Social Reward and Support Effects on Exercise Experiences and Performance: Evidence from Parkrun

Arran Davis
University of Oxford
Pádraig MacCarron
University of Limerick
Emma Cohen (emma.cohen@anthro.ox.ac.uk)
University of Oxford https://orcid.org/0000-0002-5465-3440

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Social reward and support effects on exercise experiences and performance: evidence from parkrun

Arran Davis[1], Pádraig MacCarron[2], Emma Cohen[1,3*]

[1] *Social Body Lab, Institute of Cognitive and Evolutionary Anthropology, University of Oxford, 64 Banbury Road, Oxford OX2 6PN, UK*

[2] *Dynamic Attitude Fixing in Networks Research Group, University of Limerick, Limerick, Ireland. V94 T9PX*

[3] *Wadham College, Parks Road, Oxford OX1 3PN, UK*

AD ORCiD: http://orcid.org/0000-0002-8561-7768

PM ORCiD: https://orcid.org/0000-0002-5774-9122

EC ORCiD: https://orcid.org/0000-0002-5465-3440

*Corresponding author email: emma.cohen@anthro.ox.ac.uk

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There is growing academic, civic and policy interest in the public health benefits of community-based exercise events. Shifting the emphasis from competitive sport to communal activity, these events have wide appeal. In addition to physical health benefits, regular participation can reduce social isolation and loneliness through opportunities for social connection. Taking a broad evolutionary and social psychological perspective, we develop and test the hypothesis that social reward and support are associated with more positive exercise experiences and greater performance outputs. Using a repeated-measures design, we examine the influence of social perceptions and behaviour on subjective enjoyment, energy, fatigue, effort, and objective performance (run times) among a UK sample of parkrun participants. Social factors were associated with greater subjective enjoyment and energy. Higher subjective energy, in turn, was associated with faster run times, without any corresponding increase in perceived effort. No significant main effects of social factors on fatigue, performance or effort were detected. The role of social structural factors has long been recognised in public health approaches to physical activity. Our results motivate greater research attention on how positive and rewarding social behaviours and experiences – particularly subjective enjoyment and energy, and perceptions of community social support and belonging - influence exercise-related behaviour, psychology and physiology, and promote health through collective physical activity. The research also supplements traditional emphases on social facilitation and team sport that have dominated sport and exercise psychology and offers new avenues for understanding the deep connections among psychological, social and physical function in everyday health.

Key words: physical activity, sport, exercise, social psychology, social connection, social reward, social support, fatigue, energy, *parkrun*

1. Introduction

Physical activity and social relationships are critical "flashpoints" for health policy (Kohl et al., 2012; Umberson & Karas Montez, 2010). Low levels of physical activity and high levels of loneliness have been independently associated with poorer mental and physical health outcomes and mortality (Uchino et al., 1996). Despite the established benefits of sufficient physical activity and secure social ties for mental and physical health, levels of physical inactivity are extremely high globally (e.g., Guthold et al., 2018; Guthold et al., 2019). Although evidence on the prevalence of loneliness is less well established, loneliness as the *perception* of social isolation (even when among other people), is also widely recognized as a "real mental health challenge for the nations" (Durcan & Bell, 2015) and a growing problem worldwide (Cacioppo & Cacioppo, 2018; McPherson et al., 2006). In the world's first government loneliness strategy (Department for Digital, Culture, Media and Sport, UK Government, 2018) and in its first Loneliness Annual Report (Department for Digital, Culture, Media and Sport, UK Government, 2020), the UK government committed to improving the evidence base on loneliness through the use of standard measures (Cacioppo & Cacioppo, 2018; McPherson et al., 2006).

Medicalist perspectives predominate in assessments of the negative effects of physical inactivity and loneliness (e.g., morbidity-mortality risks, "pandemic" terminology). Nevertheless, these are widely considered to be complex social issues that require collaborative, integrated and holistic public health approaches (McLennan & Ulijaszek, 2018). Evidence suggests that one problem compounds the other, with loneliness having been identified as a risk factor for physical inactivity (Hawkley et al., 2009; Shvedko et al., 2018) and physical inactivity as a risk factor for psychiatric and psychosocial health problems that are directly or indirectly associated with depression and loneliness (Galper et al., 2006; Harvey et al., 2010). Physical inactivity and loneliness can therefore be approached as interlinked problems that require integrated solutions. Toward this general aim, this paper contributes new

theoretical and empirical perspectives on the behavioural and psychological synergies between physical exercise and social relationships.

Although considerable research attention has been directed at understanding how social-environmental factors influence physical activity behaviour (e.g., McNeill et al., 2006), connections between the affective dimensions of physical activity, particularly exercise, and sociality remain underappreciated. Previous research offers some promising clues. For example, positive affect in exercise – i.e., liking or enjoyment – is a key determinant of adherence (Ekkekakis et al., 2013) and, in general, intense emotional experiences happen more often in the context of interdependent social connection and belonging than in independent situations (Jaremka et al., 2011). This suggests a possibility for social enhancement of positive affect in physical exercise (Cohen, 2017; Cohen et al., 2010; Davis et al., 2015; Tarr et al., 2015), with corresponding increases in motivation and adherence. In addition, there are links between collective physical activity in diverse forms, such as play, sport, dance, and exercise, and feelings of social bonding and belonging (e.g., Tarr et al., 2015; Tunçgenç & Cohen, 2016), which in turn are associated with positive motivation and adherence (Spink et al., 2013). Taken together, these links trace a virtuous circle between affectively rich, meaningful and positive social connections and intrinsically motivated engagement and enjoyment in collective physical activity.

Besides links to social-motivational psychology, a large and growing literature spanning the behavioural and psychological sciences, physiology and neuroscience has also elucidated the effects of perceived social support on the homeostatic regulation of stress, fatigue and pain (e.g., Davis & Cohen, 2018; Eisenberger et al., 2011; Hennessy et al., 2009). Applying these insights to the physical activity domain, it can be hypothesised that perceptions of social support buffer, or reduce, unpleasant exercise-induced affect, such as fatigue and pain (Davis et al., 2015), thereby potentially increasing performance outputs, sense of achievement, and engagement in exercise.

Despite the apparent connections among affective and behavioural dimensions of exercise and sociality, surprisingly little research has directly investigated the effects of either the rewarding or buffering aspects of social bonding and support on exercise experiences. Traditional social psychological approaches in sports and exercise science, originating in the observations of Norman Triplett in the late

19th century, have focused on competitive and evaluative aspects of social presence and their facilitating effects on motivation, effort and performance across different types of task (for a review, see Aiello & Douthitt, 2001). In a largely separate line of research, team cohesion has been studied as a predictor of effort and performance in sport. For example, group cohesion in sport settings – defined as "a group dynamic process that is reflected in the tendency of a group to stick together and remain united in the pursuit of instrumental objectives and/or for the satisfaction of member affective states" (Carron et al., 1998; p. 213) – positively predicts performance success (Carron et al., 1998), adherence to group exercise programmes (Burke et al., 2008) and physical exertion in team sports (Prapavessis & Carron, 1997). Related research drawing inspiration from social identity theory has begun to identify the importance of social-group identities for promoting physical activity engagement, adherence, enjoyment and effort. For example, in a recent parkrun study, Stevens et. al (2017) found that stronger identification with the parkrun running group positively predicted participation, life satisfaction, exercise-specific satisfaction, and group cohesion. These and other studies (Carnes & Mahoney, 2016; Graupensperger et al., 2019) (Carnes & Mahoney, 2016) offer support for the idea that individuals' perceptions of the social group as cohesive and supportive, and with which they can strongly identify as group members, can promote positive affective exercise experiences, increase participation in physical activity, and facilitate performance via socially-mediated mechanisms other than arousal, evaluation apprehension and distraction.

This literature has elucidated the types, causes and consequences of group cohesion in sports. However, the psychological, physiological, and performance effects of bonded sociality outside of team or group-based sport (e.g., in transient collectives, virtual settings, and exercise groups without clearly defined boundaries, interdependent roles and shared goals) remain relatively unexplored, both theoretically and empirically, and little is known about the psychobiological pathways via which human sociality, psychology and biology co-regulate one another in exertive physical activity (Cohen et al., 2010; Davis et al., 2015). Research across a wider range of activities, social contexts and outcome measures is needed in order to determine how social behaviours and perceptions of social support, integration and

belonging influence exercise-related affect, physiology and performance, and to better understand the public health significance and value of community exercise schemes and events.

We examine these questions in the context of *parkrun*, a community-based organisation that convenes free, weekly, timed 5 km runs in public parks and spaces. Since its inception in 2004, parkrun has seen rapid and sustained international growth; at the time of writing, parkrun events occur in over 2,000 locations in 22 countries worldwide. In the current study, we used survey and performance data to investigate effects of three predictor variables on feelings of enjoyment, fatigue, and energy as well as objective performance among parkrunners: 1) whether participants attended with friends or family vs. attended alone; 2) whether or not participants interacted with others socially before the event; 3) the degree to which participants felt a) supported by, and b) integrated into the parkrun community. Hypotheses are summarised in Table 1.

[*Insert Table 1 about here*]

2. Methods

2.1. Participants

Participants were recruited in person and through parkrun event webpages from six parkrun sites in southern England. Recruitment was on a rolling basis over approximately two months (see SOM 1). In total, 188 parkrunners consented to take part; 144 participants completed the survey at least once and there were 734 usable surveys in total (see Section 3.1). This study was approved by both the parkrun Research Board (UK) and the [Institutional Review Board blinded for peer review]. Data collection did not continue after data analysis.

2.2. Survey procedure

Participants completed surveys online via Qualtrics. The survey consisted of 14 questions concerning participant motivations, perceptions of community support and integration and other social aspects of their run, and about fatigue, pain and effort (see SOM 2 & 3 for full details).

2.3. Additional data acquisition

Participants' 5 km run times, sex, and age category were collected from the parkrun online databases for every run for which a survey response was recorded.

2.4. Inferential statistical models

Statistical analyses were performed in R version 3.5.3. The R packages *lme4* (Bates et al., 2014) and *lmer* (Kuznetsova et al., 2015) were used to perform the primary analyses. Marginal R^2 (R^2_m and R^2_c) was calculated using functions from the *piecewiseSEM* package in R (Nakagawa & Schielzeth, 2013). The R packages *mediation* (Tingley et al., 2014) and *lme4* (Bates et al., 2014) were used to perform the multilevel mediation analyses, which employed bias-corrected and accelerated (BCa) bootstrap-based confidence intervals.

All multilevel models included participant ID as the level-two grouping variable. When possible, maximal random effects structures were used (see SOM 6).

For models testing effects of social predictor variables on subjective fatigue, energy and enjoyment (Hypotheses 1.1 – 3.3), there were no covariates. Models on 5 km run times (logged to improve model fit) and mediation analyses included a 'pace influence' covariate (see SOM 7). All direct, indirect, and total effects were calculated following the procedures of Tingely et. al (2014). Additional models examined effects of response time on self-reported outcome variables and of social predictors on effort (see SOM 9 and SOM 10).

Assumption checks were carried out in accordance with the methods suggested by (Snijders & Bosker, 2011) and (Bauer et al., 2006). Full model selection criteria and assumption checks and are reported in SOM 6 and SOM 7, respectively.

2.5. Family-wise error rates

When testing families of comparisons it is necessary to control for the increased probability of Type I error due to conducting multiple hypothesis tests (Benjamini & Hochberg, 1995; Bonferroni, 1936;

Field et al., 2012). The analyses reported below used the procedures of Benjamini and Hochberg (Benjamini & Hochberg, 1995) in determining more conservative critical values for each of the three related tests in the five families of hypotheses in Table 1.

For the mediation analyses, each type of effect (indirect, direct, and total) was treated as a sub-family of tests when accounting for multiple comparisons for Hypothesis 5.1 – Hypothesis 5.3 and Hypothesis 6.1 – Hypothesis 6.3.

The full procedure used for controlling for multiple comparisons can be found in SOM 8.

3. Results

3.1. Survey responses

In total, there were 765 survey responses. Some returns could not be matched to a particular parkrun ID and were excluded from analyses. If a participant responded more than once on a given day, their first response was retained for analysis, and all subsequent responses from that day were removed (see SOM 3 for full data cleaning procedures). After exclusions, there were 734 survey responses from 143 participants (see SOM Figure S3); 49% of participants were female (n = 70), and females represented 46% of all surveys returns analysed (n = 341). Respondents were drawn from all age categories (18-20 – 75-79). The mean age of survey respondents (taking the midpoint of the age category as the respondent's age) was 48.27 years (median = 47 years, SD = 11.90 years). Participants responded to the survey an average of 5.09 times (median = 4, SD = 4.02, range = 1 – 17).

3.2. Relationship with the parkrun community

Responses to the two questions on the parkrun community were highly correlated ("How much did you feel supported by the parkrun community today?" and "How much did you feel you were a part of the parkrun community today?"; r = .72). A PCA was used to test the relationship between these two variables, based on the expectation that the questions on support and inclusion would load onto a

component related to social support from the parkrun community (see SOM 4 for a full summary of this analysis). The single component extracted from the two variables had a Kaiser's criterion of 1.72, explained 86% of the variance in answers to the two questions, and had good reliability (Cronbach's alpha = .840). The component (henceforth, the 'parkrun community component') was taken to represent the perceived strength of participants' relationship with the parkrun community, and is used as a predictor variable in the analyses described below.

3.3. Descriptive statistics

The majority of survey responses indicate that participants were more motivated to attend parkrun for social reasons, i.e., "to run together with other people" (*n* = 448, 61%), than to attend for reasons related to training ("to improve my time"; *n* = 268, 37%) or competition ("to improve my ranking" *n* = 18, 2%). In the majority of responses, participants reported running without a partner or companion (*n* = 497, 68%), with the remainder split between running "alongside one or more friends/family members" (*n* = 106, 14%) and running "alongside one or more acquaintances" (*n* = 85, 12%), and "alongside a mix of acquaintances and friends/family members" (*n* = 47, 6%). In the majority of surveys, participants reported coming or meeting up with friends and family, or a mixture of friends, family, and acquaintances (*n* = 394, 54%), versus coming or meeting up with one or more acquaintances (*n* = 202, 28%) or coming on their own (*n* = 138, 19%). Regarding what participants were doing just before the run (henceforth 'pre-run sociality'), the response most frequently chosen was 'getting ready or hanging out with others' (*n* = 462, 63%), followed by 'getting ready or hanging out on my own' (*n* = 189, 26%) or doing something else (*n* = 83, 11%).

For the inferential analyses reported below, we created binary categories for the variables on who participants came/met up with and their pre-run sociality: either coming/meeting up with friends/family (*n* = 394, 54%) or not (*n* = 340, 46%) and either being social before the run (*n* = 462, 63%) or not (*n* = 272, 37%). Regarding the two questions that made up the parkrun community component, the mean response to the question concerning perceptions of parkrun community support was 5.72 (*SD* = 1.06,

range = 2 – 7), and the mean response to the question on being part of the parkrun community was 5.76 (*SD* = 1.08, range = 1 – 7).

Although attending or meeting up with others appears to be the norm for this sample, the majority of survey responses indicate that participants ran on their own. In 74.25% (*n* = 545) of surveys participants reported running on their own; in 8.17% (*n* = 60) of surveys, participants reported slowing down to run with their partner(s), in 6.13% (*n* = 45) of surveys, participants reported speeding up to run with their partner(s), and in 11.44% (*n* = 84) of surveys participants reported running at a natural pace with their partner(s).

Participants' 5 km run times were positively skewed (skewness = 0.87; see SOM Figure S5; *M* = 27 min 52 sec, *SD* = 5 min 53 s, range = 16 min 36 s – 57 min 20 s). Regarding subjective effort, the mean response on the RPE scale was 14.61 (*SD* = 2.25, range = 6 – 20), between "13 – Somewhat hard" and "15 – Hard (heavy)". Subjective effort was highly correlated with subjective fatigue (*r* = .706). The mean rating of fatigue was 4.79 (*SD* = 1.27, range = 1 – 7). The follow-up to this question, on how physically painful the fatigue was, was only asked when participants' reported level of fatigue was 5 or greater (64.17% of surveys; *n* = 471; *M* = 4.24 *SD* = 1.32, range = 1 – 7). Participants reported enjoying their runs (*M* = 5.64 *SD* = 1.12, range = 1 – 7). Regarding subjective energy, the mean response was 5.64 (*SD* = 1.06, range = 1 – 7).

Although informative of the survey results as a whole, this descriptive picture should be interpreted with caution as it is most heavily influenced by those participants who answered the survey the most times (see SOM Figure S3).

3.4. Main effects of social predictor variables on subjective experiences and 5km run times

3.4.1. Main effects of social predictor variables on subjective fatigue (H1)

The parkrun community component and pre-run sociality did not significantly predict participants' perceptions of fatigue (see SOM Table S5 and Table S7). There was an association between who participants came/met up and perceptions of fatigue; coming/meeting up with friends/family (vs.

coming or meeting up with acquaintances or alone) predicted significantly lower fatigue, $b = -0.250$, $SE = 0.111$, t (df) = −2.245 (92.7), $p = .027$ (see SOM Table S6), but this p-value was not significant at its Benjamini-Hochberg adjusted critical value.

3.4.2. Main effects of social predictor variables on subjective energy (H2)

The parkrun community component positively predicted perceived energy, $b = 0.559$, $SE = 0.034$, t (df) = 16.51 (659.5), $p < .001$, as did coming or meeting up with friends/family, $b = 0.209$ $SE = 0.081$, t (df) = 2.60 (730.2), $p = .009$, and pre-run sociality, $b = 0.310$, $SE = 0.092$, t (df) = 3.38 (62.9), $p = .001$ (see SOM Table S8 – Table S10). All p-values were significant at their Benjamini-Hochberg adjusted critical value.

3.4.3. Main effects of social predictor variables on subjective enjoyment (H3)

The parkrun community component positively predicted enjoyment, $b = 0.439$, $SE = 0.039$, t (df) = 11.21 (673.6), $p < .001$, as did coming or meeting up with friends/family, $b = 0.230$ $SE = 0.086$, t (df) = 2.67 (714.2), $p = .008$, and pre-run sociality, $b = 0.346$, $SE = 0.010$, t(df) = 3.47 (80.8), $p < .001$ (see SOM Table S11 – Table S13). All p-values were significant at their Benjamini-Hochberg adjusted critical value.

3.4.4. Main effects of social predictor variables on 5 km run times (H4)

None of the social predictor variables predicted 5 km run times (see SOM Table S14 to Table S16).

[*Insert Figure 1 about here*]

3.4.5. Perceived energy as a mediator of main effect of social predictors on 5 km run times (H5)

All three predictor variables had significant, ergogenic indirect effects on 5 km run times, with perceived energy as the mediating variable (H5.1-5.3; see Figure 1 and SOM Figure S6).

The first mediation analysis tested whether participants' perceived energy mediated the relationship between their scores on the parkrun community factor and their (logged) 5 km run times (5.1). Analyses revealed a significant average indirect effect of −0.008 (95% CI: [−0.013, −0.001], $p < .001$), a significant average direct effect of 0. 015 (95% CI: [0.007, 0.020], $p < .001$), and a non-significant total effect of 0.007 (95% CI: [−0.001 0.020], $p = .110$): how energised participants felt mediated the relationship between the parkrun community component and participants' 5 km run times. The average indirect effect was significant at its Benjamini-Hochberg adjusted critical value (see SOM Table S17 and Table S18 for model summaries and SOM Figure S6a and Figure S6d for predictor, mediator, and outcome variable relationships).

The second mediation analysis tested whether participants' perceived energy mediated the relationship between who participants came or met up with and their (logged) 5 km run times (H5.2). There was a significant average indirect effect of −0.002 (95% CI: [−0.004, −0.001], $p = .012$), a non−significant average direct effect of 0.008 (95% CI: [−0.009, 0.020], $p = .338$), and a non−significant total effect of −0.006 (95% CI: [−0.011, 0.020], $p = .468$): the relationship between who participants came or met up with and logged run times was mediated by how energised they felt. The average indirect effect was significant at its Benjamini-Hochberg adjusted critical value (see SOM Table S19 and Table S20 for model summaries and SOM Figure S6b and Figure S6d for predictor, mediator, and outcome variable relationships).

The third mediation analysis tested whether participants' perceived energy mediated the relationship between their pre-run sociality and their (logged) 5 km run times (H5.3). Results showed a significant average indirect effect of −0.003 (95% CI: [−0.006, −0.001], $p = .006$), a non-significant average direct effect of 0.012 (95% CI: [−0.005, 0.030], $p = .138$), and a non-significant total effect of 0.010 (95% CI:

[−0.008, 0.030], $p = .236$): the relationship between participants' pre-run sociality and logged 5 km run times was mediated by how energised they felt. The average indirect effect was significant at its Benjamini-Hochberg adjusted critical value (see SOM Table S21 and Table S22 for model summaries and SOM Figure S6c and Figure S6d for predictor, mediator, and outcome variable relationships).

3.4.6. Subjective fatigue as a mediator of main effect of social predictors on 5 km run times (H6)

With fatigue as the mediating variable (H6), none of the social predictor variables had significant direct, indirect, or total effects on 5 km run times. Mediation summaries can be found in SOM Figure S7, and model summaries can be found in SOM Table S23 – Table S28.

3.4.7. Main effects of social predictor variables on subjective effort

None of the social predictor variables significantly predicted subjective effort levels (RPE; see SOM Table S29 – Table S31). This suggests that social predictor effects on participant experiences and performance are not confounded by social-motivational factors associated with competition or threat of evaluation.

4. Discussion

Community-based sports and exercise events, particularly those offered on a continuous and regular basis, have been identified as having significant but untapped public health benefits (C. Stevinson & Hickson, 2014). Existing evidence suggests that participation in collective exercise events, such as parkrun, can be encouraged not just for the physical and psychological benefits of physical activity and exercise, but also for the simultaneous wellbeing benefits of social connection, integration and support (Morris & Scott, 2018; Spink et al., 2013). Although it has been shown that individuals often draw on existing connections to initiate their participation in parkrun (e.g., Gareth Wiltshire & Stevinson, 2017),

and that stronger identification with the parkrun collective is associated with more frequent participation and higher life satisfaction (Stevens et al., 2017), little is known about the effects of social reward and support on participants' affective experiences of exercise, and related performance. Addressing this gap can begin to contribute valuable new data relevant to tackling pressing international public health challenges of physical inactivity and loneliness, while at the same time advancing our scientific understanding of the social modulation of homeostatic mechanisms that contribute to feelings of fatigue, energy, enjoyment and performance in exertive physical activity (Hartman et al., 2019).

To investigate the social determinants of affective experiences and performance in exercise in a naturalistic group setting, we analysed associations between a range of social variables and self-reported enjoyment, fatigue and energy, as well as recorded run times, in a sample of UK parkrunners. Results give partial support to our hypotheses and suggest a more nuanced account of how social environments affect experiences and outputs during physical exercise.

Survey responses confirmed previous findings of high levels of sociality at parkrun (Hindley, 2018; C. Stevinson & Hickson, 2014; Clare Stevinson et al., 2014a; GR Wiltshire et al., 2018): in the majority of surveys, participants reported coming or meeting up with friends and family, or a mixture of friends, family, and acquaintances. Running with others, rather than running to improve times or rankings, was the predominant motivation for attending. As participants primarily report running on their own, however, this motivation appears to relate more to the parkrun collective rather than specific running partners or groups. Perceived support from and integration within the parkrun community was high, as were subjective enjoyment, energy, effort and fatigue. Overall, the descriptive picture is of a positive and facilitative social context for invigorating and challenging self-paced exercise.

Social predictors had positive effects on subjective enjoyment and energy, and performance, in line with our hypotheses. The social predictor variables did not directly predict participants' perceptions of fatigue, however. Furthermore, it was only through indirect effects that they were associated with lower 5 km run times. Specifically, the social predictor variables were positively associated with subjective energy levels, and these were negatively related to 5 km run times (i.e., relatively higher subjective energy was associated with faster 5 km run times). The mediation analyses revealed that all of the social

predictor variables had significant indirect negative effects on 5 km run times, via positive effects on subjective energy. A one unit increase in the social predictor variables led to between 0.17% and 0.74% decreases (depending on the predictor variable) in 5 km run times, such that 5 km runs were between 3.34 s and 11.70 s faster for a participant with 5 km run times equal to that of the overall average of 27 min 52 s (Hayes, 2013).

Taken together, these results suggest that, even among those who generally run slower times, it is not social factors *per se* that lead to improved performance. Rather, social factors, on average, are positively associated with greater feelings of energy, and these predict faster 5 km run times. In fact, when controlling for subjective energy, there was a significant direct effect of the parkrun community factor on run times, but in the opposite direction predicted. This likely reflects the variable performance motivations represented across these participants; those with stronger motivations to improve their run times may be more likely to benefit from the energizing effects of social support and integration relative to those less concerned about their running performance.

Overall, these results point to potential beneficial effects of social reward on positive affect, including enjoyment and subjective energy, with potential regulatory effects on performance. As there is no indication that social predictors were associated with self-reported effort, it seems unlikely that the mediating effect of subjective energy on performance is attributable to motivations traditionally identified in social facilitation research (e.g., evaluation apprehension). Rather, we suggest that the felt energy and enjoyment associated with the social predictor variables can be explained, in part, by the intrinsic psychological reward of positive and supportive social engagement (Acevedo et al., 2012; Tristen K Inagaki & Eisenberger, 2013). This interpretation is in line with observational research showing that perceptions of social support and cohesion at parkrun are associated with more positive experiences (Clare Stevinson et al., 2014b). Although this study does not examine potential causal mechanisms, our interpretation is also corroborated by extensive neurobiological evidence that endogenous systems involved in sustaining physical exercise, such as the endocannabinoid and opioidergic systems, are also activated by positive social interactions (Boecker et al., 2008; Tristen K Inagaki & Eisenberger, 2013; Tristen K. Inagaki et al., 2016; Raichlen et al., 2012; Trezza et al., 2010).

Overall, we suggest that positive social engagement and perceptions of support modulate the balance of pleasure-displeasure that regulates self-selected exercise intensity and performance output, and that this could be instrumental in motivating adherence (Ekkekakis et al., 2013; Hartman et al., 2019; Williams, 2008).

Although all of the social predictor variables were positively associated with participants' subjective energy, there was no significant relationship detected between the social predictors and fatigue, nor any interaction effect of social predictors and fatigue on performance. Tthese results suggest a qualification of our account. Fatigue and energy are both conceptualized in the literature as multidimensional states that concern ability to sustain voluntary activity. Whereas feelings of fatigue relate specifically to the perceived *difficulty* of maintaining task goals (Pattyn et al., 2018), feelings of energy relate to perceived *ability* to maintain task goals, captured in standard measures as "vigour" or "vitality". Our results suggest that, in the parkrun context, both reported fatigue and reported energy were relatively high (M = 4.79, SD = 1.27 and M = 5.64, SD = 1.06, respectively, on a 1-7 scale), but that increased feelings of energy are the affective mechanism through which social cues affect performance. This suggests a distinction between "boosting" (i.e., energy-giving) and "buffering" (fatigue-reducing) mechanisms and effects on affect and related performance. Our results do not indicate substantive differences among the three social predictor variables and their effects on outcome variables. Thus, there is no suggestion of differential effects of, for example, community integration vs. pre-run socializing with friends, on subjective enjoyment and energy vs. subjective fatigue. Future research could systematically manipulate those aspects of social behaviour most directly associated with increasing pleasant affective states (e.g., social laughter, behavioural synchrony, such as in singing or dancing (Dunbar et al., 2011) and those most directly associated decreasing unpleasant affective states (e.g., safety signaling (Hornstein & Eisenberger, 2017), and measure effects on subjective energy and fatigue.

An alternative explanation for the significant mediation effect is that the presence of known social others increased levels of competition and motivation among parkrunners, and these effects were captured by the perceived energy variable. Motivation and felt energy are likely overlapping constructs,

both leading to increased physical outputs (Hettinga et al., 2017). It is possible that the presence of friends or family members increases competition levels at parkrun. However, it is unclear why socialising before the event or feeling more included and supported by the parkrun community would predict higher competition levels. Furthermore, contrary to the competitive-motivation account, we found no association between social predictor variables and subjective effort (RPE). Future studies could investigate relationships among social reward or support, felt energy and fatigue, and performance in a range of social exercise settings. Fatigue-buffering effects of perceived social support may be more likely in high-intensity exercise contexts characterized by both positive sociality, support or camaraderie and high-stakes performance near the limits of exercise tolerance (Gibson et al., 2017; Hartman et al., 2019; Marcora, 2019).

The results of this study should be considered in light of its limitations. First, the study was observational in nature and causality can only be inferred. Higher feelings of energy could, in principle, be predictive of higher sociability and perceptions of social support generally, though we are not aware of any evidence directly supporting this conjecture. More plausibly, higher performance outputs could prompt reports of higher subjective energy, via positive feedback mechanisms. Although some parkrunners track their times on personal watches, not all participants would have been aware of their objective performance during or immediately after the event. Surveys were sent out 45 min after the beginning of each parkrun. The median time taken to return the survey was approximately 4.5 hrs, and 20% of surveys were returned over 24 hrs after they were received (see SOM Figure S4a). All returned surveys were included in analyses. It is likely that some participants would have accessed their 5 km run times before completing the survey. Post-hoc appraisals of subjective energy could therefore have been informed by knowledge of objective run time data. However, analyses show no effect of response time on variables related to participants' affective experiences (i.e., their self-reports of fatigue, energy, or enjoyment) or their scores on the parkrun community component (see SOM 10), and there is no theoretical reason to assume that this prior knowledge would affect reports of pre-run sociality or who participants reported coming to or meeting up with at parkrun.

Previous qualitative research also offers some support for the hypothesised causality. Participants' statements indicate awareness and appreciation of social support received from other parkrunners, including boosting effects on performance (Hindley, 2018; Clare Stevinson et al., 2014a): "When people come through the finish line, you know, there's people there and they're all cheering you on and, you know, it just gives a real boost really; and like that first experience I had of that woman, you know, supporting me through the last little bit when I was struggling. That happens all the time" (Wiltshire et al., 2018, p. 10). The link to adherence is also explicit in these reflections: "Running with others is a massive motivation. The self-talk doubts don't creep in when in a group … I don't think I would run 5 km every week if I didn't have a group like this to run with" (Hindley, 2018; p. 12).

Second, although our primary statistical analyses accounted for the repeated measures design, multilevel model results are influenced most by those participants with relatively high numbers of survey responses (Snijders & Bosker, 2011). However, there are few significant differences between participants with high survey response counts (nine or more responses) and those with low survey response counts (fewer than nine responses; see SOM 9 and SOM Table S32).

Third, the study does not investigate factors predicting variation in perceptions of social support, or in the association between social predictors and positive experiences or performance outcomes. It is important to note that the presence of others, even family and friends, does not always serve as a cue of social reward or social support. Furthermore, being the recipient of support is not always a positive experience. For example, highly neurotic individuals focus on the interpersonal costs of receiving social support while highly independent individuals can react to social support with feelings of compromised independence (Park et al., 2013). These responses have been theorised to reduce (or even abolish) the positive effects of social support on coping with stressors (Park et al., 2013; Uchida et al., 2008). Future research could examine effects of relationship quality and personality on experiences in exercise, as well as the effects of different exercise contexts (e.g., primarily competitive or primarily cooperative) on the quality of participants' social connections and relationships and on subjective energy and self-efficacy levels, as well as how these variables relate to exercise experiences and adherence (Christensen et al., 2006; O'Connor & Puetz, 2005; Schnall et al., 2008). This work could inform the design of

interventions that better leverage and target the potential of social connection, reward and support to benefit the exercise experiences and health outcomes of individuals across a wider range of personality traits and socio-cultural backgrounds.

5. Conclusion

Affective dimensions of physical exercise and social integration and belonging are fundamental to addressing global public health challenges of physical inactivity and social isolation or loneliness. Traditionally, physical (in)activity research and social psychological research on these issues have proceeded in parallel, occupying distinct academic domains. Despite promising recent examples (Barkley et al., 2012; Stevens et al., 2017; C. Stevinson & Hickson, 2014; Gareth Wiltshire & Stevinson, 2017), cross-fertilization between domains is historically limited by parochial emphases on the social factors that influence either health and wellbeing or performance in physical activity and exercise. Whereas social-environmental approaches to physical inactivity have focused primarily on social-ecological conditions that promote or inhibit health-beneficial exercise behaviour, social psychological approaches to exercise adherence and performance have focused overwhelmingly on social facilitation effects engendered via stress (at worst) or distraction (at best), or on the benefits of cohesion for adherence, performance and health in team or group settings with clearly defined boundaries.

Here, we suggest that these issues do not belong in any single discipline, and that approaches need to draw from traditionally disparate areas of science (e.g., sports science, evolutionary anthropology, social psychology) to effectively inform public policy and civic engagement. The research here takes a broad interdisciplinary, evolutionary and psychological approach to human social behaviour, drawing from an extensive literature demonstrating that humans derive intrinsic pleasure from connecting, coordinating and cooperating together, and that our cooperative sociality profoundly influences homeostatic function, wellbeing and health (Hawkley & Cacioppo, 2010). The findings motivate new orientations on old questions about the social determinants of engagement and performance in exercise, offer novel directions for research into the public health value of community-led sports and exercise

initiatives, and contribute to our nascent understanding of the synergistic interdependencies between social, psychological and biological factors in homeostatic self-regulation in exercise.

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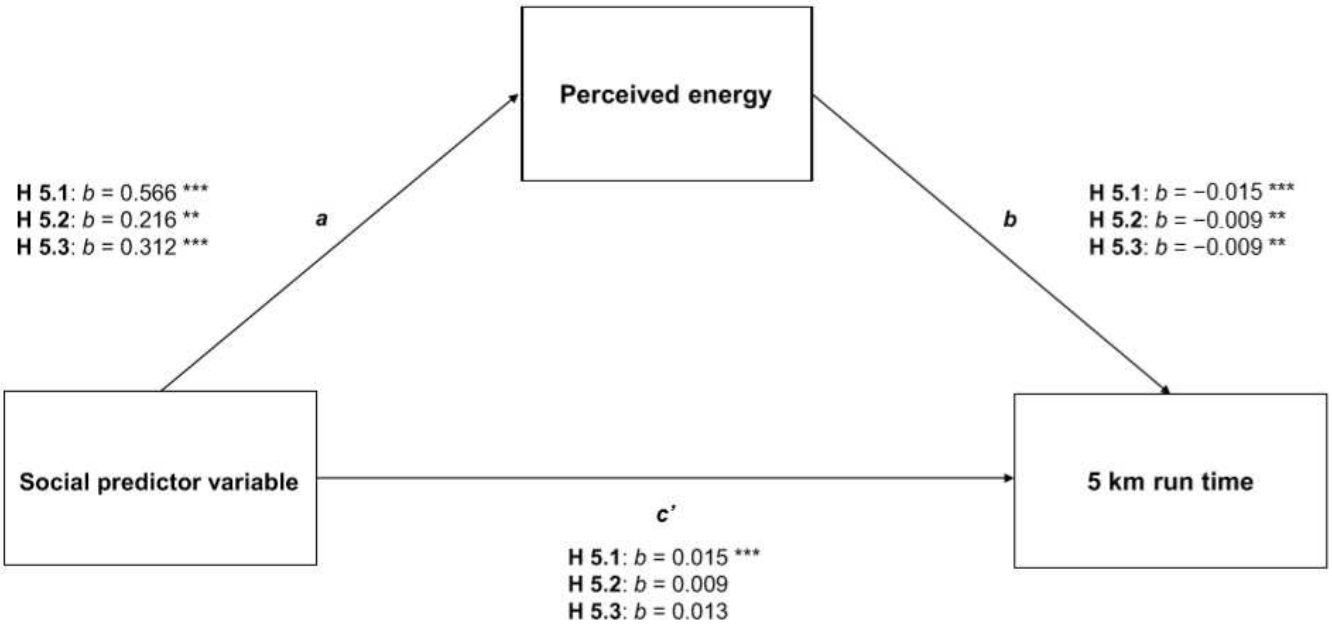
Figure 1. Mediation diagram depicting the direct, indirect, and total effects of the social predictor variables – the parkrun community component (H5.1), whether or not participants came or met up with family and/or friends (H5.2), and their pre-run sociality (H5.3) – on 5 km run times, with participants' perceived energy as a potential mediator. Statistical significance: $p < .001$ (***), $p < .01$(**), $p < .05$ (*).

Table 1. Research Hypotheses

Figures



Prediction	Indirect effect (*ab*)	Direct effect (*c'*)	Total effect (*c'* + *ab*)
5.1	−0.008, $p < .001$	0.015, $p < .001$	0.007, $p = .110$
5.2	−0.002, $p = .012$	0.008, $p = .338$	0.006, $p = .468$
5.3	−0.003, $p = .006$	0.012, $p = .138$	0.010, $p = .236$

Figure 1

Mediation diagram depicting the direct, indirect, and total effects of the social predictor variables – the parkrun community component (H5.1), whether or not participants came or met up with family and/or friends (H5.2), and their pre-run sociality (H5.3) – on 5 km run times, with participants' perceived energy as a potential mediator. Statistical significance: p < .001 (***), p < .01(**), p < .05 (*).

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