

Effects of a behaviour change intervention for Girl Scouts on child and parent energy-saving behaviours

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Energy education programmes for children are hypothesized to have great potential to save energy. Such interventions are often assumed to impact child and family behaviours. Here, using a cluster-randomized controlled trial with 30 Girl Scout troops in Northern California, we assess the efficacy of two social cognitive theory-based interventions focused on residential and food-and-transportation energy-related behaviours of Girl Scouts and their families. We show that Girl Scouts and parents in troops randomly assigned to the residential energy intervention significantly increased their self-reported residential energy-saving behaviours immediately following the intervention and after more than seven months of follow-up, compared with controls. Girl Scouts in troops randomly assigned to the food-and-transportation energy intervention significantly increased their self-reported food-and-transportation energy-saving behaviours immediately following the intervention, compared with controls, but not at follow-up. The results demonstrate that theory-based, child-focused energy interventions have the potential to increase energy-saving behaviours among both children and their parents.

Energy education and behaviour programmes for young people and families represent an increasing focus for saving energy^{1–3}. The factors and processes that influence environmental and energy-related knowledge, attitudes, and behaviours are complex^{4–8}. Moreover, much environmental and energy education research is conducted within an evaluation paradigm, intended to aid programme improvement rather than theoretical augmentation, and often relies on non-experimental designs, convenience samples, and qualitative data^{9,10}. Several studies have shown that youth education can potentially influence environmental and/or energy knowledge^{11,12}, attitudes^{13,14}, and, less frequently, behaviour^{7,15–17}. However, the outcomes of such interventions remain largely untested using true experimental designs, and few incorporate long-term follow-up^{6,18}. We know of only one prior study—with high school students—that used a randomized controlled trial (RCT) design to evaluate efficacy¹⁶.

Another critical aspect of encouraging children's and families' energy-saving behaviours relates to the family learning dynamic: household energy use is a family affair^{19,20}. In contrast to the traditional view that familial learning is unidirectional (parents teaching children), a growing research base suggests that child attitudes, knowledge, and behaviours also affect those of parents^{7,11,21–25}. Yet, few studies^{7,11} have been conducted to understand the effects of child-focused environmental and/or energy education programmes on parent behaviours.

To address these shortcomings, we use a cluster-randomized controlled trial with 30 Girl Scout troops in Northern California to evaluate the efficacy of two social cognitive theory-based

interventions focused on residential and food-and-transportation energy-related behaviours of Girl Scouts and their families. We find that Girl Scouts and parents in troops randomly assigned to the residential energy intervention significantly increased their self-reported residential energy-saving behaviours immediately following the intervention and after more than seven months of follow-up, compared to controls. Girl Scouts in troops randomly assigned to the food-and-transportation energy intervention significantly increased their self-reported food-and-transportation energy-saving behaviours immediately following the intervention, compared to controls, but not at follow-up. Our results show that theory-based, child-focused energy interventions may increase energy-saving behaviours among both children and their parents.

Programme design

Our Girls Learning Environment and Energy (GLEE) programme included two parallel, five-session behaviour change interventions—one targeting residential energy use (RE) and one targeting food-and-transportation energy use (FTE). We tested each intervention's efficacy to increase targeted energy-saving behaviours among fourth- and fifth-grade Girl Scouts and their parents in the short- and long-term using a cluster RCT with 30 Girl Scout troops in Northern California. Each intervention served as an active control comparison for the other.

Both interventions were designed based on social cognitive theory (SCT)²⁶, which posits that behaviours are driven by the reciprocal interactions between personal/cognitive, behavioural, and social/environmental influences on learning. SCT has been used

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Table 1 | Outcomes for Girl Scouts' energy-saving behaviours targeted by each intervention.

Survey item	Residential energy			Food and transportation			Difference in change between groups	
	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Adjusted difference (lower 95% CL, upper 95% CL)	
	Base	Post	Follow	Base	Post	Follow	Post	Follow
	N = 147-148	N = 147	N = 129	N = 164	N = 163	N = 137-138		
Overall residential energy	0.37 (0.14)	0.62 (0.20)	0.56 (0.18)	0.36 (0.14)	0.41 (0.16)	0.43 (0.15)	0.20 (0.15, 0.25)***	0.12 (0.06, 0.18)**
Turn off power strip at night [†]	0.13 (0.29)	0.57 (0.39)	0.48 (0.38)	0.11 (0.29)	0.16 (0.32)	0.20 (0.34)	0.39 (0.28, 0.51)	0.27 (0.10, 0.44)
Adjust refrigerator temperature [‡]	0.11 (0.32)	0.64 (0.48)	0.60 (0.49)	0.13 (0.34)	0.18 (0.38)	0.21 (0.41)	0.48 (0.38, 0.59)	0.41 (0.27, 0.55)
Cold water clothes wash [§]	0.31 (0.40)	0.71 (0.37)	0.57 (0.43)	0.31 (0.39)	0.37 (0.41)	0.36 (0.41)	0.36 (0.26, 0.46)	0.17 (0.01, 0.33)
Adjust hot water heater temperature [‡]	0.11 (0.31)	0.53 (0.50)	0.33 (0.47)	0.16 (0.37)	0.17 (0.38)	0.20 (0.40)	0.39 (0.30, 0.49)	0.15 (0.02, 0.28)
Air dry dishes [‡]	0.34 (0.47)	0.63 (0.49)	0.50 (0.50)	0.24 (0.43)	0.31 (0.46)	0.30 (0.46)	0.27 (0.15, 0.38)	0.12 (-0.05, 0.28)
Hang dry clothes [§]	0.31 (0.34)	0.54 (0.37)	0.47 (0.34)	0.31 (0.31)	0.32 (0.30)	0.35 (0.33)	0.22 (0.13, 0.32)	0.13 (0.03, 0.23)
Chargers in power strip [‡]	0.20 (0.40)	0.61 (0.49)	0.60 (0.49)	0.20 (0.40)	0.31 (0.46)	0.29 (0.46)	0.28 (0.13, 0.42)	0.34 (0.14, 0.54)
Install CFL in bedroom [‡]	0.49 (0.50)	0.76 (0.43)	0.72 (0.45)	0.37 (0.48)	0.48 (0.50)	0.49 (0.50)	0.25 (0.14, 0.36)	0.23 (0.05, 0.40)
Plug TV into power strip ^{‡‡}	0.24 (0.43)	0.56 (0.50)	0.60 (0.49)	0.20 (0.40)	0.29 (0.46)	0.38 (0.49)	0.24 (0.12, 0.36)	0.26 (0.07, 0.44)
Turn off lights when leaving room [†]	0.69 (0.29)	0.88 (0.21)	0.84 (0.21)	0.70 (0.31)	0.76 (0.29)	0.77 (0.24)	0.12 (0.05, 0.18)	0.08 (0, 0.16)
Unplug TV when not in use [†]	0.12 (0.26)	0.26 (0.35)	0.15 (0.27)	0.09 (0.24)	0.12 (0.27)	0.10 (0.23)	0.12 (0.02, 0.22)	0.06 (-0.05, 0.16)
Turn off/unplug computer during day when not in use	0.48 (0.29)	0.60 (0.28)	0.57 (0.28)	0.46 (0.27)	0.47 (0.27)	0.53 (0.24)	0.11 (0.04, 0.18)	0.03 (-0.07, 0.12)
Plug DVD player into power strip [‡]	0.20 (0.40)	0.49 (0.50)	0.55 (0.50)	0.23 (0.42)	0.28 (0.45)	0.41 (0.49)	0.21 (0.08, 0.34)	0.13 (-0.09, 0.34)
Turn off/unplug computer overnight	0.58 (0.28)	0.66 (0.30)	0.64 (0.26)	0.52 (0.28)	0.55 (0.28)	0.60 (0.26)	0.08 (0.02, 0.14)	0.02 (-0.06, 0.10)
Unplug DVD player when not in use [†]	0.25 (0.40)	0.37 (0.41)	0.27 (0.38)	0.25 (0.39)	0.25 (0.39)	0.24 (0.37)	0.16 (0.04, 0.28)	0.01 (-0.15, 0.17)
Unplug chargers when not in use [†]	0.67 (0.36)	0.74 (0.35)	0.66 (0.37)	0.61 (0.39)	0.64 (0.40)	0.65 (0.37)	0.09 (-0.01, 0.18)	-0.01 (-0.12, 0.11)
Turn off TV when not in use [†]	0.79 (0.33)	0.85 (0.29)	0.84 (0.28)	0.80 (0.31)	0.86 (0.24)	0.87 (0.26)	0.06 (-0.12, 0.24)	-0.05 (-0.30, 0.20)
Turn off DVD player when not in use [†]	0.74 (0.38)	0.72 (0.39)	0.70 (0.40)	0.72 (0.39)	0.77 (0.35)	0.79 (0.34)	-0.03 (-0.23, 0.17)	-0.19 (-0.44, 0.05)
Overall food and transportation	0.56 (0.15)	0.60 (0.15)	0.60 (0.14)	0.53 (0.15)	0.62 (0.16)	0.60 (0.16)	0.04 (0.01, 0.08)*	0.03 (-0.02, 0.08)
Overall food	0.72 (0.17)	0.77 (0.15)	0.79 (0.14)	0.72 (0.17)	0.79 (0.15)	0.79 (0.15)	0.02 (-0.01, 0.05)	0.02 (-0.02, 0.07)
One meatless dinner per week [‡]	0.62 (0.49)	0.69 (0.47)	0.71 (0.46)	0.54 (0.50)	0.82 (0.39)	0.75 (0.43)	0.16 (0.07, 0.25)	0.10 (-0.07, 0.27)
Daily meat consumption	1.92 (1.74)	1.78 (1.63)	1.50 (1.27)	1.69 (1.46)	1.37 (1.43)	1.54 (1.44)	-0.29 (-0.67, 0.08)	0.01 (-0.48, 0.50)
Daily packaged food consumption	2.38 (1.79)	1.98 (1.60)	1.64 (1.38)	2.06 (1.80)	1.55 (1.55)	1.70 (1.69)	-0.28 (-0.66, 0.10)	0.18 (-0.41, 0.77)
Daily bottled drinks consumption	2.21 (1.79)	1.94 (1.67)	1.98 (1.83)	2.15 (1.76)	1.71 (1.66)	1.72 (1.56)	-0.14 (-0.48, 0.21)	-0.26 (-0.75, 0.23)
Shop at farmers market [‡]	0.60 (0.49)	0.65 (0.48)	0.69 (0.46)	0.60 (0.49)	0.67 (0.47)	0.72 (0.45)	0.02 (-0.08, 0.12)	0.08 (-0.07, 0.23)
Frequency use reusable water bottle [‡]	0.82 (0.30)	0.87 (0.27)	0.90 (0.24)	0.79 (0.33)	0.85 (0.27)	0.87 (0.26)	-0.03 (-0.09, 0.03)	0 (-0.09, 0.08)
Daily fast food consumption	0.14 (0.35)	0.07 (0.26)	0.11 (0.31)	0.10 (0.30)	0.16 (0.37)	0.16 (0.37)	0.09 (0.01, 0.18)	0.04 (-0.07, 0.16)

Table 1 | Continued.

Survey item	Residential energy			Food and transportation			Difference in change between groups	
	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Adjusted difference (lower 95% CL, upper 95% CL)	
	Base N = 147-148	Post N = 147	Follow N = 129	Base N = 164	Post N = 163	Follow N = 137-138	Post	Follow
Overall transportation	0.39 (0.20)	0.42 (0.23)	0.42 (0.21)	0.35 (0.20)	0.44 (0.23)	0.42 (0.24)	0.07 (0.06, 0.07)	0.02 (-0.07, 0.10)
Check automobile tyre pressure [‡]	0.32 (0.47)	0.37 (0.49)	0.41 (0.49)	0.23 (0.42)	0.61 (0.49)	0.51 (0.50)	0.28 (0.15, 0.40)	0.11 (-0.03, 0.25)
Transport mode choice from troop meeting [#]	0.27 (0.39)	0.30 (0.40)	0.30 (0.38)	0.22 (0.34)	0.34 (0.38)	0.34 (0.38)	0.09 (-0.02, 0.20)	0.08 (-0.05, 0.21)
Transport mode choice from school [#]	0.47 (0.43)	0.45 (0.43)	0.48 (0.43)	0.45 (0.44)	0.45 (0.43)	0.40 (0.43)	0.02 (-0.12, 0.16)	-0.10 (-0.25, 0.06)
Transport mode choice to troop meeting [#]	0.71 (0.41)	0.68 (0.43)	0.60 (0.44)	0.61 (0.44)	0.66 (0.42)	0.57 (0.43)	0.07 (-0.03, 0.18)	0.10 (-0.11, 0.30)
Frequency walk or bike to store [§]	0.40 (0.33)	0.45 (0.34)	0.47 (0.36)	0.37 (0.32)	0.42 (0.34)	0.41 (0.33)	0 (-0.09, 0.09)	-0.07 (-0.20, 0.07)
Transport mode choice to school [#]	0.31 (0.41)	0.38 (0.42)	0.37 (0.43)	0.27 (0.40)	0.33 (0.44)	0.36 (0.43)	0.01 (-0.12, 0.15)	0.01 (-0.16, 0.19)
Saturday trips per day walking/biking* [†]	0.27 (0.31)	0.32 (0.33)	0.29 (0.31)	0.28 (0.33)	0.28 (0.30)	0.32 (0.32)	-0.04 (-0.12, 0.03)	0.02 (-0.10, 0.14)

Individual behaviours that make up overall score ordered by Cohen's *d* at post-test. Means and standard deviations reported here are calculated using complete cases. The adjusted difference is the difference in changes between groups from the mixed effects linear regression model, where the baseline to post-test change was the dependent variable, the intervention group (treatment versus control) was the independent variable, and the centred baseline value and the centred treatment × centred baseline value interaction were covariates, with 95% confidence intervals. The overall Girl Scout residential energy-saving behaviour index was created by averaging the 18 items listed below 'Overall residential energy'. The overall Girl Scout food-and-transportation energy-saving behaviour index was created by averaging the 14 items listed below 'Overall food and transportation'. Two separate indices were also created for the seven food behaviours ('Overall food') and seven transportation behaviours ('Overall transportation'). **p* < 0.05. ***p* < 0.01. ****p* < 0.001. [†]Response scale and coding: don't know/never = 0.0; a little = 0.33; a lot = 0.67; always/don't have referenced device (if applicable) = 1.0. Referenced device refers to TV, DVD player, charger(s); not power strip. [‡]Response scale and coding: don't know/no = 0.0; yes/don't have referenced device (if applicable) = 1.0. [§]Response scale and coding: don't know/never = 0.0; sometimes = 0.5; always = 1.0. [¶]Response scale and coding: don't know/leave on = 0.0; standby = 0.33; turn off = 0.67; unplug/don't have device = 1.0. ^{¶¶} Respondents were asked a series of 75 yes/no questions about food consumption over the previous four meals. Responses were summed across all four meals as estimates of the number of servings consumed over the prior 24 h. Total meat and packaged food servings were each capped at a maximum of eight per day. Servings per day were divided by eight to standardize responses to a range of 0-1 for each. Items were reverse coded in overall indices so that higher scores signified greater energy-saving behaviour. Fast food consumption was recoded to simple yes/no response over entire 24 h. As reported here, a decrease in this measure would save energy. ^{¶¶¶}Response scale and coding: being driven alone = 0.0; carpooling or taking public transport = 0.5; biking, walking or skating = 1.0. ^{¶¶¶¶} Respondents were to circle a number between 0 and 10 or more to indicate the number of trips they took the previous Saturday by walking/biking and by car. A ratio of walking/biking trips to total trips is reported here.

to explain and successfully change behaviours in experimental field and laboratory research and practice, most notably in the field of public health²⁷, but is less utilized in studies of environmentally relevant and energy-saving behaviour. Applying SCT principles to the sphere of energy-saving behaviour—which has been done successfully by a handful of authors^{16,28,29}—thus represents a novel contribution to the field. SCT identifies four key learning processes: attention, retention (memory), production (vicarious experience, cognitive rehearsal, behavioural rehearsal, guided enactment), and motivation (self and external monitoring, feedback, goals and incentives)²⁶. Together, these processes enhance outcome expectancies and efficacy expectancies, or confidence in one's ability to successfully enact a behaviour and produce the anticipated result. Thus, each GLEE session included engaging activities to promote knowledge and build skills for specific individual and family behaviours related to reducing energy use, model desired behaviours, establish perceived group norms, self-monitor targeted behaviours, set goals and commitments, and rehearse behaviours and obtain feedback—all aimed at enhancing self-efficacy for the targeted behaviour changes (see Methods and Supplementary Methods and Supplementary Tables 3–5 for more information about our theoretical approach and each intervention's content). Inherent to these strategies, Girl Scouts also took home tools to both facilitate behaviour adoption and prompt family discussion. These same techniques have also been included in successful energy interventions with high school students¹⁶ and adults^{30–33}. Moreover, working within the troop environment provided an opportunity to establish energy-saving norms among participants—another factor that has proved beneficial in successful energy interventions^{34–36}.

Study participants and participation

Of 331 members in the 30 participating troops, 327 Girl Scouts in 318 families received parental consent to participate in the study. One sibling was randomly selected from each family for analysis. After completing baseline measures, troops were randomized to receive either the RE or FTE intervention. We included all participants who returned a survey for at least one of the three measurement time points in our analysis: *N* = 313 Girl Scouts (*N* = 149 RE versus *N* = 164 FTE) and *N* = 303 parents (*N* = 146 RE versus *N* = 157 FTE) for baseline to post-test analyses; *N* = 312 Girl Scouts (*N* = 148 RE versus *N* = 164 FTE) and *N* = 301 parents (*N* = 143 RE versus *N* = 158 FTE) for the baseline to follow-up analyses. The median intervals for Girl Scouts from baseline to post-test and baseline to follow-up were 2.3 months (2.3 for both RE and FTE) and 7.4 months (8.0 for RE versus 6.9 for FTE), respectively, and for parents 3.2 months (3.3 for RE versus 3.2 for FTE) and 8.1 months (8.9 for RE versus 7.6 for FTE), respectively.

The two intervention groups did not differ significantly in terms of baseline characteristics, so we present overall numbers (see Supplementary Table 1 for baseline characteristics by treatment group). The mean ± s.d. baseline age of the participating Girl Scouts was 9.6 ± 0.8 years. Nearly all Girl Scouts (90.6%) were fourth and fifth graders. Almost half (43.1%) of the parents described their girls as white, 23.3% as Asian, 11.6% as multiracial, 3.1% as Hispanic, Latino or of Spanish origin, and the remaining 1.6% as another race. The majority of parent baseline surveys were completed by mothers (79.6%), and the mean ± s.d. age of parents completing the surveys was 43.7 ± 4.6 years. The majority of participating parents were

Table 2 | Effect sizes for Girl Scouts' energy-saving behaviours targeted by each intervention.

Survey item	Effect sizes					
	Cohen's <i>d</i>		NNT		Relative percentage change	
	Post	Follow	Post	Follow	Post (%)	Follow (%)
Overall residential energy	1.12	0.72	2	3	49	27
Turn off power strip at night	1.16	0.73	2	3	252	135
Adjust refrigerator temperature	1.05	0.79	2	2	273	196
Cold water clothes wash	0.86	0.46	2	4	98	47
Adjust hot water heater temperature	0.81	0.28	2	6	231	77
Air dry dishes	0.66	0.37	3	5	87	39
Hang dry clothes	0.66	0.34	3	5	71	37
Chargers in power strip	0.61	0.62	3	3	91	117
Install CFL in bedroom	0.56	0.44	3	4	51	46
Plug TV into power strip	0.54	0.40	3	4	82	67
Turn off lights when leaving room	0.46	0.29	4	6	16	11
Unplug TV when not in use	0.45	0.19	4	9	100	57
Turn off/unplug computer during day when not in use	0.44	0.14	4	13	24	5
Plug DVD player into power strip	0.43	0.26	4	7	76	30
Turn off/unplug computer overnight	0.36	0.13	5	13	14	3
Unplug DVD player when not in use	0.29	0.07	6	24	63	6
Unplug chargers when not in use	0.24	0.04	7	43	13	-1
Turn off TV when not in use	-0.04	-0.11	-45	-16	7	-6
Turn off DVD player when not in use	-0.15	-0.23	-12	-8	-3	-25
Overall food and transportation	0.14	0.00	13	465	7	4
Overall food	0.16	0.01	11	143	3	3
One meatless dinner per week	0.30	0.10	6	18	23	15
Daily meat consumption	-0.27	0.03	-7	65	-16	1
Daily packaged food consumption	-0.27	0.03	-7	57	-14	11
Daily bottled drinks consumption	-0.14	-0.14	-13	-13	-7	-13
Shop at farmers market	0.04	0.06	42	32	3	12
Frequency use reusable water bottle	-0.09	-0.11	-20	-16	-4	-1
Daily fast food consumption	0.27	0.14	7	13	125	40
Overall transportation	0.08	0.00	23	485	17	5
Check automobile tyre pressure	0.47	0.18	4	10	74	27
Transport mode choice from troop meeting	0.08	0.08	21	22	29	26
Transport mode choice from school	0.00	-0.18	420	-10	4	-20
Transport mode choice to troop meeting	-0.05	-0.07	-38	-27	11	16
Frequency walk or bike to store	-0.07	-0.15	-25	-12	0	-14
Transport mode choice to school	-0.12	-0.02	-15	-115	3	3
Saturday trips per day walking/biking	-0.14	0.09	-13	20	-14	6

Individual behaviours that make up overall score ordered by Cohen's *d* at post-test. Cohen's *d* is calculated as the difference between groups divided by the pooled within-group standard deviation. Here we derive it directly from our models by subtracting the least squares mean of the control group from the least squares mean of the treatment group (equivalent to the parameter estimate) and dividing by the pooled within-group standard deviation, or the root mean square error. An area under the curve approach was used to calculate NNT³⁶. The relative percentage change is included to help interpret the differences in changes between groups, as a percentage change relative to the expected rate without the intervention. It is calculated as the adjusted difference in change between groups divided by the control group post-test/follow-up mean.

married (78.0%); and 81.1% of households had at least one parent with a college degree. Approximately 58% reported annual total household earnings above \$120,000 a year, and about 66% of parents reported owning their homes. Household size ranged from 2 to 9 members, with a mean \pm s.d. of 4.3 ± 0.96 . Troop size ranged from 4 to 21 girls, with a mean \pm s.d. of 11 ± 4.1 . Girl Scout attendance at intervention sessions was high overall ($M = 4.37 \pm 0.98$ out of 5 sessions) and comparable for both groups ($M = 4.45 \pm 0.84$ for RE; $M = 4.30 \pm 1.08$ for FTE).

Survey participation rates and the median (interquartile range) number of months after baseline of the post-test and follow-up surveys for Girl Scouts were: baseline participation 98.0% RE group versus 98.2% FTE group; post-test participation 97.3% versus 91.6%, and 2.3 (1.8–3.0) versus 2.3 (1.8–2.8) months after baseline; and follow-up participation 85.4% versus 82.6%, and 8.0 (6.3–9.0) versus 6.9 (6.0–9.2) months after baseline. For parents: baseline participation was 86.7% RE versus 87.4% FTE; post-test participation 93.4% versus 87.4%, and 3.3 (2.5–4.0) versus 3.2

(2.8–3.8) months after baseline; and follow-up participation 85.4% versus 79.0%, and 8.9 (7.0–9.8) versus 7.6 (6.2–9.7) months after baseline. One troop randomized to the FTE intervention stopped the programme after the fourth session, accounting for the slightly lower survey response rates. However, all participants were included in analyses, following intent-to-treat principles, where all participants were analysed as they were randomized, regardless of subsequent participation and/or exposure to the interventions, with multiple imputation for missing data³⁷ (see Supplementary Methods and Supplementary Tables 1 and 2 for additional information about recruitment, retention and missing data).

Effects of the residential energy intervention

Girl Scouts in the RE intervention group significantly increased their overall residential energy-saving behaviours compared to Girl Scouts in the FTE group from baseline to post-test (adjusted difference = 0.20, 95% confidence interval = 0.15 to 0.25, $p < 0.0001$) and from baseline to follow-up (adjusted difference = 0.12, 95%

confidence interval = 0.06 to 0.18, $p = 0.0003$) (Tables 1 and 2 and Fig. 1). These differences represent increases in residential energy-saving behaviours from baseline to post-test and from baseline to follow-up of 49% and 27%, respectively, in RE Girl Scouts compared to FTE Girl Scouts. Parents of Girl Scouts in the RE group also significantly increased their overall residential energy-saving behaviours compared to parents in the FTE group from baseline to post-test (adjusted difference = 0.07, 95% confidence interval = 0.04 to 0.09, $p < 0.0001$) and from baseline to follow-up (adjusted difference = 0.04, 95% confidence interval = 0.01 to 0.06, $p = 0.011$) (Tables 3 and 4 and Fig. 1), representing 12% and 6% increases in residential energy-saving behaviours from baseline to post-test and baseline to follow-up, respectively. The differences between groups, for both Girl Scouts and parents, represent Cohen's d standardized effect sizes ranging from 0.38 to 1.12, which are large when compared to other environmental interventions³⁸, with low numbers needed to treat (NNT range from 2 to 5), demonstrating the substantial magnitude and efficiency of the GLEE RE intervention³⁹.

Examining individual behaviours that comprised the overall residential energy-savings score, Girl Scouts in the RE group made their greatest magnitude increases relative to FTE controls in turning off power strips at night, adjusting refrigerator temperatures, and washing clothes in cold water, from baseline to post-test; and in adjusting refrigerator temperatures, turning off power strips at night and plugging chargers into a power strip, from baseline to follow-up. Parents of Girl Scouts in the RE intervention group made their greatest magnitude increases compared to FTE controls in adjusting refrigerator temperatures, with smaller changes apparent in hang drying clothes and adjusting hot water heater temperatures, at post-test; and adjusting refrigerator temperatures, with smaller changes apparent in winter heat settings, at follow-up. Previous energy-related research has tended to distinguish between one-time behaviours (for example, adjusting hot water heater temperature) and habitual behaviours (for example, turning off lights when not in use)^{18,40}, making it notable that the GLEE RE intervention impacted both types.

Based on estimates of the potential energy savings associated with the impacted behaviours (see Supplementary Note 3 and Supplementary Table 7 for sources and calculations), we conservatively approximated that the observed post-test changes reported by the Girl Scouts are the equivalent of average annual household savings of 336 kWh and 17 therms per year, and the observed follow-up changes are the equivalent to average annual household savings of 191 kWh and 7 therms per year. These represent savings of about 5% and 3% in the average annual electricity and gas usage at post-test, respectively, and about 3% and 1%, at follow-up, respectively, for households in the public utility territory where most of our participants lived. These magnitudes in estimated annual energy savings are comparable to the impacts reported from some other energy-saving, behavioural interventions^{31,32,34}, and equivalent to avoided emissions of from 160 to 330 pounds of CO₂ per household per year.

Effects of the food-and-transportation energy intervention

Girl Scouts in the FTE intervention group also significantly increased their overall food-and-transportation energy-saving behaviours compared to Girl Scouts in the RE group from baseline to post-test (adjusted difference = 0.04, 95% confidence interval = 0.01 to 0.08, $p = 0.019$; $d = 0.14$; NNT = 13) (Tables 1 and 2 and Fig. 2). This difference represents a 7% increase in food-and-transportation energy-saving behaviours in the FTE Girl Scouts relative to RE Girl Scouts, from baseline to post-test. However, overall food-and-transportation energy-savings behaviours did not differ significantly between the FTE and RE groups at follow-up for Girl Scouts or at post-test or follow-up for parents (Tables 3 and 4

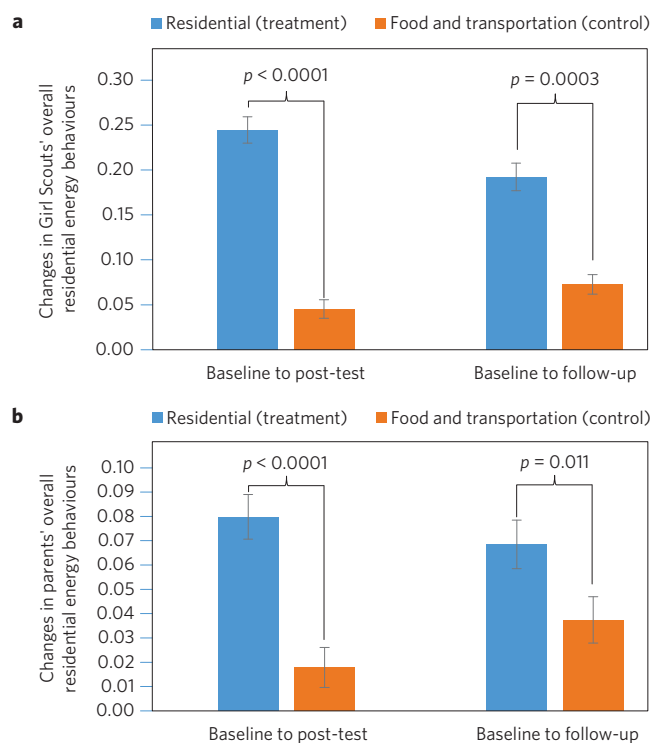


Figure 1 | Overall outcome for residential energy intervention with Girl Scouts and parents at post-test and follow-up. a, Mean changes in Girl Scouts' overall residential energy behaviours over time by intervention. **b**, Mean changes in parents' overall residential energy behaviours over time by intervention. Error bars represent standard errors, calculated as the standard deviation divided by the square root of the number of observations.

and Fig. 2). It is possible that the targeted food-and-transportation energy-related behaviours proved difficult to change because they are particularly constrained by geographic, cultural and economic factors, especially for young children who likely have little control in these domains⁸. A child's ability to select low-energy transportation, for example, is limited by her home's proximity to school and recreation, public transportation availability, and aspects of the built environment⁴¹. Similarly, a child's ability to make less-energy-intensive food choices, such as eating less meat, is embedded in family practices that include cultural considerations and may be constrained by family economics and community food availability⁴². Such constraints on individual and familial behaviour change suggest that these food-and-transportation behaviours may be more difficult to affect through brief behavioural interventions alone^{43,44}, and may benefit from being accompanied by policy interventions or infrastructure changes. Yet, SCT-based, child-focused public health interventions have proved moderately effective in encouraging better nutrition and more active transport^{45,46}. Another possibility is that by incorporating both food and transportation energy-related behaviours into one intervention, Girl Scouts spent less time on each domain, which might have limited the intervention's effectiveness.

For each of the above primary intent-to-treat analyses, a secondary complete-case analysis and a mixed effects regression model adjusting for time between observations produced similar results, demonstrating the robustness of these findings under varying assumptions (see Supplementary Note 2 for these results). We also tested potential moderators and mediators using the MacArthur Research Network methods described by Kraemer and colleagues⁴⁷. The RE intervention was most effective at changing Girl Scout energy-saving behaviours among Girl Scouts who, at

Table 3 | Outcomes for parents' energy-saving behaviours targeted by each intervention.

Survey item	Residential energy			Food and transportation			Difference in change between groups	
	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Adjusted difference (lower 95% CL, upper 95% CL)	
	Base	Post	Follow	Base	Post	Follow	Post	Follow
	N = 127-131	N = 132-138	N = 126-129	N = 141-144	N = 138-144	N = 124-130		
Overall residential energy	0.55 (0.10)	0.64 (0.11)	0.63 (0.11)	0.55 (0.08)	0.57 (0.10)	0.58 (0.11)	0.07 (0.04, 0.09)***	0.04 (0.01, 0.06)*
Adjust refrigerator temperature [†]	0.18 (0.39)	0.58 (0.50)	0.67 (0.47)	0.15 (0.36)	0.23 (0.42)	0.35 (0.48)	0.33 (0.22, 0.45)	0.33 (0.20, 0.46)
Hang dry clothes ^{‡‡}	0.20 (0.29)	0.31 (0.33)	0.26 (0.32)	0.17 (0.26)	0.21 (0.28)	0.22 (0.30)	0.08 (0.02, 0.13)	0 (-0.07, 0.08)
Adjust hot water heater temperature [†]	0.18 (0.38)	0.36 (0.48)	0.40 (0.49)	0.18 (0.38)	0.22 (0.41)	0.28 (0.45)	0.14 (0.03, 0.24)	0.06 (-0.14, 0.26)
Winter heat setting at night ^{§,}	62.01 (4.10)	61.83 (3.76)	62.44 (4.21)	63.27 (3.94)	63.07 (4.15)	63.48 (4.16)	-0.60 (-1.46, 0.26)	-0.82 (-2.00, 0.36)
Winter heat setting during day when someone is home ^{§,}	65.65 (3.87)	65.59 (3.56)	65.23 (3.57)	66.16 (3.50)	66.56 (3.80)	66.50 (3.85)	-0.84 (-1.82, 0.13)	-1.07 (-2.23, 0.09)
Percentage of light bulbs LEDs [¶]	0.12 (0.22)	0.17 (0.23)	0.15 (0.24)	0.10 (0.19)	0.12 (0.22)	0.17 (0.26)	0.04 (-0.01, 0.09)	-0.02 (-0.10, 0.05)
Summer A/C setting at night [§]	80.26 (4.25)	80.33 (4.16)	80.33 (4.02)	79.61 (4.91)	79.42 (4.73)	79.58 (4.47)	0.48 (-0.42, 1.38)	0.93 (-0.20, 2.06)
Summer A/C setting during day when someone is home [§]	79.30 (5.26)	79.63 (4.65)	79.33 (5.26)	78.58 (5.74)	78.83 (5.36)	79.40 (4.62)	0.63 (-0.41, 1.67)	0.01 (-1.15, 1.18)
Winter heat setting during day when no one is home ^{§,}	60.36 (3.02)	60.61 (3.59)	60.39 (3.16)	61.02 (3.57)	61.08 (3.73)	61.90 (4.36)	-0.23 (-0.98, 0.52)	-1.43 (-2.67, -0.20)
Cold water clothes wash [‡]	0.50 (0.37)	0.62 (0.38)	0.61 (0.38)	0.56 (0.42)	0.58 (0.39)	0.61 (0.39)	0.07 (-0.02, 0.16)	-0.02 (-0.14, 0.10)
Air dry dishes [‡]	0.38 (0.43)	0.52 (0.41)	0.43 (0.42)	0.44 (0.43)	0.48 (0.42)	0.47 (0.42)	0.11 (0, 0.21)	-0.02 (-0.14, 0.10)
Summer A/C setting during day when no one is home [§]	80.72 (4.08)	81.20 (2.58)	81.07 (3.18)	80.69 (3.77)	81.09 (2.81)	81.07 (2.65)	0.21 (-0.52, 0.93)	0.29 (-0.62, 1.19)
Percentage of light bulbs CFLs [¶]	0.45 (0.33)	0.49 (0.31)	0.47 (0.32)	0.50 (0.35)	0.51 (0.34)	0.51 (0.35)	0.01 (-0.07, 0.08)	-0.03 (-0.12, 0.07)
Overall food and transportation	0.58 (0.13)	0.60 (0.12)	0.60 (0.13)	0.57 (0.16)	0.59 (0.14)	0.59 (0.15)	0 (-0.03, 0.03)	0 (-0.05, 0.04)
Overall food	0.67 (0.11)	0.68 (0.11)	0.69 (0.11)	0.67 (0.12)	0.69 (0.10)	0.70 (0.12)	0 (-0.02, 0.03)	0.01 (-0.02, 0.03)
Weekly bottled water consumption ^{, #}	5.04 (10.17)	4.94 (9.36)	3.96 (8.31)	4.41 (8.79)	3.23 (7.15)	3.52 (8.28)	-1.76 (-3.88, 0.36)	-0.02 (-2.82, 2.78)
Weekly meatless lunch consumption*	3.27 (2.22)	3.10 (2.01)	3.20 (2.25)	3.24 (2.22)	3.34 (2.16)	3.35 (2.15)	0.24 (-0.21, 0.69)	0.07 (-0.64, 0.77)
Monthly shopping at farmers market ^{††}	0.92 (1.13)	1.09 (1.28)	1.28 (1.30)	0.99 (1.15)	1.16 (1.28)	1.57 (1.41)	-0.09 (-0.47, 0.28)	0.23 (-0.09, 0.55)
Weekly soda consumption ^{, #}	3.47 (6.45)	3.08 (6.85)	2.96 (6.66)	2.79 (5.27)	2.75 (5.26)	3.21 (7.50)	0.51 (-0.87, 1.88)	0.22 (-1.64, 2.07)
Weekly fast food consumption ^{, #}	0.64 (0.97)	0.66 (1.76)	0.54 (1.68)	0.78 (1.15)	0.62 (0.92)	0.69 (0.97)	0.09 (-0.22, 0.40)	0.14 (-0.24, 0.52)
Weekly meatless dinner consumption*	2.41 (2.19)	2.39 (2.11)	2.50 (2.22)	2.28 (2.27)	2.44 (2.10)	2.66 (2.17)	0.13 (-0.24, 0.49)	0.26 (-0.24, 0.76)
Weekly packaged food consumption ^{, #}	4.12 (5.78)	3.30 (4.88)	2.78 (3.52)	3.75 (5.39)	3.67 (3.99)	3.46 (4.98)	0.79 (-0.43, 2.00)	1.05 (-0.56, 2.66)
Overall transportation	0.41 (0.31)	0.45 (0.31)	0.44 (0.29)	0.38 (0.33)	0.40 (0.32)	0.39 (0.31)	0 (-0.07, 0.06)	-0.03 (-0.13, 0.08)
Girl transport mode choice to troop ^{‡‡}	0.63 (0.44)	0.63 (0.44)	0.56 (0.43)	0.55 (0.43)	0.58 (0.44)	0.46 (0.43)	0.01 (-0.11, 0.14)	-0.05 (-0.19, 0.10)
Girl transport mode choice to school ^{‡‡}	0.35 (0.42)	0.39 (0.41)	0.40 (0.41)	0.34 (0.42)	0.35 (0.41)	0.38 (0.41)	-0.02 (-0.10, 0.06)	-0.01 (-0.18, 0.16)
Girl transport mode choice from troop ^{‡‡}	0.31 (0.40)	0.35 (0.41)	0.33 (0.39)	0.29 (0.37)	0.30 (0.37)	0.31 (0.36)	-0.01 (-0.12, 0.10)	-0.03 (-0.17, 0.12)

Table 3 | Continued.

Survey item	Residential energy			Food and transportation			Difference in change between groups	
	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Mean (s.d.)	Adjusted difference (lower 95% CL, upper 95% CL)	
	Base	Post	Follow	Base	Post	Follow	Post	Follow
	N = 127-131	N = 132-138	N = 126-129	N = 141-144	N = 138-144	N = 124-130		
Girl transport mode choice from school ^{‡‡}	0.38 (0.43)	0.46 (0.42)	0.46 (0.41)	0.32 (0.41)	0.39 (0.41)	0.42 (0.40)	-0.02 (-0.10, 0.07)	-0.03 (-0.18, 0.11)

Individual behaviours that make up overall score ordered by Cohen's *d* at post-test. Means and standard deviations reported here are calculated using complete cases. The adjusted difference is the difference in changes between groups from the mixed effects linear regression model, where the baseline to post-test change was the dependent variable, the intervention group (treatment versus control) was the independent variable, and the centred baseline value and the centred treatment × centred baseline value interaction were covariates, with 95% confidence intervals. The overall parent residential energy-saving behaviour index was created by averaging the 13 items listed below 'Overall residential energy'. The overall parent food-and-transportation energy-saving behaviour index was created by averaging the 11 items listed below 'Overall food and transportation'. Two separate indices were also created for the seven food behaviours ('Overall food') and four transportation behaviours ('Overall transportation'). **p* < 0.05. ***p* < 0.01. ****p* < 0.001. [†]Response scale and coding: don't know/no = 0.0; yes = 1.0. [‡]Response scale and coding: don't know/never = 0.0; sometimes = 0.33; often = 0.67; always/don't have referenced device (if applicable) = 1.0. [§]Response scale and coding: off/don't have = 58; Below 60 °F = 58; 60-62 °F = 61; 63-63 °F = 64; 66-68 °F = 67; 69-71 °F = 70; 72-74 °F = 73; 75-77 °F = 76; 78-80 °F = 79; 81 °F or more = 82. For inclusion in overall parent residential energy-saving behaviour index, this item was recoded between 0.0 and 1.0. [¶]Items were reverse coded in overall indices so that higher scores signified greater energy-saving behaviour. As reported here, a decrease in this measure would save energy. [‡]Response scale and coding: don't know/none = 0.0; fewer than 10% = 0.05; 10% to 19% = 0.15; 20% to 29% = 0.25; 30% to 39% = 0.35; 40% to 49% = 0.45; 50% to 59% = 0.35; 60% to 69% = 0.65; 70% to 79% = 0.75; 80% to 89% = 0.85; 90% or more = 0.95. [¶]Response scale and coding: None = 0.0; 1 time per week = 0.024; 2-4 times per week = 0.071; 5-6 times per week = 0.13; 1 time per day = 0.17; 2-3 times per day = 0.42; 4-5 times per day = 0.75; 6 or more times per day = 1.0. ^{*}Response scale and coding: None = 0.0; 1 time per week = 0.14; 2 times per week = 0.29; 3 times per week = 0.43; 4 times per week = 0.57; 5 times per week = 0.71; 6 times per week = 0.86; 7 or more times per week = 1.0. ^{††}Response scale and coding: Never = 0.0; less than 1 time per month = 0.1; about 1 time per month = 0.2; about 2 times per month = 0.4; about 3 times per month = 0.6; about 4 times per month = 0.8; more than once per week = 1.0. ^{‡‡}Response scale and coding: being driven alone = 0.0; carpooling or taking public transport = 0.5; biking, walking or skating = 1.0.

Table 4 | Effect sizes for parents' energy-saving behaviours targeted by each intervention.

Survey item	Effect sizes					
	Cohen's <i>d</i>		NNT		Relative percentage change	
	Post	Follow	Post	Follow	Post (%)	Follow (%)
Overall residential energy	0.62	0.38	3	5	12	6
Adjust refrigerator temperature	0.72	0.63	3	3	144	95
Hang dry clothes	0.32	0.11	6	16	36	1
Adjust hot water heater temperature	0.31	0.23	6	8	62	20
Winter heat setting at night	-0.30	-0.23	-6	-8	-1	-1
Winter heat setting during day when someone is home	-0.25	-0.31	-7	-6	-1	-2
Percentage of light bulbs LEDs	0.21	-0.04	8	-44	33	-14
Summer A/C setting at night	0.19	0.16	9	11	1	1
Summer A/C setting during day when someone is home	0.15	-0.01	12	-135	1	0
Winter heat setting during day when no one is home	-0.12	-0.36	-14	-5	0	-2
Cold water clothes wash	0.11	0.02	17	108	12	-4
Air dry dishes	0.08	-0.10	21	-18	22	-4
Summer A/C setting during day when no one is home	0.04	0.00	49	n/a	0	0
Percentage of light bulbs CFLs	-0.06	-0.10	-27	-17	1	-5
Overall food and transportation	-0.07	-0.04	-24	-42	0	-1
Overall food	0.13	0.10	14	17	0	1
Weekly bottled water consumption	-0.20	-0.05	-9	-36	-36	-1
Weekly meatless lunch consumption	0.11	0.06	16	29	8	2
Monthly shopping at farmers market	0.06	0.19	31	9	-9	18
Weekly soda consumption	-0.05	0.03	-34	54	16	7
Weekly fast food consumption	-0.03	0.10	-68	18	13	26
Weekly meatless dinner consumption	0.02	0.07	85	25	5	10
Weekly packaged food consumption	0.08	0.14	22	12	24	38
Overall transport	-0.15	-0.15	-12	-12	0	-7
Girl transport mode choice to troop	-0.09	-0.21	-19	-8	2	-8
Girl transport mode choice to school	-0.10	-0.05	-18	-38	-5	-2
Girl transport mode choice from troop	-0.13	-0.03	-13	-68	-3	-8
Girl transport mode choice from school	-0.16	-0.08	-11	-22	-3	-7

Individual behaviours that make up overall score ordered by Cohen's *d* at post-test. Cohen's *d* is calculated as the difference between groups divided by the pooled within-group standard deviation. Here we derive it directly from our models by subtracting the least squares mean of the control group from the least squares mean of the treatment group (equivalent to the parameter estimate) and dividing by the pooled within-group standard deviation, or the root mean square error. An area under the curve approach was used to calculate NNT³⁶. The relative percentage change is included to help interpret the differences in changes between groups, as a percentage change relative to the expected rate without the intervention. It is calculated as the adjusted difference in change between groups divided by the control group post-test/follow-up mean.

baseline, perceived their troop, family and close friends to strongly value using less electricity, among older Girl Scouts, among those with older parents, and among those with parents who reported

less importance of environmental sustainability at baseline. The RE intervention had greater effects on parent behaviour among parents who were older and married, and those who reported

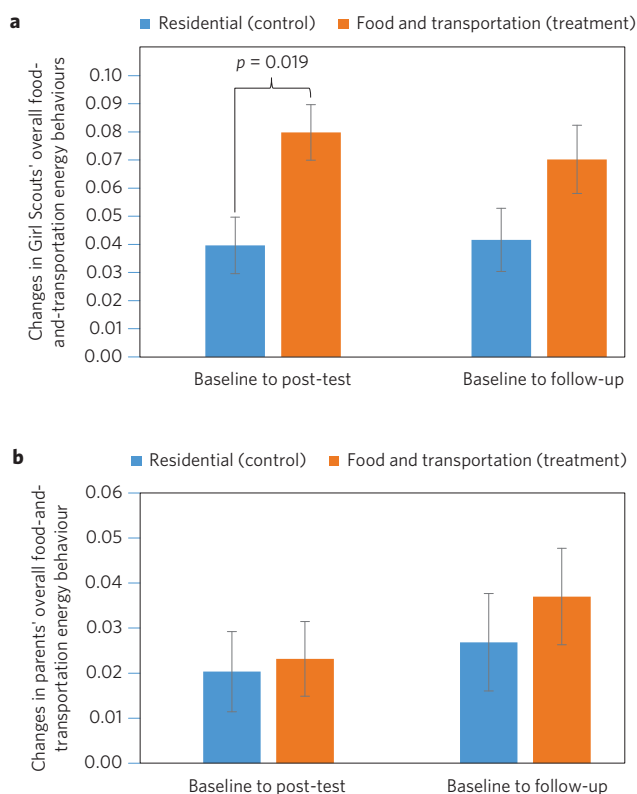


Figure 2 | Overall outcome for food-and-transportation energy intervention with Girl Scouts and parents at post-test and follow-up.

a, Mean changes in Girl Scouts' overall food-and-transportation energy behaviours over time by intervention. **b**, Mean changes in parents' overall food-and-transportation energy behaviours over time by intervention. Error bars represent standard errors, calculated as the standard deviation divided by the square root of the number of observations

less importance of environmental sustainability at baseline. The FTE intervention produced larger effects on Girl Scouts in lower grades. We found no significant possible mediators of treatment from among process measures (see Supplementary Note 4 and Supplementary Fig. 1).

Discussion

This RCT demonstrates that the GLEE social cognitive theory-based interventions significantly increased residential and food-and-transportation energy-saving behaviours among Girl Scouts. The RE intervention also yielded significant increases in parents' residential energy-saving behaviours, and produced sustained effects measured at a median of 7.4 and 8.1 months of follow-up for Girl Scouts and parents, respectively. These results highlight the potential role of promoting energy-saving behaviour changes in children, as well as the potential to change parent and household residential energy-saving behaviours through child-focused interventions. Principles from SCT such as modelling, skill development, behavioural rehearsal, behaviour monitoring, and feedback to promote perceived self-efficacy were embedded in all programmatic elements, along with tools to take home to help children translate their skills to their homes and prompt support for parent-assisted behaviours.

Our significant and positive findings suggest that employing SCT principles in similar interventions may be appropriate and effective. We join other researchers and practitioners in calling for theory-based, multi-faceted intervention designs to impact the various factors and processes that influence energy behaviour³⁰.

Because we evaluated these interventions using a rigorous RCT design, the observed changes may be causally attributed to the interventions. These results are the first of which we are aware that demonstrate efficacy using an RCT of a child-focused energy intervention, and we hope our results encourage others to employ more rigorous evaluation designs, including RCT designs using intention-to-treat primary analyses in the future. Indeed, RCTs are becoming increasingly important in analysing large-scale field experiments on energy behaviour^{32,48}. Further, the magnitudes of the effects observed are more impressive because of the rigorous nature of the control conditions. Because the RE intervention served as the control for the FTE intervention and vice versa, not only did we control for time, dose and attention, but both interventions promoted energy-saving behaviour. Any general effects on energy-saving behaviours, beyond those behaviours specifically targeted, would be expected to lead to attenuated effect sizes. The large magnitude, efficiency, and durability of the effects of the RE intervention suggest great potential to produce more widespread and far-reaching impacts. With one in every two adult women in the United States having been a Girl Scout member at some point in her life for an average of four years⁴⁹, scaling GLEE and similar interventions through Girl Scouts and other youth-serving organizations has the potential to impact the energy-saving behaviours of many US families.

Our findings are based on self-reports of energy-related behaviours, and may include measurement error that could either diminish or exaggerate the effects (see Supplementary Note 1 for more discussion)⁵⁰. We purposefully designed both interventions to target energy-saving behaviours to minimize potential biases in reporting behaviours. In addition, to further examine the pathways of influence from children to parents and other family members for energy-saving behaviours, future research may include more in-depth and parallel measures for parents and children to explore parent-child congruence and mutual influence processes, such as family communication patterns and content⁵¹⁻⁵³.

Methods

Study design and recruitment. We invited all 748 Junior (fourth- and fifth-grade) Girl Scout troops in Santa Clara, San Mateo, and Alameda counties in Northern California to participate in our study via regional office electronic mailings and in-person solicitations at troop leader meetings in September 2010. Of the 56 troops originally expressing interest in the study, 7 were located outside of the target geographic area, 3 had a significant number of participating girls outside the target age range, 15 did not respond to researcher contact attempts, and 1 was excluded due to an error in randomization, resulting in 30 troops.

These 30 troops were randomized to one of the two interventions designed to promote energy-saving behaviours in Girl Scouts, after completing baseline measures, between December 2010 and February 2012. Fifteen troops were randomly assigned to the residential energy (RE) intervention condition and fifteen troops were randomized to the food-and-transportation energy (FTE) intervention condition; thus, each condition served as an attention placebo control for the other. The study was approved by the Girl Scouts of Northern California Council, the Stanford University Administrative Panel on Human Subjects in Research (IRB-19965), and the Oregon State University Institutional Review Board (#5745). Parents or guardians provided written informed consent for their Girl Scouts' and their own participation and Girl Scouts provided assent to participation before collection of baseline data.

Intervention content. Each intervention included five, 50-to-60-min lessons delivered over consecutive troop meetings according to the troops' usual schedules, ranging from weekly to monthly, and the median (interquartile range) for completion of the five lessons was 10 (8-12.5) weeks for the RE group versus 10 (8-12) weeks for the FTE group. As an overarching thematic frame, the five lessons revolved around creating a videotaped newscast, in which the Girl Scouts played the roles of news anchors, investigative reporters, and energy experts. They rehearsed, modelled, and ultimately filmed the energy-saving behaviours learnt in each lesson to create their newscasts. Both interventions are available for download at: <https://healthimprovement.stanford.edu/GLEE>. Instructors were 19 trained, female college students or recent graduates. Two instructors were assigned to each troop, with instructor continuity maintained throughout the intervention when possible. The instructors were trained to lead both RE and

FTE lessons for different troops. We have since created an online training course to help troop leaders implement the programme: <http://glee.stanford.edu>.

Three activities comprised the majority of time in each intervention: a social behaviour monitoring and reporting activity of energy-saving behaviours performed since the last lesson (approximately 20% of total lesson time); rehearsing and videotaping the lesson's behavioural activities (approximately 50%); and a pledge of behaviours to be performed before the next lesson (approximately 15%). The remaining 15% of time included the final lesson activities and ceremony (watching the completed video and distributing patches earned for participating in the curriculum). To extend the lesson content to their homes and parents after each lesson, Girl Scouts took home items to help implement the targeted behaviours they had learnt (for example, reminder stickers, power strips, tyre pressure gauges, reusable water bottles) as well as a parent-focused newsletter, which briefly summarized the activities in each lesson. In addition, a password-protected website for each troop provided programme-related information to girls and their parents (for example, energy-saving information, electronic versions of parent newsletters, and access to view the final videos).

Survey development and implementation. Baseline, post-test, and follow-up self-administered surveys with Girl Scouts and parents were used to assess each intervention's efficacy. Parent and child surveys were first pilot tested with two non-participating troops for timing, wording and reading level. See Supplementary Methods Section 5.1 for additional information about survey development and implementation. Consistent with the design, there were two primary outcomes: residential energy-saving behaviours and food-and-transportation energy-saving behaviours. A Girl Scout residential energy-saving behaviours index was created by averaging 18 items that asked about the frequency with which the girls performed the actions listed in Table 1. A Girl Scout food-and-transportation energy-saving behaviours index was created by averaging 75 items that asked about 14 food-and-transportation behaviours, such as daily meat consumption, daily bottled water consumption, reusable water bottle usage, and transportation mode to/from school (Table 1). Two separate indices were also created for the seven food behaviours and seven transportation behaviours.

Parent residential energy-saving behaviours were assessed using 13 questions about the frequency of performing actions such as installing compact fluorescent (CFLs) and light-emitting diodes (LEDs), checking refrigerator and hot water heater temperature settings, air drying dishes, hang drying laundry, washing laundry in cold water, and setting thermostats. A parent food-and-transportation energy-saving behaviour index was created using 11 questions that asked about the frequency of daily consumption of bottled water, sweet drinks, packaged snack foods, and fast food; weekly consumption of meatless lunches and dinners; frequency of household shopping at a farmers' market; and transportation modes to and from the Girl Scout's most recent school and troop meetings (Table 2). Two separate parent indices were also created for the seven food behaviours and four transportation behaviours. See Supplementary Table 6 for survey question wording, response choices and coding. Supplementary Note 1 provides additional information about test-retest reliability/stability across waves for both child and parent surveys, as well as evidence of correspondence between child and parent surveys for similarly worded questions within households.

Analysis. To test the efficacy of our interventions and examine the potential magnitude of their effects, we compared intervention groups on the changes in reported behaviours between baseline and post-test and between baseline and follow-up. Hypotheses were tested with a mixed effects linear regression analysis (SAS Proc MIXED, version 9.3) with the Girl Scouts' overall residential energy-saving behaviours index or overall food-and-transportation energy-saving behaviours index as dependent variables, the centred intervention group (RE versus FTE) as the independent variable, and the centred baseline score of the dependent variable, and the centred treatment \times centred baseline value interaction as covariates. To account for the cluster-randomized design with troop as the unit of randomization and potentially correlated responses among troop members, we included a troop-specific random intercept term⁵⁴. The centred treatment \times centred baseline value interaction was included as a covariate in the analysis to produce an unbiased estimate of the main effect of treatment⁵⁵. Analyses followed intent-to-treat principles, where all participants were analysed as they were randomized, regardless of subsequent participation and/or exposure to the interventions. Multiple imputation (SAS Proc MIANALYZE, version 9.3) was used to handle missing data³⁷. From 4% to 24% of observations required some level of imputation across our main models. Robustness of our findings was tested with both a complete-case analysis without imputation and a secondary modelling strategy using the overall index as the dependent variable, the centred intervention group (RE versus FTE) as the independent variable, and the centred time of measurement and the centred treatment \times centred time of measurement interaction as covariates. We also tested potential moderators and mediators using the methods outlined in Kraemer and colleagues³⁷.

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Author contributions

N.M.A., K.C.A. and T.N.R. secured project funding. H.B., N.M.A., J.F., K.C.A. and T.N.R. designed the study and associated interventions. H.B. recruited participants and oversaw implementation of the interventions and data collection. H.B., J.F., M.D. and T.N.R. analysed the data. H.B. and J.F. drafted the manuscript; N.M.A., K.C.A., M.D. and T.N.R. edited the manuscript.

Additional information

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Competing interests

The authors declare no competing financial interests.