation	"Modified"	Loneliness "Modified"	-0.56***	<i>t</i> (240) = 7.42	< .01	-0.16***	<i>t</i> (236) = 5.00	< .01	0.18***	<i>t</i> (245) = 4.83	< .01	0.07	<i>t</i> (236) = 1.75	.08	[0.05; 0.14]
		Sociability	-0.56***	<i>t</i> (240) = 7.42	< .01	-0.12*	<i>t</i> (234) = 2.39	.02	0.22***	<i>t</i> (244) = 3.84	< .01	0.16*	<i>t</i> (234) = 2.41	.02	[0.01; 0.13]
		Empathy	-0.56***	<i>t</i> (240) = 7.42	< .01	-0.12***	<i>t</i> (239) = 3.76	< .01	0.14***	<i>t</i> (248) = 3.57	< .01	0.06	<i>t</i> (238) = 1.32	.19	[0.03; 0.12]

¹ Coefficients *b* are unstandardized regression coefficients.

² * denotes $p < .05$ ** denotes $p < .01$ *** denotes $p < .001$

Table 5

Pearson's correlations between thermoregulation variables and personality variables.

Independent variable	Dependent variable	Pearson's correlation	<i>t</i>	<i>p</i>
Solitary Thermoregulation	Social Dominance Orentation "Modified"	.13*	$t(244) = 1.98$	.05
	Empathy	.17**	$t(246) = 2.75$	< .01
Social Thermoregulation	Sociability	.24***	$t(245) = 3.85$	< .01

¹ *denotes $p < .05$ ** denotes $p < .01$ *** denotes $p < .001$

Robustness Analyses

Mediation models with traditional factors. To ensure the robustness of our analyses, we ran auxiliary analyses the attachment factors as they are traditionally envisioned by the original scale's creators (for the Big Five and the ECR). This thus provides a robustness check for our results. For the original Agreeableness scale we found comparable results as for the modified scales Trust and Empathy (i.e., prediction by Social Thermoregulation and mediation by Avoidance). For the original Neuroticism scale we found comparable results as for the modified scale Anxiousness (i.e., prediction by Solitary Thermoregulation and mediation by Anxiety). For the original Extraversion scale we found comparable results as for the modified scales Loneliness "Modified" and Sociability (i.e., prediction by Social Thermoregulation and mediation by Avoidance). Again, we controlled for the sex in all mediation models. The results of mediation analyses with traditional factors are displayed in **Table 6**.

Table 6

This table displays all mediation analyses for Thermoregulation → Attachment → Big Five models.

Variables			a path			b path			c path			c' path			Indirect effect
Independent variable	Mediator	Dependent Variable	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	Monte Carlo 95% CI
Solitary Thermoregulation	Anxiety	Neuroticism	0.28**	$t(239) = 2.63$	< .01	0.29***	$t(234) = 9.35$	< .01	0.12*	$t(243) = 2.11$	.04	0.04	$t(234) = 0.76$	.47	[0.02; 0.15]
		Agreeableness	0.28**	$t(239) = 2.63$	< .01	-0.14***	$t(230) = 5.33$	< .01	0.02	$t(239) = 0.40$	.69	0.04	$t(230) = 0.95$	.34	[-0.07; -0.01]
Social Thermoregulation	Avoidance	Agreeableness	-0.56***	$t(240) = 7.42$	< .01	-0.11***	$t(232) = 4.28$	< .01	0.10***	$t(242) = 3.28$	< .01	0.03	$t(232) = 0.86$	.39	[0.03; 0.10]
		Extraversion	-0.56***	$t(240) = 7.42$	< .01	-0.06	$t(233) = 1.92$	.06	0.20***	$t(242) = 5.14$	< .01	0.16***	$t(233) = 3.62$	< .01	[0.01; 0.07]

¹ Coefficients *b* are unstandardized regression coefficients.

² * denotes $p < .05$ ** denotes $p < .01$ *** denotes $p < .001$

Confirmatory Results

Conditional Random Forests. We had two confirmatory sets. Our first confirmatory set consisted of the second half of the first sample. This confirmatory set allowed us to test our predictions, and, in case our model is inaccurate, adjust before we tested in the second dataset. We tested our predictions by evaluating the replicability of each conditional random forests using the predict function. To estimate the replicability of conditional random forests models in the test dataset, we then calculated the squared correlation between these predictions and the actual values in the test dataset.

As each conditional random forest model was computed 100 times, we computed 100 squared correlations for each model prediction that were then averaged out, resulting in one squared correlation for each conditional random forest model. To evaluate the overall replicability of the conditional random forest models, we calculated the mean squared correlation resulting from the average of all squared correlations associated with each conditional random forest model. The $M_{rsquared}$ was 0.35 ($SD_{rsquared} = 0.13$, $Min_{rsquared} = 0.11$, $Max_{rsquared} = 0.65$).

To estimate the replicability of the conditional random forest models used to create each mediation model, we then calculated the mean squared correlation for each mediation model by averaging the three squared correlations associated with CRF models used to create the three paths of the mediation (a, b, and c paths). We provide the mean squared correlation for each mediation model in the left panel of **Table 7**. Overall, these squared correlations revealed a medium fit between predictions from the conditional random forest models generated in train data and actual test data. Therefore, even though this reveals sufficient replicability of conditional random forest models in the test data, we cannot exclude the possibility that we may have overfitted our models to the data and thus made the wrong assumptions about the mediation models. By subsequently replicating the mediation models we should be able to shed further light about the robustness of our models.

Regression Models. We then tested how accurate our predictions were for our regression analyses. We relied on formalized predictions from our regression models generated in the exploratory phase in our training data (see also Haslbeck, Oisín, Robinaugh, Waldorp, & Borsboom, 2021). We display these formalized predictions in **Table 8**.

Criteria for replication. We set our replication criteria a priori: to determine the replication of the exploratory results, we would examine whether the beta estimates of the three paths of the mediation (a, b, and c paths) were significant and we would examine whether the direction of the three paths (i.e., negative or positive) were identical to those in the exploratory results.

If the result were in the same direction, we would consider it a weak replication. For a medium test of the prediction, we would rely on the lower bound of the confidence intervals of the beta estimates obtained in the exploratory phase to define a minimum beta interest to be replicated in the confirmatory phase. For a strong test of the prediction, we would also test the difference between the estimate in the exploratory model and in the confirmatory models through Z-tests. Only a significant difference resulting from the superiority of the confirmatory beta estimate over exploratory beta estimate was considered as a strong replication. Because this point prediction replication approach leaves us very little margin for estimation error, we expected our replication rate to be very low for the strong test of our prediction.

A summary of the replication of the regression analyses for each path of mediation models (a, b, and c paths) is displayed in the middle panel of **Table 7**. Of the 18 paths analyzed through regression analyses in the confirmatory dataset, only three were considered as not replicated at all, 15/18 were replicated according to our weak criteria, 15/18 according to our medium criteria, and 0/18 according to our strong criteria.

As all three pathways of the mediation needed to be replicated for the meditation to be replicated, three out of six mediations were considered replicated. Specifically, we

replicated the effect of Solitary Thermoregulation on Anxiousness, with mediator Attachment Anxiety “Modified”. We also replicated the effect of Social Thermoregulation on Loneliness “Modified”, with as mediator Attachment Avoidance “Modified”. We further replicated the effect of Social Thermoregulation on Empathy, with as mediator Attachment Avoidance “Modified”. Other mediation models were considered as not replicated due to one path not being statistically significant. The results of the confirmatory mediation analyses are displayed in **Table 9**.

Discussion Study 1

In Study 1, we investigated the link between social thermoregulation and personality. We relied on an exploratory approach consisting of splitting our dataset in a training and a testing dataset. Because we conducted our study in a sample (French students in Grenoble) where little validation had been done, we first conducted exploratory factor analyses to create personality factors on multiples individual difference scales. We then investigated the relations between these new personality factors, (only somewhat) modified attachment variables, and social thermoregulation variables through machine learning. Based on machine learning results, we created mediations models that were first analyzed the first half of the data.

These analyses revealed that of the six mediation models tested, all were significant. Accordingly, we found that Attachment Anxiety “Modified” mediated the relationship between Solitary Thermoregulation and Anxiousness as well as the relationship between Solitary Thermoregulation and Trust. Moreover, we also found that Attachment Avoidance “Modified” mediated the relation between Social Thermoregulation and Trust, Social Thermoregulation and Loneliness “Modified”, Social Thermoregulation and Sociability, and Social Thermoregulation and Empathy.

Table 7

Summary of the replication of the a, b, and c paths of the Thermoregulation -> Attachment -> Personality models and mean squared correlations summarizing the replicability of CRF models used to create these mediation models

Mediation model	Mean R squared (SD, Min, Max)	Not replicated (a,b,c)	Weak (a,b,c)	Medium (a,b,c)	Strong (a,b,c)	Overall replication
Solitary Thermoregulation -> Anxiety "Modified" -> Anxiousness	M = .44 (SD = .12, Min = .35, Max = .58)	-, -, -	+, +, +	+, +, +	-, -, -	Medium replication
Solitary Thermoregulation -> Anxiety "Modified" -> Trust	M = .29 (SD = .08, Min = .2, Max = .35)	-, -, +	+, +, -	+, +, -	-, -, -	Not replicated
Social Thermoregulation -> Avoidance "Modified" -> Trust	M = .28 (SD = .07, Min = .20, Max = .33)	-, -, +	+, +, -	+, +, -	-, -, -	Not replicated
Social Thermoregulation -> Avoidance "Modified" -> Loneliness "Modified"	M = .40 (SD = .06, Min = .33, Max = .44)	-, -, -	+, +, +	+, +, +	-, -, -	Medium replication
Social Thermoregulation -> Avoidance "Modified" -> Sociability	M = .33 (SD = .01, Min = .32, Max = .34)	-, +, -	+, -, +	+, -, +	-, -, -	Not replicated
Social Thermoregulation -> Avoidance "Modified" -> Empathy	M = .29 (SD = .04, Min = .26, Max = .33)	-, -, -	+, +, +	+, +, +	-, -, -	Medium replication

¹ This table displays the nature of the replication for each path of the mediation (a, b, c)

² '+' means that the path meets the criteria of the corresponding replication type while '-' means that the path does not meet the criteria of the corresponding replication type

³ Mean squared correlations for each mediation model were computed by averaging the three squared correlations associated with the three CRF models used to create each path of the mediation

Table 8

Formalized predictions

Variables			Formalized predictions			
Independant variable	Mediator	Dependant Variable	a path	b path	c path	c' path
Solitary Thermoregulation	Anxiety "Modified"	Anxiousness	Anxiety "Modified" = 2.72 + .30 Solitary Thermoregulation + .18 Sex	Anxiousness = 1.15 + .27 Anxiety "Modified" + .13 Solitary Thermoregulation + .27 Sex	Anxiousness = 1.99 + .19 Solitary Thermoregulation + .33 Sex	Anxiousness = 1.15 + .13 Solitary Thermoregulation + .27 Anxiety "Modified" + .27 Sex
		Trust		Trust = 4.24 - .23 Anxiety "Modified" - .13 Solitary Thermoregulation + .07 Sex	Trust = 3.48 - .16 Solitary Thermoregulation + .02 Sex	Trust = 4.24 - .13 Solitary Thermoregulation - .23 Anxiety "Modified" + .07 Sex
Social Thermoregulation	Avoidance "Modified"	Trust	Avoidance "Modified" = 4.50 - .56 Social Thermoregulation + .07 Sex	Trust = 3.12 - .17 Avoidance "Modified" + .10 Social Thermoregulation - .08 Sex	Trust = 2.35 + .20 Social Thermoregulation - .11 Sex	Trust = 3.12 + .10 Social Thermoregulation - .17 Avoidance "Modified" - .08 Sex
		Loneliness "Modified"		Loneliness "Modified" = 3.31 - .16 Avoidance "Modified" + .07 Social Thermoregulation + .03 Sex	Loneliness "Modified" = 2.52 + .18 Social Thermoregulation + .06 Sex	Loneliness "Modified" = 3.31 + .07 Social Thermoregulation - .16 Avoidance "Modified" + .03 Sex
		Sociability		Sociability = 2.96 - .12 Avoidance "Modified" + .16 Social Thermoregulation - .08 Sex	Sociability = 2.42 + .22 Social Thermoregulation + .02 Sex	Sociability = 2.96 + .16 Social Thermoregulation - .12 Avoidance "Modified" - .08 Sex
		Empathy		Empathy = 4.47 - .12 Avoidance "Modified" + .06 Social Thermoregulation + .31 Sex	Empathy = 3.88 + .14 Social Thermoregulation + .30 Sex	Empathy = 4.47 + .06 Social Thermoregulation - .12 Avoidance "Modified" + .31 Sex

Table 9

Confirmatory mediation analyses for the Thermoregulation -> Attachment -> Personality models.

Variables			a path			b path			c path			c' path			Indirect effect
Independent variable	Mediator	Dependent Variable	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	Monte Carlo 95% CI
Solitary	Anxiety	Anxiousness	.27*	$t(240) = 2.50$	.01	.29***	$t(232) = 8.21$	< .01	.25***	$t(235) = 3.67$	< .01	.16**	$t(232) = 2.70$	< .01	[0.02; 0.14]
Thermoregulation	"Modified"	Trust	.27*	$t(242) = 2.50$	.01	-.24***	$t(238) = 5.33$	< .01	-.02	$t(242) = 0.20$	.84	.05	$t(238) = 0.70$	.48	[-0.12; -0.01]
Social	Avoidance	Trust	-.44***	$t(240) = 6.00$	< .01	-.21***	$t(234) = 4.52$	.14	.08	$t(243) = 1.50$	.13	-.04	$t(234) = 0.71$	.48	[0.05; 0.15]
Thermoregulation	"Modified"	Loneliness "Modified"	-.44***	$t(240) = 6.00$	< .01	-.20***	$t(230) = 6.00$	< .01	.12**	$t(239) = 2.99$	< .01	.02	$t(230) = 0.40$	.69	[0.05; 0.13]
		Sociability	-.44***	$t(240) = 6.00$	< .01	-.08	$t(231) = 1.65$	.1	.32***	$t(240) = 5.61$	< .01	.28***	$t(231) = 4.57$	< .01	[-0.01; 0.09]
		Empathy	-.44***	$t(240) = 6.00$	< .01	-.11**	$t(232) = 3.32$	< .01	.11**	$t(241) = 2.93$	< .01	.06	$t(238) = 1.59$	.11	[0.02; 0.08]

¹ Coefficients *b* are unstandardized regression coefficients.

² *denotes $p < .05$ ** denotes $p < .01$ *** denotes $p < .001$

Then, after an *In Principle Acceptance* from this journal, we replicated these mediation models in the testing set of the data. Before moving to this step, we evaluated the replicability of our conditional random forests in the test dataset by calculating the squared correlation between predictions from CRF models computed in the training and actual testing data. Overall, these squared correlations revealed medium fit between CRF model predictions and actual test data. As our mediation models were created based on CRF results, medium fit between CRF models and test data does not totally rule out the possibility that we may have made wrong mediation assumptions due to CRF overfitting.

We therefore then moved on to testing the replicability of our mediation models in the test dataset to investigate this possibility. We found that 15/18 of the effects were replicated, but only three out of the six mediations models tested could be considered as medium replications (i.e., their confidence interval was overlapping and they were not only significant at the same level): the mediation between Solitary Thermoregulation, Attachment Anxiety “Modified”, and Anxiousness; the mediation between Social Thermoregulation, Attachment Avoidance “Modified”, and Loneliness “Modified”; the mediation between Social Thermoregulation, Attachment Avoidance “Modified”, and Empathy. Other mediation models were considered as not replicated because for all of them one path was not significant.

To further increase confidence in our findings, we then aimed to refine our predictions based on confirmatory results and test them in an out-of-sample dataset in a second study. Specifically, we would only replicate mediations models that were at least considered as weak replications. Thus, we aimed to replicate three of our six mediation models. However, from Study 1 to 2, not all items were asked, as researchers that selected scales for the testweek elected to include different scales. The differences between Studies 1 and 2 are displayed in **Appendix 3**. The mediations that included different items were Solitary Thermoregulation onto Anxiousness, mediated by Anxiety “Modified” and Social Thermoregulation onto Loneliness “Modified” mediated by Avoidance “Modified”. When

we reran the mediations for those models, we again found them to replicate (ps for all paths except the c' path $< .01$; see also <https://osf.io/42xcg/>). Therefore, for an out-of-sample dataset, we predicted the same relationships as we replicated in our testing dataset from Study 1, despite the differences in items. In Study 2, we will restrict ourselves to testing the mediation models.

Study 2

Participants

Participants ($N = 334$) were recruited from Université Grenoble Alpes in France in 2019. Psychology students (41 men, 283 women, 2 others, and 8 missing) answered a battery of online questionnaires on Qualtrics. They were 90 in L1, 104 in L2, 106 in L3, 25 in M1, and 1 in M2 (8 missing). The M_{age} was 20.36 ($SD_{\text{age}} = 3.10$), $M_{\text{self-reported height}}$ was 166.87 ($SD_{\text{self-reported height}} = 8.66$)⁶ and the $M_{\text{self-reported weight}}$ was 61.26 ($SD_{\text{self-reported weight}} = 13.15$). Within participants, 77 were smokers and 248 weren't (9 missing). Also, 183 were in a relationship, 129 were not, and 14 preferred not to answer.

Confirmatory Results

Regression models. In Study 2, we relied on formalized predictions resulting from regression analyses in the whole Study 1 dataset (i.e., merged train and test datasets). We computed these predictions with identical factor to those in Study 2 (i.e., without items that were missing for the factors Anxiousness and Loneliness “Modified”) so that predictions reflect what could reasonably be expected for Study 2. May find these formalized predictions at <https://osf.io/cmbdy/>.

⁶ We again removed observations under 100cm for the calculation of the $M_{\text{self-reported height}}$ and $SD_{\text{self-reported height}}$, given the high unlikelihood of these scores (and were probably in our data due to typing errors).

Criteria for replication. We applied the same replication criteria in Study 2 as for Study 1, with the note that we compared the coefficients from the ones obtained through mediation analyses from the entire Study 1 dataset. A summary of the replication of the regression analyses for each path of mediation models (a, b, and c paths) is displayed in **Table 10**. Of the 9 paths analyzed through regression analyses in the Study 2 dataset, three were considered as not replicated at all, 6/9 were replicated according to our weak criteria, 6/9 according to our medium criteria, and 0/9 according to our strong criteria.

As all three pathways of the mediation needed to be replicated for the meditation to be replicated, only one mediation model was considered as fully replicated in Study 2: we replicated the effect of Social Thermoregulation on Loneliness “Modified”, with as mediator Attachment Avoidance “Modified”. Other mediation models were considered as not replicated due to at least one path not being statistically significant. The results of the confirmatory mediation analyses are displayed in **Table 11**.

Discussion Study 2

In Study 2, we aimed to test Study 1 predictions in an out-of-sample dataset based on regression analyses generated from the entirety of Study 1 and preregistered these predictions on the OSF. Mediation analyses revealed that 6/9 of the effects were replicated but only one out of three mediations could be considered as a replication: we replicated the effect of Social Thermoregulation on Loneliness “Modified” mediated by Attachment Avoidance “Modified”. Other models were not replicated due to at least one path not being statistically significant.

Table 10
Summary replication Study 2

Mediation model	Not replicated (a, b, c)	Weak (a,b,c)	Medium (a,b,c)	Strong (a,b,c)	Overall replication
Solitary Thermoregulation -> Anxiety "Modified" -> Anxiousness	+, -, +	-, +, -	-, +, -	-, -, -	Not replicated
Social Thermoregulation -> Avoidance "Modified" -> Loneliness "Modified"	-, -, -	+, +, +	+, +, +	-, -, -	Medium replication
Social Thermoregulation -> Avoidance "Modified" -> Empathy	-, -, +	+, +, -	+, +, -	-, -, -	Not replicated

¹ This table displays the nature of the replication for each path of the mediation (a, b, c)
² '+' means that the path meets the criteria of the corresponding replication type while '-' means that the path does not meet the criteria of the corresponding replication type
³ Mean squarred correlations for each mediation model were computed by averaging the three squarred correlations associated with the three CRF models used to create each path of the mediation

Table 11

Study 2 mediation analyses for the Thermoregulation -> Attachment -> Personality models.

Variables			a path			b path			c path			c' path			Indirect effect
Independent variable	Mediator	Dependent Variable	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	<i>b</i>	<i>t</i>	<i>p</i>	Monte Carlo 95% CI
Solitary Thermoregulation	Anxiety "Modified"	Anxiousness	.08	t(249) = 0.76	t(249) = 0.76	.26***	t(193) = 6.00	t(193) = 6.00	.08	t(224) = 1.14	t(224) = 1.14	.10	t(193) = 1.32	t(193) = 1.32	[-0.03; 0.08]
Social Thermoregulation	Avoidance "Modified"	Loneliness "Modified"	-.45***	t(245) = 5.45	t(245) = 5.45	-.15***	t(263) = 4.36	t(263) = 4.36	.14***	t(263) = 3.56	t(263) = 3.56	.06	t(219) = 1.39	t(219) = 1.39	[0.03; 0.11]
		Empathy	-.45***	t(245) = 5.45	t(245) = 5.45	-.14***	t(200) = 4.45	t(200) = 4.45	.06	t(236) = 1.64	t(236) = 1.64	.00	t(200) = 0.18	t(200) = 0.18	[0.03; 0.11]

¹ Coefficients *b* are unstandardized regression coefficients.

² *denotes *p* < .05 ** denotes *p* < .01 *** denotes *p* < .001

As an aside, the effect of Solitary Thermoregulation on the mediator Attachment Anxiety “Modified” did not replicate in Study 2 even though this relation was found in both Study 1 datasets. A rationale for this could be that we may have lacked power to detect this link. Indeed, in both Study 1 and 2, this relation had a smaller effect size than the link between Social Thermoregulation and Attachment Avoidance “Modified” (which replicated in all sets of analyses). This is also consistent with Vergara et al. (2018) who found the link between social thermoregulation and attachment avoidance to be stronger than the link between solitary thermoregulation and attachment anxiety⁷. To indeed understand whether power was a factor in non-replication, we added exploratory analyses where we merged Studies 1 and 2.

Studies 1 and 2 Exploratory Results

As these results are exploratory, they can only be used to understand why we did not replicate our analyses elsewhere and they can potentially be used for hypothesis generation, but not confirmation. To better understand why our results did not replicate, we ran the six mediation models that we had initially detected via conditional random forests in the first half of Study 1 in the entire dataset (i.e., the merged Study 1 and 2 datasets with $N = 844$) with models applied in Study 2 (i.e., without the missing items due to selections made by other researchers). While in the split approach, only one out of six replicated throughout datasets, when we ran the analyses in the entire dataset, five had three paths that were statistically significant. More specifically, 1) Attachment Anxiety “Modified” mediated the relations between Solitary Thermoregulation and Anxiousness and 2a) Attachment Avoidance “Modified” mediated the relation between Social Thermoregulation and Trust, 2b) Social Thermoregulation and Loneliness “Modified”, 2c) Social

⁷ In Vergara et al. (2018) Social Thermoregulation and Attachment Avoidance, Pearson’s correlation was $r = -.32^{***}$ whereas the Pearson’s correlation for Solitary Thermoregulation and Attachment Anxiety was $r = .08^{**}$.

Thermoregulation and Sociability, 2d) and Social Thermoregulation and Empathy. May find Study 1 and 2 exploratory mediation results at <https://osf.io/6yev2/>.

General Discussion

Altogether, in these two studies we explored the link between (social) thermoregulation on one hand and personality on the other hand and the link is mediated by attachment. Using a conservative cross-validation approach and through out-of-sample testing, the only effect that replicated throughout all datasets was the relationship between social thermoregulation desires and feelings of loneliness, which was mediated by attachment avoidance.

Why does (social) thermoregulation predict little beyond loneliness?

A priori, we had anticipated that (social) thermoregulation would be formative for personality on facets other than loneliness and attachment avoidance. However, we found little evidence to substantiate that view. Why could this be? The first and most obvious answer is that no such link exists. We consider that a reasonable possibility. However, we would like to point to some of the shortcomings in our research that could limit the extent to which that answer is certain.

Indeed, and second, our research may not have been sufficiently powered to detect these effects. In our first dataset, for instance, we did find effects on the factor sociability. To explore whether the small rate of replication was due to a lack of power, we conducted exploratory analyses for the six models analyzed in Study 1 on an entire dataset created by merging the Study 1 and Study 2 datasets. These analyses revealed that on the six mediation models tested, five were considered as statistically significant; that is, 11/12 of the effects tested were significant in our merged sample.

We then ran sensitivity analyses to understand what the minimum effect sizes we could have expected to find in Study 1 and Study 2 datasets. When we took the effect sizes

from the merged dataset and conducted a sensitivity analysis to understand whether we would have been able to observe them in the separate Studies 1 and 2, the effect sizes were smaller than the minimum effect size boundary (<https://osf.io/zj75c/>; beyond a potential cultural variation between the French and other samples, this also provides a rationale for the non-replication of the link between Solitary Thermoregulation and Attachment Anxiety in Study 2, which have been found in two previous sets of analyses and in another study; Vergara et al., 2018). Although such effects may thus replicate in larger samples, the alternative conclusion is that these effects are simply too small to care about and to invest resources into for potential interventions.

And yet, there is a third answer to why the relationship between (social) thermoregulation and personality are not detected as predicted. The questions we ask are somewhat constrained due to our measurement. When we assess social thermoregulation, we assess people's desires to socially thermoregulate, not necessarily the degree to which people know their confidence that others will be available (a crucial component when thinking about the reliability and predictability of the environment). Because of the way we had developed our measurement, the extent to which the concept of social thermoregulation maps onto the measure is thus limited. We are trying to address such limitations in a follow-up project to better measure social thermoregulation (Dujols et al., 2021).

Loneliness in the elderly and around the world: Constraints on generality (Simons, Shoda, & Lindsay, 2017)

Although we feel comfortable making strong assumptions about the statistical link between social thermoregulation and loneliness, we feel that such assumptions should be qualified. We conducted our study in students with an average age of 20.89 in Study 1 and 20.36 in Study 2. Age is known to affect people's thermoregulatory abilities, particularly in older age (e.g., Khan, Spence, & Belch, 1992). We suspect that throughout different age

groups – except the elderly - the relationship between social thermoregulation desires, attachment avoidance, and loneliness will hold. As in late adolescence (Buecker, Mund, Chwastek, Sostmann, & Luhmann, 2021), loneliness is a pressing topic. It is in fact so pressing that it has been made a priority by the World Health Organization (World Health Organization, 2021). It is all the more important that our study is replicated in older samples to understand whether our effect will hold.

Furthermore, our population lives in the French Alps in Grenoble, an area that is moderately cold in the winter (e.g., average low temperature -1.2 degrees Celsius and average high temperature 5.9 degrees Celsius in January) and warm in the summer (e.g., average low temperature 14.2 degrees Celsius and average high temperature of 26.9 degrees Celsius; Weather Atlas, 2021). We suspect that the effect size for the link between social thermoregulation desires, attachment avoidance, and loneliness is either the same or larger in colder climates and may be weaker in warmer climates. Relatedly, the STRAQ-1 instrument that we use may not be only limitedly applicable to other populations, as some of the subscales of the STRAQ-1 scored poorly on measurement equivalence across different populations that were tested (Vergara et al., 2018). The Dujols et al. (2021) project also intends to tackle that problem as people from different populations generated the items for the new STRAEQ-2 instrument.

One other limitation of our study is that our measurement focused on between-person, nomothetic assessments of personality and no individual, idiographic assessments across time and contexts (see e.g., Beck & Jackson, 2020). It is very likely that people vary across the year and seasons in how much they desire social thermoregulation and to be close to other people and this should be a focus for future prospective studies. It's also worth clarifying that self-reported social thermoregulatory desires may differ from actual thermoregulatory behaviors to an extent that is still unknown. Further, we took a very crude approach to exploring the factor structures as 1) the instruments have rarely (if ever) been tested amongst French populations and 2) our approach was intended to be as

exploratory as possible. The factor structure of a trait can vary at both the inter- and intra-individual level (Hamaker et al., 2007). Such changes in the factor structure are even more plausible as we didn't make the distinction between items measuring traits (likely more stable, e.g., "I worry about things") and items reflecting states (e.g., "I was worried about situations in which I might panic and make a fool of myself"). Better understanding such trait-state variations can also be better addressed, especially since mediational processes are time-dependent processes.

Statistical versus causal mediation

Related to the issue of time dependence is the distinction between statistical and causal mediation. Indeed, same cross-sectional – and likely biased – mediation parameters can give rise to different combinations of longitudinal mediation parameters (Maxwell et al., 2011). This makes it hard if not impossible to capture the true mediation parameters in addition to the causality. By using the joint-significance test, our analyses likely do a better job at estimating the effect sizes in comparison to other mediation tests (see Yzerbyt et al., 2018). However, there are still considerable limitations in relation to causal inference. Even though the conditional random forest models at least exclude some relevant variables of interest as potential explanatory variables, there are many other potential variables that we did not test. In other words, unobserved mediators could have biased estimates of mediation effects and that alternative causal paths may exist (Bullock, Green, & Ha, 2010). A next step in identifying causal relationships between social thermoregulation and loneliness can be done through prospective studies, for example using a longitudinal mediation structural equation modeling approach (Cole & Maxwell, 2003). We see such studies as a priority, as loneliness is a key variable in explaining people's health.

Social thermoregulation desires and loneliness: need for prospective studies

Peoples' health and longevity strongly relates to the extent to which they are socially connected, this relationship being stronger than, for instance, obesity and health or frequent alcohol usage and health, even when controlled for by many other relevant lifestyle variables (see, for instance, Holt-Lunstad, Smith, & Layton, 2010). The US Surgeon General Vivek Murthy found loneliness so troubling that he dubbed it a strategic priority (Hagland, 2019). Despite that the UK government dedicated a minister to social contact (United Kingdom Government, 2018) and despite near-immediate access to social media, loneliness has not decreased over time (AARP Foundation, 2018). Could it be that we may not completely understand the sociobiological origins of loneliness?

Somewhat counterintuitively, the regulation of core body temperature has been linked with the reasons why people form and maintain relationships (see, e.g., (Rocha IJzerman, 2021)). The present studies provide very robust evidence for a link between social thermoregulation desires and loneliness: in three different datasets, we keep finding this link and we find that this link is mediated by a lack of trust in romantic partners (i.e., attachment avoidance). We thus qualify our evidence at Evidence Readiness Level 5: candidate solutions in observational settings have been compared and formal predictions for positive expected effects have been generated (although unintended consequences have not yet been observed; IJzerman et al., 2020).

We are thus sufficiently confident to recommend investing resources into prospective studies to move to Evidence Readiness Level 6 to establish causal inference in a lab environment or a hospital, investigating first 1) whether social thermoregulation desires early in life (e.g., from parent to infant) relates to attachment avoidance and feelings of loneliness when the child grows up, after which 2) temperature interventions can be tested to examine whether social thermoregulation desires can be manipulated in adulthood. Prospective studies can be conducted by, for instance, recording newborn infant cries (Cohen, Ruinskiy, Zickfeld, IJzerman, & Lavner, 2020; Lavner, Cohen, Ruinskiy, &

IJzerman, 2016), relating them to peripheral temperature of parents (Sarda, Klein, Dujols, & IJzerman, 2021), after which attachment can be assessed between 9-18 months through the strange situation (Ainsworth, Blehar, Waters, & Wall, 2015). If such links can be established, temperature can be manipulated to simulate secure attachment through temperature actuators that are responsive to infant cries (see e.g., IJzerman et al., 2017).

But for now, the link between social thermoregulation, attachment, and loneliness at the stage of a statistical “proto-theory” (i.e., presumably robust statistical effects but without clear specification of mechanisms). Our conservative approach allowed us to draw strong claims about the replicability of a particular statistical pattern in a particular population. However, there is still supply the need for theory formalization based on valid measures and proper theory building approach to ensure clear and testable predictions (Szabelska, Dujols, Erle, Sparacio, & IJzerman, 2021). If this endeavor is met, this can constitute a stepping stone toward further interventions crafting to act effectively on feelings of loneliness.

Conclusion

So far, this study is the first examining the link between thermoregulation strategies and personality. We tested different mediation models through a strict cross-validation and out-of-sample testing approach and we found robust evidence for the link between social thermoregulation desires, attachment avoidance, and loneliness. Our study can be the starting point to understand the biological origins of loneliness and to create interventions for the health-promoting effect of social relationships. As a matter of public health, future studies should therefore investigate this possibility.

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Appendix

1140 **Appendix 1: Excluded items from the created scales and their rationale for**
1141 **exclusion.**

Created variable	Items	Original item scale	Factor loading	Rationale for exclusion
Anxiety "Modified"	I worry that I won't measure up to other people	ECR anxiety	0.44	Cross-loading with self-esteem
	My partner only seems to notice me when I'm angry	ECR anxiety	0.17	Insufficient loading
	Avoidance "Modified"			No items excluded
Anxiousness	I found it hard to wind down	DASS	0.34	Cross-loading with Wellbeing
	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)	DASS	0.35	Cross-loading with Wellbeing
	I tended to over-react to situations	DASS	0.33	Cross-loading with Wellbeing
	I felt that I was using a lot of nervous energy	DASS	0.43	Cross-loading with Wellbeing
	I was intolerant of anything that kept me from getting on with what I was doing	DASS	0.32	Cross-loading with Wellbeing
	In the last month, how often have you felt nervous and "stressed" ?	Self-reported Stress	-0.32	Cross-loading with Wellbeing
Wellbeing	I found it hard to wind down	DASS	-0.61	Cross-loading with Anxiousness
	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)	DASS	-0.41	Cross-loading with Anxiousness
	I tended to over-react to situations	DASS	-0.34	Cross-loading with Anxiousness

(continued)

Created variable	Items	Original item scale	Factor loading	Rationale for exclusion
Self-esteem	I felt that I was using a lot of nervous energy	DASS	-0.47	Cross-loading with Anxiousness
	I was intolerant of anything that kept me from getting on with what I was doing	DASS	-0.32	Cross-loading with Anxiousness
	In the last month, how often have you felt nervous and "stressed" ?	Self-reported Stress	0.47	Cross-loading with Anxiousness
	I've been feeling good about myself	Warwick-Edinburgh Mental Well-Being Scale	0.31	Cross-loading with Self-esteem
	I've been feeling confident	Warwick-Edinburgh Mental Well-Being Scale	0.48	Cross-loading with Self-esteem
	Love life	IPIP-NEO Extraversion	-0.33	Does not ostensibly measure the main construct
	I worry that I won't measure up to other people	ECR anxiety	0.41	Cross-loading with Anxiety "Modified"
	I compare myself to other people	Repetitive Thinking Mode Questionnaire	0.32	Cross-loading with Trust
	I've been feeling confident	Warwick-Edinburgh Mental Well-Being Scale	-0.36	Cross-loading with Wellbeing
Self-discipline	I am able to work effectively toward long-term goals	Self-control	-0.31	Cross-loading with Leadership

(continued)

Created variable	Items	Original item scale	Factor loading	Rationale for exclusion
Loneliness "Modified"	I am an outgoing person	UCLA Loneliness	0.19	Insufficient loading
	I am unhappy being so withdrawn	UCLA Loneliness	0.28	Insufficient loading
Social Dominance Orientation "Modified"	Feel sympathy for those who are worse off than myself	IPIP-NEO Agreeableness	0.34	Cross-loading with Empathy
	To get ahead in life, it is sometimes necessary to step on other groups	Social Dominance Orientation	0.28	Insufficient loading
	Sometimes other groups must be kept in their place	Social Dominance Orientation	0.24	Insufficient loading
	If certain groups of people stayed in their place, we would have fewer problems	Social Dominance Orientation	0.13	Insufficient loading
	In getting what your group wants, it is sometimes necessary to use force against other groups.	Social Dominance Orientation	0.21	Insufficient loading
	Some groups of people are just more worthy than others	Social Dominance Orientation	0.31	Cross-loading with Empathy
	Everyone should have their own lifestyle, religious beliefs, and sexual preferences, even if it makes them different from everyone else	Right Wing Authoritarianism	-0.36	Cross-loading with Right Wing Authoritarianism "Modified"

(continued)

Created variable	Items	Original item scale	Factor loading	Rationale for exclusion
Right Prejudice				No items excluded
Impulsiveness	Am not interested in theoretical discussions	IPIP-NEO Openness	-0.36	Does not ostensibly measure the main construct
Reflection				No items excluded
Trust	Keep others at a distance	IPIP-NEO Extraversion	0.34	Cross-loading with Sociability
	I compare myself to other people	Repetitive Thinking Mode Questionnaire	0.31	Cross-loading with Self-esteem
Right Wing	Everyone should have their own lifestyle,	Right Wing	0.41	Cross-loading with Social
Authoritarianism	religious beliefs, and sexual preferences,	Authoritarianism		Dominance Orientation
"Modified"	even if it makes them different from everyone else			"Modified"
	Some of the best people in our country are those who are challenging our government, criticizing religion, and ignoring the "normal way things are supposed to be done"		0.18	Insufficient loading
	There are many radical, immoral people in our country today, who are trying to ruin it for their own godless purposes, whom the authorities should put out of action		0.18	Insufficient loading

(continued)

Created variable	Items	Original item scale	Factor loading	Rationale for exclusion
	A "woman's place" should be wherever she wants to be. The days when women are submissive to their husbands and social conventions belong strictly in the past		0.25	Insufficient loading
	There is no "one right way" to live life; everybody has to create their own way		0.05	Insufficient loading
Stimulation				No items excluded
Sociability	Keep others at a distance	IPIP-NEO Extraversion	0.38	Cross-loading with Trust
	Prefer variety to routine	IPIP-NEO Openness	0.34	Does not ostensibly measure the main construct
	Seek adventure	IPIP-NEO Extraversion	0.33	Does not ostensibly measure the main construct
Leadership	Use others for my own ends	IPIP-NEO Agreeableness	-0.30	Cross-loading with Empathy
	Yell at people	IPIP-NEO Agreeableness	-0.30	Cross-loading with Impulsiveness
	I understand very quickly what's going on inside me	Repetitive Thinking Mode Questionnaire	0.32	Does not ostensibly measure the main construct
	I have trouble concentrating	Self-control	-0.30	Does not ostensibly measure the main construct

(continued)

Created variable	Items	Original item scale	Factor loading	Rationale for exclusion
Empathy	Feel sympathy for those who are worse off than myself	IPIP-NEO Agreeableness	0.32	Cross-loading with Social Dominance Orientation "Modified"

¹ For the created scales that are very similar to one of the original scales (i.e. created scales for which 'Modified' has been added to the name), we present the items from the original scale that we have excluded because they did not have sufficient load.

1142 **Appendix 2: Created attachment and personality variables with their**
1143 **reliabilities from the training set.**

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
Anxiety "Modified"	.90	.91	3.81	1.13	Refers to anxiety in attachment in romantic relationships.	It differs from the original scale Attachment Anxiety in that we dropped two items.	I'm afraid that I will lose my partner's love	ECR Anxiety	0.67
							I often worry that my partner will not want to stay with me	ECR Anxiety	0.73
							I often worry that my partner doesn't really love me	ECR Anxiety	0.55
							I worry that romantic partners won't care about me as much as I care about them	ECR Anxiety	0.66
							I often wish that my partner's feelings for me were as strong as my feelings for him or her	ECR Anxiety	0.56
							I worry a lot about my relationships	ECR Anxiety	0.54
							When my partner is out of sight, I worry that he or she might become interested in someone else	ECR Anxiety	0.65
							When I show my feelings for romantic partners, I'm afraid they will not feel the same about me	ECR Anxiety	0.63
							I rarely worry about my partner leaving me	ECR Anxiety	0.62
							My romantic partner makes me doubt myself	ECR Anxiety	0.47
							I do not often worry about being abandoned	ECR Anxiety	0.37

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
Avoidance "Modified"	.94	.95	2.83	1.17	Refers to avoidance in attachment in romantic relationships.	It doesn't differ from the original scale Attachment Avoidance but is named Avoidance "Modified" consistently with the idea that it results from a factor analysis.	I find that my partner(s) don't want to get as close as I would like	ECR Anxiety	0.54
							Sometimes romantic partners change their feelings about me for no apparent reason	ECR Anxiety	0.31
							My desire to be very close sometimes scares people away	ECR Anxiety	0.46
							I'm afraid that once a romantic partner gets to know me, he or she won't like who I really am	ECR Anxiety	0.35
							It makes me mad that I don't get the affection and support I need from my partner	ECR Anxiety	0.53
							I find it difficult to allow myself to depend on romantic partners	ECR Avoidance	0.74
							I feel comfortable sharing my private thoughts and feelings with my partner	ECR Avoidance	0.73
							I find it difficult to allow myself to depend on romantic partners	ECR Avoidance	0.55

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							I am very comfortable being close to romantic partners	ECR Avoidance	0.69
							I don't feel comfortable opening up to romantic partners	ECR Avoidance	0.69
							I prefer not to be too close to romantic partners	ECR Avoidance	0.72
							I get uncomfortable when a romantic partner wants to be very close	ECR Avoidance	0.63
							I find it relatively easy to get close to my partner	ECR Avoidance	0.73
							It's not difficult for me to get close to my partner	ECR Avoidance	0.44
							I usually discuss my problems and concerns with my partner	ECR Avoidance	0.74
							It helps to turn to my romantic partner in times of need	ECR Avoidance	0.75
							I tell my partner just about everything	ECR Avoidance	0.83
							I talk things over with my partner	ECR Avoidance	0.74
							I am nervous when partners get too close to me	ECR Avoidance	0.60
							I feel comfortable depending on romantic partners	ECR Avoidance	0.45
							I find it easy to depend on romantic partners	ECR Avoidance	0.60

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
Anxiousness	.88	.90	2.74	0.71	Refers to stress and concerns about life events.		It's easy for me to be affectionate with my partner	ECR Avoidance	0.78
							My partner really understands me and my needs	ECR Avoidance	0.75
							I experienced trembling (eg, in the hands)	Depression Anxiety Stress Scale	0.40
							I was worried about situations in which I might panic and make a fool of myself	Depression Anxiety Stress Scale	0.43
							I felt I was close to panic	Depression Anxiety Stress Scale	0.55
							I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat	Depression Anxiety Stress Scale	0.42
							I felt scared without any good reason	Depression Anxiety Stress Scale	0.62
							Remain calm under pressure	IPIP-NEO Neuroticism	0.38
							Worry about things	IPIP-NEO Neuroticism	0.31
							Fear for the worst	IPIP-NEO Neuroticism	0.35
							Am afraid of many things	IPIP-NEO Neuroticism	0.48

(continued)

Created variables	alpha	Omega	M	SD	Description	Notes	Items	Original item scale	Factor loading
Wellbeing	.94	.95	3.11	0.64	Refers to to happiness, serenity, and achievement.		Get stressed out easily	IPIP-NEO Neuroticism	0.51
							Panic easily	IPIP-NEO Neuroticism	0.53
							Become overwhelmed by events	IPIP-NEO Neuroticism	0.33
							I feel pressured to keep my worst fears from coming	Repetitive Thinking Mode Questionnaire	0.39
							I found it hard to wind down	Depression Anxiety Stress Scale	-0.61
							I couldn't seem to experience any positive feeling at all	Depression Anxiety Stress Scale	-0.39
							I felt that I had nothing to look forward to	Depression Anxiety Stress Scale	-0.43
							I found it difficult to relax	Depression Anxiety Stress Scale	-0.61
							I felt down-hearted and blue	Depression Anxiety Stress Scale	-0.48
							I was unable to become enthusiastic about anything	Depression Anxiety Stress Scale	-0.41
							Often feel blue	IPIP-NEO Neuroticism	-0.37
							Am often down in the dumps	IPIP-NEO Neuroticism	-0.36

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							In the last month, how often have you been upset because of something that happened unexpectedly?	Self-reported Stress	0.52
							In the last month, how often have you felt that you were unable to control the important things in your life?	Self-reported Stress	0.38
							In the last month, how often have you felt that you were effectively coping with important changes that were occurring in your life?	Self-reported Stress	0.33
							In the last month, how often have you felt that things were going your way?	Self-reported Stress	0.58
							In the last month, how often have you found that you could not cope with all the things that you had to do?	Self-reported Stress	0.48
							In the last month, how often have you felt that you were on top of things?	Self-reported Stress	0.38
							In the last month, how often have you been angered because of things that happened that were outside of your control?	Self-reported Stress	0.50

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							In the last month, how often have you been able to control the way you spend your time?	Self-reported Stress	0.46
							In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?	Self-reported Stress	0.55
							I've been feeling optimistic about the future	Warwick-Edinburgh Mental Well-Being Scale	0.55
							I've been feeling relaxed	Warwick-Edinburgh Mental Well-Being Scale	0.62
							I've had energy to spare	Warwick-Edinburgh Mental Well-Being Scale	0.38
							I've been thinking clearly	Warwick-Edinburgh Mental Well-Being Scale	0.50
							I've been feeling loved	Warwick-Edinburgh Mental Well-Being Scale	0.35
							I've been interested in new things	Warwick-Edinburgh Mental Well-Being Scale	0.31

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							I've been feeling cheerful	Warwick-Edinburgh Mental Well-Being Scale	0.58
Self-esteem	.94	.95	2.47	0.66	Refers to self-esteem and positive opinions about the self.		I felt I wasn't worth much as a person	Depression Anxiety Stress Scale	0.44
							Think highly of myself	IPIP-NEO Agreeableness	-0.63
							Have a high opinion of myself	IPIP-NEO Agreeableness	-0.75
							Feel comfortable with myself	IPIP-NEO Neuroticism	0.61
							Dislike myself	IPIP-NEO Neuroticism	0.62
							I judge myself negatively	Repetitive Thinking Mode Questionnaire	-0.62
							I feel that I'm a person of worth, at least on an equal plane with others	Rosenberg Self-Esteem	0.59
							I feel that I have a number of good qualities	Rosenberg Self-Esteem	0.53
							All in all, I am inclined to feel that I am a failure	Rosenberg Self-Esteem	0.54
							I am able to do things as well as most other people	Rosenberg Self-Esteem	0.42
							I feel I do not have much to be proud of	Rosenberg Self-Esteem	0.62

(continued)

Created variables	alpha	Omega	M	SD	Description	Notes	Items	Original item scale	Factor loading
							I take a positive attitude toward myself	Rosenberg Self-Esteem	0.74
							On the whole, I am satisfied with myself	Rosenberg Self-Esteem	0.57
							I wish I could have more respect for myself	Rosenberg Self-Esteem	0.40
							I certainly feel useless at times	Rosenberg Self-Esteem	0.46
							At times I think I am no good at all	Rosenberg Self-Esteem	0.48
							I've been feeling useful	Warwick-Edinburgh Mental Well-Being Scale	-0.33
							I've been feeling good about myself	Warwick-Edinburgh Mental Well-Being Scale	-0.59
							Often forget to put things back in their proper place	IPIP-NEO Conscientiousness	0.51
							Leave a mess in my room	IPIP-NEO Conscientiousness	0.61
							Leave my belongings around	IPIP-NEO Conscientiousness	0.62
Self-discipline	.87	.90	3.16	0.71	Refers to self-discipline in getting the work or everyday tasks done.		Put little time and effort into my work	IPIP-NEO Conscientiousness	0.32
							Waste my time	IPIP-NEO Conscientiousness	0.37

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							Have difficulty starting tasks	IPIP-NEO Conscientiousness	0.58
							Like to tidy up	IPIP-NEO Conscientiousness	0.49
							Work hard	IPIP-NEO Conscientiousness	0.37
							Am always prepared	IPIP-NEO Conscientiousness	0.35
							Am always busy	IPIP-NEO Extraversion	0.40
							Am always on the go	IPIP-NEO Extraversion	0.31
							I have a hard time breaking bad habits	Self-control	-0.40
							I am lazy	Self-control	-0.63
							I wish I had more self-discipline	Self-control	-0.47
							People would say that I have iron self- discipline	Self-control	-0.39
							Pleasure and fun sometimes keep me from getting work done	Self-control	-0.45

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
Loneliness "Modified"	.92	.93	3.10	0.57	Refers to feelings of loneliness and distance with others.	It differs from the original scale Loneliness in that we dropped two items and that we added one item from the Warwick-Edinburgh Mental Well-Being Scale.	I feel in tune with the people around me	UCLA Loneliness	0.44
							I lack companionship	UCLA Loneliness	0.44
							There is no one I can turn to	UCLA Loneliness	0.37
							I do not feel alone	UCLA Loneliness	0.42
							I feel part of a group of friends	UCLA Loneliness	0.55
							I have a lot in common with the people around me	UCLA Loneliness	0.59
							I am no longer close to anyone	UCLA Loneliness	0.59
							My interests and ideas are not shared by those around me	UCLA Loneliness	0.46
							There are people I feel close to	UCLA Loneliness	0.62
							I feel left out	UCLA Loneliness	0.39
							My social relationships are superficial	UCLA Loneliness	0.52
							No one really knows me well	UCLA Loneliness	0.35
							I feel isolated from others	UCLA Loneliness	0.44
							I can find companionship when I want it	UCLA Loneliness	0.37
							There are people who really understand me	UCLA Loneliness	0.56

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							People are around me but not with me	UCLA Loneliness	0.57
							There are people I can talk to	UCLA Loneliness	0.44
							There are people I can turn to	UCLA Loneliness	0.48
							I've been feeling close to other people	Warwick-Edinburgh Mental Well-Being Scale	0.41
Social dominance orientation "Modified"	.88	.91	5.79	0.85	Refers to positive attitudes toward the domination of a group over the others.	It differs from the original scale Social Dominance Orientation in that we dropped five items.	It's probably a good thing that certain groups are at the top and other groups are at the bottom	Social Dominance Orientation	0.46
							Inferior groups should stay in their place	Social Dominance Orientation	0.41
							No one group should dominate in society	Social Dominance Orientation	0.58
							Increased social equality	Social Dominance Orientation	0.69
							It would be good if all groups could be equal	Social Dominance Orientation	0.77
							We should do what we can to equalize conditions for different groups	Social Dominance Orientation	0.67
							We would have fewer problems if we treated different groups more equally	Social Dominance Orientation	0.70

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							Group equality should be our ideal	Social Dominance Orientation	0.69
							All groups should be given an equal chance in life	Social Dominance Orientation	0.53
							We should strive to make incomes more equal	Social Dominance Orientation	0.51
							It's OK if some groups have more of a chance in life than others	Social Dominance Orientation	0.36
Right prejudice	.91	.93	3.01	0.93	Refers to prejudice toward minorities and preferences for the right-wing parties.		Tend to vote for liberal political candidates	IPIP-NEO Openness	-0.31
							Tend to vote for conservative political candidates	IPIP-NEO Openness	-0.38
							Believe that we should be tough on crime	IPIP-NEO Openness	-0.32
							One can easily understand the anger felt by North Africans in France	Prejudice towards North Africans	0.46
							The French should be a priority when it comes to housing	Prejudice towards North Africans	0.78
							Foreigners living in France should have the right to vote	Prejudice towards North Africans	0.42
							It is normal for illegal aliens to be returned to their country of origin	Prejudice towards North Africans	0.56
							The diversity brought by foreigners is an enrichment for the country	Prejudice towards North Africans	0.54

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							The French should be given priority in terms of increasing social benefits	Prejudice towards North Africans	0.73
							The wearing of the Tchador in schools should be allowed	Prejudice towards North Africans	0.37
							The French should be a priority in terms of employment	Prejudice towards North Africans	0.73
							It makes no sense to blame Algerians and Moroccans for France's economic problems	Prejudice towards North Africans	0.33
							The entry of foreign families into France should be more strictly limited	Prejudice towards North Africans	0.64
							I consider society to be unfair to the Arabs	Prejudice towards North Africans	0.46
							If there is a lot of unemployment in France, it's because foreigners are taking jobs from the French	Prejudice towards North Africans	0.49
							More rights should be given to immigrants	Prejudice towards North Africans	0.58
							French citizenship should not be granted so easily	Prejudice towards North Africans	0.61
							I wouldn't be worried if most of my friends at university were of Arab origin	Prejudice towards North Africans	0.33
							If certain groups of people stayed in their place, we would have fewer problems	Social Dominance Orientation	-0.31

(continued)

Created variables	alpha	Omega	M	SD	Description	Notes	Items	Original item scale	Factor loading
							There are many radical, immoral people in our country today, who are trying to ruin it for their own godless purposes, whom the authorities should put out of action	Right Wing Authoritarianism	0.33
Impulsiveness	.85	.89	3.53	0.70	Refers to impulsiveness in behaviors and in decision making.		Break rules	IPIP-NEO Conscientiousness	-0.33
							Jump into things without thinking	IPIP-NEO Conscientiousness	-0.63
							Make rash decisions	IPIP-NEO Conscientiousness	-0.69
							Rush into things	IPIP-NEO Conscientiousness	-0.55
							Act without thinking	IPIP-NEO Conscientiousness	-0.68
							Act wild and crazy	IPIP-NEO Extraversion	0.34
							Yell at people	IPIP-NEO Agreeableness	-0.33
							Insult people	IPIP-NEO Agreeableness	-0.32
							Get angry easily	IPIP-NEO Neuroticism	0.38
							Lose my temper	IPIP-NEO Neuroticism	0.45

(continued)

Created variables	alpha	Omega	M	SD	Description	Notes	Items	Original item scale	Factor loading
Reflection	.88	.91	3.09	0.65	Refers to creativity and absorbtion in thoughts.		Go on binges	IPIP-NEO Neuroticism	0.39
							Sometimes I can't stop myself from doing something, even if I know it is wrong	Self-control	0.31
							I often act without thinking through all the alternatives	Self-control	0.65
							I have a vivid imagination	IPIP-NEO Openness	0.52
							Enjoy wild flights of fancy	IPIP-NEO Openness	0.67
							Love to daydream	IPIP-NEO Openness	0.60
							Like to get lost in thought	IPIP-NEO Openness	0.64
							I like to follow the spontaneous flow of my thoughts	Repetitive Thinking Mode Questionnaire	0.63
							I have all kinds of new and original thoughts	Repetitive Thinking Mode Questionnaire	0.64
							I let my ideas wander, curious where they might lead me	Repetitive Thinking Mode Questionnaire	0.67
							My mind freely produces all kinds of new ideas	Repetitive Thinking Mode Questionnaire	0.59
							My mind keeps going from one idea to another	Repetitive Thinking Mode Questionnaire	0.54
							I very quickly get impressions and hunches of what's going on	Repetitive Thinking Mode Questionnaire	0.34

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
Trust	.75	.84	2.87	0.80	Refers to trust in others.		All sorts of new thoughts spontaneously cross my mind	Repetitive Thinking Mode Questionnaire	0.60
							Keep others at a distance	IPIP-NEO Extraversion	0.34
							Distrust people	IPIP-NEO Agreeableness	0.52
							Trust others	IPIP-NEO Agreeableness	0.56
							Believe that others have good intentions	IPIP-NEO Agreeableness	0.54
							Trust what people say	IPIP-NEO Agreeableness	0.59
							I'm worried about what other people might think of me	Repetitive Thinking Mode Questionnaire	0.31
							Am attached to conventional ways	IPIP-NEO Openness	-0.48
							Our country desperately needs a mighty leader who will do what has to be done to destroy the radical new ways and sinfulness that are ruining us	Right Wing Authoritarianism	0.51
Right Wing Authoritarianism "Modified"	.88	.90	2.39	0.86	Refers to attachment to traditional values and desires for a powerful figure of authority.	It differs from the original scale Right Wing Authoritarianism in that we added one item from the scale Big Five Openness and that we dropped five items.			

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							Gays and lesbians are just as healthy and moral as anybody else	Right Wing Authoritarianism	0.60
							It is always better to trust the judgement of the proper authorities in government and religion than to listen to the noisy rabble-rousers in our society who are trying to create doubt in people's minds	Right Wing Authoritarianism	0.38
							Atheists and others who have rebelled against the established religions are no doubt every bit as good and virtuous as those who attend church regularly	Right Wing Authoritarianism	0.33
							The only way our country can get through the crisis ahead is to get back to our traditional values, put some tough leaders in power, and silence the troublemakers spreading bad ideas	Right Wing Authoritarianism	0.53
							There is absolutely nothing wrong with nudist camps	Right Wing Authoritarianism	0.56
							Our country needs free thinkers who have the courage to defy traditional ways, even if this upsets many people	Right Wing Authoritarianism	0.34

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							Our country will be destroyed someday if we do not smash the perversions eating away at our moral fiber and traditional beliefs	Right Wing Authoritarianism	0.58
							The "old-fashioned ways" and the "old-fashioned values" still show the best way to live	Right Wing Authoritarianism	0.51
							You have to admire those who challenged the law and the majority's view by protesting for women's abortion rights, for animal rights, or to abolish school prayer	Right Wing Authoritarianism	0.34
							What our country really needs is a strong, determined leader who will crush evil, and take us back to our true path	Right Wing Authoritarianism	0.52
							Gods laws about abortion, pornography and marriage must be strictly followed before it istoo late, violations must be punished	Right Wing Authoritarianism	0.68
							Our country will be great if we honor the ways of our forefathers, do what the authorities tell us to do, and get rid of the "rotten apples" who are ruining everything	Right Wing Authoritarianism	0.58

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							Homosexuals and feminists should be praised for being brave enough to defy "traditional family values"	Right Wing Authoritarianism	0.42
							This country would work a lot better if certain groups of troublemakers would just shut up and accept their group's traditional place in society	Right Wing Authoritarianism	0.43
Stimulation	.73	.79	3.77	0.73	Refers to preferences for intellectual and artistic stimulations.		Believe in the importance of art	IPIP-NEO Openness	0.43
							See beauty in things that others might not notice	IPIP-NEO Openness	0.34
							Avoid philosophical discussions	IPIP-NEO Openness	0.34
							Do not like poetry	IPIP-NEO Openness	0.39
							Do not enjoy going to art museums	IPIP-NEO Openness	0.38
Sociability	.88	.91	3.10	0.86	Refers to sociability and comfort with others.		I am an outgoing person	UCLA loneliness	0.59
							Avoid contacts with others	IPIP-NEO Extraversion	0.68
							Avoid crowds	IPIP-NEO Extraversion	0.49
							Make friends easily	IPIP-NEO Extraversion	0.63

(continued)

Created variables	alpha	Omega	M	SD	Description	Notes	Items	Original item scale	Factor loading
							Feel comfortable around other people	IPIP-NEO Extraversion	0.59
							Love large parties	IPIP-NEO Extraversion	0.36
							Talk to a lot of different people at parties	IPIP-NEO Extraversion	0.73
							Find it difficult to approach others	IPIP-NEO Extraversion	-0.70
							Am afraid to draw attention to myself	IPIP-NEO Neuroticism	-0.38
							Only feel comfortable with friends	IPIP-NEO Neuroticism	-0.43
							Complete tasks successfully	IPIP-NEO Conscientiousness	0.52
							Excel in what I do	IPIP-NEO Conscientiousness	0.33
							Handle tasks smoothly	IPIP-NEO Conscientiousness	0.44
							Know how to get things done	IPIP-NEO Conscientiousness	0.44
Leadership	.87	.90	3.25	0.65	Refers to the propensity to be successful, to take things in charge, and to direct people.		Do more than what's expected of me	IPIP-NEO Conscientiousness	0.35
							Carry out my plans	IPIP-NEO Conscientiousness	0.47

Created
variables

Created variables	alpha	Omega	M	SD	Description	Notes	Items	Original item scale	Factor loading
							Take charge	IPIP-NEO Extraversion	0.62
							Try to lead others	IPIP-NEO Extraversion	0.55
							Take control of things	IPIP-NEO Extraversion	0.60
							Wait for others to lead the way	IPIP-NEO Extraversion	0.30
							Feel that I'm unable to deal with things	IPIP-NEO Neuroticism	-0.38
							I am able to work effectively toward long-term goals	Self-control	-0.44
Empathy	.85	.88	4.40	0.58	Refers to to consideration about others' feeling and wellbeing.		Experience my emotions intensely	IPIP-NEO Openness	0.36
							Feel others' emotions	IPIP-NEO Openness	0.45
							Don't understand people who get emotional	IPIP-NEO Openness	0.54
							Use others for my own ends	IPIP-NEO Agreeableness	0.52
							Cheat to get ahead	IPIP-NEO Agreeableness	0.40
							Take advantage of others	IPIP-NEO Agreeableness	0.36

(continued)

Created variables	alpha	Omega	<i>M</i>	<i>SD</i>	Description	Notes	Items	Original item scale	Factor loading
							Am indifferent to the feelings of others	IPIP-NEO Agreeableness	0.65
							Take no time for others	IPIP-NEO Agreeableness	0.43
							Believe that I am better than others	IPIP-NEO Agreeableness	0.49
							Am not interested in other people's problems	IPIP-NEO Agreeableness	0.43
							Love to help others	IPIP-NEO Agreeableness	0.54
							Am concerned about others	IPIP-NEO Agreeableness	0.60
							Sympathize with the homeless	IPIP-NEO Agreeableness	0.34
							To get ahead in life, it is sometimes necessary to step on other groups	Social Dominance Orientation	0.39
							Some groups of people are just more worthy than others	Social Dominance Orientation	0.32

¹ alpha are Cronbach's Alpha.

² Omega are McDonald's omega total.

1144 **Appendix 3: Table 10. Differences in items part of the personality factors**
1145 **Anxiousness and Loneliness ‘Modified’ when comparing Study 1 and 2.**

Study 1			Study 2	
Personality factor	Items	Original item scale	Missing items	Original item scale
Anxiousness	I experienced trembling (eg, in the hands)	Depression Anxiety Stress Scale	I experienced trembling (eg, in the hands)	Depression Anxiety Stress Scale
	I was worried about situations in which I might panic and make a fool of myself	Depression Anxiety Stress Scale	I was worried about situations in which I might panic and make a fool of myself	Depression Anxiety Stress Scale
	I felt I was close to panic	Depression Anxiety Stress Scale	I felt I was close to panic	Depression Anxiety Stress Scale
	I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)	Depression Anxiety Stress Scale	I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)	Depression Anxiety Stress Scale
	I felt scared without any good reason	Depression Anxiety Stress Scale	I felt scared without any good reason	Depression Anxiety Stress Scale
	Remain calm under pressure	IPIP-NEO Neuroticism		
	Worry about things	IPIP-NEO Neuroticism		
	Fear for the worst	IPIP-NEO Neuroticism		
	Am afraid of many things	IPIP-NEO Neuroticism		
	Get stressed out easily	IPIP-NEO Neuroticism		
	Panic easily	IPIP-NEO Neuroticism		
	Become overwhelmed by events	IPIP-NEO Neuroticism		
	I feel pressured to keep my worst fears from coming	Repetitive Thinking Mode Questionnaire		
	I feel in tune with the people around me	UCLA Loneliness	I've been feeling close to other people	Warwick-Edinburgh Mental Well-Being Scale
	I lack companionship	UCLA Loneliness		
Loneliness "Modified"	There is no one I can turn to	UCLA Loneliness		
	I do not feel alone	UCLA Loneliness		
	I feel part of a group of friends	UCLA Loneliness		

(continued)

Personality factor	Items	Original item scale	Missing items	Original item scale
	I have a lot in common with the people around me	UCLA Loneliness		
	I am no longer close to anyone	UCLA Loneliness		
	My interests and ideas are not shared by those around me	UCLA Loneliness		
	There are people I feel close to	UCLA Loneliness		
	I feel left out	UCLA Loneliness		
	My social relationships are superficial	UCLA Loneliness		
	No one really knows me well	UCLA Loneliness		
	I feel isolated from others	UCLA Loneliness		
	I can find companionship when I want it	UCLA Loneliness		
	There are people who really understand me	UCLA Loneliness		
	People are around me but not with me	UCLA Loneliness		
	There are people I can talk to	UCLA Loneliness		
	There are people I can turn to	UCLA Loneliness		
	I've been feeling close to other people	Warwick-Edinburgh Mental Well-Being Scale		