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Built Environment Exposures of Adults in the Moving to Opportunity Experiment

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Abstract

This paper describes environmental exposures of adult participants in the Moving to Opportunity for Fair Housing (MTO) experiment over a four to seven year period from baseline to the interim evaluation. The MTO experiment randomized participants living in public housing or private assisted housing at baseline into experimental and control groups and provided a housing voucher for experimental group participants to move to neighborhoods with less than 10 percent of the population below the poverty line. However, few studies have examined how this move affected exposures to health promoting environments. We used data on residential locations of MTO participants and archival data on the built and food environment to construct environmental exposure variables. MTO participants in the experimental and Section 8 groups lived in neighborhoods with higher food prices, less high intensity development and more open space relative to the control group. The findings suggest that housing policies can have potential health consequences by altering health-related environmental exposures.

Introduction

Research suggests that certain features of neighbourhood environments may reduce or increase positive health behaviours. Studies of the association between the neighbourhood environment and obesity and its related behaviours are particularly prevalent. Overall, there are mixed findings in the literature in terms of whether an association is seen or not, however, there are several aspects of the neighbourhood environment that are consistently examined and for which many studies find positive associations.

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Studies of physical activity have shown positive associations with mixed land uses, presence of pedestrian design factors, more street connectivity, and park proximity and density (Bancroft et al., 2015; Saelens et al., 2012). Diet has also been linked to neighborhood features, with higher fast food consumption in areas with high exposure to fast food, and lower consumption of healthful foods in urban areas farther from supermarkets (Athens, Duncan, & Elbel, 2016; Burgoine et al., 2016; Michimi & Wimberly, 2010). The cost of food has been shown to influence food choices among low-income individuals, with higher consumption of low-cost, high calorie foods resulting in increased obesity (Drewnowski, 2004). Studies have found lower likelihood of obesity among disadvantaged individuals with access to supermarkets, places to exercise and safe environments (Lovasi, Neckerman, Quinn, Weiss, & Rundle, 2009), and lower average body mass index (BMI) among people in neighborhoods with mixed land uses, greater density of bus and subway stops, higher population density, and more food establishments and physical activity facilities (Hobbs et al., 2018; Rundle et al., 2007).

Green space in cities has been associated with positive health outcomes such as improved mental health and lower risk of cardiovascular disease, though there is conflicting evidence of association with other outcomes, such as physical activity (Nieuwenhuijsen, Khreis, Triguero-Mas, Gascon, & Dadvand, 2017). Population density in urban areas exposes residents to higher levels of poverty and income disparities which may contribute to the higher prevalence of diseases associated with poverty (Galea, Freudenberg, & Vlahov, 2005). These studies provide evidence of the importance of neighborhood effects on health, though they are limited by study designs that are mostly cross-sectional (Chou, Grossman, & Saffer, 2004; Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2003; Frank, Schmid, Sallis, Chapman, & Saelens, 2005), thus do not address self-selection bias and causality.

Given the potential profound effect of neighborhood features on health, it is imperative to describe and understand the neighborhood environmental exposures of individuals in the most vulnerable populations who may not have the financial means to select into neighborhoods that offer health-promoting features. One important such population is those who receive rental assistance. While differences in healthy behaviors and outcomes have been documented between those who receive rental assistance and those who do not (Antonakos & Colabianchi, 2018; Fauth, Leventhal, & Brooks-Gunn, 2004; Fenelon et al., 2017; Fertig & Reingold, 2007), fewer studies have examined the neighborhood built environment of those receiving rental assistance, especially exposures that would be related to obesity and associated behaviors (Camacho-Rivera, Rosenbaum, Yama, & Chambers, 2017; Lee, Mama, McAlexander, Adamus, & Medina, 2011).

The most comprehensive experimental study in the USA of those receiving rental assistance was the U.S. Housing and Urban Development (HUD) Moving to Opportunity (MTO) experiment, the focus of this study. In the MTO experiment, families living in impoverished neighborhoods in five cities in the United States were randomly sampled and randomly assigned to a housing voucher program. Thus the MTO study provides a unique opportunity to evaluate the impact of housing voucher programs on the environmental exposures of participants, in particular environmental exposures which are likely to affect health. Data on the residential locations of the MTO families were collected beginning at baseline (1994–

1998) and continuing for 10 to 15 years. Families were also surveyed at an interim time point during the study, four to seven years after baseline (between 2001 and 2002). This study utilizes the MTO data in combination with data on a diverse set of measures of the built and food environment, taking advantage of the causal framework of the MTO study to provide valid assessments of the effectiveness of these voucher programs to modify environmental exposures while addressing the need for high quality data on environmental exposures that may influence health. The purpose of this study is to describe the effects of the MTO experiment on environmental exposures of adult participants in the study, from baseline to the interim time point.

The MTO study was designed to assess health, economic and educational impacts on low-income families that were given the opportunity to move out of public housing or project-based assisted housing in high poverty neighbourhoods into neighbourhoods where few people lived in poverty. MTO participants were randomized into an experimental group, a Section 8 group or a control group. Participants in the experimental group were offered housing vouchers that could only be used in neighbourhoods where less than 10 percent of the population lived in poverty; after one year living in low poverty areas, the experimental group families could use the vouchers at any location. Participants in the Section 8 group could take advantage of Section 8 vouchers that were applicable anywhere Section 8-eligible housing was available. Control group participants did not receive vouchers but continued to receive project-based housing assistance. It is widely documented that the MTO demonstration was a properly implemented randomized experiment that achieved balance in baseline characteristics among its randomization groups. After the implementation of the experiment, the neighbourhoods where experimental group participants lived had lower poverty and lower unemployment rates as compared to the control group neighbourhoods. (Goering & United States. Department of Housing and Urban Development. Office of Policy Development and Research., 1999; L. L. Orr, United States. Department of Housing and Urban Development. Office of Policy Development and Research., Abt Associates., National Bureau of Economic Research., & Urban Institute., 2003) Compliance with the requirement to move to low-poverty neighbourhoods was 48% percent in the experimental group, and 63% percent in the Section 8 group (Jens Ludwig et al., 2013).

Studies at the interim and long-term follow-up time points found moderate improvements in physical and mental health and well-being among adults in the experimental and Section 8 groups relative to the control group (Kling, Liebman, & Katz, 2007; J. Ludwig et al., 2012). Among participants in Boston, perceived safety also increased in the experimental and Section 8 groups (Katz, Kling, & Liebman, 2001). Most relevant to this study, an intent-to-treat (ITT) analysis of 3,526 adult participants demonstrated significant differences in body mass index (BMI), physical activity and food consumption between those in the treatment (experimental or Section 8) and control groups at the interim time point (L. L. Orr et al., 2003). A study of the effects of the experiment four to seven years post-randomization found reduced prevalence of obesity among adults in the experimental group (Kling et al., 2007). The risk of extreme obesity and diabetes was also lower among women in the experimental group 10 to 15 years after randomization (J. Ludwig et al., 2011).

The finding of differences in health outcomes between MTO randomization groups raises questions about the mechanisms underlying these effects (Johnson, Ladd, & Ludwig, 2002), and provides an opportunity to investigate the effects of moving to neighbourhoods with lower poverty rates on exposures to specific environmental attributes known to influence health. Yet only a handful of studies have examined MTO participants' environmental exposures. Ludwig et al. (J. Ludwig et al., 2012) found that tract poverty was more important than racial composition in explaining higher subjective well-being among MTO participants who received vouchers. Zhao et al. (Zhao, Kaestner, & Xu, 2014) found no significant associations between obesity and several built and food environment factors although the MTO experimental and control groups differed on food price and commercial food establishment exposures. Nguyen et al. (Nguyen, Acevedo-Garcia, Schmidt, & Osypuk, 2017) studied neighbourhood attributes of MTO adult participants, finding improvements for the experimental and Section 8 randomization groups relative to the control group on social and built environment exposures. However, that study included baseline and interim residential locations only, and many of the social and built environmental measures differed across cities so were analysed for each city separately.

Whereas these studies presented environmental exposure data measured at a limited number of time points or used poverty as a proxy measure for environmental attributes, we obtained data for all residential locations of the adult MTO population from baseline through interim and measured specific attributes of the built and food environment in addition to poverty. We used consistent measures of environmental exposures for all locations and included the sample of participants with complete baseline data in all analyses. Many of the environmental exposures in this study used the centre of the census block group as a proxy for a participant's residential address with a buffer drawn around that centroid to represent the participant's neighbourhood. This method provides greater precision than using census tract exclusively as a geographic representation of a neighbourhood.

Research on the environmental exposures linked to health behaviours and outcomes, reviewed above, informed our choice of environmental attributes for this study, including supermarkets and fast food restaurants, commercial physical activity facilities, land use, street connectivity, food prices, park area and population density. Poverty was included in the study for comparison with environmental attributes. Although crime and public transit may influence behaviours such as physical activity, we obtained data on crime only for the five cities included in the MTO study at baseline, which did not represent all of the residential locations, and data on public transit were not readily available for the study sample, so these variables were not included in the analysis.

In this study, we describe and contrast neighbourhood exposures of adult MTO participants in each of the randomization groups. Prior studies of neighbourhoods and health have found significant associations among neighbourhood features, and used methods to combine the features (Adams et al., 2015; Frank et al., 2005; Myers, Denstel, & Broyles, 2016); so we expected correlation among the environmental exposures in this study. To address this issue, we applied factor analysis to reduce the set of variables and capture the mix of study participants' environmental exposures prior to comparing the randomization groups.

MTO participants in the experimental and Section 8 groups received support in the form of vouchers to move out of high poverty areas and experienced positive effects on health, as shown in earlier studies. Given these findings and in keeping with research on neighbourhood health effects, we expected participants in the experimental and Section 8 groups to have lower exposure to environmental attributes associated with high-poverty environments such as high intensity land use, and more exposure to attributes such as open space that are associated with less intensely developed environments.

Methods

Sample

The MTO experiment originated in five cities: Baltimore, Boston, Chicago, Los Angeles, and New York. Eligibility requirements included living in public housing or private assisted housing in high-poverty areas in the central city, and having children under the age of 18. The MTO experiment randomized families living in public housing who agreed to participate (4,608 families) into one of three groups between September 1994 and August 1998. We obtained our sample from the MTO interim evaluation conducted in 2001to 2002, which included 3,526 adult participants who responded to the interim evaluation survey. The effective response rate was 89.6 percent, accounting for a subsample of hard-to-reach families. (L. L. Orr et al., 2003). Twenty of the adult participants were missing data on one or more of the baseline characteristics and five were missing data on environmental exposure variables. This study used the sample of 3,501 adult participants with complete data on baseline characteristics and environmental exposure variables for all analyses. We obtained the datasets analysed during the current study from the Inter-university Consortium for Political and Social Research (ICPSR) (L. Orr, 2011). ICPSR obtained the data from the U.S. Department of Housing and Urban Development. Our institution's review board approved the study.

Environmental exposure variables

We linked archival data on the commercial environment, land cover, street connectivity, food prices, park area, population density and poverty to the MTO participants' residential locations (Table 1). We used the centroid of the block group to mask the residential location of the participant, while increasing the likelihood that a buffer drawn around the block group centroid would capture the relevant space of the environmental exposures. Using the centroid of the census block group as a proxy for the participant's residential location may yield more accurate estimates of a participant's environmental exposures than measures based on census tracts, in particular if a participant's residential location is close to the boundary of a tract. We summarized the environmental attribute data to produce person level environmental exposures.

Participants who received MTO vouchers were required to remain in their new housing locations for only one year. However, many participants moved one or more times between the study baseline and interim data collection. In our analysis sample, 33.1 percent of the participants moved once, 21.6 percent moved twice, and 24.0 percent moved three or more times. In order to address subsequent moves, we calculated duration-weighted neighbourhood exposures (Kling et al., 2007). We based participants' duration weights on the time spent at each residential location. For example, if a participant spent one-quarter of their time at one location and three-quarters at another location, exposure data at the first location would be multiplied by 0.25, exposure data at the second location would be multiplied by 0.75, and the two weighted exposures would be summed to obtain the duration-weighted exposure. We addressed missing data on each environmental measure for a particular residential location by adjusting the participant's total study duration to the sum of periods for which the environmental data were available. This method increased the weight given to locations with available environmental data. Across the set of observations, the average proportion of the residential history with missing data on environmental measures ranged from 0.1 percent to 2.9 percent of the study duration.

We obtained data on the commercial environment for all study years. Data for all other environmental attributes were obtained for a single year close to the last recorded residential location of participants in the interim evaluation sample and were used to measure exposures at residential locations in all years, from baseline to the interim time point. Commercial environment variables were estimated using data from Dun & Bradstreet, Inc.[1] We counted the number of supermarkets, fast food establishments and commercial physical activity facilities in each buffer for all study years. Land cover variables based on 2001 land cover data from the National Land Cover Database indicate the proportion of developed land in each census tract in high intensity land uses (apartment complexes, commercial/industrial) and open space (mostly vegetation such as lawn grass) (Homer et al., 2007). Block density was used to estimate street connectivity with higher block density indicating greater connectivity (Guo, Bhat, & Copperman, 2007). We obtained food price data for the 460 zip codes within the five original states that the MTO participants lived in at baseline (California, Illinois, Massachusetts, Maryland, New York), and summarized the data by taking the overall average of 13 food price measures. We derived park area from data obtained from Environmental Systems Research Institute (Esri). Population density is the total population divided by the land area in square miles at the census tract level, using data from the 2000 U.S. Census. The 2000 U.S. Census poverty rate is the number of people below the poverty line divided by the total population determined for the poverty line at the census tract level. We standardized measures to the control group after any transformations, so the resulting measures reflect deviation from the control group mean in control group standard deviations (Kling et al., 2007).

We used several different geographic buffers around residential locations to represent neighbourhood exposures. There is little consensus on the geographic scale that is meaningful for neighbourhood boundaries, and the appropriate scale may change based on the relationship being investigated (Diez Roux, 2001). The measurement level of the available environmental attribute data also influenced the choice of geographic buffer. A variety of buffer definitions and sizes have been used in research on the environment and health including 1 km circular and network buffers to measure green space and residential

[1]Dun & Bradstreet, Inc., provides commercially available data on businesses, including business name, address, and industry classification codes. These codes were used to classify businesses as supermarkets, fast food restaurants or commercial physical activity / recreation centers.

density, 3.2 km buffers to measure sprawl and density of development (Leal & Chaix, 2011) and 0.5 km buffers for park area (Epstein et al., 2006; Roemmich, Epstein, Raja, & Yin, 2007). A recent study of city dwellers found that perceptions of neighbourhoods averaged less than 1.6 km sq. (1 mi. sq.) (Coulton, Jennings, & Chan, 2013). We used a larger buffer than 1.6 km sq. for most of the exposures, to ensure that we measured neighbourhood conditions near a residential location, since we used block group centroids rather than residential addresses to form buffers.[2] We used a 3.2 km (2 mi.) radius around the block group centroid for the commercial environment and street connectivity measures. We derived food prices from zip code based data using a smaller 2.4 km (1.5 mi.) radius buffer to capture nearby food prices, since zip codes may vary more in size relative to census tracts and usually cover larger areas. We used a 1.2 km (0.75 mi.) buffer for park area, as people may be more likely to access parks on foot. Land cover, population density and poverty rate were measured at the census tract level so were assigned to the participant's census tract.

Data Analysis

Inverse probability of sampling weights [3] were used in all analyses, which we conducted using Stata version 14.1 (Statacorp, 2015). We estimated weighted means for baseline characteristics and duration-weighted environmental exposures for each randomization group (Tables 2 and 3) (Korn & Graubard, 1990, 1991). We investigated relationships among the duration-weighted environmental exposures using Pearson product-moment correlations. We conducted a factor analysis using the principal factor method with oblique rotation to determine whether there was a more parsimonious way to represent the set of environmental exposures. Factor analysis has the advantage of representing a set of correlated measures with a smaller number of hypothetical variables while reducing correlation among similar measures, and cancelling random error to some degree (Kim & Mueller, 1978). This approach provided information about clustering of the environmental exposures in this study population. We estimated the reliability of the set of items retained in the factor using Cronbach's alpha (Carmines & Zeller, 1979).

We used weighted linear regression or weighted multinomial logistic regression as appropriate to obtain significance tests comparing randomization groups on the baseline characteristics. In addition, we estimated weighted linear regression models unadjusted for baseline characteristics to determine whether environmental exposures differed by randomization group. We used the ITT model for all analyses, comparing participants across randomization groups regardless of whether the participants complied with the experiment. This approach provides estimates of the differences in environmental exposures between the experimental and control groups (Jens Ludwig et al., 2008). The exposures in the control group demonstrate what would likely have occurred to participants in the experimental group in the absence of the MTO experiment.

[2]Euclidean buffers were used, which are created by drawing a circle around a specific point (in this study, the point is the centre of the participant's census block group), and measuring exposures within the buffer area. The buffer radius is the distance from the centre of the buffer to the circle boundary.

[3]The inverse probability of sampling weight is a person-level weight calculated as the product of three weights adjusting for 1) changes in the randomization ratio for families assigned by the end of 1997, 2) the inverse probability of selection for the survey or testing in the full sample phase, and 3) selection into the subsample of hard-to-reach families. (L. Orr et al., 2003)

Results

About sixty percent of the MTO participants in the study sample were under age 35, more than half were African American and nearly all were female. About one-quarter of the participants were employed and three-quarters indicated they received federal assistance (AFDC/TANF) [4]. Respondents reported that they wanted to move to get away from gangs and drugs, and wanted access to better schools for their children. None of the baseline sample characteristics differed significantly by randomization group (Table 2).

Relative to the control group, experimental and Section 8 participants lived in environments with fewer commercial establishments, less high intensity land use, lower block density, more open space and higher food prices. Compared to the experimental group, participants in the Section 8 group had greater exposure to commercial establishments, high intensity land use, block density and population density, and less exposure to open space (Table 3).

Nearly all of the correlations among the environmental exposure variables were significant (Table 4). High intensity land use and population density were positively correlated with the commercial environment variables (supermarkets, fast food restaurants and commercial recreation). Block density was positively correlated with fast food restaurants and high intensity land use. Open space was negatively correlated with block density, high intensity land use, population density and poverty. Poverty was positively correlated with fast food, block density and population density.

The factor analysis resulted in a single factor with an eigenvalue greater than one (Table 5). Variables loading above 0.4 on this factor in the rotated solution included supermarkets, fast food restaurants, commercial physical activity, open space (negative loading), high intensity land use, block density and population density. A revised factor analysis excluded park area and average food price due to low rotated factor loadings of 0.05 and −0.08 respectively. The revised analysis resulted in a single factor representing exposure to more intensely developed areas with higher population densities and less open space. Using results from this analysis we estimated factor scores, then standardized the factor scores to the control group by calculating the difference from the control group mean divided by the control group standard deviation (Kling et al., 2007). Standardizing in this way results in measures that reflect deviation from the control group mean in control group standard deviations. We retained the standardized park area and average food price measures as individual items for further analysis. Cronbach's alpha for the set of environmental exposures included in the built environment factor was 0.82.

The average scores on the built environment factor differed significantly between the randomization groups ($F(2, 3499) = 25.66$, $p < .001$; experimental $M = -0.29$, $SE = 0.03$; Section 8 $M = -0.12$, $SE = 0.04$; control $M = 0.05$, $SE = 0.04$). The Section 8 group differed significantly from the experimental group on the built environment factor ($B = 0.18$, $p = .001$), as did the control group ($B = 0.35$, $p < .001$).

[4]Aid for Families with Dependent Children (AFDC) and Temporary Assistance for Needy Families (TANF) are U.S. federal assistance programs for low-income families.

Food price also differed overall between the randomization groups ($F(2, 3499) = 16.44$, $p < .001$; experimental $M = 0.30$, $SE = 0.03$; Section 8 $M = 0.24$, $SE = 0.03$; control $M = 0.07$, $SE = 0.03$). On food price, the control group differed significantly from the experimental group ($B = -0.23$, $p < .001$), but the Section 8 and experimental groups did not differ significantly.

Park area did not differ significantly between the randomization groups.

Conclusion

This study shows that moving out of high poverty neighbourhoods was associated with significantly different exposures to the built and food environment across the MTO experimental groups. The measures of the built and food environment captured features that may influence individuals' health and other outcomes. Results of the factor analysis indicate that, in this population, high density built environment variables co-varied so that exposure to one attribute reflecting more intensely developed areas implied exposure to other similar measures and a lack of exposure to open space. The experimental group tended to have lower exposure to intensely developed areas, and more exposure to open space and higher food prices. Aspects of the high intensity built environment factor that we tested have been associated with health outcomes in prior studies, including mixed land uses and physical activity (Saelens et al., 2012), proximity to supermarkets and obesity (Lovasi et al., 2009), and food prices and consumption of unhealthy food among low-income individuals (Drewnowski, 2004). Green space in cities, which is similar to the developed open space measure used in this study (Homer et al., 2007), has been associated with better mental and cardiovascular health (Nieuwenhuijsen et al., 2017). Considered in the context of other research on health and the built environment, this study has implications for the health of renters living in high-poverty areas.

Our study maintained the original randomization assignment, utilizing an ITT analysis regardless of compliance. This approach likely underestimates the differences seen across the participants relative to if examined within those who complied with the experiment. An ITT analysis is preferred for examining the effectiveness and policy implications of the MTO protocol as it indicates the likely differences that would be seen if the protocol in MTO was implemented in practice (Jens Ludwig et al., 2008).

Only a handful of studies have examined the neighbourhood exposures of MTO study participants, thus limiting our comparisons with other findings. Differences in exposures to commercial establishments and food prices and by randomization group found in this study are similar to findings in Zhao (Zhao et al., 2014). This study found that food prices were higher on average in the areas where experimental group participants lived, which had lower poverty rates as compared to areas where control group participants lived. This finding is in contrast to studies that have found higher food prices in lower income areas (Drewnowski, 2004) or no differences in food prices by poverty rate (Rahkovsky, Snyder, & United States. Department of Agriculture. Economic Research Service). MTO participants in our sample lived in areas with poverty rates greater than the national average for the United States, which was 12.2 percent in the year 2000 (Bishaw, 2013). It is possible that the measure of food stores in low-income areas in the IRI food price database was limited, as the data were restricted to stores with annual sales of over 2 million dollars a year. In addition, if IRI data for a particular location were missing from the IRI database, our method would increase the weight given to locations with available data. This could result in overestimating or underestimating the food price exposure for an individual, though missing data in our sample was very limited.

The lack of significant differences in exposure to park area in this study is in contrast to findings in Nguyen et al. (Nguyen et al., 2017). MTO experimental group participants in that study had higher exposure to "parks rated clean" in New York City. The park-related measures differed across cities (e.g., park cleanliness in New York versus recreational land in Los Angeles) so data were analysed for each city separately, and the measures were not duration-weighted, using only baseline and interim time point data. In contrast, the park area measure in our study was a duration-weighted exposure collected for all of the MTO participants' residential locations; the measure was consistent across all sites, and our analysis of park area included all sites. These differences in measurement and methods could explain in part the different findings related to exposure to parks.

Strengths of this study include the experimental design of MTO, consistent use of measures derived from external data for all locations, and duration-weighting using all residential locations from baseline through interim, yet our study is subject to a number of limitations. Duration-weighted measures reflect the proportion of time an individual spent at each of their residential locations from baseline through MTO interim, providing a more accurate view of participants' exposures than measures derived from baseline and interim only. Still, summarizing data in this way may reduce variance, and the method does not provide information on change in exposures over time. For most of the environment measures, data were available for a single time point close to the interim and were assigned to other, earlier time points. Holding values constant across different time points may have introduced error in the measures to the degree that conditions in a neighbourhood change over time. Baseline residential locations included in the duration-weighted measures may have produced conservative estimates of the effects of the intervention on environmental exposures as the baseline measures capture data from high-poverty neighbourhoods. However, since the exposures were duration-weighted, the values at baseline would likely have a small weight and have little effect on the overall exposure calculation. In addition, the results of this study do not necessarily generalize to other populations or neighbourhoods because the MTO experiment included adults living in public housing or project-based assisted housing at baseline and influenced moves to other neighbourhoods.

Future studies of the environmental effects from moving out of poverty should take into account more detailed information on food prices and parks. In addition, a broader mix of neighbourhood environment features that may benefit low-income populations could include proximity to the central business district and access to varied modes of transportation. Crime and perceived safety have been shown to affect health in prior studies of disadvantaged populations and should be considered for inclusion in future studies.

Many of the built and food environment features measured in this study were highly correlated so disentangling the effects of environmental exposures on, for example, health outcomes may be difficult if the focus of a study is on individual aspects of the environment in relation to health. Future work examining the effects of environmental exposures on population outcomes should account for correlation among measures of the built and food environment. Finally, this study focused on the MTO interim evaluation, which assessed the differences in exposures four to seven years after randomization. Future studies should examine whether these differences remained through the final evaluation.

In sum, this study found significant differences in the environmental exposures of MTO participants across randomization groups. The study provides insight into the nature of the environmental exposures over time in this population, which may be related to the differential health outcomes seen in the MTO experiment. It suggests that moving out of high poverty neighbourhoods was associated with significant changes in exposures to environmental conditions that have been associated with health in other studies. Moves out of high poverty often, but not always, led to exposure to more health promoting environments. The findings suggest that housing policies can have potential health consequences by altering health-related environmental exposures.

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TABLE 1.

Environmental exposure variables

Construct	Source	Year	Spatial Scale	Buffer radius (km)	Variable construction
Commercial environment[a]	Dun and Bradstreet	1994–2002	Address	3.2	Count of food stores, fast food restaurants, and commercial physical activity centers, for each year, summed across years
Land cover	National Land Cover Database	2001	Census tract	-	Proportion of census tract in open space, and proportion in developed, high intensity land cover
Street connectivity[b]	U.S. Census Tiger file	2000	Street	3.2	Number of blocks per 1.6 km^2
Food prices[c]	Information Resources, Inc.	2002	Zip code	2.4	Price per unit in dollars
Park area[d]	Esri	2003	Polygon	1.2	Park area (km^2)
Population density	U.S. Census	2000	Census tract	-	Population per land area in square miles
Poverty rate[e]	U.S. Census	2000	Census tract	-	Number of people below poverty line divided by total population determined for the poverty line times 100

[a]Geocodes of facility addresses were used. Commercial physical activity included facilities conducive to physical activity (e.g., gyms and YMCAs). Facility type for food (e.g., supermarket or fast food) was determined primarily by SIC code. Additional name based matching for supermarkets involved comparing names of facilities in the database against lists of known supermarket chain names using an automated software program to estimate the likelihood of two words matching across the lists. Facilities with high likelihoods (a spelling similar to a name on a known list of facility names) were manually checked and included as appropriate.

[b]Total number of blocks within a Euclidean buffer divided by the area of the buffer (1.6 km sq.). Blocks on the boundary of a buffer were weighted to include only the portion of the block inside the buffer.

[c]Information Resources, Inc. (IRI), a for-profit market information firm, provides retail, scanner-based prices for food and consumer products sold at food, drug and mass merchant outlets with annual sales volume above two million dollars including supermarkets, drug stores and big box retailers. Wal-Mart is not included in the IRI data for the year 2002. Food prices in the IRI zip-code level file are the average price per unit for each of 13 food categories selected on the basis of high price elasticity of demand: bakery snacks, lunch meat, soda, salty snacks, cold cereal, spaghetti and sauce, vegetables, frozen pizza, ice cream, processed cheese, frankfurters, oil and pies/cakes. A crosswalk file was used to link the 2.4 km radius buffers to zip codes using Zip Code Tabulation Areas (ZCTAs), generalized area representations of U.S. Postal Service ZIP Code service areas. Food prices for each zip code intersecting a buffer were weighted by the proportion of the zip code in the buffer. The food price variables were duration-weighted to reflect the proportion of time a participant lived at a given location, then averaged to create the food price measure.

[d]Parks are represented as polygons, or as shapes with three or more sides lying in one plane. Park area was estimated as the proportion of the buffer overlaid by the park polygon(s).

[e]Poverty data obtained from The Public Health Disparities Geocoding Project Monograph (Krieger, Waterman, Chen, Rehkopf, & Subramanian, 2005) were used to verify missing data on poverty for some census locations.

TABLE 2.

Sample characteristics for MTO adult participants at baseline by randomization group

	Experimental *n* = 1442	**Section 8 *n* = 988**	**Control *n* = 1071**
Age (years)			
18 to 24	0.16 (0.01)	0.15 (0.01)	0.16 (0.01)
25 to 34	0.45 (0.01)	0.46 (0.02)	0.46 (0.02)
35 to 44	0.27 (0.01)	0.26 (0.02)	0.27 (0.02)
45 to 54	0.08 (0.01)	0.10 (0.01)	0.08 (0.01)
Race			
Hispanic	0.28 (0.01)	0.30 (0.02)	0.29 (0.02)
Black	0.65 (0.01)	0.64 (0.02)	0.64 (0.02)
Other	0.04 (0.01)	0.04 (0.01)	0.04 (0.01)
Male	0.01 (0.00)	0.02 (0.00)	0.02 (0.00)
Education			
GED	0.17 (0.01)	0.18 (0.01)	0.19 (0.01)
High school graduate	0.39 (0.01)	0.38 (0.02)	0.35 (0.02)
In school	0.16 (0.01)	0.16 (0.01)	0.15 (0.01)
Not married	0.62 (0.01)	0.62 (0.02)	0.63 (0.02)
Employed	0.29 (0.01)	0.25 (0.02)	0.25 (0.01)
Household member with a disability	0.16 (0.01)	0.17 (0.01)	0.16 (0.01)
Receiving AFDC/TANF	0.74 (0.01)	0.75 (0.02)	0.75 (0.01)
Car owner	0.17 (0.01)	0.16 (0.01)	0.14 (0.01)
Household member was a crime victim	0.42 (0.01)	0.43 (0.02)	0.41 (0.02)
Lived in neighborhood 5 or more years	0.61 (0.01)	0.63 (0.02)	0.62 (0.02)
Reason for moving: get away from gangs/drugs	0.77 (0.01)	0.76 (0.02)	0.78 (0.01)
Reason for moving: access better schools	0.48 (0.01)	0.52 (0.02)	0.48 (0.02)

Reported means are the average proportions weighted by a probability weight. Numbers in parentheses are standard errors. The study groups did not differ significantly on any of the baseline measures.

TABLE 3.

Environmental exposure averages by randomization group

	Unstandardized [a]			Standardized [b]		
	Experimental	**Section 8**	**Control**	**Experimental**	**Section 8**	**Control**
Supermarkets	12.6 (0.5)	14.4 (0.7)	15.5 (0.7)	−0.11 (0.03)	−0.04 (0.04)	0.07 (0.04)
Fast food restaurants	12.2 (0.2)	12.9 (0.2)	14.4 (0.2)	−0.39 (0.03)	−0.25 (0.04)	0.02 (0.03)
Recreational facilities	33.0 (0.9)	35.8 (1.3)	39.1 (1.2)	−0.16 (0.03)	−0.07 (0.03)	0.01 (0.03)
Open space	0.05 (0.00)	0.04 (0.00)	0.03 (0.00)	0.38 (0.04)	0.16 (0.04)	−0.01 (0.03)
High density development	0.28 (0.01)	0.32 (0.01)	0.33 (0.01)	−0.26 (0.03)	−0.06 (0.04)	0.00 (0.03)
Block density	109.7 (1.2)	114.2 (1.2)	123.8 (1.2)	−0.43 (0.04)	−0.26 (0.04)	0.03 (0.03)
Average food price	2.5 (.01)	2.5 (0.01)	2.4 (0.01)	0.30 (0.03)	0.24 (0.03)	0.07 (.03)
Park area	0.22 (0.7)	0.23 (0.9)	0.23 (0.7)	−0.02 (0.03)	0.03 (0.03)	−0.00 (0.03)
Population density	27869.5 (832.7)	32536.6 (1155.9)	33818.6 (1016.7)	−0.20 (0.03)	−0.01 (0.04)	0.07 (0.03)
Poverty rate	32.3 (0.5)	34.5 (0.5)	43.2 (0.5)	−0.72 (0.04)	−0.56 (0.03)	0.05 (0.04)

N = 3501 for all variables. Means were weighted by a probability weight. Standard errors appear in parentheses. Statistical tests reported in the table were conducted using standardized measures.

[a] Unstandardized variables are in the units of the original variables.

[b] Variables were standardized to the control group. Prior to standardizing, high density development and open space were transformed by taking the square root of the arcsine; commercial environment, block density, average food price, park area and population density measures were log-transformed.

TABLE 4.

Correlation matrix of environmental exposures and poverty

	1	2	3	4	5	6	7	8	9	10
1. Supermarkets	1									
2. Fast food restaurants	0.65***	1								
3. Recreational facilities	0.69***	0.52***	1							
4. Open space	−0.37***	−0.48***	−0.42***	1						
5. High density development	0.52***	0.46***	0.69***	−0.51***	1					
6. Block density	0.31***	0.49***	0.45***	−0.40***	0.49***	1				
7. Average food price	−0.11***	−0.08***	0.08***	0.11***	−0.08***	0.01	1			
8. Park area	−0.10***	−0.07***	−0.07***	−0.24***	−0.02	−0.19***	−0.04**	1		
9. Population density	0.72***	0.52***	0.51***	−0.53***	0.37***	0.29***	−0.07***	0.22***	1	
10. Poverty rate	0.17***	0.42***	0.00	−0.31***	0.07***	0.35***	−0.06**	0.11***	0.35***	1

* $p < 0.05$

** $p < 0.01$

*** $p < .001$

TABLE 5.

Factor analysis of environmental exposures

	Factor loading	
	Unrotated	**Rotated**
Supermarkets	0.82	0.85
Fast food restaurants	0.74	0.72
Recreational facilities	0.79	0.80
Open space	−0.63	−0.60
High density development	0.72	0.70
Block density	0.57	0.53
Population density	0.72	0.73
Eigenvalue	3.59	3.55
Explained variance	90.1%	89.1%