J Sleep Res. (2014) Regular Research Paper

Odd one out: social ostracism affects self-reported needs in both sleep-deprived and well-rested persons

JEAN C. J. LIU, DEEPTI MULICK and MICHAEL W. L. CHEE
Cognitive Neuroscience Lab, Neuroscience and Behavioral Disorders Program, Duke-NUS Graduate Medical School, Singapore, Singapore

Keywords
affect, emotions, sleep loss, social behaviour, social exclusion

Correspondence
Michael W. L. Chee, Cognitive Neuroscience Lab, Duke-NUS Graduate Medical School, 8 College Road, #06-18, Singapore 169857, Singapore.
Tel.: (+65) 6516 4916;
fax: (+65) 6221 8625;
e-mail: michael.chee@duke-nus.edu.sg

Accepted in revised form 23 January 2014; received 9 September 2013

DOI: 10.1111/jsr.12141

SUMMARY
Previous research suggests that sleep deprivation may heighten normal reactions to an aversive social encounter. In this study, we explored how 24 h of sleep deprivation may influence responses to ostracism. Ninety-six healthy young adults were randomly allocated to either the sleep-deprivation or well-rested condition, wherein they engaged in two rounds of a ball-tossing game (Cyberball) programmed so that they would be included or ostracized. As compared with being included, being ostracized reduced participants' fulfillment of four essential needs (to belong; to have control; to have self-esteem; and to have a meaningful existence); participants also showed poorer mood and had poorer perceptions of their co-players. These effects were not influenced by sleep deprivation. Taken together, our findings suggest that sleep deprivation does not influence immediate distress responses to ostracism.

INTRODUCTION

In a layman's understanding, we often attribute out-of-character behaviour to sleep deprivation. For example, following a recent incident where a celebrity had an outburst at a photographer, his fellow celebrity defended him by explaining that her friend had been sleep deprived (Kitchener, 2013); in other words, his aberrant behaviour was typical of someone with insufficient sleep. Despite these lay beliefs, there have been few scientific studies exploring the social consequences of sleep loss – what happens when sleep-deprived persons interact with other individuals. This is an important ecological question, as sleep-deprived persons rarely carry out tasks in isolation. Accordingly, an understanding of social consequences is essential to predict performance during sleep deprivation.

Previous research suggests that following total sleep deprivation (TSD), sleep-deprived persons engage in more shallow conversations (Murray *et al.*, 1959) and are more likely to make inappropriate comments (Christian and Ellis, 2011). They exhibit less trust towards strangers (Anderson and Dickinson, 2010) and, when given the opportunity to cheat, are more likely to do so (Christian and Ellis, 2011). Together, these results suggest that sleep deprivation may affect social behaviours.

Whereas these findings characterize baseline alterations in sleep deprivation, other studies have looked at how TSD may affect responses to a social challenge – that is, an aversive social encounter such as interpersonal aggression or social evaluation. If the interpretation and reaction to others' social acts are influenced by sleep deprivation, this may give rise to aberrant social behaviours.

In terms of interpersonal aggression, Kahn-Greene *et al.* (2006) presented hypothetical scenarios involving characters placed in a frustrating situation. Relative to a well-rested baseline, sleep deprivation was associated with a greater tendency to assign blame and to direct aggression towards another character in the scenario. Correspondingly, sleep-deprived persons were less likely to accept blame or to offer restitution. (Note, however, that Cote *et al.*, 2013 and Vohs *et al.*, 2011 did not find evidence of increased aggression when participants had the opportunity to retaliate after actual provocation).

In terms of social evaluation, Franzen *et al.* (2011) required participants to deliver a speech defending themselves against a hypothetical crime; the speech was videotaped, and participants were informed that their speech would be rated by experts. In the absence of sleep deprivation, similar social evaluative tasks have been found to induce psychological stress and to evoke a hypothalamic–pituitary–adrenocortical axis response (for a review, see Dickerson and Kemeny, 2004). Likewise, participants showed increased systolic blood pressure during the speech task, regardless of sleep condition; however, this effect was magnified when participants were sleep deprived. Similarly, Minkel *et al.* (2012) concluded that TSD may lower the threshold at which an event is considered subjectively stressful.

Taken together, initial research suggests that sleep deprivation may augment normal reactions that one may have to an aversive social encounter. Here, we sought to extend these findings by examining the effects of sleep deprivation on another form of social challenge – ostracism, where an individual is excluded or ignored (Williams, 2007).

Ostracism is typically studied in the laboratory using Cyberball, a computerized ball-tossing paradigm (Williams and Jarvis, 2006; Williams *et al.*, 2000). Here, participants are asked to throw a ball to two or three other participants playing the game over the Internet. In fact, there are no real counterparts; the ball-tossing contingency is programmed such that participants either receive the ball equally over the course of the game (included condition), or do not receive it for the larger part of the game (ostracized condition). Relative to the inclusion condition, ostracized participants generally report lower scores on the four essential needs of: belonging; having control; having self-esteem; and having a meaningful existence (Williams *et al.*, 2000; Zadro *et al.*, 2004; see Gerber and Wheeler, 2009 for a meta-analysis). This effect is robust, such that need scores decrease even when participants are told that they are playing against a computer (Zadro *et al.*, 2004) or with out-group members from the Ku Klux Klan (Gonsalkorale and Williams, 2007), or when ostracism is tied to financial gains (Van Beest and Williams, 2006).

Based on the effects of sleep deprivation on other social challenges, we hypothesized that TSD would be associated with augmented responses to being ostracized. Specifically, using the Cyberball paradigm, we predicted that sleep-deprived persons – relative to well-rested persons – would show stronger decreases in belonging, control, self-esteem, and meaningful existence after an episode of ostracism.

MATERIALS AND METHODS

Participants

Participants were 96 healthy young adults recruited from the National University of Singapore, the Nanyang Technological University, and Duke-NUS Graduate Medical School. All experimental procedures were approved by the National University of Singapore's Institutional Review Board (#08-336). Participants gave informed consent for this study, and were paid for their involvement.

Participants were selected based on their responses to a web-based questionnaire, and were included if they: (1) were between 18 and 35 years old; (2) were non-smokers; (3) had no history of psychiatric, neurological, or sleep disorders; (4) consumed no more than two caffeinated drinks per day; (5) had good habitual sleep (sleep duration of 6.5–9 h daily, sleeping on average before 00:30 hours and waking before 09:00 hours); and (6) were not of an extreme chronotype, as assessed using the Horne–Östberg Morningness–Eveningness questionnaire (Horne and Östberg, 1976). Additionally, 1 week prior to testing, participants' sleep habits were monitored through the use of sleep diaries coupled with either motion-sensing actigraphy (82 participants; Actiwatch, Philips Respironics, Bend, OR, USA) or sleep-staging wireless electroencephalography (EEG) monitoring (14 participants; Zeo Sleep Manager, Zeo, Boston, MA, USA); only those who evidenced good habitual sleep throughout the week were included.

The 96 enrolled participants were randomly allocated to one of two sleep conditions: 47 participants were assigned to the TSD group; and 49 participants to the rested wakefulness (RW) group. TSD and RW participants did not differ in baseline characteristics (smallest $P = 0.15$; Table 1).

Materials

Cyberball task

The primary task involved Cyberball 4.0 (Williams *et al.*, 2012), a HTML5 version of the original Cyberball (Williams *et al.*, 2000). As a cover story, an instructional screen informed participants that the task was a mental visualization task, and that participants were to visualize by playing an online ball-tossing game with other participants logged onto the network. The instructional screen emphasized that ball-tossing performance was not crucial, that what was important was visualizing the experience.

Following the appearance of on-screen instructions, the Cyberball programme displayed three animated characters labelled as 'Player A', 'Player B' and 'You'; there was also a ball that could be tossed between the characters. Each round of Cyberball involved 30 ball throws: in the Included condition, the ball-throwing contingency was programmed such that each character received the ball an equal number of times; in the Ostracized condition, participants received the ball two times at the beginning of the game, and were ignored thereafter. When participants received the ball, they could toss it to another 'player' by clicking on the character of their choice.

Cyberball questionnaire

The Cyberball questionnaire was a 25-item online questionnaire (modified from Chernyak and Zayas, 2010; Kelly *et al.*, 2012; Zadro *et al.*, 2004). The first two questions assessed the effectiveness of the Cyberball manipulation ("Out of 100% of balls thrown between the players, approximately what percentage of balls were thrown to you?"; and "To what extent were you included or excluded by the other participants during the game?").

The subsequent 12 questions assessed the four fundamental needs: 'belonging' ("I felt poorly accepted by the other participants"; "I felt as though I had made a 'connection' or bonded with one or more of the participants during the Cyberball game"; "I felt like an outsider during the Cyberball game"); 'control' ("I felt that I was able to throw the ball as often as I wanted during the game"; "I felt somewhat

Table 1 Sleep-deprived and well-rested participants' baseline characteristics

Characteristic	Sleep state* TSD (n = 47)	RW (n = 49)	Test statistic† (P-value)
Demographics			
Gender	23 females	22 females	0.16‡ (0.84)
Age (years)	22.62 (2.82)	22.10 (1.93)	−1.05 (0.30)
Sleep variables			
Work days§			
Habitual bed time (h:min)	23:54 (0:38)	23:42 (0:41)	−1.37 (0.17)
Habitual wake time (h:min)	7:49 (0:41)	7:37 (0:58)	−1.14 (0.26)
Habitual sleep duration (h:min)	7:36 (0:38)	7:26 (0:59)	−0.81 (0.42)
Free days§			
Habitual bed time (h:min)	00:25 (0:49)	00:18 (0:55)	−1.28 (0.21)
Habitual wake time (h:min)	8:47 (0:55)	8:50 (1:10)	0.21 (0.84)
Habitual sleep duration (h:min)	8:05 (0:49)	8:11 (0:55)	0.62 (0.54)
Absolute social jetlag (h:min)	0:44 (0:32)	0:50 (0:42)	0.74 (0.46)
Epworth Sleepiness Scale score	7.43 (3.51)	7.93 (2.69)	0.74 (0.46)
Sleep history			
Sleep duration 2 nights prior to experimental task component (h:min)	7:26 (1:25)	7:43 (0:48)	1.13 (0.26)
Sleep duration 1 night prior to experimental task component (h:min)	NA	7:41 (0:50)	NA
Sleep monitoring device used	9 Zeos 38 Actiwatches	5 Zeos 44 Actiwatches	1.54‡ (0.21)
Personality measures			
Emotional Contagion Scale			
Positive scale	3.76 (0.57)	3.93 (0.55)	1.47 (0.15)
Negative scale	2.76 (0.58)	2.91 (0.64)	0.35 (0.73)
Overall score	3.22 (0.58)	3.32 (0.50)	0.92 (0.36)
Depression, Anxiety and Stress Scales			
Depression score	3.43 (2.66)	2.88 (2.38)	−1.03 (0.31)
Anxiety score	4.04 (3.18)	3.60 (2.68)	−0.70 (0.49)
Stress score	4.50 (3.24)	4.47 (3.04)	−0.05 (0.96)
NEO Personality Inventory – Revised¶			
Neuroticism score	140 (19.63)	141 (22.64)	0.21 (0.83)
Extraversion score	156 (19.17)	161(16.98)	1.36 (0.18)
Openness to experience score	159 (14.26)	160 (15.71)	0.24 (0.81)
Agreeableness score	157 (16.07)	159 (16.81)	0.57 (0.57)
Conscientiousness score	161 (19.67)	162 (18.96)	0.31 (0.76)

*RW, rested wakefulness; TSD, total sleep deprivation. Data reported as means (standard deviation) or counts.
†Unless otherwise stated, the test statistic refers to the *t*-statistic.
‡Pearson's chi-square statistic reported.
§Based on responses to the Munich Chronotype Questionnaire.
¶Raw scores reported.

frustrated during the Cyberball game"; "I felt in control during the Cyberball game"); 'self-esteem' ("During the Cyberball game, I felt good about myself"; "I felt that the other participants failed to perceive me as a worthy and likeable person"; "I felt somewhat inadequate during the Cyberball game"); and 'meaningful existence' ["I felt that my performance (e.g. catching the ball, deciding whom to throw the ball to) had some effect on the direction of the game"; "I felt non-existent and invisible during the game"; "I felt as though my existence was meaningless"]. Each of these questions required participants to make their ratings on a five-point scale anchored on one end with '1 = not at all' and on the other with '5 = very much'. For each need, a need score was computed by reverse scoring the relevant items and summing across all items assessing the need; a higher score was indicative of the need being met to a greater extent (i.e. a more positive state). Additionally, as a primary outcome measure, a total needs score was created by summing across the individual need scores.

Seven questions assessed participants' mood and feelings: participants were asked to rate how angry they felt, how much they enjoyed, and whether their feelings were hurt during the Cyberball game; these were again made on a five-point scale anchored on one end with '1 = not at all' and on the other with '5 = very much'. Participants were also asked to rate 'to what extent you currently feel': good or bad, happy or sad, friendly or unfriendly, and tensed or relaxed; each response was made on a five-point scale anchored with the descriptors of each pair (e.g. '1 = very bad' and '5 = very good').

Finally, four questions asked participants to rate how much they liked or disliked each player (Players A and B, respectively), followed by how much they trusted or distrusted each player; these were made on five-point scales anchored on one end with '1 = don't like Player (A/B) at all' and '5 = like Player (A/B) a lot', or '1 = don't trust Player (A/B) at all' and '5 = trust Player (A/B) a lot', respectively. For each of the like/dislike and trust/distrust ratings, scores were averaged across ratings for Player A and Player B.

Procedure

General study procedure

Each participant visited the laboratory for two sessions: (1) a briefing session; and (2) a testing session (either TSD or RW). During the briefing session, participants were issued their sleep diaries as well as either an actigraph or a wireless EEG headband. Participants also completed a battery of baseline psychometric questionnaires assessing sleep (Epworth Sleepiness Scale and Munich Chronotype Questionnaire; Johns, 1991; Roenneberg *et al.*, 2003) and individual difference variables (Emotional Contagion Scale and abbreviated Depression Anxiety Stress Scales; Doherty, 1997; Lovibond and Lovibond, 1995).

One week later, following a week of sleep monitoring, participants returned for their testing session. Across both sessions, participants arrived at the laboratory in an average group size of six participants (randomly selected); all participants indicated that they had not consumed any medication, caffeine, nicotine or alcohol for at least 24 h prior to the session.

Participants allocated to the TSD group awoke at their habitual wake time (before 09:00 hours), and were not permitted to take naps throughout the day. Participants arrived at the laboratory at 23:30 hours, and were kept under constant supervision of a research assistant. To ensure experimental control prior to the Cyberball task, participants were seated individually, and only engaged in sedentary activities (e.g. reading and writing) throughout the night. They were not allowed to converse with other participants or to watch movies or television programmes. During this waiting period, participants also completed a personality questionnaire (Revised NEO Personality Inventory; Costa and McCrae, 1992), as well as hourly assessments of vigilance (the 10-min Psychomotor Vigilance Task; Dinges *et al.*, 1997) followed by assessments of subjective sleepiness (the Karolinska and Stanford Sleepiness Scales; Akerstedt and Gillberg, 1990; Hoddes *et al.*, 1973).

Participants allocated to the RW group had their habitual 6.5–9 h of sleep on the night prior to their testing session (verified through sleep diaries and either actigraphy or EEG records). Participants arrived at the laboratory at 08:00 hours, and completed a single assessment of subjective sleepiness and vigilance.

Experimental task component

Following previous sleep-deprivation studies (Venkatraman *et al.*, 2011), the task component of each session commenced at 06:00 hours (for TSD sessions) and 08:30 hours (for RW sessions); these represent the time when vigilance hits a nadir after a night of sleep deprivation, and the start time of a regular workday (Doran *et al.*, 2001; Graw *et al.*, 2004). The effects described here represent the interaction between circadian and homeostatic effects.

A trained experimenter (either J. C. J. L. or D. M.) briefed participants that the experimental task sought to examine how sleep deprivation may modulate mental visualization, explaining the instructions on the Cyberball instructional screen. Additionally, participants were told that they would be playing two rounds of Cyberball with each other and with players connected online, and that in each round their counterparts would be shuffled and not known to them. They were further instructed that once the task started, they were to keep silent.

Thereafter, participants were seated apart from each other. For believability, the Cyberball task was loaded onto each participant's computer using an Internet browser with the web address concealed; the experimenter also ensured all participants started the task at the same time. Participants played two rounds of Cyberball with a 5-min break in between (where they were permitted to sit quietly at their computers). In one round, participants were included; and in the other, they were ostracized (order counterbalanced across participants). After each round, participants completed the Cyberball questionnaire.

Upon completing both rounds of Cyberball, participants were debriefed about the aims of the study. RW participants also completed a psychometric questionnaire (Revised NEO Personality Inventory; Costa and McCrae, 1992) and, as part of a larger study, all participants completed several other cognitive tasks during this task component.

Data analyses

A 2 $\times$ (2) repeated-measures ANOVA was run with Sleep State (TSD versus RW) and Cyberball Condition (Included versus Ostracized) as the factors; dependent variables were Cyberball questionnaire scores. Because the sleep-monitoring method (actigraphy versus wireless EEG monitoring) did not interact with Sleep State (smallest $P = 0.08$), all analyses collapsed across this variable.

For all statistical tests, Type 1 Decision Wise Error Rate was controlled at $\alpha = 0.05$. Power calculations for the main hypothesis (Sleep State $\times$ Cyberball Condition) showed that there was statistical power at the recommended 0.80 level to detect a medium effect size ($f = 0.17$, based on an estimated correlation of 0.3 between repeated-measures; Faul *et al.*, 2009). All analyses were conducted using SPSS (IBM Corp, 2011) & R (R Core Team, 2012).

RESULTS

Effectiveness of sleep manipulation

At the start of the experimental task segment, TSD participants reported greater subjective sleepiness than RW participants on the Karolinska Sleepiness Scale (mean rating for TSD group = 6.41, SD = 2.08 and mean rating for RW group = 2.66, SD = 1.19; $t_{68} = -9.44$, $P < 0.001$) and on the Stanford Sleepiness Scale (mean rating for TSD group = 4.59, SD = 1.37 and mean rating for RW group = 2.03, SD = 0.75; $t_{68} = -9.95$, $P < 0.001$). Similarly, sleep deprivation increased participants' median reaction time on the Psychomotor Vigilance Task (mean for TSD group = 380.43 ms, SD = 54.42 ms and mean for RW group = 323.77 ms, SD = 31.41; $t_{91} = -6.20$, $P < 0.001$), indicating that the sleep manipulation was successful.

Effectiveness of Cyberball manipulation

As shown in Fig. 1, there was a significant main effect of Cyberball condition on perceived percentage of balls received ($F_{1,92} = 425.60$, $P < 0.001$): participants reported receiving the ball less frequently in the ostracism than the inclusion condition. Similarly, as shown in Fig. 2, participants reported feeling less included and more excluded when ostracized than when included ($F_{1,92} = 453.98$, $P < 0.001$). On both these variables, there were no main or interaction effects involving sleep state (smallest $P = 0.47$). Taken together, these results suggest that the Cyberball manipulation was successful in both sleep-deprived and well-rested participants.

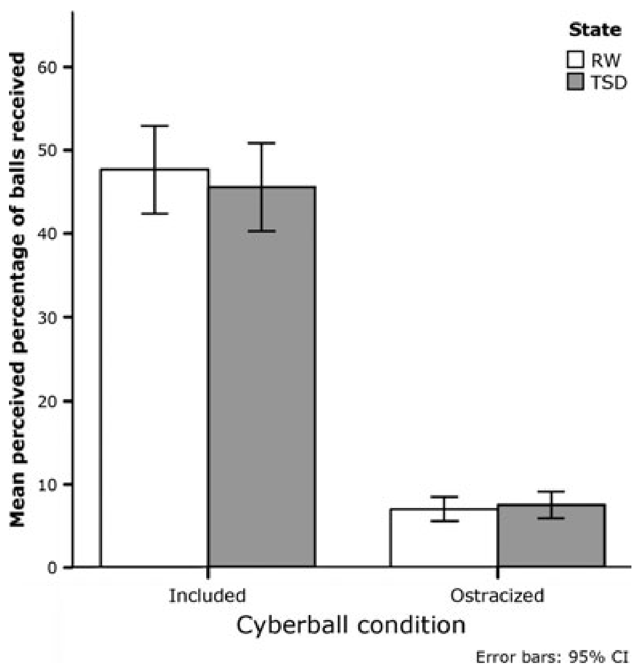

Figure 1. Sleep-deprived and well-rested participants' perceived percentage of balls received when they were included or ostracized in a game of Cyberball; vertical lines represent 95% confidence intervals for the means. RW, rested wakefulness; TSD, total sleep deprivation.

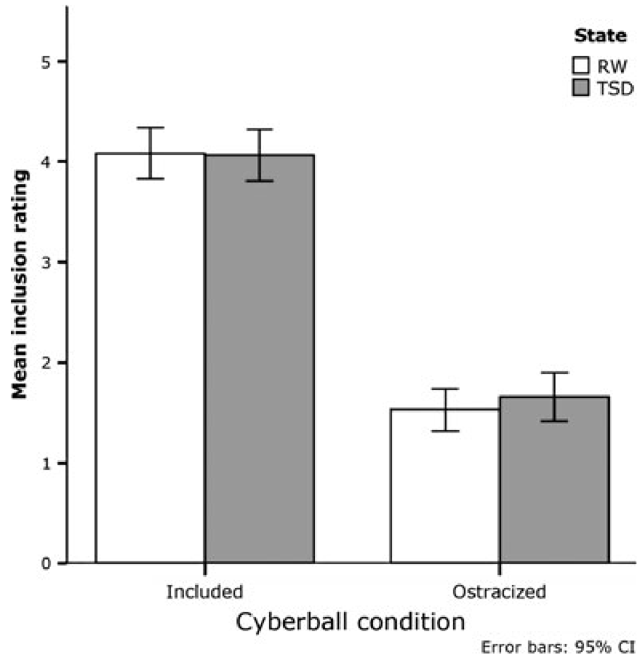

Figure 2. Ratings of the extent to which sleep-deprived and well-rested participants felt included or excluded by the other participants, following the inclusion or ostracism condition of the Cyberball game. Vertical lines represent 95% confidence intervals for the means. RW, rested wakefulness; TSD, total sleep deprivation.

Effects of sleep condition on Cyberball responses

Self-reported needs

Fig. 3 presents participants' mean scores for each of the four fundamental needs. There was a significant main effect of Cyberball condition on belonging ($F_{1,92} = 543.36$, $P < 0.001$); control ($F_{1,92} = 497.23$, $P < 0.001$); self-esteem ($F_{1,92} = 163.33$, $P < 0.001$); and meaningful existence ($F_{1,92} = 449.02$, $P < 0.001$). Namely, participants reported lower fulfillment of each of these needs after being ostracized than after being included. However, there was no main or interaction effect of state on any of these variables (smallest $P = 0.18$).

Participants' individual need scores were also summed to form a total needs score (Fig. 4). Once again, there was a significant main effect of Cyberball condition ($F_{1,92} = 579.38$, $P < 0.001$), with decreased overall need fulfillment following ostracism. There was again no main or interaction effect involving participants' sleep state (smallest $P = 0.37$).

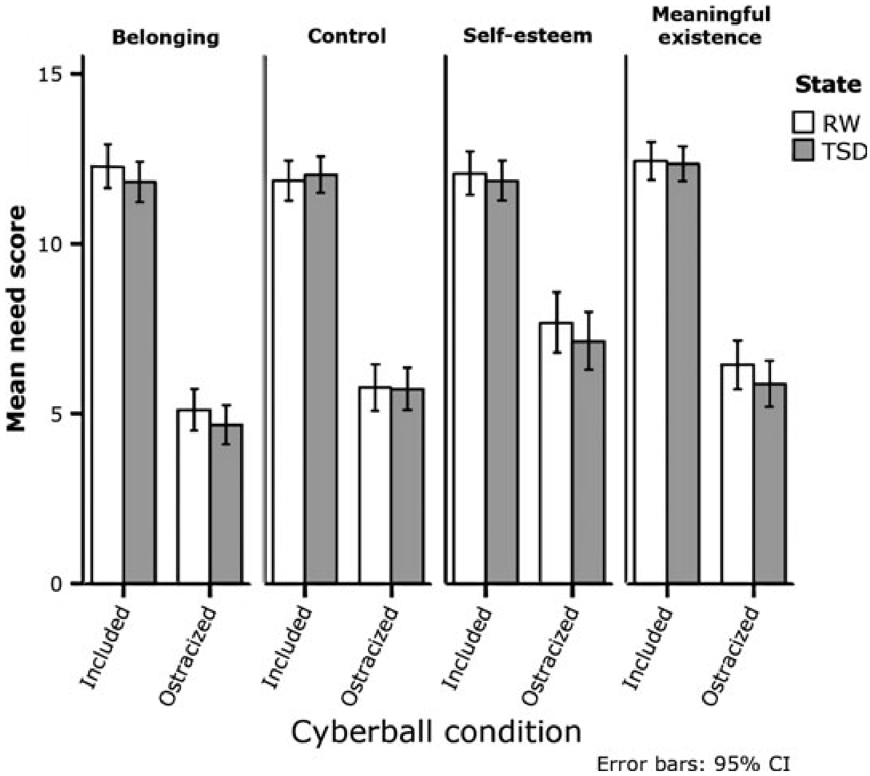

Figure 3. For each of the four fundamental needs (belonging, control, self-esteem, and meaningful existence), bars represent sleep-deprived and well-rested participants' mean need score as a function of whether they were included or ostracized in the Cyberball game. Vertical lines represent 95% confidence intervals for the means. RW, rested wakefulness; TSD, total sleep deprivation.

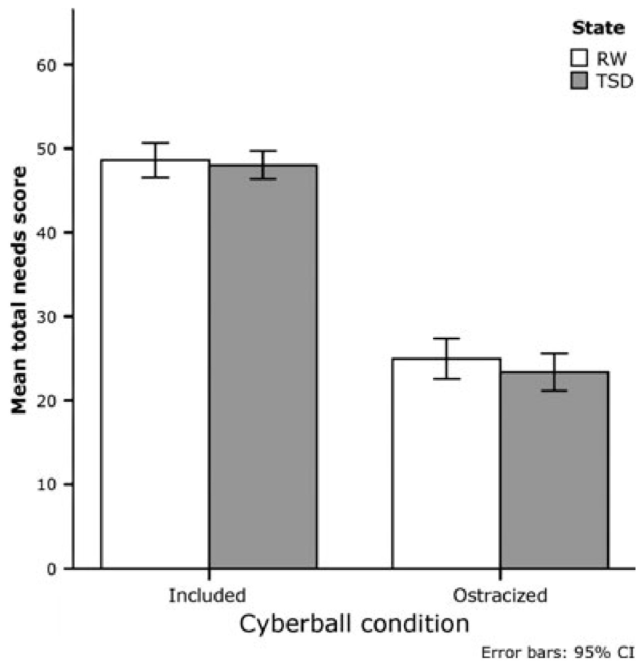

Figure 4. Total needs score for sleep-deprived and well-rested participants, as a function of whether they were included or ostracized in Cyberball; vertical lines represent 95% confidence intervals for the means.

As this was the primary dependent variable, an additional two one-sided test (TOST) was run to assess statistical equivalence (defined as <25% difference) in the Cyberball effect between TSD and RW participants. (This test is commonly applied in clinical trials to show equivalence of experimental conditions on an outcome, and not merely a lack of evidence for a difference.) Based on the TOST, the Cyberball effect was found to be statistically equivalent amongst both groups of participants (90% CI for difference = −4.29 to 2.28; $P = 0.01$).

Mood and feelings

As with the four needs, ostracized participants: felt angrier ($F_{1,92} = 123.23$, $P < 0.001$); had less enjoyment ($F_{1,92} = 155.46$, $P < 0.001$); and were more hurt ($F_{1,92} = 106.99$, $P < 0.001$) than when they were included (Fig. 5). They also reported feeling worse ($F_{1,92} = 108.64$, $P < 0.001$); less happy ($F_{1,92} = 100.69$, $P < 0.001$); less friendly ($F_{1,92} = 144.98$, $P < 0.001$); and less relaxed ($F_{1,92} = 56.43$, $P < 0.001$; Fig. 6).

There was a main effect of state on participants' happiness, with sleep-deprived participants reporting less happiness than well-rested participants ($F_{1,92} = 4.20$, $P = 0.04$); no other main or interaction effect involving state was significant (smallest $P = 0.09$).

Perception of other players

Finally, there was a main effect of Cyberball condition on the extent to which participants liked ($F_{1,92} = 149.58$, $P < 0.001$) and trusted ($F_{1,92} = 100.96$, $P < 0.001$) their co-players: specifically, participants reported liking and

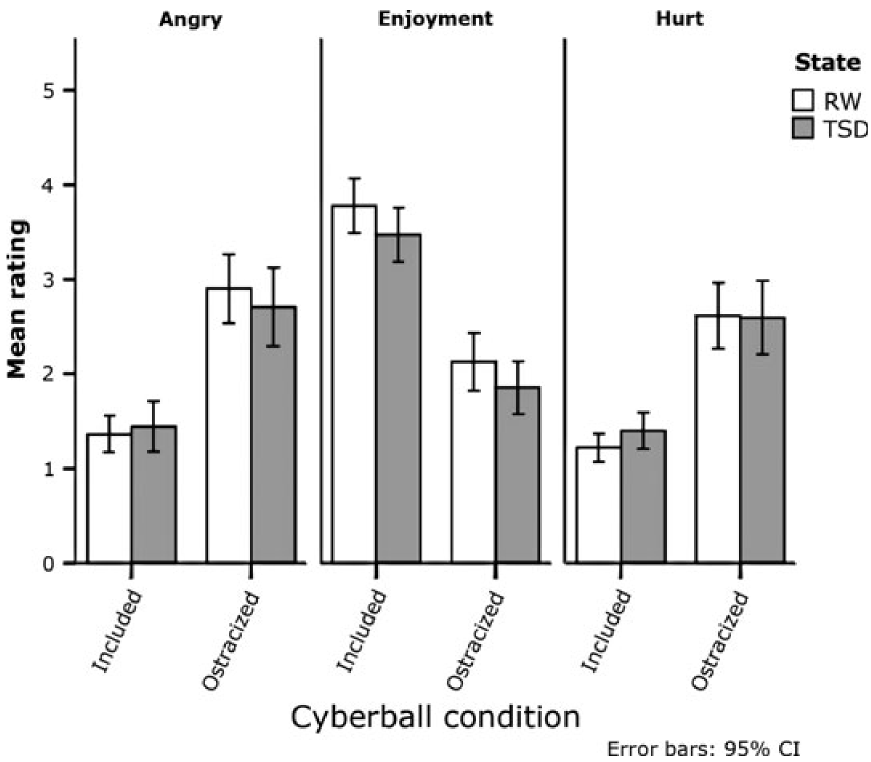

Figure 5. Sleep-deprived and well-rested participants' ratings of how angry they felt, how much they enjoyed, and whether their feelings were hurt during the Cyberball game, after they had been included or ostracized. Vertical lines represent 95% confidence intervals for the means. RW, rested wakefulness; TSD, total sleep deprivation.

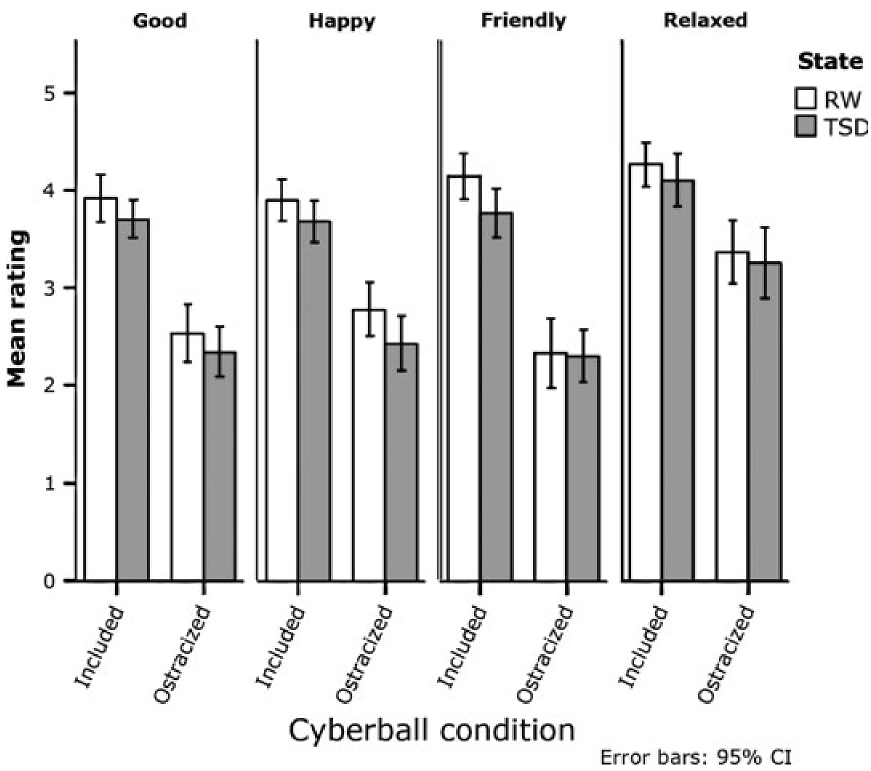

Figure 6. Sleep-deprived and well-rested participants rated to what extent they felt good, happy, friendly or relaxed following a game of Cyberball where they were included or ostracized. Vertical lines represent 95% confidence intervals for the means. RW, rested wakefulness; TSD, total sleep deprivation.

trusting their co-players less when they had been ostracized than included by them. There was no main or interaction effect involving state on either of these variables (smallest $P = 0.54$; Fig. 7).

DISCUSSION

In this study, we examined whether sleep deprivation would augment participants' responses to being ostracized. We

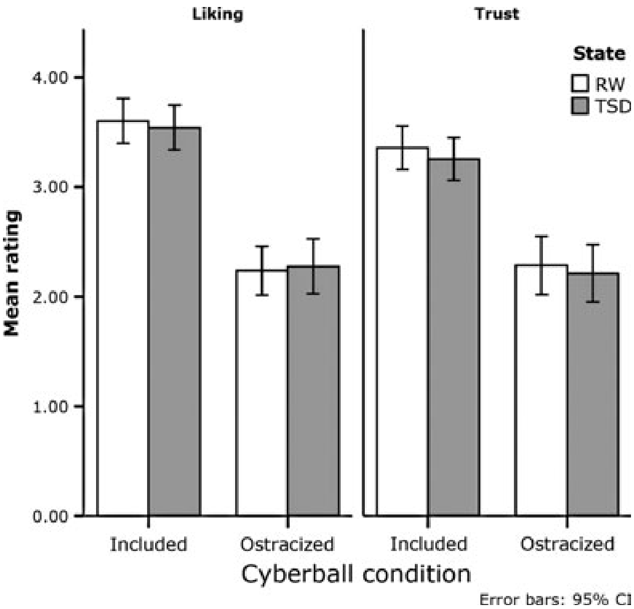

Figure 7. Bars represent sleep-deprived and well-rested participants' mean liking and trust ratings towards the other players in Cyberball, after participants had been included or ostracized. Vertical lines represent 95% confidence intervals for the means. RW, rested wakefulness; TSD, total sleep deprivation.

found several lines of evidence suggesting that the effects of ostracism were not differentiated for sleep-deprived and well-rested participants.

First, we found no evidence for such a difference across 14 measures assessing participants' four needs, mood and feelings, and perception of other players. Based on the power calculations and because test statistics were uncorrected for multiple comparisons, these null findings are unlikely to have resulted from an inadequate sample size. Second, as null findings do not allow conclusions about similarity, we ran an additional test of equivalence and found that sleep-deprived and well-rested participants showed equivalent need scores following Cyberball. Taken together, our findings suggest that an episode of ostracism exerts strong effects that are not modulated by sleep history.

Within the ostracism literature, our findings are in line with the temporal model of ostracism (Williams, 1997, 2009). This model suggests that, following detection of ostracism, there are both immediate reflexive and more delayed reflective responses. In the first stage, the immediate distress response to ostracism (e.g. as measured in this study through alterations to the four needs) is universal and robust. Several studies have found no effects of situational variables on self-reported distress (Williams, 2007); this includes manipulations such as framing (Van Beest and Williams, 2006; Gonsalkorale and Williams, 2007; Zadro *et al*., 2004) and drug administration (Alvares *et al*., 2010; Dewall *et al*., 2010). On the other hand, other manipulations have been found to modulate these responses (e.g. Van Beest *et al*., 2011); in particular, aging, whose neuropsychological effects have been compared with sleep deprivation (Harrison *et al*., 2000), is associated with altered self-reported needs following Cyberball (Hawkley *et al*., 2011). This indicates that our failure to find sleep-deprivation effects is not merely due to ostracism being so strong a manipulation that immediate responses are not amenable to modulation. Nonetheless, it remains possible that sleep deprivation could affect ostracism responses when the ostracism manipulation is not as strong (e.g. when a more ambiguous ball-tossing contingency is used). Similarly, based on the temporal model of ostracism, the possibility remains that sleep deprivation may affect delayed reflective responses to ostracism (e.g. ostracism effects may be found to last longer for sleep-deprived than for well-rested participants).

The present findings appear at odds with studies showing that sleep deprivation affects responses to a social challenge. That is, whereas sleep deprivation heightens responses to interpersonal aggression (Kahn-Greene *et al*., 2006) and social evaluation (Franzen *et al*., 2011), it seems to have no such effect in the case of ostracism. It is unclear why this should be so; however, one explanation may lie in the broader literature of sleep deprivation and affective responses. Within this literature, there appears to be a paradox: on the one hand, sleep deprivation has been found to heighten or polarize responses to affective stimuli such as positive or aversive photographs. This is seen in subjective ratings (Gujar *et al*., 2011), neural responses (Gujar *et al*., 2011; Yoo *et al*., 2007) and pupil dilation responses (Franzen *et al*., 2009). On the other hand, sleep deprivation has also been found to dampen or neutralize responses to affective stimuli, as observed in subjective ratings (Van Der Helm *et al*., 2010; see also non-significant trend in Minkel *et al*., 2011) and in decreased facial expressiveness (Minkel *et al*., 2011; Schwarz *et al*., 2013). These divergent results suggest opposing processes at play with regards to sleep deprivation and affective responses. Thus, a sleep-deprived person's response to a negative social encounter may depend on which of these processes are invoked at the time. It is also possible that other manipulations of sleep deprivation (e.g. 36 or 40 h of TSD, or partial sleep deprivation) may result in altered responses to ostracism relative to the well-rested state.

In conclusion, the present study explored how sleep-deprived individuals would react to social ostracism. Regardless of whether participants were well rested or sleep deprived, being ostracized reduced participants' fulfillment of essential needs; this response did not depend on participants' sleep condition. Thus, we conclude that in the case of social rejection, a good night's rest may not buffer you from any of its deleterious effects.

ACKNOWLEDGEMENTS

This work was supported by a grant awarded to Dr Michael Chee from the National Medical Research Council Singapore (STaR/0004/2008). The authors gratefully acknowledge

Tiffany Chia, Cher Wei Shan, Loh Kep Kee, Vinod Shanmugam and Siti Yaakub for their assistance with participant recruitment, data collection and data entry.

AUTHOR CONTRIBUTIONS

JCJL and DM designed and conducted the research; JCJL analysed the data; and JCJL and MWLC wrote the manuscript and had primary responsibility for the final content.

CONFLICT OF INTERESTS

All authors (JCJL, DM and MWLC) declare that they have no conflicts of interest.

REFERENCES

Akerstedt, T. and Gillberg, M. Subjective and objective sleepiness in the active individual. *Int. J. Neurosci.*, 1990, 52: 29–37.

Alvares, G. A., Hickie, I. B. and Guastella, A. J. Acute effects of intranasal oxytocin on subjective and behavioral responses to social rejection. *Exp. Clin. Psychopharmacol.*, 2010, 18: 316–321.

Anderson, C. and Dickinson, D. L. Bargaining and trust: the effects of 36-h total sleep deprivation on socially interactive decisions. *J. Sleep Res.*, 2010, 19: 54–63.

Chernyak, N. and Zayas, V. Being excluded by one means being excluded by all: perceiving exclusion from inclusive others during one-person social exclusion. *J. Exp. Soc. Psychol.*, 2010, 46: 582–585.

Christian, M. S. and Ellis, A. P. J. Examining the effects of sleep deprivation on workplace deviance: a self-regulatory perspective. *Acad. Manag. J.*, 2011, 54: 913–934.

Costa, P. T. J. and McCrae, R. R. *Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI) Professional Manual*. Psychological Assessment Resources, Odessa, FL, 1992.

Cote, K. A., McCormick, C. M., Geniole, S. N., Renn, R. P. and Macaulay, S. D. Sleep deprivation lowers reactive aggression and testosterone in men. *Biol. Psychol.*, 2013, 92: 249–256.

Dewall, C. N., MacDonald, G., Webster, G. D. *et al.* Acetaminophen reduces social pain: behavioral and neural evidence. *Psychol. Sci.*, 2010, 21: 931–937.

Dickerson, S. S. and Kemeny, M. E. Acute stressors and cortisol responses: a theoretical integration and synthesis of laboratory research. *Psychol. Bull.*, 2004, 130: 355–391.

Dinges, D. F., Pack, F., Williams, K. *et al.* Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4–5 hours per night. *Sleep*, 1997, 20: 267–277.

Doherty, R. W. The Emotional Contagion Scale: a measure of individual differences. *J. Nonverbal Behav.*, 1997, 21: 131–154.

Doran, S. M., s Dongen, H. P. A. and Dinges, D. F. Sustained attention perfomance during sleep deprivation: evidence of state instability. *Arch. Ital. Biol.*, 2001, 139: 253–267.

Faul, F., Erdfelder, E., Buchner, A. and Lang, A.-G. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav. Res. Methods*, 2009, 41: 1149–1160.

Franzen, P. L., Buysse, D. J., Dahl, R. E., Thompson, W. and Siegle, G. J. Sleep deprivation alters pupillary reactivity to emotional stimuli in healthy young adults. *Biol. Psychol.*, 2009, 80: 300–305.

Franzen, P. L., Gianaros, P. J., Marsland, A. L. *et al.* Cardiovascular reactivity to acute psychological stress following sleep deprivation. *Psychosom. Med.*, 2011, 73: 679–682.

Gerber, J. and Wheeler, L. On being rejected: a meta-analysis of experimental research on rejection. *Perspect. Psychol. Sci.*, 2009, 4: 468–488.

Gonsalkorale, K. and Williams, K. D. The KKK won't let me play: ostracism even by a despised outgroup hurts. *Eur. J. Soc. Psychol.*, 2007, 37: 1176–1186.

Graw, P., Krauchi, K., Knoblauch, V., Wirz-Justice, A. and Cajochen, C. Circadian and wake-dependent modulation of fastest and slowest reaction times during the psychomotor vigilance task. *Physiol. Behav.*, 2004, 80: 695–701.

Gujar, N., Yoo, S. S., Hu, P. and Walker, M. P. Sleep deprivation amplifies reactivity of brain reward networks, biasing the appraisal of positive emotional experiences. *J. Neurosci.*, 2011, 31: 4466–4474.

Harrison, Y., Horne, J. A. and Rothwell, A. Prefrontal neuropsychological effects of sleep deprivation in young adults – a model for healthy aging? *Sleep*, 2000, 23: 1067–1073.

Hawkley, L. C., Williams, K. D. and Cacioppo, J. T. Responses to ostracism across adulthood. *Soc. Cogn. Affect Neurosci.*, 2011, 6: 234–243.

Hoddes, E., Zarcone, V., Smythe, H., Phillips, R. and Dement, W. C. Quantification of sleepiness: a new approach. *Psychophysiology*, 1973, 10: 431–436.

Horne, J. A. and Östberg, O. A self-assessment questionnaire to determine morningness–eveningness in human circadian rhythms. *Int. J. Chronobiol.*, 1976, 4: 97–110.

IBM Corp. *SPSS Statistics for Mac (Version 20.0)*. IBM Corp., Armonk, NY, 2011.

Johns, M. W. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep*, 1991, 14: 540–545.

Kahn-Greene, E. T., Lipizzi, E. L., Conrad, A. K., Kamimori, G. H. and Killgore, W. D. S. Sleep deprivation adversely affects interpersonal responses to frustration. *Pers. Individ. Dif.*, 2006, 41: 1433–1443.

Kelly, M., McDonald, S. and Rushby, J. All alone with sweaty palms – physiological arousal and ostracism. *Int. J. Psychophysiol.*, 2012, 83: 309–314.

Kitchener, S. 'I love that man': Kris Jenner defends 'sleep-deprived' Kanye West over pararazzi rant. In: *Entertainment Wise*. Giant Digital Ltd, London, 2013. Available at: http://www.entertainmentwise.com/news/121213/I-Love-That-Man-Kris-Jenner-Defends-Sleep-Deprived-Kanye-West-Over-Paparazzi-Rant.

Lovibond, S. H. and Lovibond, P. E. *Manual for the Depression Anxiety Stress Scales*. Psychology Foundation, Sydney, 1995.

Minkel, J., Htaik, O., Banks, S. and Dinges, D. Emotional expressiveness in sleep-deprived healthy adults. *Behav. Sleep Med.*, 2011, 9: 5–14.

Minkel, J. D., Banks, S., Htaik, O. *et al.* Sleep deprivation and stressors: evidence for elevated negative affect in response to mild stressors when sleep deprived. *Emotion*, 2012, 12: 1015–1020.

Murray, E. J., Schein, E. H., Erikson, K. T., Hill, W. F. and Cohen, M. The effects of sleep deprivation on social behavior. *J. Soc. Psychol.*, 1959, 49: 229–236.

R Core Team. *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Vienna, Austria, 2012.

Roenneberg, T., Wirz-Justice, A. and Merror, M. Life between clocks: daily temporal patterns of human chronotypes. *J. Biol. Rhythms*, 2003, 18: 80–90.

Schwarz, J. F., Popp, R., Haas, J. *et al.* Shortened night sleep impairs facial responsiveness to emotional stimuli. *Biol. Psychol.*, 2013, 93: 41–44.

Van Beest, I. and Williams, K. D. When inclusion costs and ostracism pays, ostracism still hurts. *J. Pers. Soc. Psychol.*, 2006, 91: 918–928.

Van Beest, I., Williams, K. D. and Van Dijk, E. Cyberbomb: effects of being ostracized from a death game. *Group Process. Intergroup Relat.*, 2011, 14: 581–596.
Van Der Helm, E., Gujar, N. and Walker, M. P. Sleep deprivation impairs the accurate recognition of human emotions. *Sleep*, 2010, 33: 335–342.
Venkatraman, V., Huettel, S. A., Chuah, L. Y., Payne, J. W. and Chee, M. W. Sleep deprivation biases the neural mechanisms underlying economic preferences. *J. Neurosci.*, 2011, 31: 3712–3718.
Vohs, K. D., Glass, B. D., Maddox, W. T. and Markman, A. B. Ego depletion is not just fatigue: evidence from a total sleep deprivation experiment. *Soc. Psychol. Personal. Sci.*, 2011, 2: 166–173.
Williams, K. D. Social ostracism. In: R. M. Kowalski (Ed) *Aversive Interpersonal Behaviors*. Plenum, New York, 1997: 133–170.
Williams, K. D. Ostracism. *Annu. Rev. Psychol.*, 2007, 58: 425–452.
Williams, K. D. Chapter 6 ostracism: a temporal need-threat model. *Adv. Exp. Soc. Psychol.*, 2009, 41: 275–314.
Williams, K. D. and Jarvis, B. Cyberball: a program for use in research on interpersonal ostracism and acceptance. *Behav. Res. Methods*, 2006, 38: 174–180.
Williams, K. D., Cheung, C. K. and Choi, W. Cyberostracism: effects of being ignored over the Internet. *J. Pers. Soc. Psychol.*, 2000, 79: 748–762.
Williams, K. D., Yeager, D. S., Cheung, C. K. T. and Choi, W. Cyberball 4.0. 2012.
Yoo, S. S., Gujar, N., Hu, P., Jolesz, F. A. and Walker, M. P. The human emotional brain without sleep – a prefrontal amygdala disconnect. *Curr. Biol.*, 2007, 17: 877–878.
Zadro, L., Williams, K. D. and Richardson, R. How low can you go? Ostracism by a computer is sufficient to lower self-reported levels of belonging, control, self-esteem, and meaningful existence. *J. Exp. Soc. Psychol.*, 2004, 40: 560–567.