Nature and nurture in children's food preferences[1–4]

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ABSTRACT

Background: Health professionals identify food provision in the home as a key influence on children's food preferences. In contrast, parents often perceive children's food preferences to be inborn. One explanation for this discrepancy could be that environmental and genetic influences vary by food type.

Objective: We assessed genetic and environmental contributions to preferences for a wide variety of foods in a large pediatric twin sample.

Design: Data were from Gemini, which is a cohort of UK twins born in 2007. Preferences for 114 foods were assessed by parent-completed questionnaire when children were aged 3 y (n = 2686). Foods tried by >75% of respondents were grouped into protein, vegetables, fruit, dairy, starches, and snacks. Quantitative model-fitting analyses were used to assess genetic and environmental influences for each food group.

Results: The genetic influence was higher for vegetables (54%; 95% CI: 47%, 63%), fruit (53%; 95% CI: 45%, 61%), and protein (48%; 95% CI: 40%, 57%) but lower for starches (32%; 95% CI: 26%, 38%), snacks (29%; 95% CI: 24%, 35%), and dairy (27%; 95% CI: 20%, 35%). In contrast, shared-environment effects were higher for snacks (60%; 95% CI: 54%, 65%), starches (57%; 95% CI: 51%, 62%), and dairy (54%; 95% CI: 47%, 60%) and lower for vegetables (35%; 95% CI: 27%, 42%), fruit (35%; 95% CI: 26%, 43%), and protein (37%; 95% CI: 27%, 45%). Nonshared environment effects were small for all foods (11–19%).

Conclusions: Both genetic and environmental effects were significant for all food groups, but genetic effects dominated for more nutrient-dense foods (vegetables, fruit, and protein), whereas shared environmental effects dominated for snacks, dairy, and starches. These findings endorse the view of health professionals that the home environment is the main determinant of children's liking for energy-dense foods implicated in excessive weight gain but suggest that parents are also correct by identifying innate differences in liking, particularly for nutrient-dense foods that parents and health educators try to encourage. *Am J Clin Nutr* 2014;99:911–7.

INTRODUCTION

Health professionals and parents appear to have different perspectives on the origins of children's food preferences. Health professionals often take the view that the provision of healthy foods and absence of junk food in the home will result in healthy preferences and habits (1); therefore, the home food environment has been seen as a key influence. In contrast, parents tend to focus on characteristics of the individual child and sometimes struggle to achieve a healthy diet with a child who seems to have an inborn dislike of vegetables (2). Parents with more than one child often note how different the children are despite a common food environment (eg, "my first was fussy from the start but my second is easy" or "he won't even have vegetables on the plate and she loves them") (3).

The discovery of genes related to sensitivity to bitter, sweet, umami, and, more recently, fat (4–10) has suggested the importance of genetic influences on taste. However, there have been few genetic association studies of preferences for actual foods (rather than tastes), and results have not been consistent (11–15).

Twin studies make it possible to estimate the extent of genetic influence, even where no specific genes have been identified, by comparing the degree of resemblance of monozygotic twin pairs (who share 100% of their genes) and dizygotic twin pairs (who share 50% of their segregating genes). Few of the early studies showed consistent evidence for genetic influence on preferences, but sample sizes were often small, most studies tested a limited variety of foods, and foods varied from study to study (11, 14). The largest study analyzed preferences for 77 foods in 214 pairs of 4–5-y-old twins from the Twins Early Development Study (TEDS).[5] The categorization of foods into groups showed a substantial genetic effect for protein foods, moderate genetic effects for vegetables and fruit, and a small genetic effect for dessert foods (12). This pattern was consistent with a more-powerful genetic influence on nutrient- than energy-dense foods, but a larger sample size was needed for direct comparisons.

Twin analyses can also estimate the impact of a shared early life environment from the extent to which twin resemblance is greater than would be expected given the heritability of the trait. However, because shared environment effects are usually smaller than genetic effects, larger samples are needed for significant estimates of the shared environment (16). In TEDS analyses, shared environment effects ranged from 12% to 64%, but CIs

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[5] Abbreviations used: A, additive genetic component of variance; C, shared environmental component of variance; E, unique environmental component of variance; TEDS, Twins Early Development Study.

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meant that smaller estimates were not significant. Therefore, the aim of the current study was to get comprehensive food-preference data from a very large sample of young twins and assess genetic and environmental contributions to liking for various food types.

SUBJECTS AND METHODS

Sample

Participants were families who were taking part in the Gemini study, which is a population-based cohort of twins born in the United Kingdom in 2007 (17). Recruitment was carried out by the Office for National Statistics, which contacted all families in England and Wales with live twin births between March and December 2007 (n = 6754), of whom 2402 families (36%) consented. Ethical approval was granted by the Joint University College London/University College London Hospitals Committee on the Ethics of Human Research.

Measures

In same-sex pairs, zygosity was determined by using a validated questionnaire (18). DNA testing for zygosity was carried out in a random sample of 81 pairs, with 100% correspondence between questionnaire-allocated zygosity and DNA-test classification (19). In the full sample, zygosity was uncertain in 13 pairs because of inconclusive questionnaire results or missing data; these pairs were excluded from analyses. The sex and date of birth were reported in the baseline questionnaire, and the age at the assessment of food preferences was calculated from the date of data collection.

Food-preference data were collected with a 114-item parent-report questionnaire that was based on food lists used in TEDS analyses (12) and a study of developmental patterning of preferences (20). Parents were asked about each child's liking for each food, with 6 response options as follows: likes a lot, likes, neither likes nor dislikes, dislikes, dislikes a lot, and never tried, which was recoded to missing. Responses were scored −2, −1, 0, 1, and 2; therefore, a score of 0 indicated a neutral opinion, negative values indicated dislike, and positive values indicated liking.

Foods were excluded from analyses if they had been tried by <75% of children (n = 30 foods); typically, these were foods that are rarely consumed in the United Kingdom (eg, okra and papaya), which left 84 foods. As well as analyses on individual foods, foods were grouped into the following 6 categories that were based primarily on a principal components analysis but slightly modified to align with groupings from previous food-preference studies (12, 20): vegetables, fruit, protein (eg, meat and fish), dairy (eg, cheese, yogurt, and eggs), starches (eg, rice, bread, and pasta), and snacks (eg, chocolate, cookies, ice cream, and chips). Nine foods did not fit clearly into any category and were excluded from grouped analyses, which left 75 foods in the final analysis. Cronbach's α for the 6 food-group scales showed an acceptable internal reliability for vegetables (α = 0.88; 19 items), fruit (α = 0.88; 16 items), protein (α = 0.78; 13 items), dairy (α = 0.69; 9 items), and snacks (α = 0.76; 12 items). The internal reliability was lower for starches (α = 0.45; 6 items) but we took the decision to include it in the analyses because no previous studies examining the heritability of starch preferences could be identified. Scale scores were calculated as the mean liking for component food items. Participants were required to have completed over one-half of food items within each scale for a scale score to be calculated.

Statistical analyses

Twin analyses were carried out on preference scores residualized for age and sex effects to take into account the exact correlation for age within same-sex twin pairs that could inflate the estimate of shared environmental effects (21). Intraclass correlations were calculated for each zygosity group for residualized preference scores for the 84 individual foods and 6 food groups (which comprised 75 foods) with SPSS software (version 20 for Windows; SPSS Inc).

Maximum-likelihood structural equation modeling was performed for each of the 6 food groups by using Mx Modeling Software (version 32; Virginia Commonwealth University). The maximum-likelihood structural equation modeling modeled the covariance between twin pairs to apportion the total phenotypic variance to the following 3 variables: the additive genetic effect (A), the shared environmental effect (C), and the unique environmental effect, which also included measurement error (E) (22). Goodness-of-fit statistics are provided for the complete ACE model. The fit of nested submodels, which sequentially dropped A, C, and both A and C, were tested against the fit of the full ACE model to find the most-parsimonious solution (23).

TABLE 1
Sample demographics[1]

Characteristic	Total sample (n = 4804 twins)	Current study sample (n = 2686 twins)
Sex [n (%)]		
M	2386 (49.7)	1332 (49.6)
F	2418 (50.3)	1354 (50.4)
Gestational age (wk)	36.20 ± 2.48[2]	36.19 ± 2.51
Weight at birth (kg)	2.46 ± 0.54	2.46 ± 0.54
Zygosity [n (%)]		
MZ	1498 (31.2)	916 (34.1)[3]
DZ	3232 (67.3)	1744 (64.9)[3]
Unknown	74 (1.5)	26 (1.0)
Mother's age at twins' birth (y)	33.6 ± 5.19	33.6 ± 4.77
NS-SEC[4] [n (%)]		
Lower	944 (19.7)	394 (14.7)[3]
Intermediate	814 (16.9)	400 (14.9)[3]
Higher	3030 (63.1)	1884 (70.1)[3]
Missing	16 (0.3)	0
Feeding method of infants during first 3 mo [n (%)]		
Mostly or entirely breastfed	1571 (32.7)	990 (36.9)[3]
Equally, mostly, or entirely bottle fed	3201 (67.1)	1696 (63.1)[3]
Missing	32 (0.7)	0

[1] DZ, dizygotic; MZ, monozygotic; NS-SEC, National Statistics Socio-economic Classification.

[2] Mean ± SD (all such values).

[3] Significant difference between total and current samples, $P < 0.05$ (Pearson's chi-square analyses).

[4] NS-SEC index scores of social class were based on parent occupations and grouped into 3 categories as follows: higher (higher and lower managerial and professional occupations), intermediate [intermediate occupations, small employers, and own-account workers (self-employed with no employees)], and lower occupational classifications [lower supervisory and technical occupations, (semi)routine occupations, never worked, and long-term unemployed].

TABLE 2
Food preferences and within-pair intraclass correlations by zygosity, for individual foods[1]

Food item	Children who had tried food	Preference score[2]	MZ[3]	DZ[3]
	n (%)			
Vegetables				
Salad leaves	2482 (92.4)	−0.73 ± 1.16	0.86 (0.84, 0.88)	0.63 (0.60, 0.66)
Sprouts	2112 (78.6)	−0.29 ± 1.20	0.83 (0.81, 0.85)	0.67 (0.64, 0.70)
Mushrooms	2432 (90.5)	−0.16 ± 1.14	0.81 (0.78, 0.83)	0.57 (0.54, 0.61)
Cabbage	2417 (90.0)	0.06 ± 1.13	0.90 (0.89, 0.92)	0.67 (0.65, 0.70)
Raw peppers	2277 (84.8)	0.07 ± 1.24	0.85 (0.83, 0.87)	0.71 (0.69, 0.74)
Cooked peppers	2445 (91.0)	0.14 ± 1.06	0.94 (0.93, 0.95)	0.81 (0.80, 0.83)
Onions	2580 (96.1)	0.17 ± 0.92	0.89 (0.88, 0.90)	0.73 (0.73, 0.75)
Fresh tomatoes	2618 (97.4)	0.19 ± 1.38	0.71 (0.68, 0.74)	0.44 (0.41, 0.48)
Parsnips	2303 (85.8)	0.20 ± 1.04	0.89 (0.88, 0.91)	0.73 (0.71, 0.75)
Cauliflower	2584 (96.3)	0.24 ± 1.12	0.87 (0.86, 0.89)	0.67 (0.65, 0.70)
Green beans	2541 (94.7)	0.41 ± 1.16	0.85 (0.83, 0.87)	0.64 (0.61, 0.67)
Sweet potatoes	2272 (84.5)	0.52 ± 0.93	0.90 (0.89, 0.92)	0.82 (0.80, 0.84)
Broccoli	2660 (99.1)	0.78 ± 1.19	0.76 (0.73, 0.79)	0.47 (0.43, 0.50)
Cucumber	2607 (97.1)	0.78 ± 1.27	0.72 (0.66, 0.75)	0.56 (0.53, 0.59)
Raw carrots	2588 (96.4)	0.86 ± 1.13	0.86 (0.84, 0.88)	0.59 (0.56, 0.62)
Sweet corn	2627 (97.8)	1.00 ± 1.05	0.76 (0.73, 0.79)	0.58 (0.55, 0.61)
Peas	2667 (99.3)	1.02 ± 1.02	0.65 (0.61, 0.69)	0.52 (0.48, 0.55)
Tinned tomatoes	2643 (98.4)	1.14 ± 0.87	0.90 (0.88, 0.91)	0.70 (0.68, 0.73)
Cooked carrots	2674 (99.6)	1.17 ± 0.97	0.78 (0.75, 0.81)	0.51 (0.47, 0.54)
Fruit				
Kiwi	2164 (80.6)	0.39 ± 1.20	0.84 (0.81, 0.86)	0.58 (0.55, 0.62)
Raw apples	2666 (99.3)	0.53 ± 0.75	0.73 (0.70, 0.76)	0.37 (0.33, 0.41)
Pineapple	2410 (89.4)	0.57 ± 1.15	0.85 (0.82, 0.86)	0.67 (0.65, 0.70)
Mango	2083 (77.6)	0.60 ± 1.08	0.92 (0.91, 0.93)	0.75 (0.72, 0.77)
Plums	2318 (86.3)	0.68 ± 1.10	0.88 (0.87, 0.90)	0.73 (0.71, 0.75)
Melon	2522 (93.9)	0.80 ± 1.16	0.86 (0.84, 0.87)	0.71 (0.68, 0.73)
Peaches	2421 (90.2)	0.84 ± 1.07	0.90 (0.89, 0.91)	0.68 (0.65, 0.70)
Baked apples	2394 (89.1)	0.91 ± 0.99	0.95 (0.94, 0.95)	0.82 (0.81, 0.84)
Blueberries	2218 (82.6)	0.92 ± 1.20	0.78 (0.75, 0.80)	0.56 (0.52, 0.59)
Raspberries	2452 (91.3)	0.93 ± 1.18	0.81 (0.79, 0.84)	0.63 (0.59, 0.65)
Pears	2590 (96.5)	1.03 ± 1.00	0.85 (0.83, 0.87)	0.52 (0.48, 0.55)
Oranges	2613 (97.3)	1.05 ± 1.10	0.77 (0.74, 0.80)	0.44 (0.40, 0.48)
Tangerines	2606 (97.0)	1.15 ± 1.09	0.73 (0.70, 0.76)	0.40 (0.36, 0.44)
Strawberries	2663 (99.1)	1.43 ± 0.99	0.67 (0.63, 0.70)	0.43 (0.39, 0.47)
Bananas	2670 (99.4)	1.47 ± 0.87	0.59 (0.54, 0.63)	0.36 (0.32, 0.40)
Grapes	2660 (99.0)	1.58 ± 0.84	0.69 (0.65, 0.72)	0.38 (0.34, 0.42)
Protein foods				
Beef burger	2064 (76.8)	0.45 ± 1.02	0.86 (0.84, 0.88)	0.63 (0.60, 0.66)
Tuna	2267 (84.4)	0.61 ± 1.09	0.83 (0.80, 0.85)	0.71 (0.68, 0.73)
Pork	2220 (82.3)	0.62 ± 0.90	0.88 (0.86, 0.89)	0.68 (0.65, 0.71)
Lamb	2136 (79.5)	0.64 ± 0.94	0.88 (0.86, 0.89)	0.70 (0.68, 0.73)
Beef	2493 (92.8)	0.74 ± 0.95	0.81 (0.79, 0.84)	0.58 (0.55, 0.61)
Bacon	2221 (82.7)	0.85 ± 1.05	0.81 (0.78, 0.83)	0.54 (0.50, 0.57)
Turkey	2292 (85.3)	0.87 ± 0.80	0.81 (0.78, 0.83)	0.76 (0.73, 0.78)
White fish	2402 (89.6)	0.88 ± 0.91	0.88 (0.87, 0.90)	0.71 (0.68, 0.73)
Chicken nuggets	2148 (80.0)	1.00 ± 0.98	0.86 (0.84, 0.88)	0.75 (0.72, 0.77)
Ham	2540 (94.5)	1.15 ± 1.01	0.75 (0.71, 0.77)	0.35 (0.31, 0.39)
Battered fish	2603 (96.9)	1.27 ± 0.85	0.83 (0.81, 0.85)	0.60 (0.57, 0.63)
Chicken	2608 (97.1)	1.31 ± 0.82	0.72 (0.69, 0.75)	0.60 (0.57, 0.63)
Sausages	2571 (95.7)	1.45 ± 0.83	0.76 (0.74, 0.79)	0.54 (0.50, 0.57)
Dairy foods				
Scrambled eggs	2497 (92.9)	0.45 ± 1.26	0.82 (0.80, 0.84)	0.62 (0.59, 0.65)
Cream	2208 (82.2)	0.54 ± 1.00	0.85 (0.83, 0.92)	0.57 (0.53, 0.60)
Processed cheese	2242 (83.4)	0.60 ± 1.24	0.80 (0.77, 0.82)	0.68 (0.65, 0.71)
Cream cheese	2061 (76.7)	0.61 ± 1.04	0.89 (0.87, 0.91)	0.74 (0.72, 0.77)
Eggs	2544 (94.7)	0.63 ± 1.27	0.77 (0.74, 0.79)	0.59 (0.56, 0.62)
Margarine	2160 (80.4)	0.91 ± 0.90	0.86 (0.84, 0.87)	0.77 (0.75, 0.79)
Butter	2546 (99.3)	1.21 ± 0.85	0.80 (0.78, 0.82)	0.67 (0.64, 0.70)
Hard cheese	2646 (98.5)	1.26 ± 0.99	0.64 (0.60, 0.68)	0.39 (0.35, 0.43)
Yogurt	2667 (99.3)	1.74 ± 0.60	0.72 (0.69, 0.75)	0.42 (0.38, 0.46)

(Continued)

TABLE 2 (*Continued*)

Food item	Children who had tried food	Preference score[2]	MZ[3]	DZ[3]
Snacks				
Sweet buns	2524 (94.0)	1.00 ± 0.94	0.82 (0.91, 0.93)	0.77 (0.74, 0.78)
Dessert mousse	2389 (88.9)	1.05 ± 1.02	0.91 (0.90, 0.92)	0.78 (0.76, 0.80)
Sweets	2182 (81.2)	1.19 ± 1.00	0.86 (0.84, 0.88)	0.64 (0.61, 0.67)
Chips	2669 (99.4)	1.23 ± 0.81	0.81 (0.79, 0.83)	0.60 (0.57, 0.63)
Savory snacks	2540 (94.6)	1.27 ± 0.79	0.88 (0.86, 0.89)	0.72 (0.70, 0.75)
Cakes	2674 (99.6)	1.38 ± 0.78	0.82 (0.80, 0.84)	0.60 (0.57, 0.63)
Ice lollies	2585 (96.2)	1.42 ± 0.88	0.91 (0.90, 0.92)	0.73 (0.70, 0.75)
Plain biscuits	2670 (99.4)	1.50 ± 0.61	0.92 (0.91, 0.93)	0.70 (0.67, 0.72)
Ice cream	2660 (99.0)	1.51 ± 0.83	0.74 (0.71, 0.77)	0.47 (0.43, 0.50)
Crisps	2651 (98.7)	1.61 ± 0.62	0.81 (0.78, 0.83)	0.63 (0.60, 0.66)
Chocolate biscuits	2652 (98.8)	1.64 ± 0.65	0.65 (0.62, 0.69)	0.61 (0.58, 0.64)
Chocolate	2669 (99.4)	1.70 ± 0.78	0.63 (0.59, 0.67)	0.46 (0.42, 0.49)
Starchy foods				
Porridge	2487 (92.6)	0.75 ± 1.19	0.78 (0.76, 0.81)	0.65 (0.62, 0.67)
Rice	2668 (99.3)	0.97 ± 0.94	0.86 (0.85, 0.88)	0.70 (0.68, 0.72)
Brown bread	2636 (98.1)	1.15 ± 0.71	0.91 (0.90, 0.92)	0.83 (0.81, 0.84)
White bread	2635 (98.1)	1.18 ± 0.70	0.88 (0.87, 0.90)	0.85 (0.84, 0.87)
Cereals (nonsugared)	2659 (99.0)	1.40 ± 0.73	0.81 (0.78, 0.83)	0.63 (0.60, 0.66)
Pasta	2681 (99.8)	1.53 ± 0.72	0.83 (0.81, 0.85)	0.50 (0.47, 0.54)
Ungrouped foods				
Mayonnaise	2035 (75.8)	0.32 ± 1.12	0.82 (0.80, 0.85)	0.60 (0.57, 0.63)
Roasted potatoes	2618 (97.5)	0.92 ± 0.96	0.89 (0.88, 0.90)	0.73 (0.71, 0.75)
Custard	2521 (93.9)	0.94 ± 1.07	0.90 (0.89, 0.91)	0.73 (0.70, 0.75)
Jam	2628 (97.8)	0.95 ± 1.05	0.67 (0.63, 0.71)	0.42 (0.38, 0.46)
Pizza	2640 (98.3)	1.01 ± 0.97	0.72 (0.69, 0.75)	0.57 (0.53, 0.60)
Baked beans	2641 (98.3)	1.02 ± 1.12	0.61 (0.57, 0.65)	0.51 (0.48, 0.55)
Potatoes	2679 (99.7)	1.03 ± 1.00	0.81 (0.79, 0.83)	0.55 (0.51, 0.58)
Ketchup	2591 (96.5)	1.24 ± 1.00	0.62 (0.58, 0.66)	0.41 (0.36, 0.47)
Raisins	2653 (99.8)	1.43 ± 0.90	0.73 (0.70, 0.76)	0.52 (0.49, 0.55)

[1] US translations of UK food names are as follows: chips = French fries; chocolate biscuits = chocolate cookies; crisps = chips; ice lollies = popsicles; jam = fruit preserve; plain biscuits = plain cookies; porridge = oatmeal; sweets = candy. DZ, dizygotic; MZ, monozygotic.

[2] All values are means ± SDs. Higher scores indicate a higher liking.

[3] All values are intraclass correlations; 95% CIs in parentheses.

Akaike's information criterion (24) and the likelihood ratio test were used to determine the best-fitting and most parsimonious model for each food group.

RESULTS

Food-preference data were collected from 1343 families (56% of the total sample) when twins were, on average (±SD), 3.5 ± 0.27 y old. Characteristics of the study sample and total sample are shown in **Table 1**. The study sample was comparable to the full cohort in terms of sex, gestational age, birth weight, and mother's age. The study sample had a higher proportion of monozygotic twins [chi-square (1) = 5.92, P = 0.015], more families in the high National Statistics Socioeconomic Classification category [chi-square (2) = 41.53, $P < 0.001$], and a higher number of breastfed children [chi-square (1) = 11.81, P = 0.001] than did the full cohort, but absolute differences were small.

Results for the 84 individual foods are shown in **Table 2** within each food group as well as for ungrouped foods ordered by liking within the group. The only foods that were disliked (negative score) were in the vegetable group, and only 4 vegetables were liked (score ≥1). In contrast, snacks were all liked. However there was significant variation within each category.

Results of liking for the 6 food groups are shown in **Table 3**. As expected, the vegetable category was the least liked (mean preference: 0.44), and was followed by dairy (0.90), protein (0.93), and starch (1.17). Snacks were the most well liked (1.38) and also had the smallest SD, which indicated less variation in children's snack preferences. Paired-samples tests indicated that food-group preference scores were all significantly different from one another (all $P < 0.01$) except for dairy and protein preferences (P = 0.054). Comparisons of preference scores by zygosity revealed no mean differences between monozygotic and dizygotic twins.

There was an overall liking effect, with positive correlations between all the food groups (all $P < 0.01$). Vegetable and fruit preferences had the highest correlation (r = 0.5, $P < 0.001$), and the lowest correlation was between vegetables and snacks (r = 0.1, $P < 0.001$).

The comparison of monozygotic and dizygotic intraclass correlations gives an indication of the extent of genetic and environment influences. For all 84 foods (Table 2), monozygotic correlations were higher than dizygotic correlations, which indicated a consistent, although sometimes small, genetic contribution to preferences. Dizygotic correlations were more than one-half of monozygotic correlations for all except one food (ham), and most dizygotic correlations were >0.5, which indicated a consistent,

TABLE 3
Food preferences and within-pair intraclass correlations by zygosity for food groups[1]

Food group	Preference score[2]	MZ[3]	DZ[3]
Vegetables (*n* = 2660)	0.44 ± 0.61	0.89 (0.87, 0.90)	0.62 (0.59, 0.65)
Fruit (*n* = 2613)	1.00 ± 0.64	0.88 (0.86, 0.89)	0.61 (0.57, 0.63)
Protein (*n* = 2582)	0.93 ± 0.51	0.84 (0.82, 0.86)	0.62 (0.59, 0.65)
Dairy (*n* = 2651)	0.90 ± 0.56	0.81 (0.79, 0.83)	0.68 (0.65, 0.70)
Snacks (*n* = 2672)	1.38 ± 0.42	0.88 (0.87, 0.90)	0.76 (0.74, 0.78)
Starch (*n* = 2676)	1.17 ± 0.44	0.88 (0.86, 0.89)	0.73 (0.71, 0.76)

[1] DZ, dizygotic; MZ, monozygotic.
[2] All values are means ± SDs. Higher scores indicate a higher liking.
[3] All values are intraclass correlations; 95% CIs in parentheses.

although sometimes small, effect of the shared environment. The same patterns are shown for the 6 food groups (Table 3, **Figure 1**).

Quantitative modeling was done by food group. In all cases, the full ACE model fitted the data best; dropping either A or C (or both) led to a worse fit. Results of the ACE model–fitting analyses are shown in **Table 4**.

Heritability was substantial for vegetables (54%; 95% CI: 47%, 63%), fruit (53%; 95% CI: 45%, 61%), and protein (48%; 95% CI: 40%, 57%). Preferences for the other 3 food groups showed a moderate to low genetic influence [starches (32%; 95% CI: 26%, 38%), snacks (29%; 95% CI: 24%, 35%) and dairy (27%; 95% CI: 20%, 35%)].

The shared environment effect was substantial for preferences for snacks (60%; 95% CI: 54%, 65%), starches (57%; 95% CI: 51%, 62%), and dairy (54%; 95% CI: 47%, 60%), and moderate for fruit (35%; 95% CI: 26%, 43%), vegetables (35%; 95% CI: 27%, 42%), and protein (37%; 95% CI: 27%, 45%). The non-shared environment effect (which included the error term) was small for all food groups [snacks (11%; 95% CI: 9%, 12%), starch (11%; 95% CI: 10%, 13%), vegetables (11%; 95% CI: 10%, 13%), fruit (13%; 95% CI: 11%, 15%), protein (15%; 95% CI: 13%, 17%), and dairy (19%; 95% CI: 16%, 22%)].

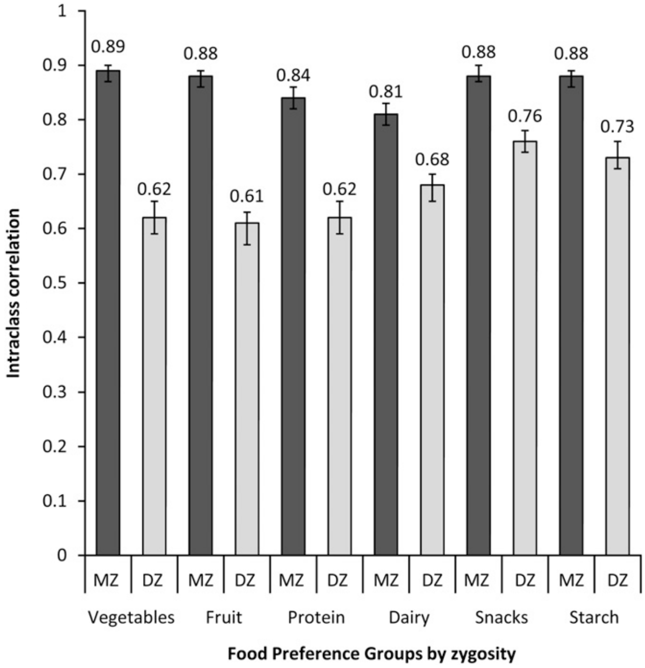

FIGURE 1. Intraclass correlations (95% CIs) between twin pairs by zygosity for standardized food group–preference scores (*n* = 1343 twin pairs). MZ, monozygotic twins; DZ, dizygotic twins.

DISCUSSION

The aim of the current study was to investigate the relative contribution of genetic and shared environment factors to the variation in children's preferences for a large number of foods assessed individually and combined into food groups. The results of food-group analyses confirmed previous findings of a substantial genetic influence on preferences for fruit, vegetables, and protein foods (48–54%), with a lower genetic influence on the preference for snacks (29%). Preferences for dairy and starch were also less heritable (27–32%). Mirroring this result, shared environment effects were substantial for dairy, starch, and snacks (54–60%) and smaller for fruit, vegetables, and protein foods (35–37%).

These results were broadly similar to those of a previous twin study in a similar age group (12), which also showed a stronger genetic effect for fruit and vegetables and a stronger shared environment effect for snacks and desserts. Preferences for protein foods appeared to be less heritable in the current study than the previous one [48% (95% CI: 40%, 57%) compared with 78% (95% CI: 63%, 92%)]. This difference may have been a result of slight differences in foods grouped into protein categories in the 2 studies, but the sample size was small in the previous study (214 twin pairs) and CIs were wide, and thus, the difference was more likely a result of chance. The current results should probably be considered more robust because of the large sample size.

To our knowledge, the relative influence of genes and the environment on the variation in the preference for starches and dairy foods has not been previously explored, but these findings suggested that preferences for these foods follow a similar pattern to snacks, with shared environment effects driving the preferences. Although some dairy and starch foods are nutrient dense, other dairy and starch foods (ie, cream or cereals) that comprised these groups in the current study were also high in energy. Therefore, the similar heritability for dairy and starch foods as for energy-dense snacks may have resulted from the high energy density of the majority of individual foods included in the dairy and starch categories.

Nonshared environmental effects were low for all 6 food groups (11–19%). This result was not surprising because of the relatively young age of the children. Before starting school, the

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TABLE 4
Model fit and variable estimates for ACE model-fitting for food group preferences[1]

Food group and model	Additive genetic effect (a^2)	Shared environment effect (c^2)	Nonshared environment effect (e^2)[2]	−2LL	df	AIC	Change in AIC	Change in chi-square (df)	*P*
Vegetables (n = 2640)									
ACE	0.54 (0.47, 0.63)[3]	0.35 (0.27, 0.42)	0.11 (0.10, 0.13)	6328.787	2635	1058.787	—	—	—
CE	—	0.71 (0.68, 0.74)	0.29 (0.26, 0.32)	6525.959	2636	1253.959	195.172	197.172 (1)	<0.001
AE	0.89 (0.87, 0.90)	—	0.11 (0.10, 0.12)	6383.172	2636	1111.172	52.385	54.385 (1)	<0.001
E	—	—	1.00 (1.00, 1.00)	7447.984	2637	2173.984	1115.197	1119.197 (2)	<0.001
Fruit (n = 2588)									
ACE	0.53 (0.45, 0.61)	0.35 (0.26, 0.43)	0.13 (0.11, 0.15)	6269.131	2583	1103.131	—	—	—
CE	—	0.70 (0.67, 0.73)	0.30 (0.27–0.33)	6430.708	2584	1262.708	159.577	161.577 (1)	<0.001
AE	0.88 (0.86, 0.89)	—	0.12 (0.11, 0.14)	6320.54	2584	1152.541	49.409	51.409 (1)	<0.001
E	—	—	1.00 (1.00, 1.00)	7309.289	2585	2139.289	1036.158	1040.158 (2)	<0.001
Protein (n = 2558)									
ACE	0.48 (0.40, 0.57)	0.37 (0.27, 0.45)	0.15 (0.13, 0.17)	6309.826	2553	1203.826	—	—	—
CE	—	0.69 (0.66, 0.72)	0.31 (0.28, 0.34)	6430.590	2554	1322.590	118.764	120.764 (1)	<0.001
AE	0.86 (0.84, 0.87)	—	0.14 (0.13, 0.16)	6367.369	2554	1259.369	55.543	57.543 (1)	<0.001
E	—	—	1.00 (1.00, 1.00)	7259.670	2555	2149.670	945.844	949.844 (2)	<0.001
Dairy (n = 2625)									
ACE	0.27 (0.20, 0.35)	0.54 (0.47, 0.60)	0.19 (0.16, 0.22)	6447.645	2620	1207.645	—	—	—
CE	—	0.72 (0.70, 0.75)	0.28 (0.25, 0.30)	6490.010	2621	1248.010	40.365	42.365 (1)	<0.001
AE	0.82 (0.80, 0.84)	—	0.18 (0.16, 0.20)	6579.406	2621	1337.406	129.761	131.761 (1)	<0.001
E	—	—	1.00 (1.00, 1.00)	7452.421	2622	2208.421	1000.776	1004.776 (2)	<0.001
Snacks (n = 2646)									
ACE	0.29 (0.24, 0.35)	0.60 (0.54, 0.65)	0.11 (0.09, 0.12)	6081.378	2641	799.378	—	—	—
CE	—	0.80 (0.77, 0.81)	0.20 (0.19, 0.23)	6180.701	2642	896.701	97.324	99.324 (1)	<0.001
AE	0.89 (0.88, 0.91)	—	0.11 (0.09, 0.12)	6294.856	2642	1010.856	211.478	213.478 (1)	<0.001
E	—	—	1.00 (1.00, 1.00)	7505.133	2643	2219.133	1419.756	1423.756 (2)	<0.001
Starches (n = 2650)									
ACE	0.32 (0.26, 0.38)	0.57 (0.51, 0.62)	0.11 (0.10, 0.13)	6170.494	2645	880.494	—	—	—
CE	—	0.78 (0.76, 0.80)	0.22 (0.20, 0.24)	6273.471	2646	981.471	100.978	102.978 (1)	<0.001
AE	0.89 (0.87, 0.90)	—	0.11 (0.10, 0.13)	6349.586	2646	1057.586	177.092	179.092 (1)	<0.001
E	—	—	1.00 (1.00, 1.00)	7512.963	2647	2218.963	1338.470	1342.470 (2)	<0.001

[1] Scores modeled were residuals adjusted for the age of the child when the parent completed the questionnaire and for sex. Presented models included all infants with valid data for age, sex, and food group–preference score. Standard ACE model-fitting analyses for continuous data were used. CE, AE, and E models were nested within the full ACE model. The ACE model dissected the phenotypic variance into a^2, c^2, and e^2; the CE model dropped the a^2 variable and assessed the variance explained by c^2 and e^2 variables only; the AE model dropped the c^2 variable and assessed the variance explained by a^2 and e^2 variables only; the E model dropped both a^2 and c^2 variables and assessed the variance explained by e^2 only. Two fit indexes are reported from structural equation modeling analyses to evaluate nested submodels against the full ACE model: *P* values were based on the likelihood ratio test and AIC. A better-fitting submodel showed a change in chi-square that did not represent a significant worsening of fit designated by the *P* value. A, additive genetic component of variance; AIC, Akaike's information criterion; C, shared environmental component of variance; E, unique environmental component of variance; −2LL, −2 log likelihood.

[2] Includes measurement error.

[3] Estimate; 95% CI in parentheses (all such values).

majority of food encounters and experiences of young children occur within the family home environment. However, the pattern of influence might change as children get older and have more autonomy. Food choices of peers have been shown to strongly influence preferences in the school setting (25, 26).

Several previous studies have focused on the parent-child resemblance in food preferences, and this resemblance has generally been shown to be relatively low (27). This finding was likely due in part to the age difference between children and parents because siblings have shown a stronger resemblance (28). The few twin studies that have investigated actual foods (as opposed to specific tastes or flavor compounds) have provided limited evidence of a heritable component to the preference for some foods (11, 12, 14, 15), although other studies have produced negative results (13, 29, 30). However, with one exception (12), the number of foods included in the studies was very limited, twin sample sizes were low (<72 pairs), and CIs were not reported; which made it likely that null findings resulted from a limited power to detect anything other than very large genetic effects.

The sample size in the current study was considerably higher than that in any previous study of genetic and environmental influences on children's food preferences, which provided greater statistical power and more-reliable estimates. CIs in the current study were also smaller for all variables than those reported previously, which indicated more-robust estimates. Furthermore, the nonshared environment effect, which incorporated the measurement error, was small for all 6 food groups, even for the dairy group.

The results relied on parental reports because the children were too young to reliably report their own preferences from lists of foods (31), and behavioral observations were not possible because of the sample size. However, the differential pattern of estimates across the different foods argued against a parental bias toward consistently rating monozygotic more similar than

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dizygotic twins. In addition, support for the use of twin studies to assess genetic contributions to behavioral traits came from the molecular genetic literature in which specific polymorphisms, such as variants of *TAS2R38*, have been linked with taste perception (32).

These findings suggest that, for some foods, particularly vegetables, fruit, and protein foods, parents are correct in perceiving their children's preferences to be innate. However, high heritability does not mean that environmental interventions are without value; indeed, many studies have shown that food preferences are modifiable, especially in early childhood (33–36). For other foods such as dairy, starch, and energy-dense snacks, these results support the view of health professionals that differences in the home environment are the main determinant of the variation in children's liking. Parents, as the principal architects of young children's environments, could benefit from evidence-based guidance on how best to foster healthy food preferences and eating habits by using the effective techniques such as repeated exposure and parental modeling that have emerged from the literature (34–37) while preventing the development of unhealthy preferences through restricting the availability of energy-dense snacks in the home.

In conclusion, this study provides strong evidence that food preferences in early childhood are influenced both by genes and the shared environment. Parents are correct in perceiving a moderately strong genetic component for commonly rejected foods such as vegetables, whereas health professionals are right in seeing the home environment as highly influential in children's liking for energy-dense snacks and starchy foods. Therefore, different types of interventions may be needed for different types of foods.

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