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Ogilvie, D. and Mitchell, R. and Mutrie, N. and Petticrew, M. and Platt, S. (2006) Evaluating health effects of transport interventions: methodologic case study. *American Journal of Preventive Medicine* 31(2):pp. 118-126.

<http://eprints.gla.ac.uk/archive/2929/>

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Evaluating health effects of transport interventions: methodologic case study

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Reference to published version

Am J Prev Med 2006; 31: 118-126

Abstract

Background

There is little evidence about the effects of environmental interventions on population levels of physical activity. Major transport projects may promote or discourage physical activity in the form of walking and cycling, but researching the health effects of such “natural experiments” in transport policy or infrastructure is challenging.

Methods

Case study of attempts in 2004–2005 to evaluate the effects of two major transport projects in Scotland: an urban congestion charging scheme in Edinburgh, and a new urban motorway (freeway) in Glasgow.

Results

These interventions are typical of many major transport projects. They are unique to their context. They cannot easily be separated from the other components of the wider policies within which they occur. When, where, and how they are implemented are political decisions over which researchers have no control. Baseline data collection required for longitudinal studies may need to be planned before the intervention is certain to take place. There is no simple way of defining a population or area exposed to the intervention or of defining control groups. Changes in quantitative measures of health-related behavior may be difficult to detect.

Conclusions

Major transport projects have clear potential to influence population health, but it is difficult to define the interventions, categorize exposure, or measure outcomes in ways that are likely to be seen as credible in the field of public health intervention research. A final study design is proposed in which multiple methods and spatial levels of analysis are combined in a longitudinal quasi-experimental study.

Introduction

Changing people's social, physical, and economic environments is increasingly seen as important for improving population health.^{1 2} However, although cross-sectional and ecologic studies have found associations between environmental characteristics (such as markers of "walkability") and health-related behavior (such as physical activity),³ there is comparatively little evidence about the actual effects of intervening to change people's environments.^{4 5} It is often difficult or impossible to conduct true experimental studies in this field. Consequently, there have been several recent calls for more opportunistic research on the health effects of environmental interventions, sometimes described as "natural experiments."⁶⁻⁹

The aim of this paper is to explore how such research can be conducted in one particular area: the relationship between transport, the urban environment, and physical activity. An urgent need to reverse declining population levels of physical activity is now recognized, and recent work has highlighted the importance of understanding and acting on environmental determinants of physical activity, including transport-related physical activity, as a means to achieving this.^{2 4 10 11} "Active travel" (walking and cycling), including that made as part of a journey by public transportation, can contribute to achieving recommended levels of physical activity.¹² However, current public health interest in how to increase levels of active travel is poorly reflected in the existing body of intervention research in transport and health, which has been concerned largely with injury prevention.¹³ Empirical studies of the effects of transport policy measures or infrastructure projects have often not considered important health-related effects, not measured them appropriately, or been subject to other major methodologic weaknesses.¹⁴⁻¹⁶

Major transport projects may not appear to be "public health interventions" in the conventional sense, but they do have the potential to influence health (for better or for worse), and therefore warrant the attention of public health researchers. Some recent studies — such as a cross-sectional study of safer routes to school¹⁷ and uncontrolled studies of the construction and promotion of walking and cycling trails^{18 19} — have shed further light on intervention effects, but they also illustrate some of the difficulties in applying the most robust longitudinal methods to this type of opportunistic intervention research.²⁰ Researchers need to steer between the Scylla of unrealistic methodologic expectations — for example, calls for randomized controlled trials where these are neither necessary nor feasible²¹ — and the Charybdis of producing evidence of insufficient credibility to compete with research on more clinical or individualistic approaches to improving health.^{8 21-23}

This paper outlines a case study of an attempt to navigate these methodologic waters in order to investigate the effects of two controversial major transport projects in Scotland: an urban congestion charging scheme in Edinburgh, and a new urban motorway (freeway) in Glasgow. These interventions are typical of those already commonplace or under consideration²⁴ in cities throughout the developed world, and which are therefore likely to constitute a significant determinant of health for large numbers of people. The case study does not offer a "solution" to the methodologic challenges of assessing the health effects of natural experiments in transport policy; rather, it offers one concrete illustration of what sort of public health evidence might be generated and how this might be done.

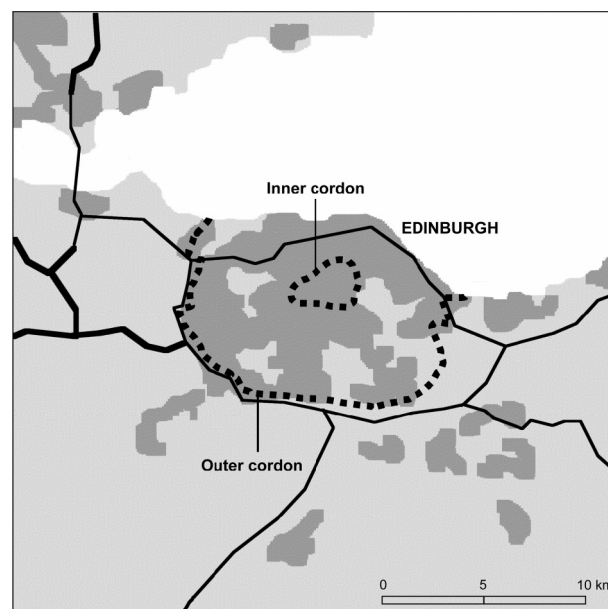
Case study interventions

Work on study designs for both interventions took place in 2004 and 2005 before the scheduled implementation of the interventions in 2006.

The Edinburgh congestion charging scheme

The local authority in Scotland's capital city planned to tackle traffic congestion by introducing two charging cordons for inbound motor vehicles—an inner cordon to protect the historic city center from through traffic, and an outer (perimeter) cordon to reduce inbound commuter traffic (Figure 1). Drivers were to be charged 2 pounds (about US\$3.75) per day to cross either or both cordons. The revenue raised was to be invested in additional public transport and related infrastructure.^{25 26}

Figure 1. Proposed congestion charging scheme for Edinburgh



The M74 urban motorway in Glasgow

Scotland's largest city has had a motorway, the M8, passing through the city center since the 1960s. Another motorway, the M74 (the main road link between England and Scotland) currently ends at the edge of the city. Local and national government agreed to build a new, predominantly urban, 5-mile section of motorway at an estimated cost of 500 million pounds (~US\$940 million) (Figure 2). This new motorway link was intended to relieve through-traffic congestion on the M8, rather than to provide direct access to the city center. It was also intended to promote regeneration, reduce accidents, and improve conditions for pedestrians and cyclists by reducing traffic on local streets.^{27 28} Numerous health-related claims were made for and against the new motorway (Table 1).

Figure 2. Proposed new motorway for Glasgow

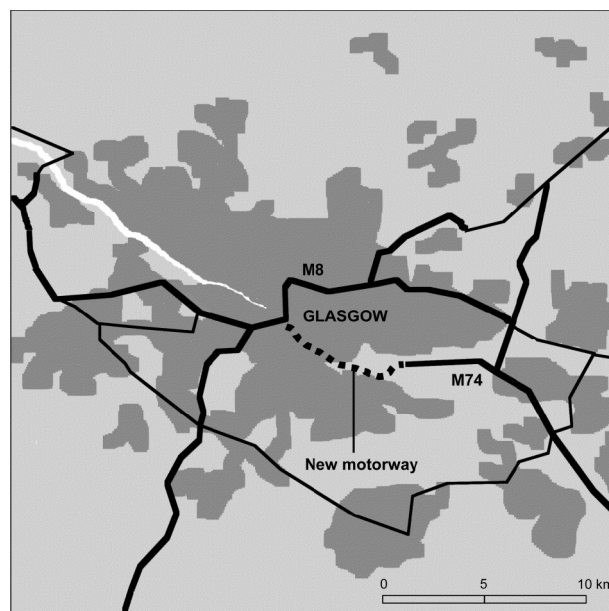


Table 1. Claims related to health and wellbeing made for and against the new motorway

Domain ^a	Claims made in favour of the intervention ^b	Claims made against the intervention ^b
Economic	<p>Will create up to 20,000 jobs by enabling regeneration and encouraging inward investment</p> <p>Will increase business competitiveness by improving just-in-time delivery times</p> <p>Will create 350 jobs during construction</p>	<p>Will redistribute economic activity from other parts of Scotland rather than producing a net increase</p> <p>Will displace 100 local businesses</p>
Traffic	<p>Will reduce journey times, relieve congestion on existing motorways and main roads, and reduce traffic on local roads</p>	<p>Will increase traffic in general and on feeder roads in particular</p>
Injuries	<p>Will reduce accidents</p>	
Active travel	<p>Quieter local roads will lead to improved conditions for pedestrians, cyclists and public transport</p>	<p>Will encourage use of motor vehicles</p> <p>Local pedestrian and cyclist journeys will be made more difficult by having to cross new motorway junctions</p>
Environmental	<p>Noise and air pollution will be reduced on balance throughout the area</p> <p>Will produce minimal severance effects because much of the route follows an existing main line railway</p> <p>Chromium-contaminated land will be handled safely during construction</p>	<p>Moderate-to-major increases in noise are predicted at some sites</p> <p>Nitrogen dioxide concentrations will be increased within 100 metres of the route</p> <p>Very severe, highly undesirable combined impacts predicted in four residential areas close to the route</p> <p>Chromium will be dispersed from contaminated land into the air or river during construction</p> <p>Contradicts stated overall sustainability objectives of transport policy</p>
Social justice	<p>Will improve quality of life in local communities</p> <p>Will result in better employment opportunities for local people</p>	<p>Unacceptable opportunity cost, e.g. the money could be used to fund improved public transport</p> <p>Will mostly benefit motorists from more distant and more affluent areas, causing adverse effects on local communities which have low levels of car ownership</p>

^a Claims grouped into domains post hoc by the authors

^b Summarised and adapted from the government's case for the project²⁷ and the report of the public local inquiry²⁸

Methods

The validity and utility of an intervention study depends on many different aspects of its design.²⁹⁻³² It is useful to consider these design issues under four headings: population, intervention, comparisons, and outcomes to be considered.³³ For “social” interventions, the context of the intervention is also likely to be important.³⁴ The methodologic analysis in this case study focused on specific issues encountered under these headings that posed particular challenges to the investigators.

Population

Two obvious ways of defining the population exposed to a major transport project were to identify people who lived in a relevant geographic area or to identify people who participated in the intervention in some way.

A geographic definition has obvious appeal, particularly for an intervention such as congestion charging, which is applied to a whole city. However, the effects are clearly not confined to city residents. Much of the traffic entering the city is commuter traffic originating from the surrounding region, so car drivers from a wide area would have been personally affected by the scheme. Similarly, the new motorway was intended to facilitate long-distance personal and freight journeys, not just journeys within the local area, so the motorway could have changed travel patterns across the whole region, producing both benefits (such as increased access to employment) and disadvantages (such as increased reliance on private cars).

Studying people who “participate” in an intervention may not be satisfactory either. In Edinburgh, residents living without a car inside a charging cordon may have benefited from reduced local traffic, but never personally interacted with the charging scheme. Similarly, people without cars living close to the new motorway may have experienced a range of effects, both positive (such as reduced local traffic) and negative (such as noise and visual intrusion), without any direct effect on their personal patterns of car use.

Intervention and context

It can be difficult to define exactly what the “intervention” in a major transport project consists of or to distinguish its content from its context. For example, the fact that congestion charging begins at a precise point in time suggests that it is a discrete intervention whose effects can be isolated, but this may be an erroneous assumption. The Edinburgh scheme formed only one component of the local transport strategy,²⁵ which was intended (among other things) to raise revenue to fund other projects. At least some of the benefits of congestion charging are therefore “locked up” in the revenue raised and cannot be assessed until that revenue has been spent.³⁵ A new motorway also has an apparently obvious start date—the day when traffic begins to use it — but in Glasgow it became clear that some of the claimed benefits would depend on local authorities taking subsequent, discretionary action such as installing traffic-calming features on local streets, while others would depend on private-sector responses such as increased inward investment to the region.^{27 28} In other words, the effects of the motorway could not readily be disentangled from those of a larger set of local and national policies and actions.

The political context may also complicate attempts to conduct longitudinal research based on collecting “before” and “after” data. This requires that researchers know when to collect baseline data and are able to do so, but for

both projects in this case study, the path toward implementation was unpredictable and controversial. In Edinburgh, the congestion charging scheme had some political backing, but little business backing; a public local inquiry recommended implementation,²⁶ but the local authority then sought a specific popular mandate through a referendum. In Glasgow, in contrast, the new motorway had much wider political and business backing. A public local inquiry recommended against the scheme;²⁸ the government overruled this advice, but its decision was then the subject of a legal challenge. Such uncertainties present a dilemma for researchers: If they wait until a definite start date is announced, there may not be enough time to design a study, obtain ethical approval, and collect baseline data; if they do plan ahead, they may have difficulty obtaining funds to research something that might never happen.

One possible solution to the difficulties of collecting original baseline data is to use existing, routinely collected data to establish a series of “before” time points to form the basis of an interrupted time-series analysis. However, this depends on the relevant outcome data having been collected with sufficient frequency, and from a sufficiently large number of respondents. In practice, for example, the Scottish Health Survey collects population physical activity data only every few years, and makes no claim to representative sampling below the level of relatively large administrative areas.³⁶

Comparisons

Before and after

Even if baseline data are successfully collected, there may be a tension between competing potential designs for the follow-up phase: should it be a panel (cohort) study or a repeated cross-sectional study? A cohort design would typically be considered to have stronger internal validity, and appears essential for investigating change at the individual level, but other research questions may require other approaches, particularly those concerned with detecting inequitable effects and effects on whole communities for which a repeated cross-sectional study may be more appropriate. For example, people who choose to move away (or are compulsorily relocated) from the area might be excluded from a cohort study on the grounds of incomplete exposure to the intervention, but their experiences could be crucial to understanding some of its effects. More practically, where an intervention (such as motorway construction) takes years to be implemented, it may be difficult to find enough original participants still living in the area to constitute a credible longitudinal cohort. Conversely, where an intervention results in regeneration or gentrification of an area, it may also be important to study people who migrate into the area because the benefits may be concentrated among the more affluent migrants.³⁷

Intervention versus control

It is axiomatic that using control groups strengthens the internal validity of an intervention study,³⁰ but identifying groups that are sufficiently comparable can be difficult, particularly where the intervention is highly specific to its context. This may help to explain why relatively few controlled studies of major transport projects have been reported.^{14 15} For the congestion charging scheme, the obvious requirement would be for a comparable control city. Scotland contains only three other cities with a population of $\geq 100,000$, all of which differ from Edinburgh in important ways³⁸ (Table 2). Cities elsewhere in the United Kingdom or Europe might appear more similar, but may also be subject to other confounding trends and policies. An alternative approach would be to select study neighborhoods within the intervention city and compare changes with those

observed in similar neighborhoods in other cities, but even at this scale, matching is very difficult. For example, parts of central Edinburgh are extremely atypical in terms of affluence, commuting patterns, and so on, even compared with other Scottish cities (data not shown). In Glasgow, it would be possible to identify areas within the conurbation with somewhat similar spatial, social, and morphologic characteristics to those close to the new motorway, but there is no way of avoiding the reality that each area of a city is, to some extent, unique. It may therefore be unrealistic to aspire to anything more than “broadly comparable” control areas.

Table 2. Selected population characteristics for the four city council areas in Scotland^a

	Aberdeen	Dundee	Edinburgh	Glasgow
Total population	212,125	145,663	448,624	577,869
Households living in social rented accommodation	27%	32%	16%	39%
Households with no access to a car or van	34%	46%	40%	56%
People who had migrated into the area within the last year	5%	4%	7%	4%
People with a limiting long-term illness	18%	22%	17%	26%
Commuters whose main mode of travel to work was by car or van	51%	49%	40%	38%

^a Source: 2001 Census³⁸

Dose–response

A stronger claim for causal inference can often be made if a “dose–response” relationship can be shown between intervention and outcome. It may be attractive, for example, to use distance from a new piece of infrastructure, such as a new motorway, as a marker of exposure and use this to stratify the analysis. Such an approach might be taken in an environmental epidemiologic study of the effects of exposure to air pollution. However, this is unlikely to be adequate where other effects, such as changes in travel behavior, are of interest. In this case, factors such as proximity to an access point (junction or on-ramp) or, especially, access to a motor vehicle may be more salient markers of people’s susceptibility to the effects of a new motorway than simple proximity to the road surface.

Outcomes

Selection

Interventions of this type are often not primarily intended to improve health, although health-related claims may be implicit in the case for the project and may subsequently be aired explicitly by both proponents and opponents (Table 1). For example, there was no explicit claim that congestion charging in Edinburgh would lead to an increase in active travel and resulting health benefits, but such an assumption was implicit in the scheme’s central place within the local transport strategy, which included the aim “to promote better health and fitness” and the specific objective of promoting a modal shift away from private car travel.²⁵ Similarly, the explicit claims that the new motorway would improve conditions for

pedestrians and cyclists on local streets, and quality of life for local residents,²⁷ surely imply that people living in the local area were expected both to walk and cycle more and to feel better as a result of the project. The indirect or implicit nature of these health effects poses a problem if evaluation research is understood in simple terms of “what works?” or, in other words, whether an intervention has achieved its stated aims and objectives.³⁹ In this context, it may be at least as important for public health researchers to focus on investigating indirect or unintended effects on aspects of health and well-being of particular interest.

Detection

However, recent systematic reviews have shown that it may be premature or unrealistic to expect to attribute changes in “hard” health or disease outcomes directly to transport interventions.^{14 15} Upstream links in the putative causal chain still require testing—notably the influence of interventions on patterns of physical activity.⁹ But even at this level, designing a study capable of detecting likely effect sizes may be difficult. Most studies of transport interventions have not quantified changes in time spent in active travel, but the few studies that have reported relevant data suggest a mean population-level effect size of no more than 2 to 4 minutes per day.^{15 19 40-43} Leaving to one side the question of whether this is a significant effect in public health terms, the assumption that changes in travel behavior are associated with changes in overall levels of physical activity remains largely untested. Although devices such as accelerometers provide more valid measures of physical activity than self-reported data, they may not be feasible or affordable for use in a large population survey, in which case a validated questionnaire such as the International Physical Activity Questionnaire (IPAQ) may be the most practical choice.^{44 45} In a recent UK population survey using IPAQ, however, the mean reported time spent walking was >300 minutes per week, with a standard deviation of >500 minutes.⁴⁶ Against this baseline and noise of background variation, it would be hard to detect the signal of a population-level intervention effect without an overwhelmingly large sample size.

Results

The Edinburgh congestion charging scheme was finally abandoned following a referendum in February 2005 in which city residents voted against the proposal by a majority of three to one.⁴⁷ The result of this case study therefore comprises a design for a single study that is now being applied to the M74 motorway project in Glasgow (www.msoc-mrc.gla.ac.uk/M74/M74-MAIN.html).

The M74 motorway study

Focus

No research study could conceivably evaluate effects across all possible domains identified in the public discourse about the motorway (Table 1). The investigators therefore chose to focus on the comparatively under-researched question of effects on active travel and physical activity — whether directly, or via changes in perceptions of the urban environment, as suggested by the findings of cross-sectional and ecologic studies.^{3-6 9}

Conceptual model

The conceptual model for the study provides a framework for examining causal relationships between various health-related domains that remain largely unproven in intervention studies (Figure 3). The possible effects of the intervention according to this model were articulated using vignettes of two alternative extreme cases (Table 3). Although the vignettes are specific to the motorway, the conceptual model in principle has more general applicability; if the Edinburgh congestion charging scheme had gone ahead, a similar model would have been applied and similar methods adopted.

Figure 3. Simple conceptual model of causal relationships to be examined

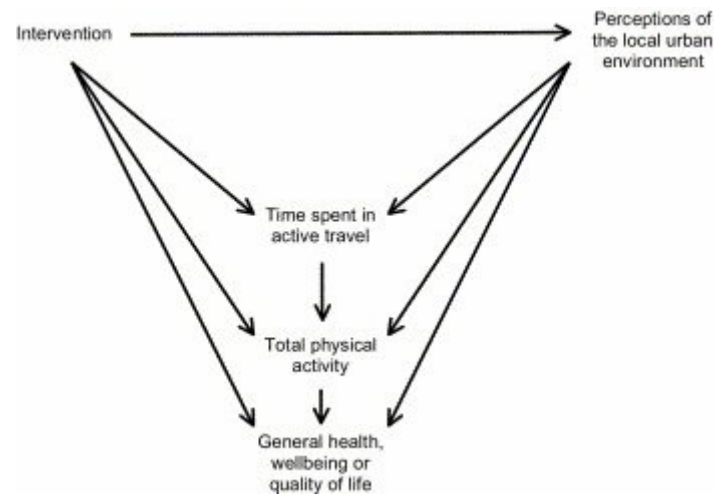


Table 3. Vignettes to illustrate alternative extreme cases of possible effects of the new motorway

Virtuous spiral	Vicious spiral
The opening of the motorway encourages inward investment to the area, providing new local opportunities for work	The opening of the motorway displaces some local businesses, whose employees now have to travel further to work, and gives easier access between the motorway network and the local area
Through traffic on local roads is reduced, which makes conditions more pleasant for pedestrians and cyclists and encourages people to spend more time out and about on local streets	This increases traffic on local roads and encourages local people to travel further and by car, not just for work but also for shopping and leisure
Local businesses thrive	At the same time, the motorway and its junctions degrade the local environment, making conditions less pleasant or safe for people in their homes and for pedestrians and cyclists
People perceive the local environment to have more positive attributes	The combination of fewer people out and about on local streets and the tendency to travel further afield to amenities leads to a decline in local shops and other amenities, which reinforces the decline in the attractiveness of the area and the car-bound exodus in search of alternatives
Any noise or air pollution produced by the motorway is not noticed against the background of existing urban conditions	The wellbeing of local people and opportunities for physical activity both decline
The wellbeing of local people and opportunities for physical activity both increase	

Methodologic decisions

The important methodologic decisions made by the investigators in designing this study were as follows:

Population: In order to explore the sociospatial distribution of benefits and harms across a wide area while simultaneously making the most efficient use of research resources, the study will combine multiple methods and spatial levels of analysis. Initially, routine government household survey data at regional level (which includes travel behavior, but not physical activity) will be combined with specially collected local survey data. Qualitative interviews will also be used to explore both the effects in particular communities and the reasons and mechanisms behind changes observed in particular individuals.

Intervention and context: The response to the uncertainties and complexities surrounding implementation is to frame the baseline study as a cross-sectional study in its own right, exploring the relationships between travel behavior, perceptions of the urban environment, physical activity, and socioeconomic position, and to use these cross-sectional findings to develop and refine more-precise longitudinal hypotheses to be tested at follow-up.

Comparisons: Within the local area survey, uncertainties about the feasibility of following up cohort participants led to the selection of a repeated cross-sectional design as the primary method. A nested cohort of original respondents will also be followed up in a more exploratory study, which aims particularly to identify typologies of response to the intervention to be explored in a subsequent qualitative study. Data will be collected in three local study areas broadly matched on aggregate sociospatial characteristics: an intervention area, a pre-intervention control area with no motorway, and a post-intervention control area adjacent to existing motorways. This three-way comparison is intended to increase the value of the cross-sectional study and to strengthen the causal explanatory power of the longitudinal study. Social, spatial, and environmental heterogeneity within each study area will enable dose-response relationships and other influences on effects to be explored, using appropriate statistical techniques to account for the clustered nature of the data.

Outcomes: Given the difficulties of detecting changes in total physical activity, or even total walking, a 1-day travel diary will be used to detect changes in time spent in active travel as the primary outcome measure, using an instrument adapted from those used in current government travel surveys and recent rigorous transport studies.^{15 48 49} Total physical activity (measured using the IPAQ) will be used both as a stratifying variable (to explore how effects are distributed between sedentary and less-sedentary groups) and as a secondary, exploratory outcome measure.

Discussion and conclusions

"Natural experiments" may sometimes offer the only opportunity to investigate changes in population health and health-related behavior associated with interventions in the social, physical, and economic environments. Researching these effects is unquestionably difficult and involves taking some risks. Some may feel that the conceptual or practical problems are overwhelming and that researchers and funders should therefore stick to "safer" areas of investigation,⁵⁰ but such a response appears incompatible with political and professional rhetoric about the importance of social determinants of health and about evidence-based policymaking.^{51 52}

It is not yet possible to "prove" the complete causal chain linking transport interventions, physical activity, and health outcomes according to established principles of causal inference in epidemiology.⁵³ However, real-world intervention research is not the same thing as classical risk-factor epidemiology, and there is no a priori reason why this chain should need to be proved within a single study. Given current policy interest in this field, the lack of knowledge about intervention effects provides an important opportunity to contribute to that knowledge in a way that is both methodologically thoughtful and appropriate to the nature of the problem. For example, it may now be more important to attempt studies of "natural experiments" that are occurring in public policy—advocating and making pragmatic choices about methods and outcome measures that will add to the "best available evidence," however tentative, about intervention effects—rather than striving for theoretical or technical perfection in the increasingly detailed cross-sectional analysis of correlates of physical activity, which has the capacity only to generate rather than test causal hypotheses.⁹ Having said that, those who call for — or succeed in conducting — opportunistic intervention studies should be aware that they may be unlikely to produce the type of clear answer that is implicitly demanded by policy questions framed in terms of "what works?" They may have more to contribute in terms of highlighting uncertainties, contradictions, and inequities in the effects of public policy than in terms of producing generalizable estimates of effect sizes. The latter may come only, if ever, from the subsequent synthesis of multiple heterogeneous studies using innovative methods of systematic review⁵⁴—both between studies of a single link in the putative causal chain (e.g., the effects of interventions on travel behavior) and, eventually, between the different links in that chain in order to elucidate how health really can be created or destroyed by changes in wider public policy.^{1 55}

DO is funded by a Medical Research Council fellowship. MP, and the Research Unit in Health, Behaviour and Change (RM, SP), are funded by the Chief Scientist Office of the Scottish Executive Health Department (SEHD). The opinions expressed here are those of the authors, and not those of the SEHD.

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