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ORIGINAL RESEARCH ARTICLE

Socio-cultural norms of body size in Westerners and Polynesians affect heart rate variability and emotion during social interactions

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Abstract

The perception of body size and thus weight-related stigmatization vary between cultures. Both are stronger in Western than in Polynesian societies. Negative emotional experiences alter one's behavioral, psychological, and physiological reactions in social interactions. This study compared affective and autonomic nervous system responses to social interactions in Germany and American Samoa, two societies with different body-size related norms. German (n = 55) and Samoan (n = 56) volunteers with and without obesity participated in a virtual ball-tossing game that comprised episodes of social inclusion and social exclusion. During the experiment, heart rate was measured and parasympathetic activity (i.e., high-frequency heart rate variability) was analyzed. We found differences in both emotional experience and autonomic cardio-regulation between the two cultures: during social inclusion, Germans but not Samoans showed increased parasympathetic activity. In Germans with obesity, this increase was related to a more negative body image (comprising high rates of weight-related teasing). During social exclusion, Samoans showed parasympathetic withdrawal regardless of obesity status, while Germans with obesity showed a stronger increase in parasympathetic activity than lean Germans. Furthermore, we found fewer obesity-related differences in emotional arousal after social exclusion in Samoans as compared to Germans. Investigating the interplay of socio-cultural, psychological, and biological aspects, our results suggest influences of body size-related socio-cultural norms on parasympathetic cardio-regulation and negative emotions during social interactions.

Keywords Emotion · Culture · Obesity · Social cognition · Samoa · Parasympathetic activity · Body image · Social exclusion

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Extended author information available on the last page of the article

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Introduction

Culture and idealized bodies

Human bodies and their shapes, sizes, and variations are significantly embodied in social relations. They are both reflection and construction of a society's beliefs and norms. Hence, they create identity and either affiliation to or dissociation from a social group (McCullough 2013; Waskul and van der Riet 2002). Regarding body size, ethnographic research demonstrates a huge variability of body norms and body perception in different cultures, ranging from idealization to stigmatization of higher body weight (Brown and Konner 1987; Treloar et al. 1999).

In today's Western societies, the idealized body is slender. In addition, being obese is often accompanied by weight-related stigmatization and social exclusion. Individuals with excess weight—especially women (Puhl et al. 2007)—are facing disadvantages in professional contexts such as on the labour market (Puhl and Brownell 2001) but also in private areas, for example in the form of teasing in significant interpersonal relationships (Puhl et al. 2008).

In other societies, excess body weight does not always have the same negative social consequences as in Western societies. Although an idealization of slim bodies has been increasingly reported worldwide (Becker 2004; Brewis et al. 2011; Swami et al. 2010), there is still considerable variation between cultural groups (Anderson-Fye 2012; Furnham et al. 2002; Gupta et al. 2001; Kronenfeld et al. 2010; Swami et al. 2013). A parallel development has been reported for weight-related stigmatization: prejudice towards individuals with excess body weight is spreading worldwide, even in cultures that were conventionally understood to show no to little weight-related stigmatization (Brewis et al. 2011). Nevertheless, the extent of prejudice still varies between cultural groups (Brewis and Wutich 2014; Hebl et al. 2009; Pepper and Ruiz 2007; Puhl et al. 2015).

Polynesian societies are particularly known to value bigger bodies. Traditionally, Pacific Islanders relate individual plumpness to the well-being of the community and, especially in women, to fertility (Pollock 1995). Although morbid obesity was not valued per se, excess weight was traditionally more likely to be associated with a certain rank or status within the society and represented authority or power (Mavoa and McCabe 2008; Pollock 2001). Nowadays, an idealization of slim body sizes has been observed in the overall population of Polynesian societies (also on the Samoan islands; Brewis et al. 1998; Swami et al. 2007; Wilkinson et al. 1994). Nevertheless, this idealization is generally less pronounced in Pacific Islanders than in Westerners (Brewis and McGarvey 2000; Craig et al. 1999; Metcalf et al. 2000; Wilkinson et al. 1994). Further, an increased idealization of slim body sizes might not be accompanied by increased stigmatization in Samoa. Research suggests that Samoans do not view individuals with obesity as negatively as Westerners do (Brewis et al. 1998). Hardin (2015) described in her study in Samoa an ambivalent interpretation of body fat, which is dependent on the person's relations and behavior. On the one hand, oversized bodies identify ranked positions, are a visible display of the quality of interpersonal relationships, and represent generosity, caregiving, and reciprocity (Becker 1995; Hardin 2015; Pollock 2001). On the other hand, wealth accumulation, greed, or sickness can similarly be embodied in large body sizes—as signs of unethical behavior and violation of the society's interests (Hardin 2015). In the context of health care, obesity is widely accepted as a major concern for public health in Samoa (McGarvey 2009). In summary, (1) size and shape of human bodies play an important role in social relations, but (2) bigger bodies are not stigmatized per se in every culture—despite a spreading slim ideal worldwide. Individuals with obesity in different cultures might therefore be affected differently in social interactions—on emotional and psychophysiological levels.

The impact of stigma on emotionality and physiology

To understand the impact of weight-related stigmatization on individuals with obesity, the literature was reviewed for general effects of social exclusion: Stigmatization, exclusion, and rejection have effects on emotionality and behavior in social situations and impact the target's well-being by increasing emotional distress, depressive symptoms, and risks for psychopathology (e.g., eating disorders; Baumeister and Leary 1995). Indeed, experimentally induced social exclusion in Western participants was associated with negative affect (Blackhart et al. 2009). Further, individuals with recurrent negative social experiences anticipate potentially stigmatizing situations in future social interactions (Swim et al. 1998) and show an increased attention to signs of prejudice (Kaiser et al. 2006; Tanaka and Ikegami 2015). This adaptive behavior allows the target of prejudice to apply coping strategies—such as avoidance or disengagement—that reduce the negative impact on psychological well-being (Barreto and Ellemers 2015).

Social exclusion is associated not only with behavioral and affective, but also with autonomic alterations. Studies analyzing heart rate (HR) and HR variability (HRV) linked socio-emotional processes to activity of the autonomic—particularly the parasympathetic (PNS)—nervous system: The "polyvagal theory" relates PNS or vagal activation (measurable as increased HRV) to emotional and particularly social processing or behavior (Porges 2003, 2007). In this view, vagal withdrawal supports the mobilization of fight-or-flight behavior, whereas increased vagal influence supports emotion regulation, attention, and (spontaneous) social engagement behaviors (Porges 2003, 2007). The "neurovisceral integration model" associates increased HRV with physiological and behavioral flexibility to changing environmental demands (Thayer and Lane 2000, 2009). It thereby connects psychological phenomena like affect and attention (also in the shape of emotion regulation) to the nervous systems (Thayer and Lane 2000, 2009). Studies support these models by associating heightened PNS activity with attention to motivationally relevant stimuli like threatening animals (Jönsson and Hansson-Sandsten 2008), angry facial expressions (Jönsson and Sonnby-Borgström 2003), receiving negative as compared to positive social feedback (Vanderhasselt et al. 2015), or watching other people suffer (Stellar et al. 2015). Associations between heightened PNS activity and effortful emotion regulation have also been found: participants reappraising or suppressing their emotions during social interactions showed higher PNS activity than uninstructed participants (Butler et al. 2006). Other studies report increased PNS activity relative to baseline during emotion suppression while watching a negative but not while watching a positive film clip (Musser et al. 2011) and a general association between increased HRV and better self-regulation (Holzman and Bridgett 2017). During negative social interactions and rejection, PNS activity has been reported to decrease (Iffland et al. 2014; Murray-Close 2011; Shahrestani et al. 2015) but also to increase (Gunther Moor et al. 2014; Gunther Moor et al. 2010; Papousek et al. 2014). These divergent results provide first evidence for alterations in autonomic activity during negative social feedback but require further investigation.

To our knowledge, there has been little psychophysiological research on how individuals with obesity and stigmatizing experiences respond to social situations. The two existing studies are from our own lab: We found that women with obesity compared to lean women showed slower response times during the anticipation of social compared to monetary feedback. This differential response was more pronounced in women with obesity with higher body mass index (BMI) and more intense weight-related teasing experiences (Kube et al. 2016). Further, we showed that German women with obesity responded with a stronger increase in PNS activity during a social interaction episode than lean participants. This increase in PNS activity in the group with obesity but not in the lean group was positively associated with negative body image. Additionally, women with obesity reported a stronger decrease in mood after social exclusion than other participants (Schrimpf et al. 2017). Other studies found that participants with higher BMI perceive themselves as less socially included than participants with lower BMI (Hartung and Renner 2013) and women with a negative body image perceived social feedback regarding their own body portrait as more negative in comparison with another woman's body portrait, even though the feedback was equal (Alleva et al. 2014). In conclusion, there is first evidence that negative social experiences in general—and weight-related stigmatization in particular—affect emotionality and autonomic activity during social situations. However, these studies did not consider culture or varying cultural norms.

Cultural differences in emotional and physiological responses

To date, research comparing emotional or physiological responses to social-cognitive tasks in different human populations is scarce and research comparing body-size related socio-emotional experiences in different cultural environments is nonexistent. At the same time, the few existing studies suggest that populations differ considerably in their behavior during experimental tasks (see for review: Henrich et al. 2010). Further, a line of research showed that, on a continuum, collectivistic (personal goals overlap with goals of the in-group, e.g. family) and individualistic (personal goals might be independent of in-group goals) self-concepts vary between cultural groups and influence social experiences (Markus and Kitayama 1991; Triandis 1989). Individuals from individualistic backgrounds spend equal time with in-group and out-group members and belong to more groups, whereas individuals from collectivistic backgrounds spend more time with in-group members and differentiate more strongly between in-group and out-group members (see meta-analysis by Oyserman et al. 2002). Lower individualism was also related to higher levels of conformity during social interactions (Bond and Smith 1996). Emotional responses to social interactions are also influenced by culture: empirical results support the hypothesis that more individualistic groups are more strongly affected by social exclusion than more collectivistic groups as their social ties might differ in their reliability. That is, members of a more interdependent group can rely more strongly on social networks (Markus and Kitayama 1991; Over and Uskul 2016; Pfundmair et al. 2015). For instance, farmers children (a more interdependent group) rated social exclusion as less painful than herders children (a more independent group) in Turkey (Over and Uskul 2016) and German participants (a more independent group) showed lower fulfillment of basic social needs after social exclusion than Turkish, Chinese, or Indian participants (more interdependent groups; Pfundmair et al. 2015).

Dissecting the more biological, interculturally relatively stable components of emotional responses and the aspects that are modified by culture is difficult (Barrett 2012; Gerber 1985; Lindquist et al. 2013; Scherer and Wallbott 1994). According to a recent "biopsychosocial framework" (Immordino-Yang and Yang 2017), socio-emotional experience and its psychophysiological components depend on culturally constructed norms of emotional behavior and emotion expression. In particular, the model mentions culture-specific expectations about appropriate behavior (Immordino-Yang et al. 2016; Mesquita et al. 2016; Mesquita and Frijda 1992) and verbal descriptions and definitions of emotions (Crivelli et al. 2016; Gerber 1985; Saxbe et al. 2012). Thus, varying cultural demands and contexts can result in different interpretations of emotions as well as in different physiological responses during emotional arousal.

The present study

Although HRV has been associated with social and emotional processing and socio-emotional phenomena are influenced by culture (Barrett 2012; Immordino-Yang and Yang 2017), cultural aspects are not explicitly part of either of the prominent theories of HRV (see above and Porges 2003, 2007; Thayer and Lane 2000, 2009). Furthermore, most HRV studies have been conducted with Western participants and the association between culture and HRV is rarely investigated (but cf. Immordino-Yang and Yang 2017). Cross-cultural research using HRV in individuals with obesity and potentially differing body ideals is nonexistent. By investigating socio-emotional experience and parasympathetic cardioregulation during social interactions in different cultures, we aimed to contribute to a more comprehensive understanding of the psychophysiology of HRV and of emotion in general. The present study was carried out in Germany, an individualistic society, and American Samoa, a collectivistic society. We investigated (1) general differences in emotional and physiological responses to social situations between a Western and a Polynesian population, and (2) how socio-cultural norms regarding body size influence the psychophysiological processing of social interactions in individuals with and without obesity. We used a virtual ball-tossing game ("Cyberball" by Williams et al. 2000) to induce standardized episodes of social inclusion and exclusion. With regard to general location differences (1), we hypothesized—in accordance with the "biopsychosocial framework" (Immordino-Yang and Yang 2017) and with studies showing differences in emotional responses to social exclusion between individualistic and collectivistic societies (Over and Uskul 2016; Pfundmair et al. 2015)—an effect of location on affective and PNS responses to social interactions. With regard to body size-related socio-cultural norms (2), we expected to find a comparable ideal in slim body sizes as has been shown in previous studies (Brewis et al. 2011; Swami et al. 2010). However, as the Samoan society does not entertain the same negative attitudes towards individuals with excess body weight as Western societies (Brewis et al. 2011), we expected to find less weight-related teasing experiences and body dissatisfaction in the former than in the latter. We also expected the Samoan sample to show fewer obesity-related differences in affective and PNS responses during social inclusion and exclusion—due to a more ambiguous interpretation of body sizes (Hardin 2015)—than we found in the German sample (Schrimpf et al. 2017). We also expected in Germans with obesity and with a potential history of weight-related negative social experiences psychophysiological alterations in the social inclusion session due to a potential enhanced sensitivity to social cues even in neutral social situations (Barreto and Ellemers 2015; Kaiser et al. 2006; Swim et al. 1998; Tanaka and Ikegami 2015). As these previous results from Germany were more pronounced in women with obesity, we hypothesized interactions with sex in affective and PNS responses during social interactions. Lastly, we examined potential influencing factors such as negative body image and/or interpersonal stress, which we anticipated to alter emotional and psychophysiological responses to social interactions.

Methods

Participants

Two sets of data were collected in Germany (from 12/2012 to 03/2014) and American Samoa (from 09/2015 to 12/2015). The German sample has been described in more detail in Schrimpf et al. (2017). German participants were recruited from the database of the Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany and pre-selected by weight status. A total of 112 healthy individuals, matched for educational background and age, were included in the study. Participants were required to be between 18 and 35 years of age and have BMIs $\geq$ 30.0 kg/m^2 for obese, or between 18.5 and 24.9 kg/m^2 for lean participants. Exclusion criteria were a self-reported history of neurological and psychiatric disorders, smoking, and regular substance or medication use. In the previous study (Schrimpf et al. 2017), half of the 112 participants first completed the social inclusion and then the social exclusion session while the experiment for the other half of participants consisted of two social inclusion sessions. As we were particularly interested in social exclusion, we adapted the experiment for American Samoa. There, all participants first completed the social inclusion and then the social exclusion session (more details of the procedure below). To ensure comparability between the two data sets, we only included German participants that underwent the same procedure as in American Samoa. Thus, 55 German participants entered the analyses (14 lean women, 14 women with obesity, 13 lean men and 14 men with obesity).

As the recruited participants in Germany were mostly University students, we recruited a comparable sample—young, educated adults—in American Samoa. The American Samoa Community College is the only institution on the island for higher education, which is why study participants were randomly recruited at the campus area by (1) availability and (2) by a pre-weight screening. A total of 60 healthy individuals, matched for educational background and age, participated in this study. Inclusion criteria were similar to the ones in Germany (i.e., participants should be between 18 and 35 years of age). Additionally, participants were required to be fluent in English. BMI criteria were adjusted to a recommended cut-off for Polynesian populations as Pacific Islander's body composition consists of a higher percentage of muscle mass and thus differs from Europeans with an equivalent BMI (Rush et al. 2009): BMI $\geq$ 32.0 kg/m^2 for participants with obesity and BMI between 18.5 and 27.9 kg/m^2 for lean participants. Exclusion criteria were the same as in the German sample. Four individuals were excluded because of a BMI between 28.0 and 31.9 kg/m^2, so that 56 participants were included in the analyses: 13 lean women, 15 women with obesity, 12 lean men and 16 men with obesity (detailed sample characteristics for both data sets in Table 1).

All participants gave written informed consent and received a monetary reimbursement for their participation. The study was carried out in accordance with the Declaration of Helsinki and was approved by the research ethics committees of the Leipzig University and the American Samoa Department of Health, respectively.

Procedure

All participants completed questionnaires assessing demographic information, body image, stress, depressive symptoms, and rejection sensitivity. Body weight, body height, as well as waist and hip circumference were measured and a full-body picture was taken of each participant. Participants then completed the Cyberball paradigm, a virtual ball-tossing game to induce a standardized social interaction experience (Williams et al. 2000). They were instructed by the experimenter that two other invited participants were sitting in nearby rooms (in Germany) or online (in American Samoa) and would play a ball game with the participant. In reality, the two confederates were computer-generated. All players were represented on the computer screen by avatars and a full-body picture. The participant's avatar and picture were located at the bottom center (Fig. 1). The two confederates had the same sex as the participant. To induce a potentially stigmatizing situation, the pictures of the computer-generated players were in a lean body shape. Photographs of the two female and male lean players were taken of coworkers at the Max Planck Institute.

At the beginning, participants completed initial visual analogue scales (VASs) to assess baseline mood, happiness, and feelings of being accepted (Table 1). Scores

Table 1 Sample characteristics

	Germany		American Samoa		Weight		Culture		Weight *culture	
	Lean individuals n = 27	Individuals with obesity n = 28	Lean individuals n = 25	Individuals with obesity n = 31	F	*p*	F	*p*	F	*p*
Anthropometrics										
Age	27.11 ± 3.2	27.43 ± 3.3	19.84 ± 2.0	20.55 ± 1.8	0.963	.329	190.533	**.001**	0.142	.707
BMI	21.90 ± 1.7	35.18 ± 3.3	25.55 ± 2.7	40.55 ± 6.5	309.073	**.001**	9.695	**.002**	1.217	.273
WHR	.77 ± .06	.90 ± .11	.78 ± .04	.85 ± .07	93.797	**.001**	0.698	.406	11.008	**.001**
Sports h/week	3.64 ± 3.7	2.84 ± 2.7	4.54 ± 3.8	2.87 ± 2.7	4.081	**.046**	0.324	.570	0.558	.457
Components derived from questionnaires										
Social stress	− .42 ± .77	− .48 ± .73	.47 ± .95	.42 ± 1.1	0.085	.771	7.850	**.006**	0.002	.962
Negative body image	− .92 ± .54	.93 ± .75	− .61 ± .50	.45 ± .78	150.463	**.001**	2.128	.148	11.101	**.001**
Interpersonal trust	.16 ± 1.1	.04 ± 1.1	.15 ± .90	− .30 ± .80	2.164	.144	0.152	.697	0.916	.341
Low self-monitoring in public	.73 ± .70	.59 ± .72	− .72 ± .81	− .59 ± .80	0.016	.900	21.497	**.001**	0.828	.365
Visual analogue scales baseline										
Mood (mm)	7.30 ± 1.3	7.68 ± 1.4	8.24 ± 1.1	7.45 ± 2.2	0.587	.445	1.424	.236	3.894	.051
Happiness (mm)	6.70 ± 1.3	6.54 ± 1.2	7.66 ± 1.9	7.15 ± 2.2	1.092	.299	4.033	**.047**	0.289	.592
Feelings of acceptance (mm)	7.70 ± 1.5	7.76 ± 1.5	7.95 ± 1.6	8.12 ± 1.7	0.106	.746	2.283	.134	0.008	.928
Heart rate baseline										
Mean HR (bpm)	81.40 ± 11.6	79.75 ± 8.1	70.90 ± 11.4	75.74 ± 10.8	0.814	.369	7.878	**.006**	2.804	.097
LF power (ms^2)	1346 ± 1293	1403 ± 1221	2774 ± 3797	1908 ± 2174	1.086	.300	1.849	.177	1.311	.255
HF power (ms^2)	516 ± 611	787 ± 822	1874 ± 2613	1237 ± 1566	0.298	.586	0.641	.425	2.497	.117
HF power n.u.	26.67 ± 17.3	34.47 ± 20.3	40.37 ± 19.4	38.51 ± 14.9	1.030	.313	0.916	.341	2.068	.153

Table 1 continued

	Germany		American Samoa		Weight		Culture		Weight *culture	
	Lean individuals n = 27	Individuals with obesity n = 28	Lean individuals n = 25	Individuals with obesity n = 31	F	*p*	F	*p*	F	*p*
LF/HF power (log10)	.51 ± .41	.35 ± .47	.18 ± .38	.22 ± .30	0.986	.323	1.102	.296	2.121	.148

Significant *p*-values appear in bold

BMI Body Mass Index, *WHR* waist-to-hip-ratio, *HR* heart rate, *LF* low frequency power, *HF* high frequency power, *HF power n.u.* normalized units, *LF/HF* ratio between LF and HF power. Univariate ANCOVAs. Values represent mean ± SD

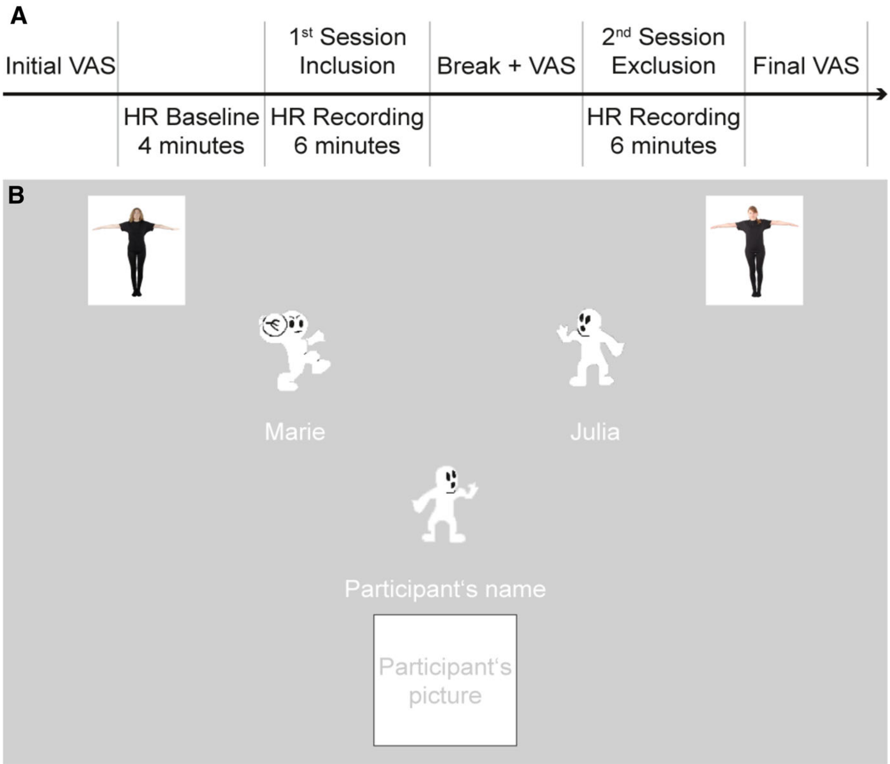

Fig. 1 Paradigm. **a** Overall experimental timeline. **b** The participant and the two confederates were represented on the computer screen by drawings, a full-body picture, and their names. The participant's character, picture, and name were located at the bottom center

ranged from "not at all" (0 mm) to "very much" (100 mm). Then, the ECG electrodes were attached (see below for details). Before the start of the experiment, a 4-min HR measurement at rest was acquired. This was followed by two 6-min sessions of the Cyberball game. In the first session, all participants were included in the game, whereas in the second session, all participants were excluded. Participants were able to throw the ball to the confederates with a computer mouse. The inclusion session consisted of approximately 150 ball throws and every player received the ball equally often throughout the game. Each trial of the computer-generated players lasted between 1600 and 4600 ms, consisting of a randomized waiting period (1000–4000 ms) and a "throw and flight" period (600 ms).

The inclusion session ended with a break, during which participants completed a second set of VASs to assess mood, happiness, and feelings of being accepted. In the exclusion session of the game, participants received just one ball per minute after the first three throws. This resulted in approximately seven ball tosses during the 6 min (as compared to $\sim$ 50 in the inclusion condition). At the end, participants completed a final set of VASs to again measure mood, happiness, and feelings of being accepted. All participants were debriefed at the end of the experiment.

Psychometric measures and factor analysis

All participants completed a battery of questionnaires in German or English, to assess individual personality traits, body image, and stress: Body Image Avoidance Questionnaire (BIAQ, Legenbauer et al. 2007; Rosen et al. 1991), Body Shape Questionnaire (BSQ, Cooper et al. 1987; Pook et al. 2002), Eating Disorder Inventory (EDI-2, Garner 1991; Thiel et al. 1997), Figure Rating Scales (FRS, Stunkard et al. 1983), NEO Five-Factor Inventory (NEO-FFI, Borkenau and Ostendorf 1993; Costa and McCrae 1992), Perceived Stress Questionnaire (PSQ-20, Fliege et al. 2001; Levenstein et al. 1993), Perceived Stress Scale (PSS-10, Cohen et al. 1983; Klein et al. 2016), Perception of Teasing Scale (POTS, Thompson et al. 1991), Rejection Sensitivity Questionnaire (RSQ, Downey and Feldman 1996; Staebler et al. 2011), and Trier Inventory for Chronic Stress (TICS, Schulz and Schlotz 1999).

A principal component analysis (PCA) with oblique rotation (oblimin) was conducted using IBM SPSS Statistics 23 (Armonk, NY, USA) to reduce the number of variables and extract convergent latent factors across different measures of self-related social experiences. Only those total scores of questionnaires or specific subscales were included that fulfilled criteria for PCA. The Kaiser–Meyer–Olkin (KMO) measure of .86 (with all KMO values for individual scales > .65 and thus above the threshold of .5) confirmed the sampling adequacy for the analysis. The correlations between scales were sufficiently large for a PCA (Bartlett's test of sphericity $\chi^2(300) = 1673.343$, $p < .001$). In the initial analysis, five components had eigenvalues over 1 (Kaiser's criterion) and explained 67.25% of the variance. The scree plot showed inflexions that justified retaining four components (explaining 61.97% of the variance). Cronbach's alpha was sufficient for the first two components (Table S1), which is why only those two were included in further analysis. After evaluation of the scales that clustered on the same component, component one was summarized as *social stress* and component two as *negative body image*. Scales clustering on component *social stress*, among others, high social tensions, social isolation, and social overload. Scales clustering on component *negative body image* included, among others, body dissatisfaction, high frequency of weight-related teasing and a pronounced drive for thinness.

HR data recordings and analysis

For the German sample, a one-lead ECG was recorded at 500 Hz using a BrainAmp ExG amplifier and BrainVision Recorder software (Version 1.20.0506, Brain Products, München, Germany). Three Ag/AgCl electrodes (MES Forschungssysteme GmbH, Gilching, Germany) were placed between the right clavicle and sternum, on the left side between the two lower rips, and on the right lower abdomen.

For the Samoan sample, a one-lead ECG was measured using a Polar H6 chest strap (centered on the sternum) and interbeat (RR) intervals were recorded (in ms, i.e., at 1000 Hz) using the app "Heart Rate Variability Logger" (http://www.marcoaltini.com/apps.html) via Bluetooth on an Android smartphone (LG L40).

Before the data acquisition in Samoa, comparability between the two devices, setups, and electrode placements was tested in a small validation experiment, which showed that simultaneously acquired interbeat intervals were correlated with $r > .99$ (the details including data, scripts, and results with figures can be found at https://github.com/michagaebler/Polar_H6_ECG_Test/), confirming previous observations by other researchers (e.g., http://www.marcoaltini.com/blog/heart-rate-variability).

Raw ECG data (for the data acquired in Germany) and tachograms (for the data acquired in Samoa) were imported into Kubios (Version 2.2, Biosignal Analysis and Medical Imaging Group, University of Eastern Finland, http://kubios.uef.fi/) and visually inspected. The Kubios artifact correction level "very low" was applied, which identifies and (cubic-spline) interpolates RR intervals that differ more than 0.45 s from the local mean RR interval. The amount of corrected peaks did not exceed 0.3% of the total analyzed data and the number of corrected peaks was equally distributed in subsamples (interaction of location * weight: $F(3, 107) = 0.003$, $p = .957$). HR and HRV were analyzed in the frequency domain, the latter through Fast Fourier transformation using Welch's periodogram method with a sliding window of 256 s and 50% overlap. We extracted low frequency (LF, 0.04–0.15 Hz) and high frequency (HF, 0.15–0.4 Hz) power but will focus on HF power, since it is more clearly interpretable as PNS activation (Billman 2013; Thayer and Lane 2000). LF power was used to transform HF power into normalized units (n.u.) by dividing HF power through the total LF and HF power. This normalization removes unequal distribution of the raw data and increases comparability between individuals and studies (Burr 2007). The values of mean HR and HF power n.u. were normally distributed. All raw HRV values for baseline and experimental sessions can be found in Table S2.

Statistical analysis

All statistical analyses were carried out using IBM SPSS Statistics 23 (Armonk, NY, USA) with a two-sided α-level of .05. Greenhouse–Geisser corrections were used to adjust the degrees of freedom in mixed-design analyses of variance (ANOVAs) in case the assumption of sphericity was violated according to the Mauchly test. In this case, we report uncorrected degrees of freedom, corrected p-values, and epsilon (ε). Estimated effect sizes are reported using partial eta squared (η_p^2). Post-hoc tests were adjusted using Bonferroni correction. Between-subject factors are defined as follows: "weight" (lean, obese), "location" (Germany, American Samoa), and "sex" (women, men). As the two location groups significantly differed in age, the mean-centered covariate "age" was included in all mixed-design analyses of covariance (ANCOVAs). Age has been found to decrease PNS activity at rest (Agelink et al. 2001), cardiac reactivity to induced emotions (Labouvie-Vief et al. 2003), as well as intensity of emotions experienced during social interactions (Charles and Piazza 2007). Even in our sample, which had a relatively restricted age range, higher age was significantly associated with lower PNS activity (HF power: $r(111) = -.30$, $p = .002$; HF power n.u.: $r(111) = -.24$, $p = .011$) and with lower negative emotional responses after social exclusion (changes in happiness: r(111) = .19, p = .050; changes in mood.: r(111) = .19, p = .048).

Group differences in the participant characteristics (components, body size preference, and weight-related teasing) and baseline affect and HRV data (Table 1) were analyzed using univariate ANCOVAs with between-subject factors "weight", "location", and "sex". VAS changes over time were analyzed using separate mixed-design ANCOVAs for all time points, employing the within-subject factor "time" (baseline, social inclusion, social exclusion) and between-subject factors "location", "weight", and "sex". HRV changes from baseline to social inclusion and HRV changes from baseline to social exclusion were examined separately. Mixed-design ANCOVAs for all time points were used with the within-subject factor "time" and between-subject factors "weight", "sex", and "location".

Furthermore, two-sided bivariate correlations were calculated to analyze the association of HRV with state and trait variables (VAS and principle components).

Results

Weight-related teasing and body image

Means and standard deviations for each variable in each group can be found in Table 1. Statistics on group characteristics can be found in the online supplementary material (Supplement S3). To test the assumption that while body size ideal is comparable between the two locations, American Samoans experience less weight-related teasing and have a more positive body image than Westerners/Germans, the (1) preferred body figure on the Figure Rating Scale and the two POTS sub-scales (2) frequency of weight-related teasing and (3) emotional pain after teasing were analyzed: (1) We did not find a significant difference in body size preference between the two locations ($F(1, 103) = 0.812$, $p = .157$, $\eta_p^2 = .019$). (2) A significant main effect of weight ($F(1, 102) = 34.931$, $p < .001$, $\eta_p^2 = .255$) indicates that individuals with obesity reported a higher frequency of weight-related teasing than lean individuals. No effects of sex, location, or interactions were found. (3) The analysis of emotional pain after teasing showed a main effect of weight ($F(1, 102) = 32.925$, $p < .001$, $\eta_p^2 = .244$), a location * weight interaction ($F(1, 102) = 7.608$, $p = .007$, $\eta_p^2 = .069$), and a location * sex * weight interaction ($F(1, 102) = 4.520$, $p = .036$, $\eta_p^2 = .042$). The latter interaction indicated that Samoan women with obesity reported lower emotional pain after teasing ($M = 1.62$, $SE = .26$) than German women with obesity ($M = 3.15$, $SE = .28$, $p < .001$). While German women with obesity reported more emotional pain after teasing ($M = 3.15$, $SE = .28$) than German lean women ($M = 1.09$, $SE = .27$, $p < .001$), there was no statistically significant difference between Samoan women with ($M = 1.62$, $SE = .26$) and without obesity ($M = 1.27$, $SE = .29$, $p = .315$). Further, German men with obesity reported more emotional pain after teasing ($M = 2.22$, $SE = .28$) than German lean men ($M = 1.30$, $SE = .28$, $p = .011$).

The PCA component *negative body image* showed significant group differences (main effect of sex: $F(1, 102) = 6.410$, $p = .013$, $\eta_p^2 = .059$; main effect of weight:

$F(1, 102) = 150.463$, $p < .001$, $\eta_p^2 = .596$; location * weight interaction: $F(1, 102) = 11.101$, $p = .001$, $\eta_p^2 = .098$). The interactions indicated that German participants with obesity had a more negative body image ($M = 1.05$, $SE = .15$) than Samoan participants with obesity ($M = .35$, $SE = .14$, $p = .003$).

Social stress

A significant main effect of location for the component *social stress* ($F(1, 102) = 7.850$, $p = .006$, $\eta_p^2 = .071$) indicated more social stress in the Samoan ($M = .41$, $SE = .17$) as compared to the German group ($M = -.42$, $SE = .17$).

Experimental results: affect

The analyses over all three measurement times for *mood* showed significant main effects of time ($F(2, 204) = 13.341$, $p < .001$, $\eta_p^2 = .116$), location ($F(1, 102) = 5.253$, $p = .024$, $\eta_p^2 = .049$), and a location * weight interaction ($F(1, 102) = 4.788$, $p = .031$, $\eta_p^2 = .045$). Samoans had a better mood ($M = 7.85$, $SE = .28$) than Germans ($M = 6.73$, $SE = .28$) and mood was decreasing from social inclusion ($M = 7.35$, $SE = .17$) to exclusion ($M = 6.86$, $SE = .19$, $p = .010$). Further, Samoan lean participants had a better mood ($M = 8.29$, $SE = .37$) than German lean participants ($M = 6.54$, $SE = .35$, $p = .003$) as well as Samoan participants with obesity ($M = 7.41$, $SE = .32$, $p = .033$, Fig. 2a).

For *happiness,* we found significant main effects of time ($F(2, 204) = 5.178$ $\varepsilon = .801$, $p = .011$, $\eta_p^2 = .048$) and location ($F(1, 102) = 6.728$, $p = .011$, $\eta_p^{2-} = .062$). Participants felt less happy after social exclusion ($M = 6.56$, $SE = .18$) compared to baseline ($M = 7.00$, $SE = .16$, $p = .031$), whereas there was no difference between social inclusion ($M = 6.90$, $SE = .16$) and baseline ($M = 7.00$, $SE = .16$, $p = 1.000$). Samoans ($M = 7.47$, $SE = .29$) felt overall happier than Germans ($M = 6.17$, $SE = .29$) (Fig. 2b).

For the *feeling of being accepted*, we found significant main effects of time ($F(2, 204) = 40.760$, $\varepsilon = .723$, $p < .001$, $\eta_p^2 = .286$) and location ($F(1, 102) = 8.734$, $p = .004$, $\eta_p^2 = .079$). Participants felt less accepted after social exclusion ($M = 6.51$, $SE = .20$) compared to social inclusion ($M = 7.68$, $SE = .16$) and to baseline ($M = 7.88$, $SE = .15$). Samoans ($M = 8.06$, $SE = .28$) felt overall more accepted than Germans ($M = 6.65$, $SE = .28$). A significant between-subject interaction of location*sex*weight ($F(1, 102) = 6.684$, $p = .011$, $\eta_p^2 = .061$) indicated that Samoan women with obesity ($M = 8.28$, $SE = .43$) felt more accepted than German women with obesity ($M = 6.30$, $SE = .44$, $p = .004$) and Samoan lean men ($M = 8.31$, $SE = .48$) felt more accepted than German lean men ($M = 6.02$, $SE = .45$, $p = .002$, Fig. 2c).

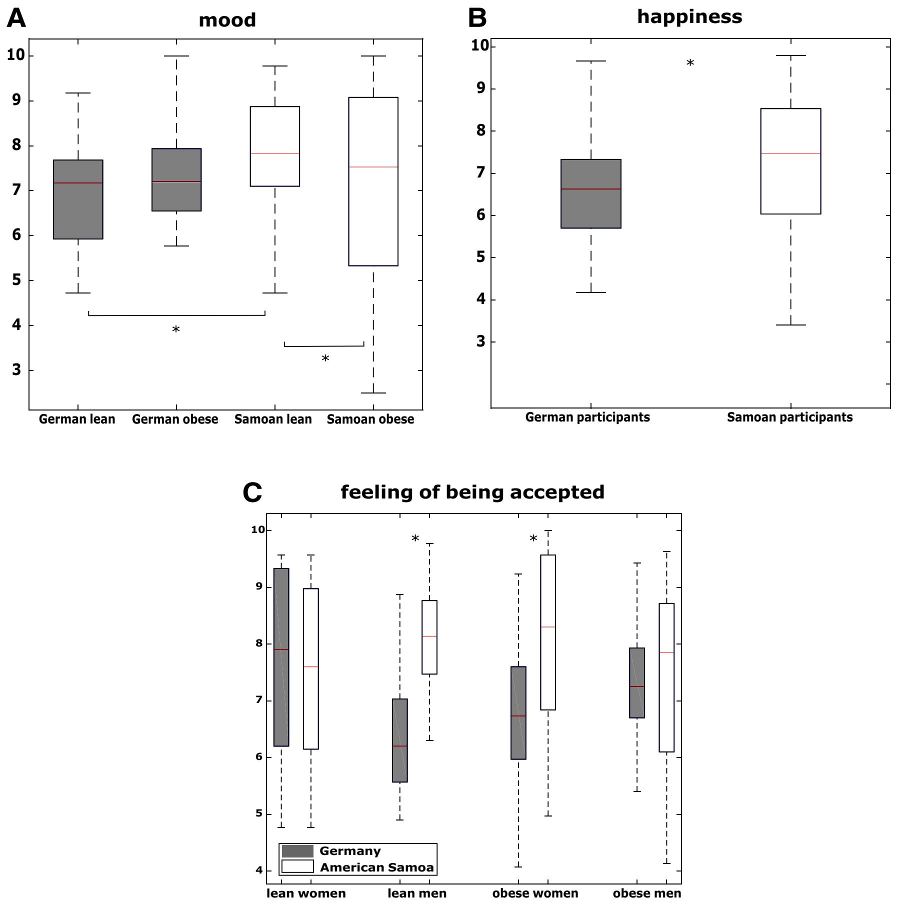

Fig. 2 Affect ratings assessed with visual analogue scales. **a** Differences in mood between individuals with and without obesity in Samoa and Germany (location * weight interaction: ($F(1,\ 102) = 4.788$, $p = .031$, $\eta_p^2 = .045$). Samoan lean participants had a better mood than German participants as well as Samoan participants with obesity. **b** Differences in happiness between the two locations (main effect location: $F(1,\ 102) = 6.728$, $p = .011$, $\eta_p^2 = .062$). Samoans felt happier than Germans. **c** Feeling of being accepted (location * sex * weight interaction: $F(1,\ 102) = 6.684$, $p = .011$, $\eta_p^2 = .061$). Samoan women with obesity felt more accepted than German women with obesity, Samoan lean men felt more accepted than German lean men. Values represent mean ± SE

Experimental results: cardiac measures

Social inclusion

The analysis of the HF power n.u. showed significant main effects of time ($F(1,\ 102) = 10.941$, $p = .001$, $\eta_p^2 = .097$) and sex ($F(1,\ 102) = 19.717$, $p < .001$, $\eta_p^2 = .162$). A significant time * location interaction ($F(1,\ 102) = 4.825$, $p = .030$, $\eta_p^2 = .045$) indicated a significant increase in HF power n.u. in German (baseline: $M = 32.25$, $SE = 3.31$, social inclusion: $M = 42.23$, $SE = 2.87$, $p = .001$) but not in

Samoan participants (baseline: $M = 37.69$, $SE = 3.29$, social inclusion: $M = 37.12$, $SE = 2.86$, $p = .838$). A time * sex * weight interaction ($F(1, 102) = 7.698$, $p = .007$, $\eta_p^2 = .070$) showed that only women with obesity and lean women had a significant increase from baseline to social inclusion (lean women baseline: $M = 37.18$, $SE = 3.41$, social inclusion: $M = 43.91$, $SE = 2.96$, $p = .022$; women with obesity baseline: $M = 39.77$, $SE = 3.28$, social inclusion: $M = 53.42$, $SE = 2.85$, $p < .001$; lean men baseline: $M = 29.33$, $SE = 3.54$, social inclusion: $M = 32.99$, $SE = 3.07$, $p = .224$; men with obesity baseline: $M = 33.59$, $SE = 3.24$, social inclusion $M = 28.38$, $SE = 2.81$, $p = .060$). Further, the increase in HF power n.u. was stronger in women with obesity ($M = 13.65$, $SE = 2.78$) than in men with obesity ($M = -5.22$, $SE = 2.74$, $p < .001$) and in lean women ($M = 6.73$, $SE = 2.88$, $p = .087$). Men with obesity had a stronger decrease ($M = -5.22$, $SE = 2.74$) than lean men ($M = 3.66$, $SE = 2.99$, $p = .031$; Fig. 3a).

Social exclusion

The analysis of HF power n.u. showed a main effect of sex ($F(1, 102) = 18.407$, $p < .001$, $\eta_p^2 = .153$), a time * location interaction ($F(1, 102) = 8.069$, $p = .005$, $\eta_p^2 = .073$), and a non-significant trends for the interactions of location * weight ($F(1, 102) = 3.880$, $p = .052$, $\eta_p^2 = .037$) and time * sex * weight ($F(1, 102) = 3.840$, $p = .053$, $\eta_p^2 = .036$). Women had a higher HF power n.u. ($M = 40.08$, $SE = 1.95$) than men ($M = 28.14$, $SE = 1.98$, $p < .001$). German participants showed an increase in HF power n.u. during exclusion (baseline: $M = 32.25$, $SE = 3.31$, social exclusion: $M = 38.02$, $SE = 2.95$, $p = .063$), whereas Samoan participants showed a decrease (baseline: $M = 37.69$, $SE = 3.29$, social exclusion: $M = 28.50$, $SE = 2.94$, $p = .003$). In the German sample, individuals with obesity had a higher HF power n.u. ($M = 39.69$, $SE = 3.40$) than lean individuals ($M = 30.57$, $SE = 3.35$, $p = .023$), while there was no group difference in the Samoan sample. Further, women with obesity showed a stronger response of HF power n.u. during social exclusion ($M = 46.25$, $SE = 2.93$) than lean women ($M = 37.14$, $SE = 3.04$, $p = .033$) and men with obesity ($M = 24.11$, $SE = 2.89$, $p < .001$). Over time, women with obesity showed an increase in HF power n.u. (baseline: $M = 39.77$, $SE = 3.28$, social exclusion: $M = 46.25$, $SE = 2.93$, $p = .035$), whereas men with obesity showed a decrease (baseline: $M = 33.59$, $SE = 3.24$, social exclusion: $M = 24.11$, $SE = 2.89$, $p = .002$; Fig. 3b). There was no difference in HF power n.u. over time in lean women and men.

Psychometrics and HRV

Correlation coefficients were calculated between changes in HF power n.u. and the components social stress and negative body image. The analysis of the changes from baseline to *social inclusion* showed in the German group with obesity a significant positive correlation between the changes of HF power n.u. and negative body image ($r(28) = .38$, $p = .047$).

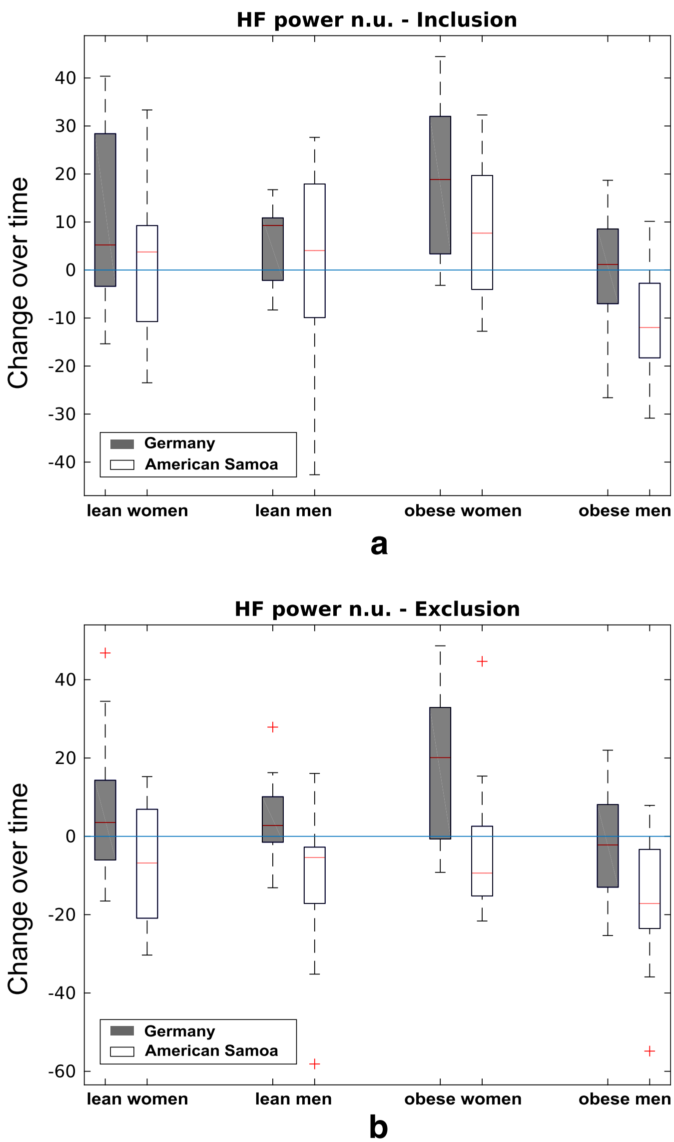

Fig. 3 Parasympathetic cardio-regulation. **a** Changes in high-frequency (HF) power normalized units (n.u.) for social inclusion (relative to baseline): a significantly stronger increase in women with obesity during social interaction independent of culture (time * sex * weight interaction: $F(1,\ 102) = 7.698$, $p = .007$, $\eta_p^2 = .070$). **b** Changes in HF power n.u. for social exclusion showed that German individuals with obesity had a higher HF power n.u. than German lean individuals, while there was no group difference in the Samoan sample. Women with obesity showed a stronger response of HF power n.u. during social exclusion than lean women and men with obesity (non-significant trend for a location * weight interaction: $F(1,\ 102) = 3.880$, $p = .052$, $\eta_p^2 = .037$; and time * sex * weight interaction: $F(1,\ 102) = 3.840$, $p = .053$, $\eta_p^2 = .036$). Values represent mean ± SE

Discussion

The present study investigated the influence of the socio-cultural environment on the psychological and physiological processing of social interactions. Participants with and without obesity were tested in Germany (high exposure to weight-related prejudice and more negative perception of excess body weight) and the Samoan Islands (less exposure to weight-related prejudice and less negative perception of excess body weight). We found complex influences of weight status, location, and sex, and their interactions on psychometrics as well as on affect and parasympathetic cardioregulation during social interactions. Each finding will be discussed below.

Weight-related teasing and body image

In line with the literature, we expected to find no significant difference in body size preference between the two locations (Brewis et al. 1998; Swami et al. 2007; Wilkinson et al. 1994). Indeed, the body size preference did not vary between the populations which has been explained with reference to increasing Westernization and Western media exposure (Brewis et al. 1998; Swami et al. 2007). We further expected to find differences in weight-related teasing experiences and body dissatisfaction between the two cultures due to differences in body size-related socio-cultural norms. While our results did not show significant cultural differences in the frequency of weight-related teasing, we found that emotional pain after teasing differed between cultures: Samoan women with obesity reported to be less affected by teasing than German women with obesity. Also, obesity-related differences in emotional pain after teasing were found in Germans but not in Samoans. Importantly, Germans with obesity held a significantly more negative body image than Samoans with obesity. These results partially confirmed our hypothesis: although BMI was higher in the Samoan sample, negative body image and emotional pain after weight-related teasing were lower than in the German sample. This is in line with previous comparative research on body image (Brewis and McGarvey 2000; Metcalf et al. 2000; Wilkinson et al. 1994).

Social stress

In this sample, Samoans reported more social stress than Germans. Rapid socio-cultural and economical transitions have been related to psychosocial stress in Samoans (Bergey et al. 2011; McDade 2002), but also to increased incidences of suicide since the 1970s (Booth 1999). It has been hypothesized that the gap between expectations—caused by westernization, new consumer goods, and media—and traditional norms and values might favor suicide rates (Macpherson and Macpherson 1987). Other scholars discussed additional causes, such as repeated familial conflicts and the simultaneous refusal of expressing anger due to traditional community values and fear of a potential bad reputation for the family (Tousignant 1998). Hence, higher self-reported social stress in Samoans might be associated with the discrepancy between traditionally strict social obligations and progressive Westernization.

Affective responses during social interactions

We hypothesized to find differences in emotional responses to experimentally induced social interactions between the two locations. We measured mood, happiness, and the feeling of being accepted prior, between, and after the two sessions. In this study, participants generally felt worse, less accepted, and were less happy after social exclusion as compared to baseline. These findings indicate that we—like previous studies (cf. Blackhart et al. 2009; Gerber and Wheeler 2009)—successfully induced the experience of social exclusion. The average level of mood, happiness, and the feeling of being accepted was higher in Samoan than in German participants, which is in line with the claim that socio-emotional experience is shaped by the cultural environment (Barrett 2012; Immordino-Yang and Yang 2017; Mesquita et al. 2016). The public display of strong negative emotions is discouraged in Samoa and the maintenance of interpersonal harmony is a strongly approved value (Gerber 1985; Shore 1982). The expressed emotions via visual analogue scales in this sample might thus be influenced by cultural norms.

We also hypothesized fewer obesity-related differences in affect after social exclusion in Samoan than in German participants. We found that Samoan women with obesity and Samoan lean men generally felt more accepted than German women with obesity and German lean men, respectively. Since Polynesian as compared to Western societies have been reported to be less preoccupied with their body sizes (Brewis and McGarvey 2000; Metcalf et al. 2000; Teevale 2011; Wilkinson et al. 1994) and have fewer negative attitudes towards excess body weight (Becker 1995; Brewis et al. 1998; Hardin 2015; Pollock 2001), Samoans might not expect weight-related prejudice in a new social situation. Alternatively, due to a more ambiguous interpretation of body weight (Hardin 2015), Samoan participants might be less likely to attribute social exclusion to body weight. Further, social exclusion has been found to be less painful in collectivistic societies due to more reliable social networks (Over and Uskul 2016; Pfundmair et al. 2015). As a collectivistic society, Samoans might be less affected by social exclusion independent of weight status. In Western societies, it has been shown that especially women with overweight attribute ambiguous negative social feedback to their weight and are more negatively affected by it than lean women (Crocker et al. 1993). These results suggest that cultural norms regarding slimness might influence negative emotions during social interactions in individuals with overweight or obesity particularly in Westerners.

Cardiac activity during social interactions: location effects

The hypothesized differences in PNS activity during social inclusion and exclusion between the two locations could be confirmed: German participants exhibited a significant increase in PNS activity when engaged in an inclusive social situation relative to a resting baseline. This effect was absent in Samoan participants (with a significant time * location interaction). According to the models of PNS cardioregulation, a heightened engagement with the environment would be accompanied by increased PNS activity to improve an individual's capacity to make effective and rapid responses (Porges 2003, 2007; Thayer and Lane 2000, 2009). Heightened PNS activity has also been associated with attention to motivationally relevant social stimuli (Jönsson and Sonnby-Borgström 2003; Stellar et al. 2015; Vanderhasselt et al. 2015) and effortful emotion regulation (Butler et al. 2006; Musser et al. 2011). Accordingly, the increase in PNS activity in German participants might be interpreted as stronger emotion regulation during social inclusion compared to Samoan participants. Due to the preliminary nature of the experimental results, we would like to cautiously discuss this finding in two potential directions. First, as mentioned above, in the traditional Samoan society the expression of emotion was described to be under external control and focus on their implication for social cohesion: negative emotional display, especially anger, was discouraged and obedience to those in authority was emphasized (Gerber 1985; Shore 1982). Developmental research in Western societies found associations of emotion regulation abilities with parental encouragement of and control over emotional display (Morris et al. 2007). Further, individuals with emotion regulation difficulties showed reduced PNS activation while watching anger-eliciting movies (Berna et al. 2014). Second, the effort, for example for emotion suppression, might differ between individualistic and collectivistic societies. That is, to maintain relationship harmony, individuals in collectivistic societies more frequently and habitually use the suppression of discouraged emotions—even during positive social interactions (Butler et al. 2007). In contrast, in individualistic societies, emotion regulation might be more frequently used in negative social situations to protect the self (Butler et al. 2007; Gross and John 2003). However, further studies are needed to investigate these potential interpretations in more detail.

During social exclusion, German participants showed increased PNS activity while Samoan participants showed a PNS withdrawal. Based on the aforementioned literature, results might indicate higher attentional engagement or stronger emotion regulation during social exclusion in German than in Samoan participants (Butler et al. 2006; Jönsson and Hansson-Sandsten 2008; Jönsson and Sonnby-Borgström 2003; Vanderhasselt et al. 2015). PNS withdrawal, in contrast, has been associated with disengagement from threat-related but not from happy or neutral cues (Schwerdtfeger and Derakshan 2010) as well as with emotional deficits (Beauchaine 2001; Berna et al. 2014). However, it has also been interpreted as response mobilization (Oppenheimer et al. 2013) and related to better recovery from stress (Rottenberg et al. 2007) or depression (Rottenberg et al. 2005). Although our study design does not allow a differentiation of disengagement or response mobilization potentially reflected in the PNS responses, we would like to propose the observed PNS withdrawal during social exclusion in Samoan participants as indicating a greater disengagement or a better ability to recover from potential threat (Rottenberg et al. 2007; Schwerdtfeger and Derakshan 2010). In the anthropological literature about the Samoan culture, the term *musu* is found in relation to emotion regulation in Samoans. Musu refers to an emotional state of withdrawal from stressful situations as a strategy to cope with interpersonal conflicts or criticism and, simultaneously, to avoid the display of socially undesirable emotions, like anger or impulse (Gerber 1985; Steele and McGarvey 1996). Musu might therefore be a socially learned behavior to disguise inappropriate feelings and might be reflected in the PNS response to social exclusion.

Cardiac activity during social interactions: weight effects

The hypothesized obesity-related differences during social inclusion in German but not in Samoan individuals could not be confirmed. Independent of location, we found an effect that corroborated our previous study results: the increase in PNS activity to social inclusion was more pronounced in women with obesity. This might be interpreted as an anticipatory regulation or increased vigilance. We argued that in the presence of a full-body picture, women with obesity—exhibiting the highest increase in PNS activity from baseline to social inclusion—might show higher attention to or emotion regulation in a novel and potentially stigmatizing social interaction (Schrimpf et al. 2017). Fittingly, it has been shown that individuals that played the Cyberball paradigm in an MRI and attributed social exclusion to (racial) discrimination showed more activity in brain regions linked with emotion and pain regulation during social exclusion (Masten et al. 2011). Further, women with higher BMI are more sensitive to their social inclusion or exclusion status than women with lower BMI (Hartung and Renner 2013) and that visibility of weight status might enhance this effect (Blodorn et al. 2016). It has been proposed that individuals with a higher need to belong show greater sensitivity to potential social threats (Pickett and Gardner 2005)—provoked in the present study via a full-body picture. Indeed, we observed a positive association between PNS activity during social inclusion and negative body image in Germans with obesity, but not in Samoans with obesity or lean individuals. Notably, the factor *negative body image* in this study included not only body dissatisfaction, but also a high frequency of weight-related teasing. The anticipation of being a target of weight-related prejudice might increase attention or emotion regulation during social interactions. Hence, the visibility of weight status in this study and the culturally stronger preoccupation with slimness in Western societies (Brewis and McGarvey 2000; Metcalf et al. 2000; Wilkinson et al. 1994) might have evoked a higher attention or emotion regulation during new social situations in German individuals with obesity and a more negative body image.

During social exclusion, a non-significant location * weight interaction suggested that PNS activity is more pronounced in German individuals with obesity than in German lean individuals, while this difference might be absent in the Samoan group. As we argued above, the results might indicate that German participants with obesity might be more attentionally engaged or regulate their emotional response more actively in a social exclusion interaction in which their weight status is visible. The Samoan group showed no obesity-related difference in PNS activity, which might suggest that body size is less salient during social interactions. Further studies could directly test this interpretation.

Additional findings

As in our previous study and as described in a meta-analysis on sex differences in autonomic cardiac control (Koenig and Thayer 2016), baseline HF-HRV indicated significantly greater dominance of PNS activity in females relative to males. Interestingly, groups in this study differed in WHR in that German men with obesity have a higher WHR than Samoan men with obesity—although Samoan men with obesity have a higher BMI than German men with obesity. It has been described that the percentage of muscle mass is higher and the percentage of body fat mass is lower in Polynesians as compared to Westerners with the same BMI (Rush et al. 2009), which is why we adjusted the BMI cut-offs for obesity accordingly. Since lower WHR is also an indicator for a healthier fat distribution (De Koning et al. 2007), it might be that WHR needs to be adjusted for ethnic differences in body composition as well—although the evidence for the need of WHR cut-offs in Polynesians is insufficient (Lear et al. 2010).

Limitations

We did not account for the influence of respiration on HF-HRV (Grossman and Taylor 2007; Penttilä et al. 2001). However, it has been argued that the influence can be neglected for tasks with comparable demands and under spontaneous breathing (Denver et al. 2007; Grossman and Taylor 2007). We did not expect changes in breathing frequencies between participants and tasks as participants were instructed to sit calmly without speaking during ECG measurements. Further, the amount of motor responses between inclusion and exclusion differed, which might influence HRV. However, small increases in motor activity have not been found to be related to changes in cardiac measures (Porges et al. 2007).

As the Cyberball paradigm is an experimental instrument designed to be highly standardized, the social interaction is restricted to tossing a ball and contains—besides the body pictures—little contextual information. The paradigm is therefore restricted in its transferability to real-life, complex social interactions. Hence, inferences from affective and psychophysiological results obtained with the Cyberball paradigm in the lab to real-life interactions must be carefully considered. Further, this paradigm has never been used in a Polynesian population and its applicability has not been sufficiently investigated. Additionally, the confederates' pictures were the same as in Germany. Although American Samoans are very familiar with Westerners, mainly with US citizens working in American Samoa, the depiction of Western-looking confederates might generate an out-group setting and may have influenced the results. However, previous studies found similar effects of social exclusion with out-group and in-group confederates (Gonsalkorale and Williams 2007; Hartgerink et al. 2015). In addition, the instruction of the procedure slightly varied between the two locations, which might be a confounding factor: Participants were told they would play with two other individuals either sitting in nearby rooms (Germany) or connected online (Samoa). The Cyberball paradigm has been shown to induce negative emotions even when participants were told beforehand that the other players' behavior was scripted (Zadro et al. 2004) or when comparing social exclusion by humans with computers (Filipkowski and Smyth 2012; Zadro et al. 2004). Social exclusion therefore might induce negative affect robustly in varying situations and experimental designs.

In addition, the order of social inclusion and exclusion was not balanced but fixed for all participants (first inclusion, second exclusion). In our between-subject analyses of weight- and location-related differences, potential order effects should have cancelled out. In addition, we were interested in psychophysiological effects of previous negative social experiences in novel, inclusive social interactions. Research showed that chronic stigmatization might enhance sensitivity to social cues even in neutral social situations (Barreto and Ellemers 2015; Kaiser et al. 2006; Swim et al. 1998; Tanaka and Ikegami 2015). Therefore, we kept the order of the sessions constant to preserve the psychological experience across participants: starting with an exclusion session might have provoked the expectation of being excluded in the second session as well.

As participants in both locations were young and had an above average education, they do not represent the entire population. Further, we recommend including the whole weight range including overweight participants in future studies. Importantly, due to the small sample size and the small statistical power of some results, they have to be considered preliminary and require further replication. Additionally, we recommend including factors as social status and reputation in future studies on weight-related stigmatization in Samoa or in other collectivistic societies, as it has been shown that these factors contribute considerably to the view on body weight and stigma (Hardin 2015).

Implications

HRV has rarely been studied in non-Western participants. Our study contributes an underrepresented cultural perspective to the two main theoretical frameworks of parasympathetic function ("polyvagal theory", Porges 2003, 2007; "neurovisceral integration model", Thayer and Lane 2000, 2009) and supports models about the influence of culture on socio-emotional phenomena (Barrett 2012; Immordino-Yang and Yang 2017). Further, the results indicate that socio-cultural norms regarding body size and—the potentially associated—stigmatizing experiences influence the processing of new social situations on a psychological and a physiological level. In Western societies, behavioral interventions for individuals with obesity that put a special focus on body image might be promising for an improvement in well-being and social functioning. On a more general note, our results support the importance of body size neutral media representations to reduce weight bias.

Conclusion

Our findings add to the understanding of (1) cultural influences on psychophysiological functioning, and (2) how social norms regarding body size accompanied by recurrent negative social experience might affect the processing of new social encounters. We confirm that Samoans' excess body weight has a smaller impact on well-being and social relationships than Germans' excess body weight. We previously found that Western women with obesity exhibit higher PNS activity during social interactions, which we interpreted as a higher vigilance to quickly detect signs of prejudice and apply adaptive psychophysiological strategies. We now add that Polynesians show fewer obesity-related psychophysiological differences during social interactions. These results emphasize the importance of perceptions of size, shape, or appearance of the human body for social interactions. By jointly investigating socio-cultural, psychological, and biological aspects of emotional processing, our "traveling experiment" contributes to better understanding socio-cultural aspects of HRV as well as the nature of emotion.

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Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest.

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