Repeatedly adopting power postures does not affect hormonal correlates of dominance and affiliative behavior

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Abstract

Background. Adopting expansive versus constrictive postures related to high versus low levels of social power has been suggested to induce changes in testosterone and cortisol levels, and thereby to mimic hormonal correlates of dominance behavior. However, these findings have been challenged by several non-replications recently. Despite this growing body of evidence that does not support posture effects on hormone levels, the question remains as to whether repeatedly holding postures over time and/or assessing hormonal responses at different time points would yield different outcomes. The current study assesses these methodological characteristics as possible reasons for previous null-findings. Additionally, it investigates for the first time whether expansive and constrictive postures impact progesterone levels, a suggested correlate of affiliative motives and behavior. By testing effects of repeated but short posture manipulations in between the blocks of a social task while using a cover story, it further fulfills the conditions previously raised as potentially necessary for the effects to occur.

Methods. 82 male participants repeatedly adopted an expansive or constrictive posture for 2 minutes in between blocks of a task that consisted in categorizing faces based on first impressions. Saliva samples were taken at two different time points in a time window in which hormonal responses to stress, competition and other manipulations are known to be strongest.

Results. Neither testosterone and cortisol levels linked to dominance behaviors, nor progesterone levels related to affiliative tendencies, responded differently to adopting expansive as opposed to constrictive postures. The present results suggest that even repeated power posing in a context where social stimuli are task-relevant does not elicit changes in hormone levels.

Introduction

Individuals' position in a social hierarchy greatly determines their response to stressful situations as well as their opportunities for social contact and relationships (de Waal, 1986; Sapolsky, 2005). Because individuals' social power changes over time and across different contexts, the physiological mechanisms underlying power-related behavior need to allow flexible adaptation to new situations. Steroid hormone levels, including cortisol, testosterone and progesterone are key players in the implementation of this behavioral flexibility: not only do their baseline levels influence individuals' tendencies for certain behaviors, but their levels also change in situations that involve stress, opportunities for gaining social status or affiliating with others, or threats to social status and affiliative needs (Mehta & Josephs, 2011; Schultheiss, 2013). Although there are complex interactions between these three steroid hormones and the behaviors they modulate (Mehta & Josephs, 2011), cortisol is predominantly involved in the regulation of stress responses (Sapolsky, 1990), testosterone seems to mediate behaviors that serve to achieve or maintain social status (Archer, 2006; Mehta & Josephs, 2011; Eisenegger, Haushofer & Fehr, 2011; Nave et al., 2018), and progesterone has been suggested to contribute to the regulation of affiliative behavior (Schultheiss, Wirth & Stanton, 2004; Wirth, 2011).

Positions of high and low power are associated with distinct endocrine profiles: whereas high-ranking individuals have higher baseline testosterone levels and lower cortisol levels, the reverse is observed in low-ranking individuals (Sapolsky, 1990; Virgin & Sapolsky, 1997; Mehta & Josephs, 2010). Building on theories of embodiment, which postulate that many aspects of cognition are shaped by representations of body actions, Carney, Cuddy and Yap (2010) assessed whether exhibiting non-verbal dominant or submissive behavior, namely expanding or constricting one's body, would induce corresponding changes in testosterone and cortisol levels. They did indeed observe an increase of testosterone and a decrease of cortisol in individuals who had adopted an expansive posture and the reverse changes in individuals who had adopted a constrictive posture. Although these findings seemed consistent with the hormonal correlates of status and power, four subsequent studies could not replicate them despite large sample sizes that ensured high statistical power in three of the replications (Ranehill et al., 2015; Ronay et al., 2016; Smith & Apicella, 2017; Davis et al., 2017). The first replication (Ranehill et al., 2015) exhibited small but potentially crucial methodological differences with the original study (see Carney, Cuddy & Yap, 2015). Two others attempted to improve the original study's setting by testing effects in more ecologically valid social contexts that bear implications for power, status and dominance, such as competition or public speaking (Smith & Apicella, 2017; Davis et al., 2017). Only Ronay et al.'s study (2016) was a direct replication of the original study by Carney et al. (2010), but also observed no significant effects.

All these studies focused on only power-related behavior and hormones. Yet, there is considerable evidence that power also impacts individuals' affiliative tendencies (Magee & Smith, 2013; Guinote, 2017). For instance, lack of power enhances motivation to connect with others (Lammers et al., 2012; Case, Conlon & Maner, 2015) and cues of low social status have positive effects on pro-social behavior (Guinote et al., 2015). Moreover, facing threats and stressful situations can enhance affiliative motivation and behavior (Schachter, 1959; Gump &

85   Kulik, 1997; Dezecache, Grèzes & Dahl, 2017), as bonding with others represents an efficient
86   coping strategy (Taylor, 2006; Dezecache, 2015). The display of constrictive and submissive
87   postures generally occurs in threatening situations and serves to appease aggressive
88   conspecifics by signaling friendly intentions (Schenkel, 1967; de Waal, 1986). Adopting
89   constrictive postures may thus be linked with affiliative tendencies. Progesterone is known to be
90   released together with cortisol in response to stress in general, but particularly social stress
91   (Wirth, 2011). It correlates with both naturally fluctuating (Schultheiss, Dargel & Rohde, 2003)
92   and experimentally induced affiliative motivation (Schultheiss, Wirth & Stanton, 2004; Wirth &
93   Schultheiss, 2006) and may promote social bonding as a coping behavior in response to stress
94   (Wirth, 2011). The question remains as to whether adopting constrictive postures would lead to
95   a change in salivary progesterone, thereby indicating an increase of affiliation motivation.
96
97   Although expansive and constrictive postures' effects on cortisol and testosterone were not
98   replicated, their effect on feelings of power and control, also originally reported by Carney et al.
99   (2010), has been confirmed by a meta-analysis (Gronau et al., 2017) of six pre-registered and
100 highly powered studies (Ronay et al., 2016; Bombari, Mast & Pulfrey, 2017; Jackson et al.,
101 2017; Keller, Johnson & Harder, 2017; Klaschinski, Schnabel & Schröder-Abé, 2017; Bailey,
102 LaFrance & Dovidio, 2017). On the basis of a p-curve analysis, Cuddy, Schultz and Fosse
103 (2018) further suggested that the literature existing prior to these pre-registered studies also
104 contains evidence for an effect on feelings of power. It should be noted that this analysis
105 confounded significant posture effects in opposite directions (Credé, 2018), and further included
106 several studies that did not satisfy the criteria for a robust and reproducible p-curve result
107 (Simonsohn, Nelson & Simmons, 2017). Nevertheless, and despite previous null-findings for
108 hormones, the evidence for posture effects on feelings of power and other emotional and
109 affective self-report measures in their p-curve analysis have led Cuddy et al. (2018) to call for
110 more studies on psychophysiological outcomes. Specifically, they suggest that future
111 experiments should apply more precise hormone methods or assess incremental effects of
112 adopting a posture several times. Davis et al. (2017) have also raised the question of whether
113 null-effects for hormones could be related to the timing and dose of the posture manipulation.
114 They speculated that larger doses of posture or collection of samples at different time points
115 after the posture could yield different outcomes. Indeed, adopting expansive postures for about
116 15 minutes throughout a stressful experience boosted the cortisol response to stress (Turan,
117 2015). This suggests that expansive postures are maladaptive in certain contexts, but also
118 illustrates that adopting postures for longer durations may induce hormonal changes.
119
120 Altogether, it appears that additional empirical evidence is necessary to reach final conclusions
121 about whether expansive and constrictive postures induce changes in testosterone or cortisol
122 levels at different time points than assessed previously or when adopted for longer durations. In
123 addition, it remains unexplored whether these postures affect hormonal correlates of affiliative
124 behavior, such as progesterone. In 2015, before the publication of the first non-replication of the
125 power posing effect on hormone levels (Ranehill et al., 2015), we conducted a study which we
126 believe can contribute to the ongoing discussion about whether expansive and constrictive
127 postures induce changes in testosterone or cortisol levels, and that additionally assessed
128 progesterone levels for the first time. It provides an answer to questions regarding the timing of

129   hormone measurements and the "dose" of posture recently raised by Cuddy et al. (2018) and
130   Davis et al. (2017). First, hormone levels were measured at longer time intervals after the start
131   of the posture manipulation than in previous studies. Second, incremental posture effects were
132   examined by having participants repeatedly adopt an expansive or constrictive standing posture
133   in between the blocks of a face categorization task. Additionally, participants were encouraged
134   to adopt a freely adaptable open or closed sitting posture throughout the task.
135
136   The study's design met the criteria which Carney et al.'s (2015) pointed out as potentially
137   necessary conditions for posture effects in their response to the first non-replication.
138   Specifically, the study's procedure included (1) a credible cover story, (2) instructions delivered
139   by an experimenter instead of a computer, (3) short time windows for adopting the postures in
140   order to avoid discomfort, and (4) a face categorization task resembling the social filler task in
141   the original study (Carney et al., 2010). The original social filler task consisted of forming
142   impressions of faces without providing a response, and is commonly interpreted as a "social
143   context" in the posture literature (Cesario & McDonald, 2013; Carney et al., 2015). Aiming for a
144   stronger emphasis on social aspects, we made faces task-relevant, having participants
145   categorize them according to their implicitly assigned minimal group membership. Knowing that
146   affective state and dominance-related personality traits can influence individuals' body posture
147   (Weisfeld & Beresford, 1982; Canales et al., 2010; Aviezer, Trope & Todorov, 2012), and may
148   therefore modulate hormonal responses to transiently adopted postures, we collected several
149   state and trait self-report measures to check for any potentially relevant differences between the
150   two posture groups, and control for these if necessary. In summary, the current study
151   investigated changes in salivary testosterone, cortisol and progesterone levels in response to a
152   repeated expansive or constrictive posture manipulation in the context of a face categorization
153   task.
154

Materials & Methods

Participants

157   Carney et al. (2010) reported effect-sizes of r=.34 for testosterone and r=.43 cortisol. We
158   performed a power-analysis in G-Power (Faul et al., 2007) based on the smaller one of these
159   two effect-sizes, i.e., r=.34. This yielded a minimal necessary sample of n=63 to achieve 80%
160   power to detect effects as large as those of Carney et al. (2010). These were the only available
161   effect sizes for posture effects on hormone levels when we conducted our study. Given inherent
162   biological differences in testosterone and progesterone production between men and women,
163   analyses of these hormones need to be done separately for each sex (Stanton, 2011).
164   Therefore, we included only male participants to achieve sufficient power with the maximum
165   sample size possible under our feasibility constraints.
166
167   We recruited a total of 82 male participants via a participant pool mailing list and student job
168   advertisement websites. Participants were between 17 and 32 years old, reported not to be
169   regular smokers or under medical treatment, and to not have a history of endocrine illness,
170   neurological and psychiatric disorders, or dependency to alcohol or other drugs. All participants

171   provided written informed consent and were paid for their participation. The experimental
172   protocol was approved by INSERM and licensed by the local research ethics committee (Comité
173   de protection des personnes Ile de France III - Project CO7-28, N° Eudract: 207-A01125-48)
174   and carried out in accordance with the Declaration of Helsinki.
175
176   It should be noted that our sample size was estimated with a power-analysis based on an effect
177   size (r=0.34), which is unrealistically large given the evidence acquired since 2010. Repeating
178   the same power analysis based on a more realistic estimate of r=0.10 (in line with the effect on
179   feelings of power, see Gronau et al., 2017) yields a much larger required sample size of 779.
180   Given that our sample size was much smaller, we conducted a sensitivity analysis to estimate
181   the smallest effect size we could detect with 80% power. This further allowed considering
182   specificities of our design, such as the three time points of saliva collection. The sensitivity
183   analysis in G*Power for a between (2 groups) by within (3 time points) interaction with 82
184   participants suggested that we had 80% power to detect effect sizes larger than partial eta-
185   squared = 0.06.
186

187   **Measures**

188   **Questionnaires**. For assessing potential differences between the posture groups, we
189   administered a collection of self-report questionnaires. Because power as opposed to lack of
190   power decreases anxiety and inhibition, increases confidence, self-esteem, and approach
191   motivation in general (Keltner, Gruenfeld & Anderson, 2003; Guinote, 2017), we included the
192   French version of the State-Trait Anxiety Inventory (STAI, Spielberger, 1983), the Rosenberg
193   Self-Esteem Scale (Vallières et Vallerand, 1990), and the BIS/BAS scales which assess the
194   behavioral activation and inhibition systems (Caci, Deschaux & Baylé, 2007). Participants
195   completed the trait measures prior to the testing session in the lab, but filled out the state
196   version of the STAI after arrival at the laboratory. In addition, questions regarding compliance
197   with behavioral restrictions before saliva collection and the dominance scale from the
198   International Personality Item Pool (Goldberg et al. 2006, scale representing the California
199   Psychological Inventory: http://ipip.ori.org/newCPIKey.htm#Dominance) were administered at
200   the end of the experiment to avoid raising suspicion about the real purpose of the posture
201   manipulation.
202

203   **Saliva collection.** We collected three saliva samples (1ml each) per participant using small
204   tubes and stored them below -20°C immediately after collection. After completion of the study
205   (duration: 51 days), they were packed in dry ice and shipped to the laboratory of Clemens
206   Kirschbaum in Dresden, where they were analyzed with commercially available
207   chemiluminescence immunoassays with high sensitivity (IBL International, Hamburg, Germany).
208   For a more detailed description of the assay methods used by this laboratory, see for example
209   Ronay et al. (2016). To exclude the possible influence of external factors on hormone levels,
210   participants were requested to refrain from drinking alcohol and exercising intensively within 24
211   hours before the session, from smoking or taking medical drugs on the testing day, and from
212   eating, drinking anything except water, and tooth brushing 1.5 hours before the session. The

213 debriefing questionnaire after the experiment showed that they largely complied with these
214 instructions (5 exceptions for alcohol, 2 for smoking).
215

216 **Procedure**

217 All testing sessions took place between 13h and 19h to attenuate effects of diurnal variation of
218 hormone levels. Saliva samples were collected as part of another study (Metzler, 2018, see
219 Study 1 in Chapter 6) during which participants had to categorize faces into in- and outgroup
220 members while repeatedly adopting postures between task blocks. Figure 1A and B depict the
221 time course of postures, saliva samples and interleaved blocks of the face categorization task.
222

223 Upon arrival, participants signed consent forms and completed the STAI state questionnaire.
224 Following the example of a previous study (Ratner et al., 2014), we implicitly assigned
225 participants to one of two arbitrary groups using a traditional minimal group procedure (Tajfel,
226 1970). Participants' task was to choose either their in- or outgroup members from pairs of faces
227 based on their first impression. This setting provided a credible cover story, namely that the
228 saliva samples were collected to assess associations between face categorization and
229 physiological indices. The cover story for the postures was that a second, unrelated project on
230 the impact of body posture on heart rate was conducted simultaneously. Participants would
231 adopt the posture three times for 2 min each time in between the blocks of the face
232 categorization task. This supposedly served to acquire heart-rate data for a total of 6 min while
233 avoiding discomfort from holding the same posture for too long, and offered breaks during the
234 visually demanding task. At this point of the instructions, approximately 15 min after arrival,
235 participants provided a first saliva sample.
236

237 Thereafter, the female experimenter determined the posture condition using a randomizing
238 function and provided corresponding instructions for either the expansive (n=42) or the
239 constrictive (n=40) posture. Up to the point where posture instructions were provided, i.e., at the
240 end of all other procedures, the experimenter was blind to participant's posture in order to
241 minimize possible experimenter biases. She first placed electrodes on participant's wrists and
242 hooked them up to the acquisition system, and demonstratively turned it on. Next, she verbally
243 provided instructions on how to place each body part without demonstrating the posture herself.
244 The expansive and constrictive posture involved open or closed limbs, erect or slumped upper
245 body and straight or downward head tilt, respectively (see Fig. 2). The experimenter informed
246 participants that she would check whether they correctly adopted this standing posture each
247 time via a camera. Depending on the participant's posture condition, she finally instructed
248 participants to (1) sit upright with feet apart or (2) keep back and shoulders slumped and legs
249 parallel or crossed during the task as far as comfortable for them, which supposedly served to
250 "stabilize" the effect of postures on heart rate. This short instruction for the sitting posture was
251 repeated on screen at the beginning of each task block. Although allowing participants to freely
252 adjust their posture for their own comfort during the task constitutes a less controlled posture
253 manipulation, it ensures higher ecological validity, as it corresponds to what we typically do in
254 everyday life. Together, the repeated 2 minute periods in which participants adopted one of two
255 standing postures, together with the encouragement of a similar, but freely adaptable sitting

256 position during the face categorization task, added up to a "larger dose" of posture while
257 avoiding discomfort. Participants were alone while they adopted the postures and performed the
258 task. The experimenter only briefly re-entered the room for the collection of two more saliva
259 samples.
260
261 In total, participants thus adopted the standing posture three times, i.e., before task block 1, 3
262 and 5. Saliva samples were collected before the first posture and block and after block 4 and 6.
263 Participants had thus adopted the posture twice before sample 2, and three times before
264 sample 3. Median block duration was 4.58 minutes (interquartile range [3.46-6.25]) depending
265 on participants' speed in the face categorization task. This resulted in collection of saliva
266 samples 2 and 3 approximately 23 and 36 minutes after the first posture, respectively, although
267 the exact timing varied between participants (min. 14 minutes, max. 50). This corresponds to
268 collection of samples 2 and 3 approximately 11 and 24 minutes after the second posture,
269 respectively, and collection of sample 3 approximately 10 minutes after the third posture.
270
271 At the end of the experiment, participants were carefully debriefed regarding suspicions about
272 the postures. None of them had suspected a link between the posture manipulation and the
273 saliva samples and only one participant raised doubts about our interest in a posture effect on
274 heart-rate. Excluding him from analyses did not affect the results.
275

Data analysis

277 Outliers were determined per time point and hormone using a conservative threshold of three
278 times the absolute deviation from the median (Leys et al., 2013), given that mean ± SD rules are
279 problematic for endocrine data which are rarely normally distributed (Pollet & Meij, 2017).
280 First, we excluded one participant from all time points and hormones due to extreme
281 progesterone values (around 1500pg/ml, outside of normal range even for women, see Liening
282 et al., 2010), clearly indicating a problem with his salivary samples. Within the remaining sample
283 of 81 participants (age 21.36 ± 2.78, expansive n=41, constrictive n=40), there were six outliers
284 above the median plus three absolute deviations for cortisol, seven for testosterone and nine for
285 progesterone. Results calculated without outliers did not differ from results with the full sample
286 (see Supplementary Table S1), i.e., the same effects yielded significant or non-significant p-
287 values with and without outlier exclusion.
288
289 All hormone levels were log-transformed to correct for right-skewed distributions and subjected
290 to a mixed-effects ANOVA with posture (expansive, constrictive) as a between-subject and time
291 (T1, T2, T3) as a within-subject factor. Even when the time*posture interaction was not
292 significant, we performed between-posture t-tests on the change T1-T2 or T2-T3, to allow for
293 comparison with previous studies with only two time points. As partial eta-squared differs
294 between within- and between-subject designs, we additionally report generalized eta-squared
295 as an effect-size. The latter allows for comparison between different designs, as it includes
296 within-subject variance, and excludes variance due to other factors in the design (Lakens,
297 2013). All analysis were done in R (R Core Team, 2018) using the packages ez, psych,
298 latticeExtra, ggplot2 and dplyr (Wickham, 2009; Lawrence, 2016; Sarkar & Andrews, 2016;

299   Revelle, 2017; Wickham et al., 2017). Data and analysis scripts are available at
300   https://osf.io/3nrsy/.

Results

302   All hormone levels are reported in pg/ml. Descriptive statistics for raw levels of cortisol,
303   testosterone and progesterone separated per posture and time point, including confidence
304   intervals, are presented in Table 1. The results are depicted in Fig. 3. Confidence intervals
305   reported with t-tests, which were all done on log-transformed data, are log-transformed values.

Cortisol

307   Cortisol levels similarly decreased over time (F(2,148)=79.40, p<.001, η^2_p = 0.51, η^2_G= 0.16) in
308   both posture groups (time*posture: F(2,148)=1.17, p=.313, η^2_p = 0.02, η^2_G= 0.00), in the
309   absence of any overall difference between the groups (F(1,74)=0.32, p=.576, η^2_p = 0.00, η^2_G=
310   0.00). Both the decrease from T1 to T2, i.e., from before the first posture to after adopting the
311   posture twice, and the decrease from T2 to T3, i.e., from after the first two postures to after the
312   third posture, were significant (T1-T2: t(75)=-10.67, p<.001, d_z=-1.22, 95% CI [-0.48, -0.33]), T2-
313   T3: t(75)=-3.78, p<.001, d_z=-.43, 95% CI [-0.24, -0.07]). The changes T1-T2 and T2-T3 were not
314   significantly different between postures (see Table 2). Cortisol baseline levels at T1 did not
315   significantly differ between postures t(74)=0.95, p = 0.346, d=0.11, [-0.14, 0.40]).

Testosterone

317   Levels of testosterone also decreased throughout the experiment (F(2,146)=19.76, p<.001, η^2_p =
318   0.21, η^2_G= 0.03) with no different changes as a function of posture (time*posture: F(2,146)=
319   1.09, p=.340, η^2_p = 0.01, η^2_G= 0.00), and no main effect of posture (F(1,73)=0.13, p=.721, η^2_p =
320   0.00, η^2_G= 0.00). The decrease over time was significant from the first to the second (t(74)=-
321   3.53, p=.001, d_z=-.41, 95% CI [-0.15, -0.04]), as well as the second to the third time point
322   (t(74)=-3.19, p=.002, d_z=-.37, 95% CI [-0.11, -0.03]). Again, the decrease was similar in both
323   posture groups (see Table 2). Testosterone baseline levels did not differ significantly between
324   the groups (t(73)=0.83, p=0.411, d=-0.10, [-0.27 0.11]).

Progesterone

326   As with the two other hormones, progesterone levels declined over time (F(2,142)=33.07,
327   p<.001, η^2_p = 0.32, η^2_G= 0.06) in the same manner in both posture groups (time*posture:
328   F(2,142)=0.04, p=.965, η^2_p = 0.00, η^2_G= 0.00). There was no general difference between the two
329   postures (F(1,71)=2.52, p=.117, η^2_p = 0.00, η^2_G= 0.03). Declines between both pairs of time
330   points were significant (T1-T2: t(72)=-4.63, p<.001, d_z=-.54, 95% CI [-0.31, -0.12]; T2-T3: t(72)=-
331   3.92, p<.001, d_z=-.46, 95% CI [-0.21, -0.07]). As for the other hormones, this decrease was not
332   different between posture groups (see Table 2). Progesterone baseline levels were not
333   significantly different between the two postures (t(71)= 1.52, p = 0.132, d=0.18, 95% CI [-0.06,
334   0.48]).
335

Self-report questionnaires

Participants from the two posture groups did not rate themselves as significantly different on self-esteem (t(77)= -0.73, p=.469, d=-0.08, 95% CI [-2.89, 1.34]), trait anxiety (t(77)=0.02, p=.99, d=0.00, 95% CI [-3.82, 3.88]), behavioral activation (t(77)=-0.15, p=.88, d=-0.02, 95% CI [-2.06, 1.77]), and inhibition (t(77)=0.58, p=.562, d=0.07, 95% CI [-1.05, 1.92]) prior to the testing day, nor on state anxiety at the beginning (t(79)=0.40, p=.689, d=0.045, 95% CI [-2.68, 4.04]) or trait dominance at the end of the experiment (t(79)=-0.90, p=.372, d=-0.10, 95% CI [-3.37, 1.28]).

Discussion

The present experiment investigated whether adopting expansive and constrictive postures, associated with high and low social power, respectively, impacts salivary levels of hormones related to power, stress and affiliation. Prior to our study, only one out of five studies had observed significant posture effects on testosterone and cortisol, and none had investigated effects on progesterone. Several factors had been raised as explanations for why initial findings of Carney et al. (2010) for testosterone and cortisol did not replicate. Our design met most of the conditions which Carney et al. (2015) suspected to be necessary for observing postural feedback effects: first, we assessed postural effects on hormones during a face categorization experiment, second, we used a cover story, third, the instructions were given by an experimenter, and fourth, participants adopted postures for maximum two minutes at a time. Moreover, following up on hypotheses raised by Cuddy et al. (2018) and Davis et al. (2017), we investigated the possibility that repeatedly holding postures over time (i.e., larger doses of posture) and/or assessing hormonal responses at longer time intervals than previous studies would induce hormonal changes.

Under these specific experimental conditions, neither testosterone and cortisol levels linked to dominance behaviors and stress reactions, nor progesterone levels related to affiliative tendencies, changed from before to after adopting expansive or constrictive postures. Salivary levels of testosterone, cortisol and progesterone declined from baseline to two later post-posture samples, and did so similarly in the expansive and constrictive posture group. The first post-posture sample captured the potential incremental effect of adopting a posture twice, at approximately 23 and 11 minutes before sample collection. The second post-posture sample reflected the effect of adopting the same posture three times, at approximately 36, 24, and 10 minutes before sample collection.

Akin to four previous studies using a single posture manipulation (Ranehill et al., 2015; Ronay et al., 2016; Smith & Apicella, 2017; Davis et al., 2017), we did not replicate the effects reported by Carney et al. (2010). Our results add to a growing body of evidence that does not support an effect of postures on testosterone and cortisol levels. They demonstrate that even adoption of expansive and constrictive postures, for repeated but short periods of time to avoid discomfort, in between the blocks of a social task, and after providing a credible cover story, does not trigger significant hormonal changes. Thus, all the experimental characteristics listed by Carney et al. (2015) as possible reasons for null-results in Ranehill et al.'s replication (2015) were

378   respected in the present study. An insufficient dose of posture as well as the collection of
379   hormone samples at inappropriate time points after the posture manipulation (see Davis et al.,
380   2017) therefore seem unlikely explanations for previous non-replications. The time points at
381   which we collected saliva samples after onset of the first posture fell into the time window (20 to
382   40 minutes) in which experimentally induced cortisol responses are strongest (Dickerson &
383   Kemeny, 2004). Testosterone and progesterone responses to arousal of power and affiliation
384   motives have been observed in a similar time window (e.g., Schultheiss, Wirth & Stanton, 2004;
385   Seidel et al., 2013). Still, our study does not support the conclusion that power postures elicit
386   physiological changes associated with the experience of power and stress or the need for
387   affiliation (Mehta & Josephs, 2011; Wirth, 2011; Schultheiss, 2013).
388
389   Three methodological differences with previous studies merit a more detailed discussion: First,
390   we collected three samples in total in contrast to two in all previous studies, both with a longer
391   delay after the onset of the first posture manipulation. This procedure revealed a decline from
392   the first to the last time point for all three hormones. This decline may either simply reflect the
393   diurnal pattern of these hormones (Faiman & Winter, 1971; Delfs et al., 1994; Brambilla et al.,
394   2009; Liening et al., 2010), and/or a reduction in arousal from the start to the end of the
395   experiment as far as cortisol is concerned. Second, we examined an exclusively male sample,
396   whereas previous studies included mostly women (with the exception of Smith & Apicella,
397   2016). If anything, this reduced variation of our dependent variables and should hence have
398   facilitated the detection of posture effects. Moreover, in the initial study (Carney et al., 2010) and
399   one of its replications (Ranehill et al., 2015), effects on testosterone and feelings of power were
400   stronger in men than in women (see Credé & Phillips, 2017). Nevertheless, we did not observe
401   any effect in an exclusively male sample. Third, and this is a first potential limitation of our study,
402   hormone samples were not collected at exactly the same time points for all participants as in
403   previous studies, but after participants had finished a fixed number of blocks from the face
404   categorization task at their own speed. Yet, the distribution of sampling time points was very
405   similar in both posture groups and all samples were collected in a time window in which
406   hormonal responses generally occur (Dickerson & Kemeny, 2004; Schultheiss et al., 2012). A
407   second limitation is that we cannot assess whether adopting the postures was a successful
408   power manipulation, as our study did not include any behavioral measures related to power. A
409   final limitation concerns the size of potential posture effects on hormone levels we could detect
410   with our sample size: all effects observed in our study were smaller than the minimal effect size
411   of η^2_p =0.06 which we could have detected with 80% power. Therefore, our sample size is too
412   small to draw any conclusions regarding potentially existing effects below this threshold.

Conclusions

414   The current study assessed whether repeatedly adopting expansive and constrictive postures
415   known as power postures induces endocrine responses that resemble the hormonal correlates
416   of dominance and affiliative behavior. In doing so, it assessed whether larger doses of posture
417   or collection of saliva samples at longer time intervals than previous studies would produce
418   similar effects on testosterone and cortisol as the study by Carney et al. (2010) in contrast to
419   previous non-replications. Second, it investigated for the first time whether adopting postures

420 elicits changes in progesterone levels, a hormone that seems to be associated with affiliative
421 motives. Participants adopted an expansive or constrictive posture three times for two minutes
422 each, in between the blocks of a face categorization task. Salivary testosterone, cortisol and
423 progesterone levels did not differ between posture groups within a time window of 14 to 50
424 minutes from the beginning of the first posture. Together with results from four previous non-
425 replications, our study thus makes it seem more unlikely that short-term manipulations of
426 postural expansiveness or constrictiveness elicit changes of testosterone or cortisol levels, even
427 when postures are adopted repeatedly in the context of a social task. Additionally, our results do
428 not provide evidence for an effect of power postures on progesterone levels. Although effects on
429 other outcome variables described as promising by Cuddy et al. (2018) might be reproducible,
430 the total available evidence in favor of an effect on hormones is thus currently very weak.

431

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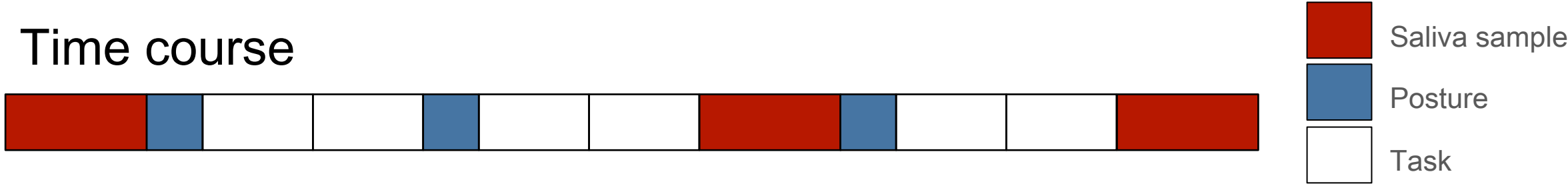
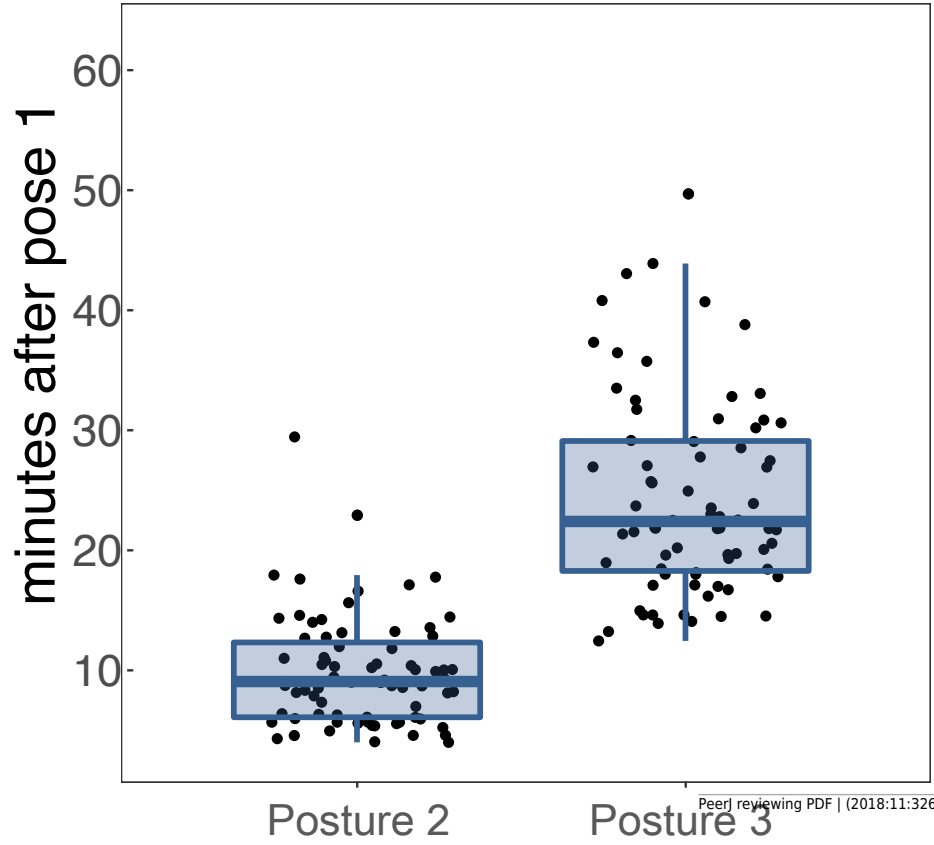
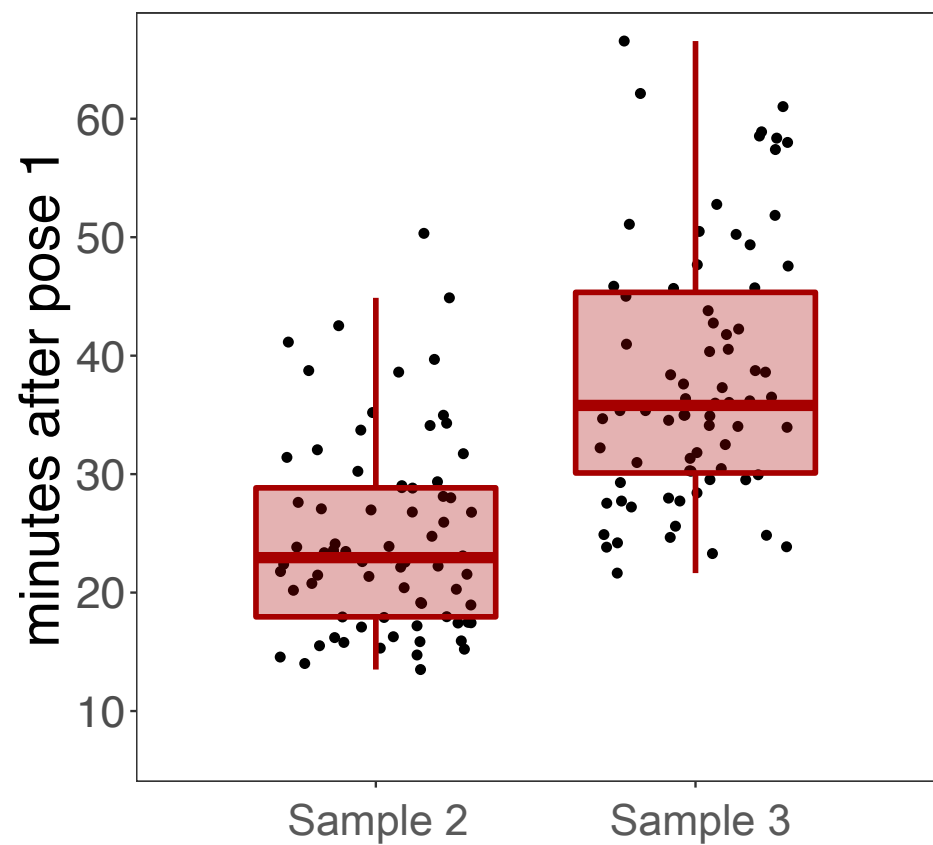
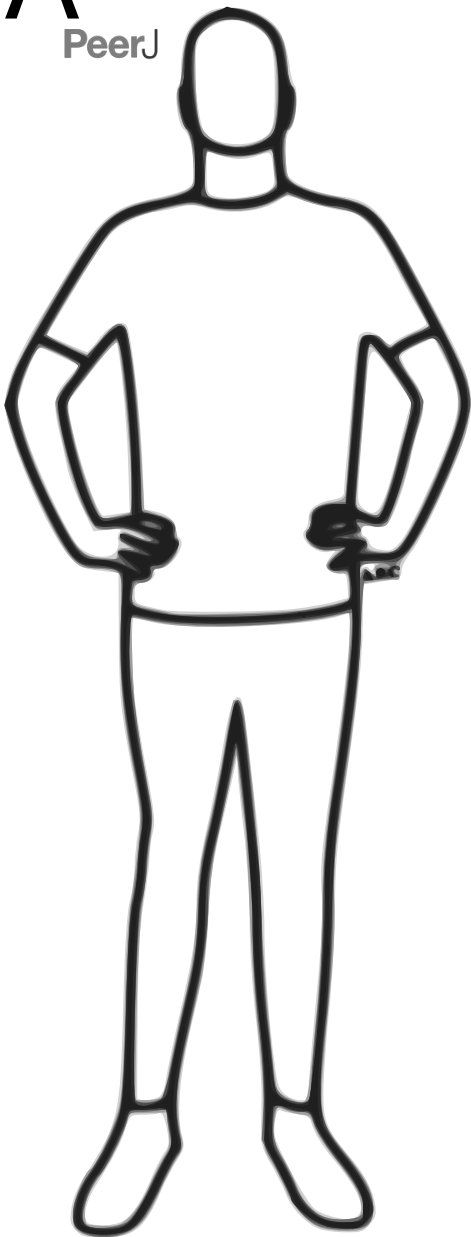
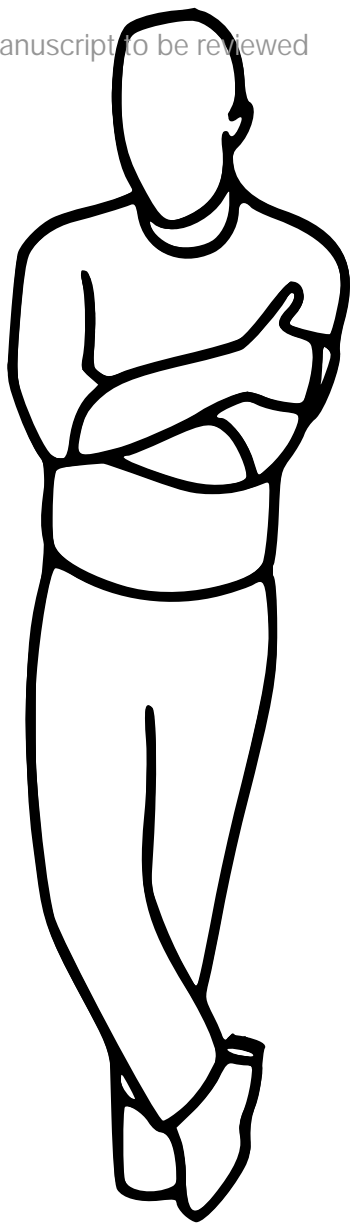
607

Time course of the experiment and adopted body postures.

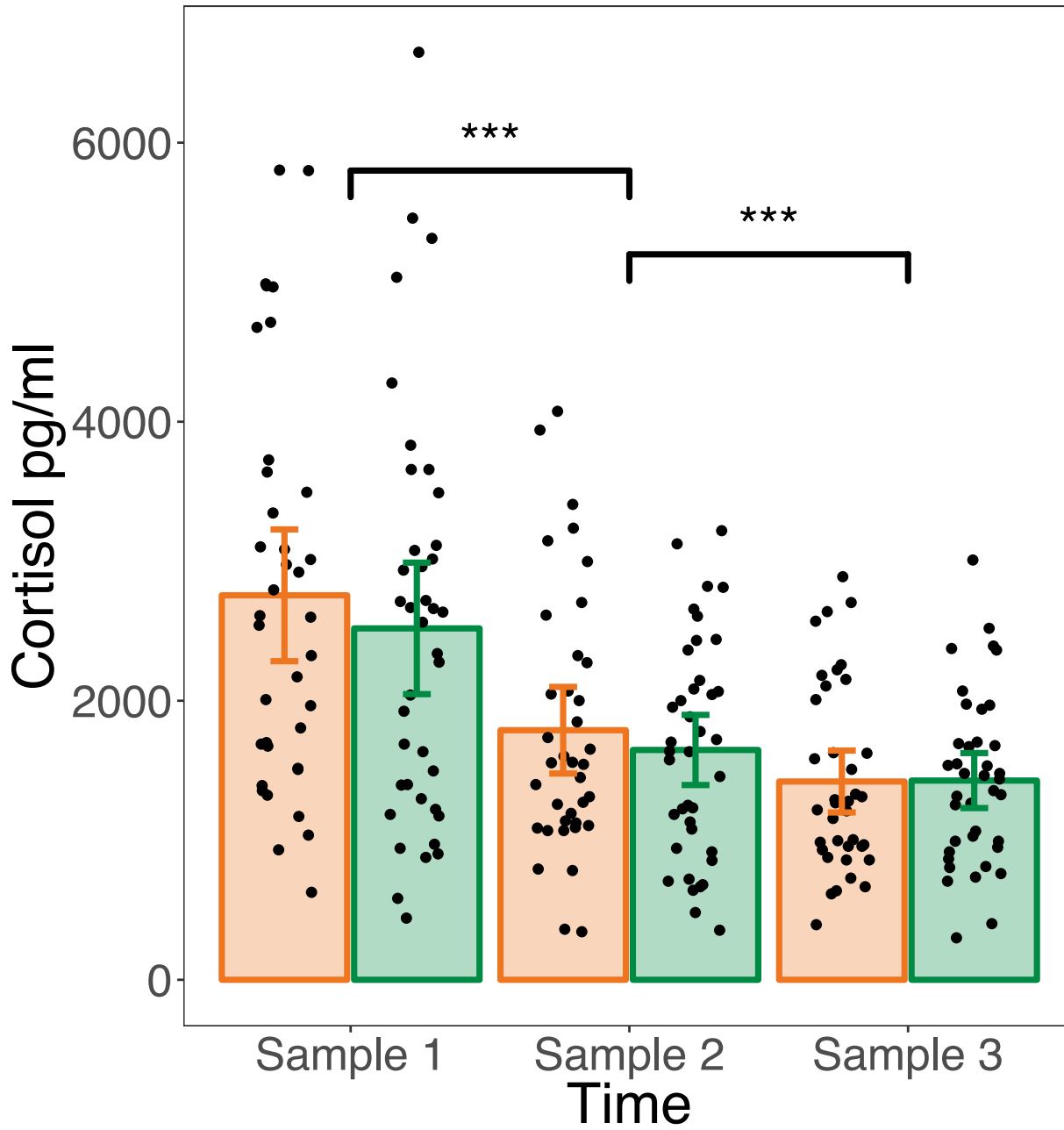
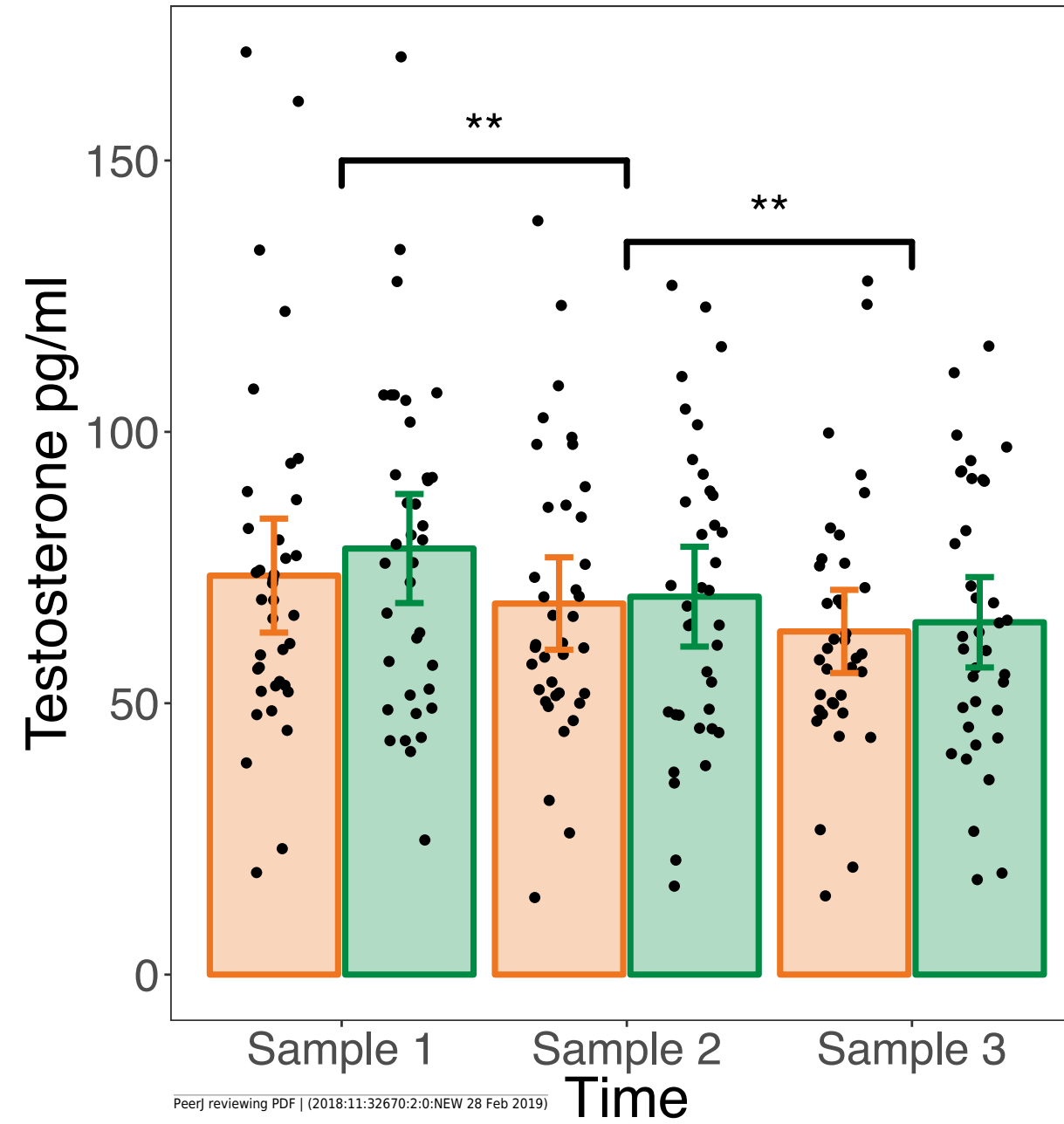
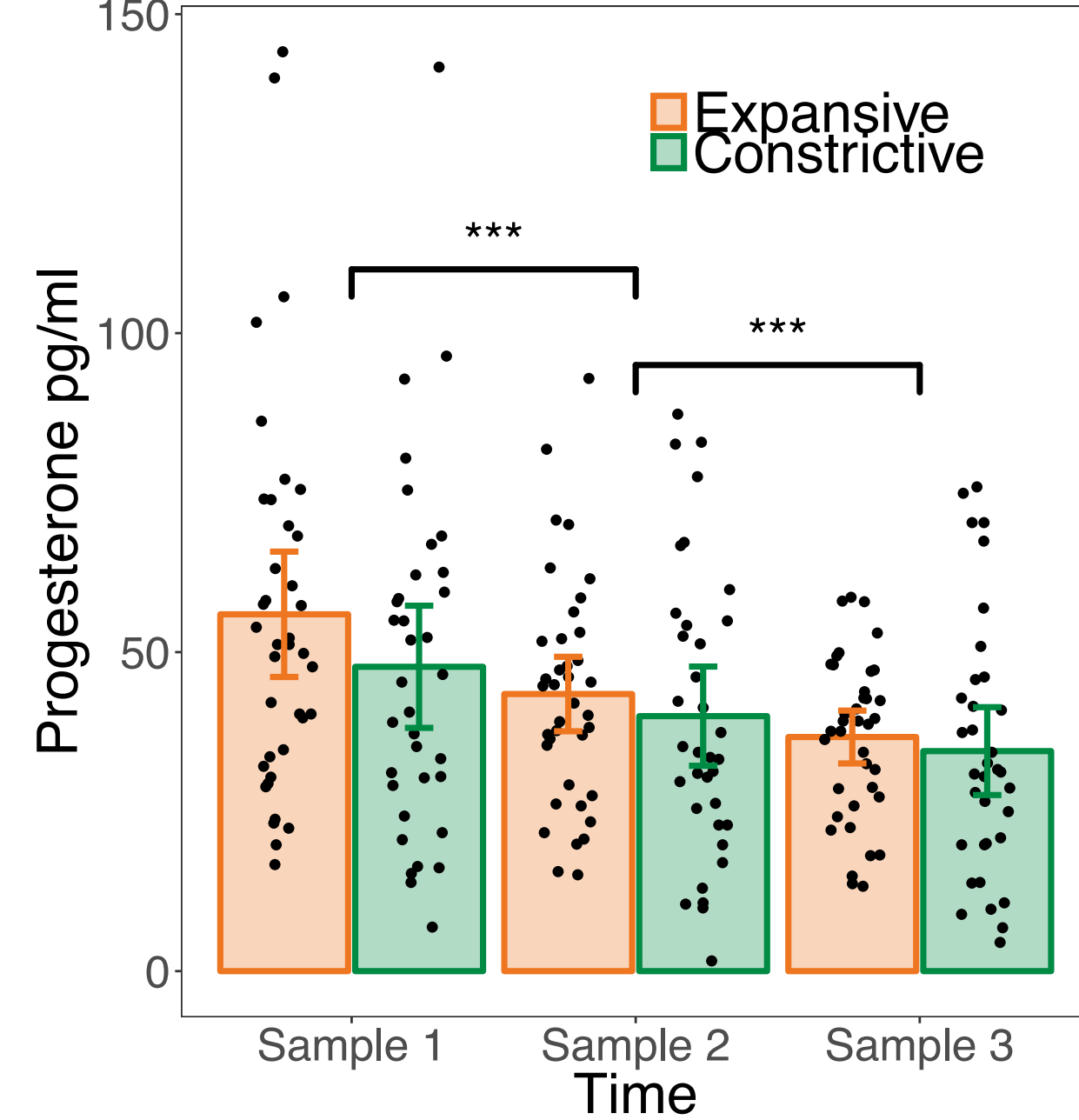
A) Time course of postures, saliva sample and task blocks. Participants adopted the same posture 3 times, before every other block of a face categorization task. Before the first posture, and after block 4 and 6, they provided a saliva sample. **B)** Time from the beginning of posture 1 to posture 2 and 3. **C)** Time from the beginning of posture 1 to saliva sample 2 and 3.

Adopted postures

Postures adopted by the two experimental groups. **A)** Expansive posture. **B)** Constrictive posture. Images created by Antoine Balouka-Chadwick.

A

B

Expansive

Constrictive

Changes in hormone levels from before to after the posture manipulation.

Means, between-subject confidence intervals and individual data points for raw values of all hormone samples (C) in pg/ml. Sample 1 was collected before the first posture. Sample 2 and 3 reflect the effect of adopting the same posture two and three times, respectively. Asterisks indicate significance in t-tests between time points at *** = $p<.001$ and ** $p<.01$. **A)** Cortisol. **B)** Testosterone. **C)** Progesterone.

Descriptive statistics for raw values of cortisol, testosterone and progesterone in samples without outliers.

Confidence intervals are between-subject to allow for between-posture comparisons.

	Posture	N	Sample	Mean	Median	SD	95% CI	
Cortisol pg/ml	Expansive	37	1	2755.88	2599.13	1416.89	2299.33	3212.44
			2	1788.89	1555.13	930.94	1488.92	2088.86
			3	1421.20	1268.75	665.40	1206.79	1635.60
	Constrictive	39	1	2518.72	2562.88	1453.86	2062.43	2975.02
			2	1647.33	1638.50	775.28	1404.01	1890.65
			3	1428.06	1439.13	608.28	1237.16	1618.97
Testosterone pg/ml	Expansive	38	1	73.52	69.05	31.96	63.35	83.68
			2	68.37	60.95	25.90	60.13	76.60
			3	63.23	59.60	23.32	55.81	70.64
	Constrictive	37	1	78.51	79.30	30.14	68.79	88.22
			2	69.64	67.90	27.59	60.74	78.53
			3	64.92	62.30	24.97	56.87	72.96
Progesterone pg/ml	Expansive	38	1	55.93	51.20	29.89	46.42	65.43
			2	43.43	43.35	17.76	37.79	49.08
			3	36.69	38.95	12.59	32.69	40.70
	Constrictive	35	1	47.70	45.30	27.87	38.47	56.94
			2	39.97	34.30	22.63	32.47	47.46
			3	34.49	31.20	20.05	27.84	41.13

T-tests and confidence intervals for hormone differences between time points in samples without outliers

T-tests were performed on log-transformed values. Confidence intervals are between-subject to allow for between-posture comparisons.

	t	df	p	d_z	95% CI Expansive		95% CI Constrictive	
Cortisol T2-T1	-0.73	74	0.470	-0.08	-0.54	-0.33	-0.48	-0.27
Cortisol T3-T2	-1.02	74	0.310	-0.12	-0.32	-0.07	-0.22	-0.01
Testosterone T2-T1	1.32	73	0.190	0.15	-0.14	0.02	-0.21	-0.06
Testosterone T3-T2	-0.21	73	0.840	-0.02	-0.13	-0.02	-0.13	0.00
Progesterone T2-T1	0.10	71	0.920	0.01	-0.32	-0.10	-0.37	-0.07
Progesterone T3-T2	-0.32	71	0.750	-0.04	-0.24	-0.06	-0.24	-0.02