Public Health Nutrition: 16(3), 505–514 doi:10.1017/S1368980012002807

Associations between neighbourhood and household environmental variables and fruit consumption: exploration of mediation by individual cognitions and habit strength in the GLOBE study

Nannah I Tak[1], Saskia J te Velde[1,*], Carlijn BM Kamphuis[2], Kylie Ball[3], David Crawford[3], Johannes Brug[1] and Frank J van Lenthe[2]

[1]Department of Epidemiology & Biostatistics and the EMGO Institute for Health and Care Research, VU University Medical Center, Van der Boechorststraat 7, 1081 BT Amsterdam, the Netherlands: [2]Department of Public Health, Erasmus University Medical Center, Rotterdam, the Netherlands: [3]Centre for Physical Activity and Nutrition Research, Deakin University, Melbourne, Australia

Submitted 28 August 2011: Final revision received 4 March 2012: Accepted 24 April 2012: First published online 13 June 2012

Abstract

Objective: The present study examined associations of several home and neighbourhood environmental variables with fruit consumption and explored whether these associations were mediated by variables derived from the Theory of Planned Behaviour (TPB) and by habit strength.

Design: Data of the Dutch GLOBE study on household and neighbourhood environment, fruit intake and related factors were used, obtained by self-administered questionnaires (cross-sectional), face-to-face interviews and audits.

Setting: The city of Eindhoven in the Netherlands

Subjects: Adults (*n* 333; mean age 58 years, 54 % female).

Results: Multiple mediation analyses were conducted using regression analyses to assess the association between environmental variables and fruit consumption, as well as mediation of these associations by TPB variables and by habit strength. Intention, perceived behaviour control, subjective norm and habit strength were associated with fruit intake. None of the neighbourhood environmental variables was directly or indirectly associated with fruit intake. The home environmental variable 'modelling behaviour by family members' was indirectly, but not directly, associated with fruit intake. Habit strength and perceived behaviour control explained most of the mediated effect (71·9 %).

Conclusions: Modelling behaviour by family members was indirectly associated with fruit intake through habit strength and perceived behaviour control. None of the neighbourhood variables was directly or indirectly, through any of the proposed mediators, associated with adult fruit intake. These findings suggest that future interventions promoting fruit intake should address a combination of the home environment (especially modelling behaviour by family members), TPB variables and habit strength for fruit intake.

Keywords
Fruit consumption
Mediation
Environmental variables
Cognitive variables
Habit strength

Large proportions of the population in many Western countries do not meet the dietary recommendations for fruit intake[1–4]. To stimulate fruit intake, we need to gain insight into the important and modifiable determinants of this behaviour. Social cognitive models, especially the Theory of Planned Behaviour (TPB), have been widely used to explain dietary behaviours[5]. The TPB proposes that behaviour can be predicted from the intention to perform a particular behaviour and by perceived behavioural control (PBC), and that intention is determined by attitude, subjective norm and PBC[6]. Despite the validity of the theoretical assumptions of the TPB and empirical evidence supporting this validity[3,7–12], calls have been made for the inclusion of additional variables, such as habit strength[13], to further understand health behaviour. Inclusion of habit strength into theoretical models (i.e. the TPB) predicting dietary behaviour may be justified because dietary behaviours are frequently repeated and it has been argued that dietary behaviour may become habitual. Habitual behaviour is considered to be an 'automatic' response triggered by environmental cues instead of conscious evaluations of possible outcomes,

*Corresponding author: Email s.tevelde@vumc.nl

the opinion of other people or confidence about being able to perform the behaviour[13]. Furthermore, in recent years a series of studies has provided evidence for habit strength as a possible determinant of dietary behaviours[13–17].

In addition to cognitive individual-level variables, physical and social environmental factors have gained more attention as possible determinants of eating behaviours over the last decade[18–22]. It has been argued that such home and neighbourhood environmental factors may directly or indirectly influence eating behaviours[18,23,24]. The Environmental Research framework for weight Gain prevention (EnRG)[25] aimed at integrating individual-level variables and environmental variables by proposing direct and indirect pathways by which environmental factors may influence eating behaviour. According to this EnRG framework, on the one hand, environmental variables may influence intakes through individual cognitions such as those described in the TPB (i.e. a mediated pathway). For example, potentially important environmental influences for dietary behaviours such as availability and accessibility of health food products at home[18,22] or social environmental factors such as modelling of healthy eating by family members[18] may result in increased PBC or more positive attitudes towards healthy eating, which in turn may increase the likelihood of consumption of healthy foods. On the other hand, such environmental cues may also influence eating behaviours via a more direct pathway that does not involve conscious decision-making processes.

The EnRG framework has not yet been evaluated with regard to home and neighbourhood environmental influences on adults' fruit consumption and potential mediation through cognitive variables and/or habit strength. It is important to investigate such associations to better understand underlying mechanisms and to further improve theoretical frameworks such as the EnRG framework; they often form the basis for future intervention development and should therefore be tested in observational and intervention studies.

Therefore, the present study specifically aimed to examine: (i) the associations of several home and neighbourhood environmental variables with fruit consumption; (ii) the associations of TPB constructs and habit strength with fruit consumption; and (iii) whether possible associations of neighbourhood and home environmental variables with fruit consumption are mediated by TPB variables and/or by habit strength in Dutch adults (see Fig. 1 for a presentation of the conceptual framework). In line with the EnRG framework[25], we hypothesized that neighbourhood and home availability of fruit and home social environmental support for fruit intake are directly and indirectly associated with fruit intake in adults.

Methods

Participants and procedures

Adults (n 333) included in the current study participated in the Dutch GLOBE study. That study aimed at examining determinants of socio-economic inequalities in health and comprised a stratified population-based sample from the south-eastern region of the Netherlands. Detailed information about the objectives, design and findings of the GLOBE study are available elsewhere[26]. Briefly, GLOBE was initiated in 1991 in the city of Eindhoven and a number of surrounding municipalities. The sample for GLOBE was randomly drawn from the municipal population registries, stratified by age, socio-economic position

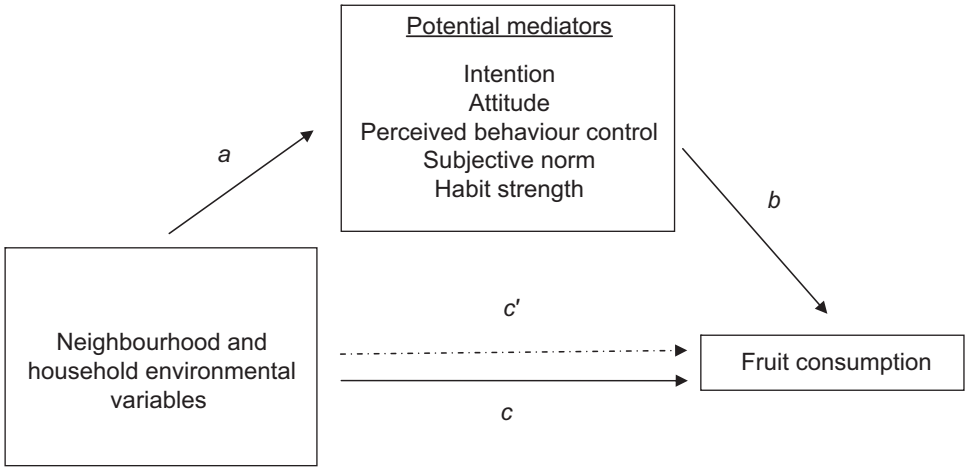

Fig. 1 Conceptual model for the mediated effect of Theory of Planned Behaviour constructs and habit strength in the association of neighbourhood and household environmental variables with fruit consumption (a = associations of neighbourhood and household environmental variables with the potential mediators; b = associations of significant mediators with fruit intake, adjusted for environmental variables; c = total association of neighbourhood and household environmental variables with fruit intake, unadjusted for mediators; c' = direct association of neighbourhood and household environmental variables with fruit intake, adjusted for significant mediators)

and degree of urbanization. The initial sample consisted of 27 070 non-institutionalized persons in the age range 15–74 years, of whom 18 973 responded to a postal questionnaire (70·1 % response). In 2004, a follow-up postal survey was sent to 10 270 persons. Participants in the most recent wave of the GLOBE study (*n* 6377, response rate 64·4 %) consisted of two sub-samples. One of these (*n* 4323, response rate 74·4 %) comprised participants who responded to the baseline questionnaire of the GLOBE study. Attrition from the baseline postal survey was due to death (12·3 %), emigration (2·0 %), refusal to be followed up longitudinally (2·2 %) and addresses that could not be traced (2·8 %). Owing to these factors, the sub-sample was no longer representative for the population. Therefore, a second sub-sample comprising new participants (*n* 2054, 55·0 % response rate) was added to restore the population representativeness of the GLOBE study sample.

In addition to the follow-up postal survey, a sub-sample (*n* 410, 234 females) of survey participants was interviewed face-to-face in the period 2004–2005. These respondents resided in seven of the most disadvantaged (*n* 204) and seven of the most advantaged neighbourhoods of Eindhoven (*n* 206). Data for the present study were available from both the 2004 follow-up postal survey and the 2005 interview data from the GLOBE study. Respondents with missing data on any of the relevant cognitive variables, habit strength and fruit intake were excluded in order to prevent that the different steps of the mediation analyses were conducted on slightly different samples, as advised by MacKinnon[27]. This resulted in a study sample of 333 adults.

Measures

Fruit intake

Based on a validated questionnaire to assess fruit consumption[28,29], respondents were asked in the interview to indicate on how many days per week they consumed fruits in the last month. They were additionally asked to indicate how many pieces of fruit they consumed on such a day. Multiplying frequency and usual amount and dividing the resulting score by 7 resulted in an average daily amount of pieces of fruit.

Theory of Planned Behaviour variables and habit strength

TPB variables specific to fruit consumption (intention, attitude, PBC and subjective norm) were assessed only during the face-to-face interview, using items with 5-point bipolar scales based on instructions derived from Conner and Norman[30]. Since these variables were essential for the present study, it was necessary to combine the data from the questionnaire and the interview data. Therefore, the study sample consisted of 333 adults. During the interview, TPB variables and habit strength were not assessed for vegetable intake; therefore the focus of the present study is on fruit consumption. The main reason for excluding questions on TPB variables and habit strength for vegetable intake was the length of the interview, which had to be below 90 min.

The intention to consume fruit was assessed with two items: (i) 'I intend to eat an adequate amount of fruit each day'; and (ii) 'I am planning to eat an adequate amount of fruit each day'. The two items were collapsed into a single intention variable by calculating the mean item score (Cronbach's $\alpha = 0{\cdot}87$). Attitude was assessed with eight items regarding the statements 'I believe eating an adequate amount of fruit per day is…': (i) 'very tasteful' (+2) to 'very tasteless' (−2); (ii) 'very healthy' (+2) to 'very unhealthy' (−2); (iii) 'very pleasant' (+2) to 'very unpleasant' (−2); (iv) 'convenient' (+2) to 'inconvenient' (−2); (v) 'messy' (−2) to 'not messy' (2); (vi) 'very inexpensive' (+2) to 'very expensive' (−2); (vii) 'unproblematic' (+2) to 'problematic' (−2); and (viii) 'very good' (+2) to 'very bad' (−2). To investigate if these eight items measured the same construct, Cronbach's α was calculated (= 0·77). Since this was quite low for a construct with eight factors, explorative factor analysis in SPSS was accordingly conducted. Results indicated that the item 'very inexpensive'–'very expensive' did not load well on the factor, and it was therefore excluded from the attitude construct. The other seven statements were collapsed into a single attitude variable by calculating the mean item score (Cronbach's $\alpha = 0{\cdot}82$). Subjective norm was assessed with three items, in which respondents were asked to indicate if they believed (i) their partner, (ii) their family and (iii) and their friends expected the respondents to eat an adequate amount of fruit (+2 = 'yes definitely'; –2 = 'no definitely not'). The three items were collapsed into a single subjective norm variable by calculating the mean item score (Cronbach's $\alpha = 0{\cdot}69$). PBC was assessed with nine items (+2 = 'yes definitely'; –2 = 'no definitely not') in which respondents were asked to indicate whether they would be able to eat an adequate amount of fruit, even: (i) 'on the weekend'; (ii) 'on work days'; (iii) 'when on holiday'; (iv) 'in the winter'; (v) 'when in lack of time'; (vi) 'when feeling tense or stressed'; (vii) 'there are few fruits available at home'; (viii) 'when not really feel like eating fruit'; and (ix) 'when I do not feel like preparing fruit'. These nine items were collapsed into a single PBC variable by calculating the mean item score (Cronbach's $\alpha = 0{\cdot}90$).

Habit strength of fruit consumption was assessed by means of four items from the Self report Habit Strength Scale proposed by Verplanken and Orbell[31]: (i) 'Eating fruit every day is something I do automatically'; (ii) 'Eating enough fruit is part of my daily routine; (iii) 'I eat enough fruit each day, without even realizing it'; and (iv) 'Eating enough fruit each day is something that is typically "me" '. These four items were assessed on 5-point bipolar scales, ranging from 'I completely disagree' (–2) to 'I completely

agree' (+2). An overall score for habit strength was constructed by summing the item scores (Cronbach's $\alpha = 0{\cdot}94$).

Household and neighbourhood environment

Based on focus group research[32] and systematic reviews[33], home and neighbourhood environmental factors possibly relevant for fruit consumption were identified and included in the postal questionnaire and in the interview. In the questionnaire, participants were presented with a series of statements relating to each of these selected environmental factors: 'There is not much fruit in my household' ('home availability'); 'My family does not eat much fruit' ('modelling); 'In my neighbourhood there are no shops where I can by fruit' ('availability of fruit shops'); 'It is difficult to get to shops that sell fruit ('getting to fruit shops'); 'The selection of fruit is limited' ('selection of fruit'); and 'The fruit is of bad quality' ('quality of fruit)'. These six statements were provided with the response categories 'agree' and 'disagree'. For analytic and interpretation reasons the answer alternatives were re-coded into 'agree' = '0' and 'disagree' = '1', so that '1' coded for a positive or supportive environment.

In the interview, participants were asked whether the store/shop where they usually buy their fruit is located within a 10 min walk from their home ('yes'/'no'). Furthermore, environmental audits of food shopping environments in the fourteen neighbourhoods were conducted through site visits by trained researchers. An area with a radius of 1 km from the centre of each neighbourhood was audited. During the audits, the number of shops where fruit and vegetables can be bought in each neighbourhood was assessed.

Demographics

The postal questionnaire included questions on gender, age and highest attained educational level. From the eight response categories, two categories were constructed: 'elementary and lower secondary' (≤11 years) and 'higher secondary and tertiary' (≥12 years). Gender, age and educational level were considered as potential confounders.

Statistical analyses

Each step of the mediation analyses was conducted on exactly the same sample, as advised by MacKinnon[27]. Only participants with complete data were included to prevent the occurrence that, in the case of missing values, path *a* is calculated on a slightly different sample than path *b*.

Since some participants had missing data for some of the predictor variables, the number of adults differed slightly between the different analyses (n 299–311).

Descriptive statistics were used to assess proportions, means and standard deviations. Pearson and biserial (for dichotomous variables) correlations between fruit intake, neighbourhood and household environmental variables, cognitions and habit strength were calculated.

To examine individual cognitions and habit strength as potential mediators of the associations between neighbourhood and household environmental factors with fruit consumption, a series of regression analyses was conducted according to the steps described by MacKinnon[27]. To be considered a mediator: (i) the environmental variable has to be associated with the different cognitive variables and habit strength (potential mediators); and (ii) the potential mediator has to be associated with fruit consumption after controlling for the predicting variable. To assess the associations between the potential mediators and fruit consumption, multiple mediator models were applied, i.e. all potential mediators were included in the same regression model. Only the significant mediators in this model were selected for the final model. Thus, the final multiple mediator model included only the significant mediators (see Fig. 1). The criteria of the mediation framework of MacKinnon suggests, in contrast to the mediation framework of Baron and Kenny, that potential mediating effects should also be analysed even if the association between the predictor and outcome is not significant[27,34]. Therefore, in the current study, mediating analyses were also performed for non-significant associations between several household and neighbourhood variables and fruit intake.

First, the total association between the environmental variables and fruit consumption was calculated (path *c*, total association). Second, the association between the environmental and the potential mediators was calculated (path *a*). Third, the association between the potential mediators and fruit intake, controlled for the environmental variable, was calculated using one regression model (path *b*). The final regression model was run including those mediators that had a significant association with the environmental variables and with fruit consumption. This final model provided estimates for the *b* values and for the direct effect (c'; see Fig. 1).

The product-of-coefficients method ($a \times b$)[27] was used to calculate the mediated effect and the total mediated effect was calculated as the sum of the individual mediated effects ($\Sigma a \times b$)[27]. Proportion mediated was calculated as the mediation effect divided by the total effect (path *c*; $(a \times b)/c$ and $(\Sigma a \times b)/c$). The total effect was estimated by a regression model without the potential mediators.

Subsequently, a bootstrapping method (with 5000 bootstrap resamples) was used to calculate the bias-corrected confidence intervals around the mediated effects. For this, the SPSS macro developed by Preacher and Hayes[35] was used.

Since our sample resided in fourteen neighbourhoods, clustering of fruit intake in neighbourhoods was tested in MLwiN 2·12 (Centre for Multilevel Modelling, University of Bristol, Bristol, UK) by calculating the intra-class correlation coefficient. No clustering was observed (all intra-class correlation coefficients were <0·001, see Table 3).

Clustering on the household level was not possible, since only one person per household could participate in the study. Therefore, it was decided to conduct all analyses in the SPSS statistical software package version 18·0 (SPSS Inc., Chicago, IL, USA) without adjustments for clustering at neighbourhood level. All analyses were adjusted for the following possible confounders: gender, age and educational level. Significance level was set at $P < 0{\cdot}05$.

Results

Participants' characteristics

As can be seen in Table 1, just over half of the participants were female and the mean age was 58·3 (SD 13·7) years. The mean intake of fruit was 1·52 (SD 1·12) servings/d. The adults generally had positive cognitions regarding fruit consumption. The proportion of participants who perceived a lack of shops to buy fruits in their neighbourhood, who found it difficult to get to shops and who perceived the variety and quality of fruit in the shops as limited/bad was only 1–2 %. About 4 % of the respondents perceived the availability of fruit in their home as low. Clearly, the variation in these neighbourhood variables was low, which makes it almost impossible to find associations with other variables (the proposed mediators and the outcome variable). Therefore, these variables were omitted from further analyses.

Associations of neighbourhood and home environmental variables with fruit intake (path c)/total association

Modelling by family members was positively and significantly correlated with self-reported fruit consumption. However, the association was weak ($r < 0{\cdot}2$; see Table 2). Analyses adjusted for gender, age and educational level showed no significant associations between any of the neighbourhood environment variables and fruit consumption (see Table 3).

Associations between home environment variables and potential mediators (path a)

In unadjusted analyses, home availability and modelling were significantly correlated with the potential mediators, whereas for most neighbourhood variables no significant correlations were observed with potential mediators (see Table 2). Adjusted associations (for gender, age and educational level) of modelling by family members with the potential mediators were significant (first column of Table 4). The only significant association found for 'fruit shop is within a 10 min walk' was with PBC.

Associations between potential mediators and fruit intake (path b)

Pearson and biserial correlation coefficients between potential mediators and fruit consumption ranged between 0·25 (subjective norm with fruit intake) and 0·55 (habit strength with fruit intake; see Table 2). When included in the same regression model and adjusted for the confounders, intention, PBC, subjective norm and habit strength were significantly associated with fruit consumption (see Table 4).

Mediation effects and direct effects

Since we did not find significant associations for the predictor variable 'audit of number of fruit shops' with the potential mediators, these mediators did not fulfil the

Table 1 Description of demographics, individual cognitions and habit strength, neighbourhood and household variables and fruit consumption of the study population: adults (*n* 333), Eindhoven, the Netherlands, 2004 and 2005 (GLOBE study)

	Mean	SD	%
Demographics			
Age (years)	58·3	13·7	
Gender (female; %)			54·1
Education level (high, ≥12 years; %)			72·3
Individual cognitions towards fruit consumption and habit strength of fruit consumption (−2; +2)			
Intention	1·28	0·84	
Attitude	1·29	0·60	
Perceived behavioural control	1·02	0·87	
Subjective norm	0·29	0·92	
Habit strength	0·57	1·12	
Household environment variables (% agree)			
Low availability of fruit in the household			4·1
Low perceived fruit consumption of family members (negative descriptive norm; = modelling)			11·1
Neighbourhood environment variables (% agree)			
Store/shop where fruit is usually bought is within a 10 min walk (yes)			59·2
Lack of stores/shops in the neighbourhood where fruit can be bought (= availability of fruit shops)			2·4
Difficult to get to stores/shops that sell fruit (= getting to fruit shops)			1·2
Limited selection of fruit available in the store/shop where fruit is usually bought			2·2
Bad quality of fruit in the store/shop where fruit is usually bought			1·9
Audit of number of stores and shops in the neighbourhood that sell fruit (range: 1–14)	5·4	3·0	
Behaviour			
Self-reported fruit consumption (servings/d)	1·52	1·12	

Table 2 Pearson and biserial (in the case of dichotomous variables) correlation coefficients for fruit consumption, cognitions, habit strength, neighbourhood and home environmental variables; adults (*n* 312 to 333), Eindhoven, the Netherlands, 2004 and 2005 (GLOBE study)

	Self-reported fruit intake	Fruit shop within a 10 min walk	Availability of fruit shops	Getting to fruit shops	Selection of fruit	Quality of fruit	Audit of number of fruit shops	Home availability	Modelling	Intention	Attitude	PBC	Subjective norm
Fruit shop within a 10 min walk†	−0·079	–	–	–	–	–	–	–	–	–	–	–	–
Availability of fruit shops†	−0·027	0·029	–	–	–	–	–	–	–	–	–	–	–
Getting to fruit shops†	0·011	0·078	0·342**	–	–	–	–	–	–	–	–	–	–
Selection of fruit†	0·006	0·050	0·250**	0·175**	–	–	–	–	–	–	–	–	–
Quality of fruit†	−0·004	0·026	0·125*	0·192**	0·294**	–	–	–	–	–	–	–	–
Audit of number of fruit shops	−0·046	0·154**	−0·121*	0·005	0·004	0·056	–	–	–	–	–	–	–
Home availability†	0·098	−0·076	0·068	−0·024	0·077	0·204**	−0·031	–	–	–	–	–	–
Modelling	0·179**	0·053	0·009	−0·039	0·017	0·104	0·044	0·450**	–	–	–	–	–
Intention	0·471**	−0·097	0·136*	0·139*	0·036	0·074	0·028	0·134*	0·175**	–	–	–	–
Attitude	0·435**	−0·115*	0·020	0·131*	0·052	0·051	0·020	0·151**	0·274*	0·642**	–	–	–
PBC	0·517**	−0·120*	0·021	−0·008	0·014	−0·005	0·004	0·118*	0·218**	0·526**	0·668**	–	–
Subjective norm	0·254**	0·013	−0·022	0·006	0·010	−0·022	−0·001	0·120*	0·180**	0·244**	0·282**	0·216**	–
Habit strength	0·547**	−0·099	0·091	0·083	0·048	0·050	−0·013	0·138*	0·201**	0·654**	0·640**	0·751**	0·204**

PBC, perceived behaviour control.
*$P < 0·05$, **$P < 0·01$.
†Predictors re-coded so that '1' codes for a positive or supportive environment.

Table 3 Total associations in pieces of fruit/d (*c*) and direct associations in pieces of fruit/d (*c′*) between neighbourhood and household environmental variables and fruit intake; adults, Eindhoven, the Netherlands, 2004 and 2005 (GLOBE study)

Neighbourhood and household variables	Source of data	No. of adults	Total association in pieces fruit/d between environmental variables and fruit intake, unadjusted for mediators† (path *c* in Fig. 1)	95 % CI	Direct association in pieces fruit/d between environmental variables and fruit intake, adjusted for significant mediators† (path *c′* in Fig. 1)	95 % CI	ICC
Fruit shop within a 10 min walk‡	Interview data	309	−0·082	−0·333, 0·168	0·050	−0·170, 0·270	<0·001
Audit of number of fruit shops	Audit	311	−0·018	−0·059, 0·023	§	§	<0·001
Modelling‡	Interview data	299	**0·688**	**0·290**, **1·087**	0·193	−0·153, 0·540	<0·001

ICC, intra-class correlation for clustering at neighbourhood level.
Bold indicates significant associations.
†Adjusted for gender, age and educational level
‡Predictors re-coded so that '1' codes for a positive or supportive environment.
§Direct association not calculated, because none of the proposed mediators reached statistical significance.

Table 4 Results from regression analyses for all steps in mediation analyses for the association between neighbourhood and household environmental variables and fruit intake (pieces/d); adults, Eindhoven, the Netherlands, 2004 and 2005 (GLOBE study)

	Final model†								
	Associations between environmental variables and the potential mediators (path *a*)		Associations between potential mediators and fruit intake (path *b*)		Associations between significant mediators and fruit intake in pieces/d (path *b*)		Mediation effect (*a*×*b*)‡		
Potential mediators	Estimate	95 % CI	Estimate	95 % CI	Estimate	95 % CI	Estimate	95 % CI§	% of mediation (*a*×*b*)/*c*
Fruit shop within a 10 min walk (*n* 309)‖									
Intention (−2; +2)	−0·109	−0·297, 0·079	**0·195**	**0·022**, **0·367**	–	–	–	–	–
Attitude	−0·097	−0·231, 0·037	−0·011	−0·267, 0·246	–	–	–	–	–
PBC	**−0·204**	**−0·394**, **−0·015**	**0·260**	**0·067**, **0·454**	**0·647**	**0·516**, **0·777**	**−0·133**	**−0·265**, **−0·012**	>100
Subjective norm	0·031	−0·174, 0·237	**0·153**	**0·034**, **0·271**	–	–	–	–	–
Habit strength	−0·160	−0·408, 0·088	**0·275**	**0·122**, **0·428**	–	–	–	–	–
All significant multiple mediators					–	–	–		
Audit of number of fruit shops (*n* 311)									
Intention (−2; +2)	0·001	−0·030, 0·032	**0·208**	**0·036**, **0·380**	–	–	–	–	–
Attitude	−0·004	−0·026, 0·018	−0·023	−0·279, 0·232	–	–	–	–	–
PBC	−0·002	−0·034, 0·030	**0·263**	**0·070**, **0·456**	–	–	–	–	–
Subjective norm	−0·001	−0·035, 0·033	**0·151**	**0·034**, **0·269**	–	–	–	–	–
Habit strength	−0·015	−0·056, 0·026	**0·263**	**0·111**, **0·415**	–	–	–	–	–
All significant multiple mediators					–	–	–		
Modelling (*n* 299)‖									
Intention (−2; +2)	**0·480**	**0·179**, **0·781**	**0·234**	**0·058**, **0·410**	**0·223**	**0·059**, **0·387**	**0·107**	**0·021**, **0·249**	**15·6**
Attitude	**0·503**	**0·294**, **0·713**	−0·044	−0·310, 0·222	–	–	–	–	–
PBC	**0·560**	**0·262**, **0·858**	**0·277**	**0·076**, **0·477**	**0·264**	**0·078**, **0·451**	**0·148**	**0·047**, **0·314**	**21·5**
Subjective norm	**0·518**	**0·189**, **0·846**	**0·141**	**0·020**, **0·262**	**0·138**	**0·018**, **0·258**	**0·072**	**0·001**, **0·174**	**10·5**
Habit strength	**0·720**	**0·324**, **1·117**	**0·235**	**0·079**, **0·391**	**0·234**	**0·078**, **0·389**	**0·168**	**0·064**, **0·333**	**24·4**
All significant multiple mediators							**0·495**	**0·263**, **0·771**	**71·9**

PBC, perceived behaviour control.
All analyses adjusted for gender, age and educational level.
Bold indicates significant associations.
†Final regression model including those mediators that had a significant association with the environmental variable and fruit consumption.
‡Not computed for non-significant mediators (as indicated by '–' in cells).
§Bias-corrected 95 % CI derived from bootstrapping (*n* 5000).
‖Predictors re-coded so that '1' codes for a positive or supportive environment.

requirements to be considered in the mediation analyses for associations of this predictor variable with fruit intake (see Table 4).

PBC was considered a mediator in the association between 'fruit shop is within a 10 min walk' and fruit consumption and provided a significant mediated effect (−0·133; 95 % CI −0·265, −0·012). However, this was an inconsistent mediation model as the mediated effect was more than 100 % due to the non-significant total association between 'fruit shop is within a 10 min walk' and fruit consumption.

In the association of modelling by family members with fruit intake, all potential mediators, except attitude, were included in the final model to estimate the mediated effects. All four mediators showed a statistical significant mediated effect (0·495; 95 % CI 0·263, 0·771), with habit strength (24·4 %) and PBC (21·5 %) as the strongest mediators. All mediators together explained 71·9 % of the association between modelling among family members and fruit consumption (see Table 4). For this association complete mediation was found through these four mediators, as indicated by the non-significant direct effect (c') shown in Table 3.

Discussion

The main aim of the current study was to examine associations of several home and neighbourhood environmental variables with fruit consumption in Dutch adults and explore whether these associations were mediated by variables derived from TPB and by habit strength. The findings showed that adults' fruit consumption was indirectly associated with modelling by family members, and was mainly mediated by habit strength and PBC. Although fruit intake was associated with the potential mediators, these cognitive mediators were in general not associated with the neighbourhood environmental variables. None of the neighbourhood environmental variables was significantly directly or indirectly associated with fruit consumption. These findings do not support our hypotheses that such neighbourhood physical environmental factors may be important correlates of fruit intake.

Other studies conducted in the USA have found that the food shopping environment could play a significant role in dietary choice in low-income households[36,37]. Further, Cummins and Macintyre found neighbourhood differences in price and availability of foods, with 'healthier' foods generally more expensive, and less readily available, in poorer than in wealthier communities in the USA and Canada. Accessibility to supermarkets was poorer in low-income neighbourhoods, with fewer supermarkets and more small independent grocery stores available to local residents[38]. A Scottish study found that availability of fruit and vegetables was lower in small shops located within deprived neighbourhoods compared with similar shops in affluent areas[39].

However, two recent systematic reviews examining the empirical evidence for environmental factors associated with energy, fat and fruit and vegetables intakes concluded that there is little evidence for the association between the neighbourhood environment and dietary intake[33,40]. Similarly, from the results of another multilevel study based on the GLOBE data by Giskes *et al.*, the authors concluded that improving access to fruit and vegetables in the household and food shopping environments would make only a small contribution to improving population consumption levels[41].

Despite the fact that we recruited participants for the interview from the seven most and seven least deprived neighbourhoods in Eindhoven, we did not observe much variation in the perceived physical neighbourhood environmental variables. This lack in variation might partly explain the lack of direct and indirect associations between the neighbourhood environmental variables and fruit intake. Although some of the neighbourhood environmental variables were associated with intention, PBC or attitude, these associations did not lead to an indirect association with fruit intake.

Mediation analyses showed that 'modelling by family members' was significantly indirectly but not directly associated with fruit intake, i.e. fully mediated by the TPB constructs (except for attitude) and habit strength. Habit strength was the strongest mediator for this association, but PBC also explained a large proportion (21·5 %) of the association between modelling by family members and fruit intake. The finding that habit strength was the strongest mediator supports earlier findings of significant associations between habit strength and dietary intake[31,42]. It further supports our hypothesis that environmental cues, such as a family member eating fruit, may trigger and promote the development of habit strength for fruit intake. Once this habit has been developed, eating a piece of fruit may 'automatically' follow seeing a family member eating fruit or observing a fruit bowl at home. However, given the cross-sectional design of the present study, such causal inferences should of course be further explored and tested in longitudinal and experimental studies.

Contrary to the EnRG model, we included habit strength as a mediator and not as a moderator in our models. Results of the current study support the proposal that habit strength may function as a mediator in the proposed associations between environmental variables and behaviour. Future studies need to replicate these findings and may result in refining the EnRG model.

For our study we defined modelling as a home environmental variable, while others have conceptualized this as a cognitive factor. For example, the Attitude–Social influence–Efficacy (ASE) model includes perceived modelling behaviour as a social cognition, as part of 'perceived social influences'[43]. In the multiple mediation

model for 'modelling behaviour by family members', our results showed that subjective norm was the only non-significant mediator and also the correlation between 'modelling behaviour by family members' and subjective norm was low.

Some limitations of the present study need to be addressed. As is common with large observational surveys, most measurements were based on self-reported data, which may have resulted in socially desirable answers and same-source bias. Further, all neighbourhood and home environmental variables consisted of single items questions and had only two response options. The cross-sectional design of the study has already been mentioned and another limitation of the study is relatively old data. Despite this, the current study contributes to the literature with a better understanding of the relationship between environmental variables and fruit consumption for several reasons. An important strength was that the study investigated neighbourhood- and household-level characteristics as well as individual-level variables related to fruit intake. Furthermore, the current study included objectively measured indicators and data based on interviews. These are less likely to have been influenced by social desirability. Finally, the current study is to our knowledge the first study to test the EnRG model in its application to adult fruit intake.

Taking into account these strengths and weaknesses, our results suggest that future interventions should address a combination of the home environment (especially modelling behaviour by family members), TPB variables and habit strength for fruit intake. Yet our results need to be replicated in future studies.

Conclusions

Modelling behaviour by family members was indirectly associated with fruit intake through habit strength and perceived behavioural control. None of the neighbourhood variables was directly or indirectly, through any of the proposed mediators, associated with adult fruit intake.

Acknowledgements

Sources of funding: The study was supported by the World Cancer Research Fund (grant number 2007/47) – WCRF-NL and by grants of the Ministry of Public Health, Welfare and Sport and the Health Research and Development Council (ZON; number 40050009). K.B. was supported by an Australian National Health and Medical Research Council Senior Research Fellowship (ID 479513). D.C. was supported by a Public Health Research Fellowship from the Victorian Health Promotion Foundation. The GLOBE study is carried out by the Department of Public Health of the Erasmus University Medical Centre in Rotterdam, in collaboration with the Public Health Services of the city of Eindhoven and region South-East Brabant. *Conflict of interest:* The authors declare that they have no competing interests. *Authorship responsibilities:* N.I.T. analysed the data and drafted the manuscript. S.J.t.V. supported in the data analyses and provided critical input in drafting the manuscript. C.B.M.K. coordinated data collection. F.J.v.L. initiated the most recent wave of data collection in the GLOBE study and coordinated data collection. J.B. had critical input in coordination of the data collection and drafting the manuscript. All authors gave intellectual input to the manuscript and approved the final manuscript.

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