nature food

BRIEF COMMUNICATION

https://doi.org/10.1038/s43016-020-0132-8

Order of meals at the counter and distance between options affect student cafeteria vegetarian sales

Emma E. Garnett[1]✉, Theresa M. Marteau[2], Chris Sandbrook[3], Mark A. Pilling[2] and Andrew Balmford[1]

Altering the order in which meals are presented at cafeteria counters has been proposed as a way of lowering meat consumption, but remains largely untested. To address this, we undertook two experimental studies involving 105,143 meal selections in the cafeterias of a British university. Placing vegetarian options first on the counter consistently increased their sales when choices were widely separated (>1.5 m; vegetarian sales as a percentage of total meal sales increased by 4.6 and 6.2 percentage points) but there was no evidence of an effect when the options were close together (<1.0 m). This suggests that order effects depend on the physical distance between options.

Shifting towards plant-based diets is a commonly proposed strategy to mitigate climate change and protect the natural environment[1], particularly in high-income countries with high levels of animal product (meat, dairy, eggs, fish) consumption[2]. Traditional approaches to changing behaviour include information provision and taxation[3]. A third set of interventions that target non-conscious processes and the contexts in which behaviours occur—so-called 'nudging' or 'choice architecture' approaches—hold promise but are largely untested[3]. Rearranging the physical order in which foods are presented—for example, on cafeteria counters—is widely advocated to achieve dietary change[4], but the evidence for this is limited in both quantity and quality (see Methods)[5,6]. If effective, placing vegetarian options first would be a simple approach for reducing meat consumption.

To test the effect of order on vegetarian meal sales, we worked in two college cafeterias (A and B) in the University of Cambridge (United Kingdom), using data on 105,143 meal selections across two academic years (Table 1). Experiments were run on weekday lunchtimes and dinnertimes during university terms and involved alternating weekly between a vegetarian option ('VegFirst') and a meat option ('MeatFirst') being placed first in line, that is, nearest the cafeteria entrance (Supplementary Figs. 1–4 and Supplementary Tables 1–3). We hypothesized that the main-meal options placed first would be preferentially selected and therefore have higher sales. To better understand our initial results, we conducted a second study focused on the distance between choice options. In both studies, we assessed the persistence of any effects detected through a follow-up monthly alternation of VegFirst and MeatFirst. We discuss results using binomial logistic generalized linear models with order as the only predictor variable (univariate models) and when controlling for other predetermined independent variables (multivariate models, Table 1, Supplementary Methods and Supplementary Tables 4–9).

In study 1, in college A, changing the order of meal options had no significant effect on vegetarian sales in either univariate ($P=0.876$) or multivariate models ($P=0.058$; Fig. 1a and Table 1). However, in college B, placing the vegetarian option first increased vegetarian sales by 4.6 percentage points (25.2%, Table 1) with the weekly alternation and by 6.2 percentage points (39.6%) with the monthly alternation. Meal order was a significant predictor of vegetarian sales in both univariate and multivariate analyses. The effect size of order was not significantly different between the weekly and monthly alternation, that is, the confidence intervals of the meal order odds ratio overlapped (Table 1), suggesting diners did not become habituated to order for at least one month after meal order was changed.

To summarize study 1, we found no effects of altering meal order on vegetarian sales at college A, but strong and persistent effects at college B. We hypothesized that this result was due to the different distances between the vegetarian and meat options: 85 cm in college A and 181 cm in college B. Previous studies have found that foods placed farther away from participants are selected less frequently[6], although interactions between distance and order remain poorly understood. We designed study 2 to test this hypothesis and rearranged college B's cafeteria to reduce the distance between the focal meal options to 67 cm. The same methods were implemented as in study 1 (see Methods and Supplementary Methods). Unfortunately, increasing the separation of meal options in college A was not physically possible because of the cafeteria design.

In college B, study 2, under the short-distance condition with weekly alternation of meal order, vegetarian sales were unexpectedly and significantly lower for VegFirst in both a univariate ($P<0.001$) and a multivariate model (4.2 percentage points lower (18.5%), $P<0.001$; Table 1). Further investigation of this result showed an interaction between mealtime and meal order (interaction term $P<0.001$): at lunchtimes vegetarian sales were 6.7 percentage points (29.7%) lower for VegFirst compared with MeatFirst, but there was no significant difference at dinnertimes.

In the follow-up, monthly order alternation had no significant effect on vegetarian sales in the univariate analysis ($P=0.477$) or in the multivariate analysis ($P=0.560$; Fig. 1e). However, a significant interaction was again found between mealtime and meal order ($P<0.001$): there was no significant change in

[1]Department of Zoology, University of Cambridge, Cambridge, UK. [2]Behaviour and Health Research Unit, University of Cambridge, Institute of Public Health, Cambridge, UK. [3]Department of Geography, University of Cambridge, Cambridge, UK. ✉e-mail: ee.garnett@gmail.com

Table 1 | Summary of experiments and multivariate model estimates for order of meals in studies 1 and 2

Study characteristics							Multivariate model				
Study	Term	College	Distance between options (cm)	Order alternation	Number of mealtimes	Number of meals	R^{2a}	MeatFirst: veg sales (%) [CI]b	VegFirst: veg sales (%) [CI]c	Difference between VegFirst and MeatFirst (% difference)d	Meal order odds ratio [CI]e	Meal order *P* value[f]
1	Spring 2017	A	Short (85)	Weekly	92	11,683	0.084	17.5 [14.8, 20.5]	15.7 [13.5, 18.2]	−1.8 (−10.3)	0.88 [0.77, 1.00]	0.058
1	Summer 2017	B	Long (181)	Weekly	96	20,544	0.070	18.2 [16.8, 19.7]	22.8 [21.2, 24.6]	4.6 (25.3)	1.33 [1.24, 1.42]	<0.001
1	Autumn 2017	B	Long (181)	Monthly	86	22,518	0.111	15.6 [14.2, 17.2]	21.8 [20.0, 23.8]	6.2 (39.7)	1.51 [1.30, 1.75]	<0.001
2	Spring 2018	B	Short (67)	Weekly	87	20,224	0.099	22.7 [21.0, 24.4]	18.5 [17.1, 20.0]	−4.2 (−18.5)	0.77 [0.72, 0.83]	<0.001
		Lunchtimes[g]			45	10,236	0.115	24.0 [22.3, 25.9]	17.3 [15.9, 18.8]	−6.7 (−27.9)	0.66 [0.60, 0.73]	<0.001
		Dinnertimes			42	9,988	0.115	18.6 [17.1, 20.3]	17.5 [16.0, 19.0]	−1.1 (−5.9)	0.92 [0.83, 1.02]	0.126
2	Summer 2018	B	Short (67)	Monthly	88	28,688	0.180	17.9 [16.6, 19.3]	18.5 [16.9, 20.2]	0.6 (3.4)	1.04 [0.92, 1.18]	0.560
		Lunchtimes[g]			45	14,177	0.189	18.7 [17.3, 20.2]	17.1 [15.5, 18.8]	−1.6 (−8.6)	0.89 [0.78, 1.03]	0.132
		Dinnertimes			43	14,511	0.189	12.4 [11.4, 13.5]	14.7 [13.3, 16.4]	2.3 (18.5)	1.22 [1.06, 1.40]	0.007

[a]McFadden's pseudo R^2 for the multivariate model. [b]Model estimates for vegetarian sales (percentage of total sales) under MeatFirst. [c]Model estimates for vegetarian sales (percentage of total sales) under VegFirst. [d]Difference between VegFirst and MeatFirst vegetarian sales model estimates in percentage points. [e]Odds ratio (OR) for effect of VegFirst compared with MeatFirst (the reference category). [f]Meal order variable *P* value in the multivariate model. [g]Model estimates for vegetarian sales at mealtimes from the multivariate model with an interaction between order and mealtime; the same model was run twice, once with Lunch–MeatFirst and once with Dinner–MeatFirst as the reference categories, in order to generate ORs for both. The independent variables included in the multivariate model were mealtime, ambient temperature (°C), days since the start of the experiment, day of the week. Variables in college A only (as invariant in college B): vegetarian price differential, menu rotation, presence of an additional vegetarian option (Supplementary Methods).

vegetarian sales with meal order at lunchtimes, but at dinnertimes vegetarian sales were 2.3 percentage points higher with VegFirst (Fig. 1g). Overall, the results of study 2 suggest that the effects of order did not persist in college B when the options were presented close together, and are perhaps influenced by other aspects of the choice environment.

Our studies are based on 105,143 meal selections recorded over 2 yr. A recent systematic review found a combined total of only 11,290 observations across 18 studies that tested other choice architecture interventions to reduce meat consumption[5]. By testing one intervention only, we could avoid the confounding effects present in other studies on order[6]. Also, by alternating the order of meals both weekly and monthly, we were able to show that under the long-distance condition customers did not habituate to the effects of order for at least a month, which is obviously a key consideration in designing interventions for sustained effects. Follow-up experiments tested the inconsistent effects of order and established that the distance between options also influenced vegetarian sales. Finally, fidelity to protocol was high, estimated (from 76 observations) to be over 95% at both colleges.

Some limitations of our studies must be noted. First, individual-level data on cafeteria visitors were not available to the researchers. This is common in field studies on food sales[6] and means that there is some uncertainty in the *P*-value estimates. Second, the studies were conducted in British university cafeterias, a convenient but unrepresentative study setting. Studies in different populations and other countries are needed to test the generalizability of our results. Third, we can only hypothesize why the results in study 2 did not replicate in the monthly alternation. Further studies are needed to explicitly test for interactions and other influences on order, particularly the type of non-focal options and the effect of distance (ideally the long-distance condition would be replicated in other cafeterias) (Supplementary Discussion).

There are several possible mechanisms that might result in higher vegetarian sales under VegFirst when there is a longer (>1.5 m) distance between the vegetarian and meat options, but generally not under shorter distances (<1 m). The distance between meal options might be a proxy for effort—generally, food options are chosen more frequently when less effort is required to obtain them[6,7]. A complementary hypothesis is that with increased distance the second option becomes less visible and salient than the first. Placing a vegetarian (instead of meat) meal on the counter, so that it was visible to restaurant customers at the point of meal selection, increased vegetarian sales in one study[8]. Further studies could test these mechanisms, and examine how effort and salience might interact with order (Supplementary Discussion).

To summarize, placing vegetarian options first consistently increased their relative sales when all options were widely separated, but not when they were close together. These findings have important implications for catering policies: a nudge that we predicted would increase vegetarian sales can work, but can also have no effect or even be counterproductive. For caterers interested in reducing meat sales, changing order—at least without pilot testing its impacts—may be an unreliable and less effective strategy than alternative approaches such as increasing the relative availability of vegetarian options[9] or reducing the serving sizes of meat[5]. Further studies are needed to reveal more precisely the conditions under which placing vegetarian meals first increases the likelihood of their selection.

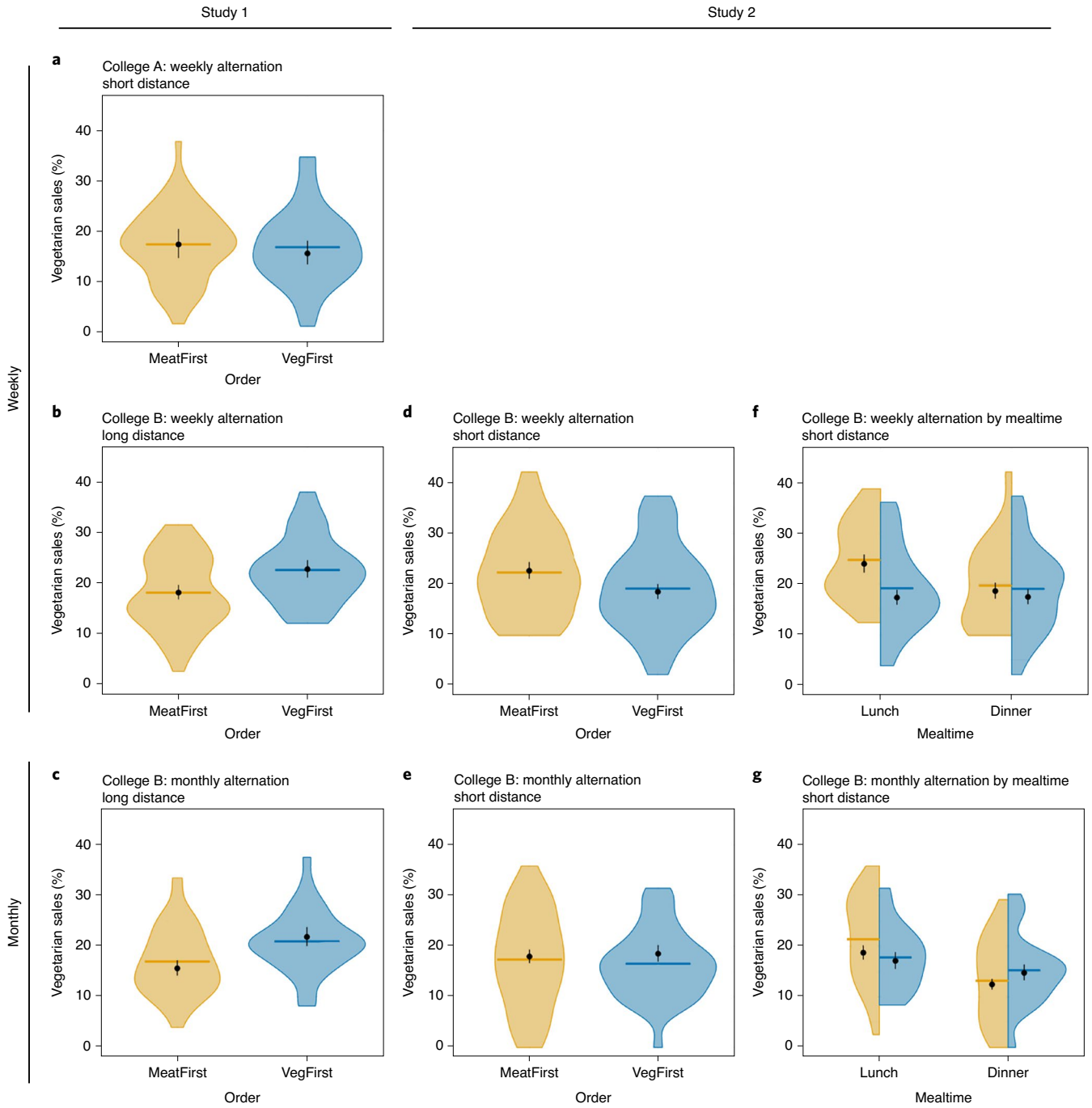

Fig. 1 | Effects of order and distance on vegetarian sales. a–c, Effects of order on vegetarian sales in study 1. **d–g**, Effects of order and distance on vegetarian sales in study 2. Meals were alternated weekly (**a**,**b**,**d**,**f**) or monthly (**c**,**e**,**g**). Panels **f** and **g** present the same data as panels **d** and **e**, respectively, but show the interaction between mealtime and order. Yellow, MeatFirst data; blue, VegFirst data. Horizontal lines show the means of the raw data; black circles and vertical lines show the model predictions and 95% CIs, respectively. The violin plots show the distribution of the data, with each datapoint representing one mealtime.

Methods

Evidence indicates that increasing the proportion of vegetarian options available[10], making vegetarian options the default on menus[11,12] and serving more appealing vegetarian food[11] have the potential to increase vegetarian meal selections. Another commonly proposed strategy involves changing the physical position of food. A recent Cochrane review found only four studies testing the effect of the order of the physical presentation of food[6]. While all reported that items nearer the start of a line were more likely to be selected, one study found this was not the case for all food products[13], three introduced additional confounding interventions, such as more prominent labelling[13–15], and two were based on only a single mealtime on one day[13,16]. Furthermore, none of the studies focused on lowering meat consumption, and we cannot assume that the effects of intervening on order and position of, for example, foods of different calorie densities is necessarily the same for vegetarian and non-vegetarian meals. Interventions targeting meat consumption might have similar effects to interventions targeting sugar consumption, for example, but the different cultural meanings of these products means we cannot assume this.

The two studies reported here consisted of multiple treatment reversal design experiments, swapping the order each week (or month) in which customers were presented with vegetarian and meat main-meal options at lunchtimes and dinnertimes. The experiments were conducted in two University of Cambridge

college cafeterias; a college is similar to a hall of residence or dorm. College A is a graduate college with over 600 students. College B has over 900 students, both undergraduate and graduate. Both colleges admit students of any gender identity. Meals are not included in the tuition or accommodation fees: students can choose to eat in the college cafeteria, cook their own meals or eat at other establishments. Students pay for meals by swiping their university cards. The cafeterias are largely self-service: students take a tray, view the different meal options available, and ask the serving staff for their preferred meal and side dishes. Students serve themselves salads, desserts and other cold items. In college A, diners have to walk past all options to reach the cash register. However, in college B, the entire cafeteria is square rather than rectangular (with an island in the middle with salad components) and diners do not need to walk past all the options to reach the cash registers on the left-hand side of cafeteria. These studies were approved by the University of Cambridge Psychology Research Ethics Committee (PRE.2016.100). Consent was obtained from catering managers; diners were not informed about the studies.

The primary outcome variable was the number of vegetarian meals sold at each mealtime, expressed as a percentage of the total meal sales. Salads, sandwiches and side dishes were not included. College A provided four options at lunchtime and five at dinnertime; sometimes a second vegetarian or vegan option was provided but this did not count towards the sales of the focal vegetarian option (Supplementary Table 1). College B had a third main option, placed towards the back of the cafeteria. In summer term 2017, this third option was always meat at lunchtimes and dinnertimes (Supplementary Table 2), but starting in autumn term 2017, a vegan option was provided at lunchtimes (Supplementary Table 3). Similarly, the vegan sales did not contribute to the vegetarian sales considered in our analysis (see Supplementary Tables 10 and 11). Following the recommendation of Simmons et al.[17], we discuss results from both univariate and multivariate models (Supplementary Methods).

Sales data were downloaded from the online catering platform Uniware[18]. Many individuals buy more than one meal from their college cafeteria over a term. In the absence of individual-level data, each meal selection was treated as independent. While this approach has been used in numerous other studies[6], it adds uncertainty to *P*-value estimates. We therefore focused primarily on the effect size of our intervention, presenting the odds ratios and 95% confidence intervals (CIs) and McFadden's pseudo R^2. The OR—that is, the effect size—was calculated by taking the exponential of the model estimate. Model diagnostics were used to check that the models did not violate any regression assumptions. We carried out all analyses in R version 3.5 (ref. [19]).

Data availability

Data for the results in this paper can be found at https://doi.org/10.17863/CAM.41481.

Code availability

The code used for this analysis is available from the corresponding author on request.

Received: 28 November 2019; Accepted: 17 July 2020;
Published online: 13 August 2020

References

1. Poore, J. & Nemecek, T. Reducing food's environmental impacts through producers and consumers. *Science* **992**, 987–992 (2018).
2. Bryngelsson, D., Wirsenius, S., Hedenus, F. & Sonesson, U. How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. *Food Policy* **59**, 152–164 (2016).
3. Lehner, M., Mont, O. & Heiskanen, E. Nudging—a promising tool for sustainable consumption behaviour? *J. Clean. Prod.* **134**, 166–177 (2016).
4. Thaler, R. & Sunstein, C. *Nudge: Improving Decisions about Health, Wealth and Happiness* (Penguin, 2009).
5. Bianchi, F., Garnett, E., Dorsel, C., Aveyard, P. & Jebb, S. A. Restructuring physical micro-environments to reduce the demand for meat: a systematic review with qualitative comparative analysis. *Lancet Planet. Health* **2**, e384–e397 (2018).
6. Hollands, G. J. et al. Altering the availability or proximity of food, alcohol and tobacco products to change their selection and consumption. *Cochrane Database Syst. Rev.* **9**, CD012573 (2019).
7. Meiselman, H. L., Hedderley, D., Staddon, S. L., Pierson, B. J. & Symonds, C. R. Effect of effort on meal selection and meal acceptability in a student cafeteria. *Appetite* **23**, 43–55 (1994).
8. Kurz, V. Nudging to reduce meat consumption: immediate and persistent effects of an intervention at a university restaurant. *J. Environ. Econ. Manage.* **90**, 317–341 (2018).
9. Garnett, E. E., Balmford, A., Sandbrook, C., Pilling, M. A. & Marteau, T. M. Impact of increasing vegetarian availability on meal selection and sales in cafeterias. *Proc. Natl Acad. Sci. USA* **116**, 20923–20929 (2019).
10. Garnett, E. E., Balmford, A., Sandbrook, C., Pilling, M. A. & Marteau, T. M. Impact of increasing vegetarian availability on meal selection and sales in cafeterias. *Proc. Natl Acad. Sci. USA* **116**, 201907207 (2019).
11. Campbell-Arvai, V., Arvai, J. & Kalof, L. Motivating sustainable food choices: the role of nudges, value orientation, and information provision. *Environ. Behav.* **46**, 453–475 (2014).
12. Gravert, C. & Kurz, V. Nudging à la carte—a field experiment on climate-friendly food choice. *Behav. Pub. Pol.* **3**, 1–18 (2019).
13. Kongsbak, I. et al. Increasing fruit and vegetable intake among male university students in an ad libitum buffet setting: a choice architectural nudge intervention. *Food Qual. Prefer.* **49**, 183–188 (2016).
14. Cohen, J. F. W. et al. Effects of choice architecture and chef-enhanced meals on the selection and consumption of healthier school foods. *JAMA Pediatr.* **169**, 431 (2015).
15. Greene, K. N., Gabrielyan, G., Just, D. R. & Wansink, B. Fruit-promoting smarter lunchrooms interventions: results from a cluster RCT. *Am. J. Prev. Med.* **52**, 451–458 (2017).
16. Wansink, B. & Hanks, A. S. Slim by design: serving healthy foods first in buffet lines improves overall meal selection. *PLoS ONE* **8**, e77055 (2013).
17. Simmons, J. P., Nelson, L. D. & Simonsohn, U. False-positive psychology: undisclosed flexibility in data collection and analysis allows presenting anything as significant. *Psychol. Sci.* **22**, 1359–1366 (2011).
18. Uniware (Uniware, 2019); http://www.uniware.co.uk/
19. R Core Team *R: A Language and Environment for Statistical Computing* (R Foundation for Statistical Computing, 2020); https://www.R-project.org/

Acknowledgements

This work was supported by E.E.G.'s NERC studentship grant number NE/L002507/1 and A.B.'s Royal Society Wolfson Research Merit award. We thank Ivan, Danielle and Ian for participating and generously contributing their time and the cafeterias' data. We thank G. Stewart, J. Williams and J. Chambers for assisting with monitoring fidelity to protocol; B. Simmons, K. Saunders and D.-L. Couturier for assistance with analyses and coding in R; and R. Pechey, E. Cartwright, G. Hollands and M. Vasiljevic for their advice in setting up the experiment and interpreting our findings. We thank K. Nielsen for his feedback on drafts of this manuscript.

Author contributions

E.E.G., A.B., C.S. and T.M.M. designed the research; E.E.G. performed the research; E.E.G. and M.A.P. analysed the data; and E.E.G., A.B., C.S. and T.M.M. wrote the paper.

Competing interests

The authors declare no competing interests.

Additional information

Supplementary information is available for this paper at https://doi.org/10.1038/s43016-020-0132-8.

Correspondence and requests for materials should be addressed to E.E.G.

Reprints and permissions information is available at www.nature.com/reprints.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.