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Peer Presence Increases Session Ratings of Perceived Exertion.

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3 exertion
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1 **Abstract**

2 **Purpose:** This study aimed to examine the effect of peer
3 presence on the session rating of perceived exertion (RPE)
4 responses. **Method:** Fourteen males, with mean (standard
5 deviation) age 22.4 (3.9) years, peak oxygen uptake 48.0 (6.6)
6 mL·kg⁻¹·min⁻¹ and peak power output 330 (44) W, completed an
7 incremental cycling test and three identical experimental
8 sessions, in groups of four or five. Experimental sessions
9 involved 24 min of cycling, whereby the work rate alternated
10 between 40% and 70% peak power output every 3 min. During
11 cycling, heart rate was collected every 3 min, and session-RPE
12 was recorded 10 min after cycling, in three communication
13 contexts: in written form unaccompanied (intrapersonal
14 communication); verbally by the researcher only (interpersonal
15 communication); and in the presence of the training group.
16 Session-RPE was analysed using ordinal regression and heart
17 rate using a linear mixed-effects model, with models fit in a
18 Bayesian framework. **Results:** Session-RPE was voted higher
19 when collected in the group's presence compared to when
20 written (odds ratio = 4.26, 95% credible interval = 1.27 to 14.73).
21 On average, the posterior probability that session-RPE was
22 higher in the group setting than when written was 0.53. Session-
23 RPE was not different between the group and verbal, or verbal
24 and written collection contexts. **Conclusions:** This study
25 suggests contextual psychosocial inputs influence session-RPE,
26 and highlights the importance of session-RPE users controlling
27 the measurement environment when collecting votes.

28
29 **Keywords:** Effort, exercise, load, monitoring, training load, bias
30

31 **Introduction**

32 Quantifying training load using the session rating of
33 perceived exertion (RPE) method¹ has been widely adopted as a
34 simple approach to understanding the effects of training load on
35 athlete fitness, performance and fatigue.²⁻⁴ Many internal (e.g.,
36 heart rate, HR), external (e.g., Global Positioning System and
37 accelerometers) and indices (e.g., training impulse) of training
38 load exist.⁵ However, the ease (i.e., Training load = RPE x time
39 (min)), low cost and capacity of the session-RPE based approach
40 to accommodate differing exercise modes has seen widespread
41 uptake of the instrument.⁶

42 Although session-RPE has been correlated with
43 objective physiological measures of training load, including
44 variables of HR, oxygen uptake and lactate,⁷ other influencing
45 factors might explain measurement variation. It has long been
46 evidenced that momentary RPE should be interpreted as the
47 integration of physiological, psychological and experiential
48 influences.⁸ For example, anxiety, somatic perception,
49 depression and neuroticism directly correlate with momentary
50 RPE, while interestingly, inversely correlated with

51 extroversion.⁸ Further evidencing psychological contribution,
52 the dissociative attentional effects of music and video can reduce
53 momentary RPE scores during high-intensity exercise.⁹
54 Understanding of the collective psychophysiological construct
55 represented in the momentary RPE, and likely session-RPE
56 training load measurement, are important considerations when
57 reviewing the response to a given training impulse. Appreciation
58 for the influences on the measure outside of the prescribed
59 training also highlights the need for vigilance in standardising
60 session-RPE collection to ensure data quality and targeted
61 constructs.

62 Despite the popularity of the session-RPE approach to
63 training load measurement, methodological reports relating to
64 best practice collection are lacking. The timing used to recall
65 session-RPE appears to have little effect.^{10,11} However, to the
66 authors' knowledge, the influence of the administration mode is
67 relatively unknown. Methods of session-RPE measurement
68 standardisation (e.g., questioner, face-to-face, electronic,
69 anchoring, and privacy) are sporadically reported, and rarely, in
70 full. Such variables can introduce bias that greatly affects data
71 quality.¹² Risk of these biases may be highest in team sports like
72 rugby union, where 89% of coaches surveyed collected session-
73 RPE scores verbally,¹³ risking introducing effects of peer
74 influence.

75 Peer presence is known to have ranging effects on health
76 and social decision making.¹⁴ Further, socio-environmental cues
77 may affect exercise and sports performance,^{15,16} potentially by
78 altering self-confidence¹⁷ and physical discomfort associated
79 with fatigue.¹⁸ Accordingly, it could be reasoned that the
80 company of others in a competitive team environment would
81 adjust session-RPE scores in a socially desirable way.¹³ This
82 study aimed to examine the effect of peer presence on session-
83 RPE responses. It was hypothesised that participants would rate
84 session-RPE higher in the presence of an audience than when
85 collected by a researcher, or via intra-personal communication,
86 in written form.

87

88 **Methods**

89 Participants

90 A convenience sample of 14 adult males volunteered for
91 the study. Participants were considered recreationally trained,¹⁹
92 consistently partaking in team and/or individual sport training
93 and competition three or more times each week in the prior six
94 months. Their mean (standard deviation, SD) demographic and
95 fitness characteristics were: age 22.4 (3.9) years; height 180 (5)
96 cm; nude body mass 79.7 (9.4) kg; peak oxygen uptake ($\dot{V}O_{2peak}$)
97 48.0 (6.6) mL·kg⁻¹·min⁻¹; peak power output 330 (44) W;
98 maximal HR 183 (9) b·min⁻¹. Participants were undergraduate
99 exercise science students and completed cycling activity as a part
100 of their training/cross-training activities. They were non-

101 smokers and free of any injury and illness (Exercise and Sports
102 Science Australia adult pre-exercise screening tool). Ethical
103 approval was granted by the University Human Research Ethics
104 Committee (#51165). After the experimental procedures and
105 associated risks were explained, all participants provided written
106 informed consent.

107 Procedures

108 Participants visited the laboratory on four separate days.
109 The first visit involved familiarisation to the study procedures,
110 including perceptual scales, and an incremental cycling test. The
111 session-RPE scale was discussed with participants, and recall
112 anchoring was performed.²⁰ The session-RPE scale ranges from
113 0 'Rest' to 10 'Maximal', increments of 1, with descriptors
114 assigned to most ratings: 1 'Very, Very, Easy', 2 'Easy', 3
115 'Moderate', 4 'Somewhat Hard', 5 'Hard' and 7 'Very Hard'.¹
116 As recommended,¹ participants were asked '*how was your*
117 *workout?*'. This wording (verbal and written formats) was
118 standardised across all conditions. Visits 2–4 comprised of three
119 identical experimental cycling trials. Ten min after cycling,¹⁰
120 session-RPE votes were collected, in three communication
121 contexts, with session-RPE recorded: via intrapersonal
122 communication, unaccompanied in written form (written); via
123 interpersonal communication, verbally to the researcher only
124 (verbal); and via verbal interpersonal communication in the
125 presence of the training group (group). These conditions were
126 completed in a random, cross-over manner. The block
127 randomisation sequence was computer-generated (Microsoft
128 Excel, Redmond, USA). Each experimental session was
129 conducted in groups of at least three, but no more than five
130 participants.

131 Participants were blinded from the research question to
132 minimise the potential for bias in session-RPE responses.
133 Instead, participants were informed that the study aimed to
134 examine the effects of a new line of sports drinks on responses
135 to the cycling task. The true study aim was disclosed after all
136 data collection. Fluid consumption and fan cooling were
137 restricted during exercise. Participants were asked to avoid
138 caffeine, alcohol and strenuous activity in the 24 hours before
139 testing. Adherence to these requests was visually assessed via
140 the inspection of diet and physical activity diaries. Experimental
141 cycling trials were separated by four or five days.

142 During the initial visit, participants completed an
143 incremental cycling test to determine their $\dot{V}O_{2peak}$, PPO and
144 maximal HR. The test commenced at 50 W, increasing by 25
145 $W \cdot min^{-1}$ until voluntary exhaustion (Excalibur Sport; Lode,
146 Groningen, Netherlands). Expired gas and flow volumes were
147 collected during the test and were analysed by a calibrated
148 metabolic cart (TrueOne 2400, ParvoMedics, Salt Lake City,
149 USA). Values were taken as the average of the two highest
150 consecutive 15-second epochs. Peak power output was

151 considered the value achieved during the final minute before
152 volitional exhaustion. The peak power output value used to
153 calculate the exercise intensity of intervals (i.e., 40% and 70%
154 peak power output) during the cycling trials.

155 Cycling trials were completed in groups of four or five
156 participants, at a matched time of day (± 2 hours), in laboratory
157 conditions [24.2 (0.5) °C, 62 (7) % relative humidity]. In line
158 with the deceptive study aim, 20 min before cycling, each
159 individual consumed 400 mL of an unidentified sports drink
160 solution (Gatorade, Chicago, USA) from an opaque, brand-free
161 drink bottle. The exercise protocol involved 24 min of cycling
162 intervals, whereby the work rate alternated between 40% and
163 70% peak power output every 3 min. During trials, the cycle
164 ergometer (Keiser M3, Keiser Corporation, Fresno, USA),
165 including settings, remained consistent within a participant, with
166 self-selected gearing identified during the familiarisation
167 session.

168 The Daily Analyses of Life-Demands for Athletes
169 (DALDA) questionnaire was completed on arrival for testing
170 days.²¹ Responses for the ‘Symptoms of stress’ section were
171 summed (i.e., a = 1, b = 2, c = 3).²¹ Higher scores indicate fewer
172 symptoms. A mid-stream urine sample was collected on arrival
173 to assess hydration via specific gravity (PAL-10S, Atago Co.
174 Ltd., Tokyo, Japan).²² Nude body mass (WB-110AZ; Tanita
175 Corp., Tokyo, Japan) was recorded before cycling. Standard
176 athletic clothing was worn during trials (i.e., t-shirt, shorts, and
177 running shoes). A HR monitor chest strap and wrist-watch
178 receiver (F1, Polar, Electro-oy, Kempele, Finland) were fitted
179 before cycling, with HR recorded at baseline (i.e., 0 min) and
180 every 3 min throughout cycling. Capillary blood lactate samples
181 were drawn from the finger before and within 1 min after cycling
182 (Lactate Scout; SensLab GmbH, Leipzig, Germany). Finally, 10
183 min after cycling,¹⁰ a session-RPE was collected in the
184 prescribed communication format.

185 Statistical analysis

186 All analyses were performed in R (version 3.4.0). Models
187 were fit in a Bayesian framework, using Stan²³ with the *brms*
188 interface.²⁴ Missing data were visually inspected, with data
189 assumed missing at random (Supplement 1).²⁵

190 Session-RPE was analysed using ordinal regression. The
191 model included *Condition* and *Trial Order* as a fixed factors, and
192 *DALDA Symptoms of Stress* scores and the absolute *Change in*
193 *Lactate* (i.e., $\Delta_i = \text{post}_i - \text{pre}_i$) as standardised covariates (mean
194 = 0, SD = 1). The mean (SD) *DALDA Symptoms of Stress* scores
195 for each condition were: written 49 (2), verbal 50 (3) and group
196 49 (2); and the mean (SD) *Change in Lactate* was: written 5.3
197 (3.8) mmol·L, verbal 4.6 (3.4) mmol·L and group 4.8 (3.6)
198 mmol·L. The session-RPE model also included a random
199 intercept for each participant in the study to account for the
200 correlation between repeated observations on an individual. A

201 Normal (mean = 0, SD = 1) prior distribution was used for the
202 regression coefficients and half *t*-distribution (df = 3, mean = 0,
203 scale = 2.5) prior for the SD of the random effects.

204 Urine specific gravity (logged), nude body mass, blood
205 lactate (Gamma response distribution), and HR were analysed
206 using linear mixed-effects models. Urine specific gravity and
207 nude mass were modelled with *Condition* as a fixed factor.
208 Blood lactate was fit with *Time* (i.e., pre- and post-cycling),
209 *Condition*, and *Time* by *Condition*, as fixed factors. Urine
210 specific gravity, nude body mass, and blood lactate models
211 included a random intercept term for *Participant ID*. The HR
212 model included *Condition* and *Time* (cubic smoothing spline,
213 with 5 knots) as fixed effects; and *Interval* and *Participant ID* as
214 random effects (intercept only). Weakly informative prior
215 distributions were used for the regression coefficients and
216 variance parameters in these models.

217 Posterior estimates were generated using Markov chain
218 Monte Carlo methods, and are reported as the mean, mean
219 difference (MD) or odds ratio (OR) and 95% credible interval
220 (CrI) unless otherwise stated. Pairwise posterior probabilities
221 were computed to compare that on average, session-RPE votes
222 in condition '*k*' were: greater than, and equal to, session-RPE
223 votes in condition '*l*'. Posterior predictive checks were
224 performed to assess the suitability of all models.

225

226 **Results**

227 Session-RPE was four times more likely to be rated in a
228 higher category when collected in the group setting compared to
229 the written setting (OR = 4.26, 95% CrI = 1.27, 14.73). On
230 average, the posterior probability that participants would rate a
231 higher session-RPE category in the group compared to the
232 written setting was 0.53, and the posterior probability of equal
233 ratings between these two conditions was 0.29. Session-RPE
234 votes collected in the verbal setting were not different to the
235 written setting (OR = 1.90, 95% CrI = 0.61, 5.99). On average,
236 the posterior probability that participants would rate a higher
237 session-RPE category in the verbal than the written setting was
238 0.41, and the posterior probability of equal ratings between these
239 two conditions was 0.34. There was no evidence for a difference
240 in Session-RPE votes collected in the group setting compared
241 with votes collected in the verbal setting (OR = 2.48, 95% CrI =
242 0.76, 8.25). On average, the posterior probability that
243 participants would rate a higher session-RPE category in the
244 group setting compared to the verbal setting was 0.45, and the
245 posterior probability of equal ratings between these two
246 conditions was 0.30.

247 There was no evidence that nude body mass, urine
248 specific gravity and pre-cycling lactate were different between
249 conditions (Table 1). Lactate increased over the task ($\beta = 4.7$,
250 95% CrI = 3.2, 6.6; Table 1), but was not different between

251 conditions. HR increased during cycling ($\beta = 7.6$, 95% CrI = 6.0,
252 9.4). There was evidence of a condition effect on HR ($\beta = 2.02$,
253 95% CrI = 0.04, 4.35), with HR responses higher in the verbal
254 condition compared to both the written (MD = 2.02 b·min⁻¹, 95%
255 CrI = 0.04, 4.35) and group conditions (MD = 2.27 b·min⁻¹, 95%
256 CrI = 0.07, 4.42). The posterior probability that HR during
257 cycling was at least 2 b·min⁻¹ higher in the verbal condition
258 compared to the written and group settings was 0.56 and 0.60,
259 respectively.

260

261 **Discussion**

262 This study investigated the effect of peer presence on
263 session-RPE responses. While others have proposed that the
264 influence of peer presence on the rating of session-RPE is a
265 limitation of subjective training load monitoring²⁶, to our
266 knowledge, this is the first study to address this issue directly.
267 As hypothesised, session-RPE was more likely to be rated higher
268 when collected in the group setting compared to when collected
269 in written form (Figure 1). Heart rate was 2 b·min⁻¹ higher when
270 cycling in the verbal collection condition; however, this did not
271 appear to affect session-RPE responses. This study suggests that
272 contextual psychosocial inputs could influence session-RPE, and
273 may highlight the importance of controlling the measurement
274 environment to reduce circumstantial variance in data that
275 informs training-related decisions.

276 Participants were more likely to provide higher session-
277 RPEs in the presence of an audience (Figure 1). This finding
278 might be explained by participants wanting to communicate (to
279 others) a high effort ethic.²⁷ Consciously or otherwise, social
280 contagion could also factor owing to concern and subsequent
281 influence on responses.²⁸ This notion goes towards the idea of
282 self-concept, and a sense of identity, that individuals were giving
283 an equal effort so to be valued by their peers.²⁹ Such a scenario
284 seems possible in team sports where winning coaches value
285 hard-working athletes³⁰, and these expectations could influence
286 athletes' session-RPE responses. Concern regarding altered
287 training schedules (i.e., more or less sessions) and indirect
288 effects on team selection based on session-RPE responses also
289 cannot be dismissed. This line of thinking could arguably be
290 worse in emerging athletes where their age/maturity and career
291 ambitions lead them towards appraisal seeking behaviours.³¹

292 The effect of peer presence on session-RPE has
293 implications for training load monitoring, and in some instances
294 could explain previous observations of a disconnect between
295 session-RPE and training prescriptions.³² Individuals working
296 with athletes or persons who use session-RPE as a training load
297 monitoring tool in team settings should be mindful of the
298 contexts in which responses are collected. Users of session-RPE
299 must have an awareness of the influence that peer presence may
300 have on ratings for some athletes. This thinking further

301 reinforces the need for coaches, managers and team selectors, to
302 develop good, trustworthy relationships with athletes, so to
303 better understand how a certain individual or personality may, or
304 may not, be affected by responding to the presence of the wider
305 team.

306 While it would be convenient to suggest that collection
307 via a mobile application could be used to overcome the influence
308 of peer presence, recent evidence suggests that face-to-face
309 collections may be more valid.³³ Under the assumptions, and
310 with the sample size, of the current study, session-RPE responses
311 collected unaccompanied in written form were not different
312 compared to those collected in the presence of only the
313 researcher (Figure 1). The posterior probability that session-RPE
314 was higher when collected by the researcher compared to written
315 form was 0.41. Future work is required to investigate whether
316 the presence of a single individual influence's session-RPE
317 responses, as many of the discussions above hold for collection
318 via face-to-face—particularly if collected by a coach—
319 compared to collection when unaccompanied (e.g., mobile
320 application or written form).

321 Despite the matched mechanical work, a higher HR was
322 observed in the verbal condition. Although this may be affected
323 by the measurement sampling rate (i.e., every 3 min), the
324 physiological meaningfulness of this difference ($2 \text{ b}\cdot\text{min}^{-1}$) is
325 most arguably negligible. The primary limitation of the study is
326 the sample size. Although we used estimation methods in a
327 Bayesian framework to quantify differences between conditions,
328 the small sample size was reflected in large uncertainty of some
329 of the estimates. For example, the large width of the 95% CrI of
330 the OR between the intra-individual and group setting
331 conditions. Future research should replicate this study with a
332 larger sample size to confirm the generalisability of the findings;
333 and investigate other potential sources of bias for session-RPE
334 ratings, such as scale modifications (e.g., removing verbal
335 anchors, adding scale colourings). Exploring the associations
336 between witnessed session-RPE responses and
337 sociopsychological profiling may also be insightful. Similarly,
338 current perspectives may be advanced further by examining
339 responses to varying exercise intensities.

340

341 **Practical Applications**

342 The presence of other athletes and coaches seemingly affects the
343 session-RPE score. Standardising the session-RPE measurement
344 processes and environment is recommended to minimise the risk
345 of introducing error. Further, interpretation of session-RPE data
346 should occur through the lens of the collection context.

347

348 **Conclusion**

349 Findings from this study provided evidence supporting
350 the influence of contextual psychosocial inputs on session-RPE

351 responses. These outcomes highlight the importance of
352 controlling the measurement environment to reduce
353 circumstantial variance in data that informs training-related
354 decisions. Users of the session-RPE need to be consistent with
355 the environment in which session-RPE is collected and be aware
356 of the influence that peer presence may have on responses from
357 some individuals.

358

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468
469

470 **Figure captions**

471 **Figure 1.** Mean and 66% (thick inner line) and 95% (thin outer
472 line) credible interval posterior probability of rating each
473 session-RPE category in the three experimental conditions.

474

475 **Figure 2.** Mean and 66% (thick inner line) and 95% (thin outer
476 line) credible interval heart rate responses at minute zero and
477 during cycling for the three experimental conditions. Asterisk
478 indicates a higher heart rate in the verbal condition compared to
479 both the written and group condition.

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481 **Table captions**

482 **Table 1.** Markers of hydration and metabolism.

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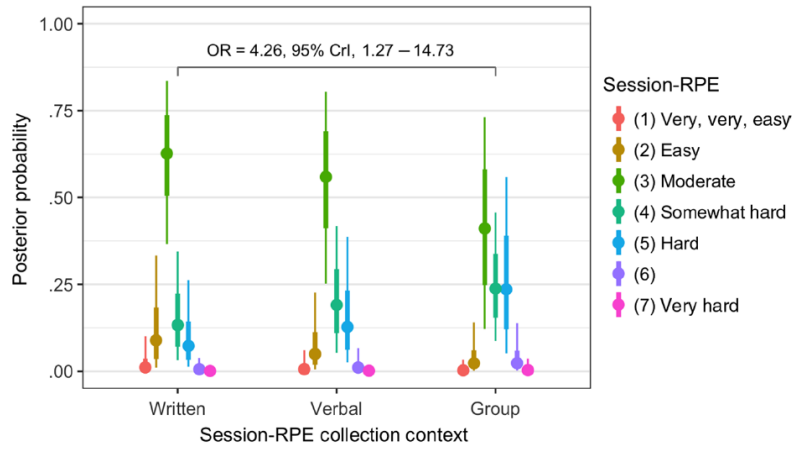
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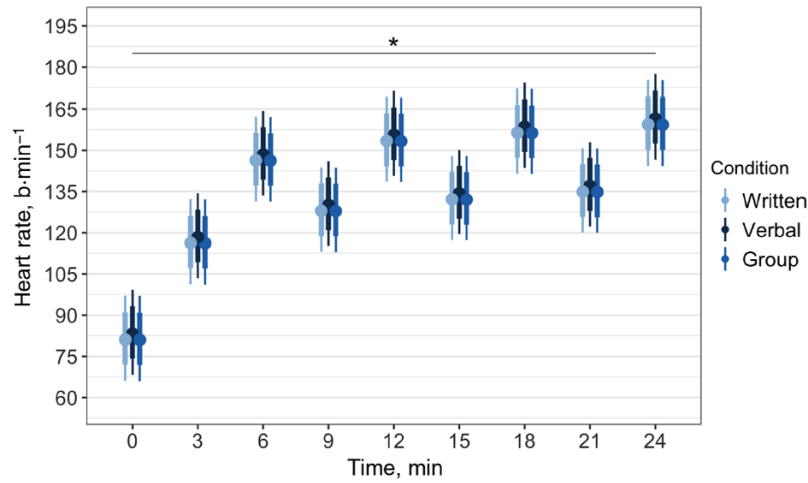
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498 Figure 1.



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Figure 2.



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Table 1.

Variable	Communication context		
	Written (intrapersonal)	Verbal (interpersonal)	Group
Urine specific gravity	1.017 (1.012-1.022)	1.016 (1.011-1.020)	1.016 (1.011-1.021)
Nude body mass, kg	79.9 (74.6-85.4)	79.8 (74.5-85.3)	79.8 (74.5-85.2)
Lactate, mmol·L ⁻¹			
Precycling	1.5 (1.2-1.9)	1.3 (1.0-1.7)	1.4 (1.0-1.8)
Postcycling	6.8 (5.2-8.8)*	5.9 (4.5-7.6)*	6.2 (4.8-8.0)*

507

*Effect of time ($\beta=4.7$, 95% credible interval = 3.2-6.6).

