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Research Paper

The effectiveness of 'shared space' residential street interventions on self-reported activity levels and quality of life for older people

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HIGHLIGHTS

- A longitudinal study of 'home zone' changes to the street environment.
- Focus on quality of life and physical activity levels in an elderly population.
- We find positive changes in perceptions of the environment but results are more ambiguous for wider outcomes.

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ABSTRACT

The role of the built environment in facilitating physical activity is well recognised. However, longitudinal studies into the effects of changes to the built environment on levels of activity and quality of life outcomes are lacking, especially for older people. This paper presents results from a longitudinal study of 'home zone' style changes to residential streets, designed to make streets more 'liveable' by reducing the dominance of vehicular traffic and creating shared space. The interventions were focused in deprived areas, where the changes followed an inclusive, community-led approach. The intervention sites were matched with comparison sites receiving no intervention. Whilst existing studies into the outcomes of home zone type interventions have tended to focus on tangible measures such as road casualties or traffic speeds, this study examines broader, self-reported behavioural (i.e. activity levels and perceptions), health and quality of life outcomes. Results were gathered pre-intervention in 2008 and then, post-intervention, in 2010 or 2011 for participants aged 65 or older. They show that interventions are associated with a significant improvement in perceptions of how easy it is to walk on the street near home. Participants also considered that they were significantly more active post-intervention. However, there was less evidence of positive change in health, quality of life, frequency of activities outdoors, time spent outdoors, or better social connectedness. One potential reason is that a greater time period post-implementation is needed for such outcomes to become manifest.

1. Introduction

Maintaining outdoor activity is an important component of quality of life in an ageing population (Schwanen & Ziegler, 2011). Maintaining mobility may contribute to wellbeing in later life through physical activity and enabling access to different environments, which in turn may help physical health, mental health and wellbeing through a reduced risk of cognitive decline (Yaffe, Barnes, Nevitt, Lui, & Covinsky, 2001) and maintained social contact.

The strong link between mobility and wellbeing presents a challenge in ageing societies (Nordbakke & Schwanen, 2014) for whom maintaining mobility may be compromised as ageing progresses. The built environment can be an important factor in facilitating mobility (Saelens & Handy, 2008), yet it has the potential to disproportionately affect older people either positively or negatively, given that environmental influence is likely to be greater for those with reduced mobility (Lawton & Nahemow, 1973). Saelens and Handy (2008) identify a need both for more detailed studies of older people's walking and for longitudinal studies focussing on the relationship between the built environment and walking. Wahl, Iwarsson, and Oswald (2012) express a need for longitudinal studies to explicitly study ageing in the context of the environment.

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We define environment as the objective and perceived characteristics of the physical context in which people spend their time (Van Cauwenberg et al., 2011) and in this paper we are referring to the *outdoors* or the built environment and, in particular, the local streets and open spaces surrounding a person's home. Exclusion from parts of the built environment because of poor or insensitive design can be seen as an environmental justice issue (Day, 2010). In an ageing population, an unsupportive environment may reduce the ability to get outside and lead to a spiral of decline. Conversely, good design of streets and pedestrian environments can contribute to support for healthy activity into old age and thus enhance the health and wellbeing of elderly people through inclusive design. Yet there is a lack of longitudinal studies in this field (Ogilvie et al., 2010; Saelens & Handy, 2008; Wahl et al., 2012). There is limited empirical research relating to the effects of transport or street design interventions on the mobility and wellbeing of older people and little understanding of which aspects of the built environment, real or perceived, lead to increased levels of activity in that environment (Morrison, Thomson, & Petticrew, 2004; Ogilvie et al., 2010; Ward Thompson, 2013). This paper describes results from an attempt to address some of these issues via a longitudinal study of older people's perceptions and experience of changes in their local street design.

2. Background

'Home zone' style street design interventions in the UK have been developed based on the Dutch *woonerf* (living yard) (DfT, 2005; Hamilton-Baillie, 2008), which have attracted worldwide interest in recent decades (Ben-Joseph, 1995; Hamilton-Baillie, 2008). 'Home zones' consist of low-speed residential streets are designed based on a concept of 'shared space', balancing the needs of pedestrians and vehicular traffic (DfT, 2007). A home zone is defined as:

> "a residential area where the design of the spaces between homes provides shared space for all users, including motor vehicles and other road users, with the wider needs of residents, including pedestrians, children and cyclists, being fully accommodated" (Biddulph, 2003).

This is achieved through aspects of street design such as: unconventional road surface; use of raised platforms; gateway features to signal the entrance to a home zone; build-outs to slow down traffic; planters; benches; and lighting. Sustrans is a sustainable transport charity in the UK which has taken a community based approach to implementing changes to street design based on home zone principles, which they have termed 'DIY Streets'. These are designed to be affordable alternatives to traditional home zones and retrofitted to existing streets (Sustrans, 2013). We use Sustrans' DIY Streets approach as an example of a street design intervention to study the effect of a change in the environment on the perceptions, behaviour and quality of life of older people. One of the key features of home zones is the involvement of, and consultation with, local residents in the process of redesigning the streets (Biddulph, 2003; DfT, 2007) and this approach was fundamental to Sustrans' DIY Streets pilot projects.

Although their inclusive nature is open to critique (Imrie, 2012) due to concerns for particular groups in society, such as blind and partially sighted people, such environments are intended to be inclusive environments which improve the quality of the streetscape and lead to environmental, economic, health and quality of life benefits for all (Biddulph, 2003; Hamilton-Baillie, 2008). According to Biddulph (2003), home zones should be of particular benefit to those who may be less mobile, such as children, older and disabled adults, and encourage walking and cycling in the local area. It is thus no surprise that there have been studies focused on the effects of home zones on children's play activities (Gill, 2006; Van Andel, 1985) and on pedestrian activity (Morrison et al., 2004; Webster, Tilly, Wheeler, Nicholls, & Buttress, 2006) but we have not found any studies focussing particularly on the effects for an elderly population.

Webster et al. (2006) evaluated nine pilot home zone schemes in England and used post hoc interviews with adults aged 17 plus (mean age = 47) as well as accident and traffic flow data. They found that walking was considered to be more pleasant, notably amongst residents who were in favour of the schemes, traffic levels were reduced and there was a slight increase in time spent outside the home. In drawing together evidence from a number of pilot home zone schemes in England, Biddulph (2008) presents objective measures of changes in accidents and traffic speeds as well as residents' views post-scheme implementation, using survey data which collected their perceptions and observations of the home zones. Results were mixed; whilst overall support was generally high, this varied by scheme. In most cases, over 50% of respondents felt the scheme had improved safety and that it was safer for children to play in the streets, but that sociability, vandalism and antisocial behaviour had become worse. It must be noted that the evaluation by Biddulph (2008) and Webster et al. (2006) are based on residents' retrospective evaluations of the schemes rather than using repeated measures to understand whether the interventions had effected change. As Biddulph points out, these perceptions could be affected by the expectations residents had of the schemes. Given that many of the homes zones do not end up being implemented in full, it is possible that, even if residents perceive safety to have improved relative to the baseline situation, if their expectations were greater, then retrospective evaluations may be negative.

Drawing together several evaluations of UK home zones, Gill (2006) suggests they are viewed favourably by both adults and children and that increases in children playing outside as a result have been observed. However, none of these studies used repeated measures to examine outcomes before and after implementation of a shared space intervention which makes it difficult to be confident about the influence of changes at the individual level. Ståhl, Horstmann, and Iwarsson (2013) evaluated similar environmental interventions in Sweden, but which were designed specifically to enhance the mobility and wellbeing of an elderly population; in this sense the interventions were more targeted than DIY Streets. They found that amongst the older population, women and those with better health had greater appreciation of the improvements.

In summary, whilst the wider health and wellbeing benefits of transport interventions, such as shared space or home zone schemes are often discussed, empirical evidence is limited and what does exist is often retrospective. Existing evaluations of home zone interventions have focussed on objective outcomes such as road casualties or traffic speeds and qualitative assessments of residents' post hoc satisfaction, rather than on outcomes-based improvement, for example in health and wellbeing, which also can be said of transport interventions more broadly (Morrison et al., 2004). Measuring tangible outcomes such as traffic speeds and resident satisfaction, whilst valuable, does not inform as to whether the changes have improved the quality of life for residents or encouraged any change in travel behaviour, which they are designed to achieve. Whilst Ståhl et al. (2013) undertook a pre–post-study, they did not have a comparator site against which to measure change over time attributable to the intervention, and Morrison et al. (2004) focussed on a traffic calming scheme rather than a wider environmental intervention. Without a comparison site it is difficult to establish whether any change can be attributed to the intervention or whether the change would have occurred regardless. To date, we have not found a longitudinal study of the

wider outcomes from such a scheme that includes a comparator (non-intervention) site and is based on repeated measures using validated scales as part of the user perspective, rather than perceptions based on recall post-intervention.

The study described here attempts to address this gap. It is part of a wider study that used a mixed-methods approach, including a household questionnaire, street audit and behaviour observations (Ward Thompson, Curl, Aspinall, Alves, & Zuin, 2014). Previous analysis of the questionnaire data focused principally on the repeated cross-sectional survey results pre- and post-intervention, using factor analysis to assist in understanding perceptions of the neighbourhood environment and analysing differences in the factor scores over time. The results showed that there was a positive change over time in perceptions of neighbourhood safety in the streets after dark but a negative change in perceptions relating to outdoor facilities at home, such as gardens and car parking. For those living in the comparison streets, there were no significant differences over time (Ward Thompson et al., 2014). In this paper we focus on the longitudinal cohort, focusing on change for individuals over time.

Across all sites, based on the cross-sectional surveys, there were no significant differences in health, quality of life and activity outcome measures over time, but there was a significant ($p < 0.05$) decline in the amount of time spent outdoors in the intervention sites. Regression models to predict such outcomes from each wave of the survey showed that environmental and social barriers and nuisances were significant predictors at some level for all outcome measures. Good paths and cycleways and ease of getting out and about in the neighbourhood were significant predictors of some health and quality of life measures, as well as time outdoors, but not of activity levels (Ward Thompson et al., 2014).

The analyses reported here seek to seek to better illuminate the effect of the environmental interventions in the study by focusing on the survey results from a longitudinal cohort consisting of the same participants in the household questionnaire pre–post-intervention.

3. Aims

The focus of this paper is on how residents' perceptions, behaviour and wider quality of life outcomes have changed pre–post-DIY Street interventions by comparison with participants from non-intervention streets.

This paper presents the results from the questionnaire to a longitudinal cohort of participants in intervention and comparison streets ($n = 36$), before and after the interventions.

The key research questions the paper addresses are as follows.

1 Does a shared space project in residential streets result in environments where older people:
   a. Have better health or quality of life?
   b. Go out more often or spend more time outside in the local environment?
   c. Have better social networks?
2 Do the shared space environmental interventions enhance perceptions of the environment that might explain any observed change in these measures?

4. Methodology

We used a longitudinal cohort as a subset of a larger, repeated cross-sectional household survey to examine perceptions and self-report physical activity and health, both before and after implementation of the street changes. This paper reports on changes in these same measures, over time, based on household survey results pre and post-intervention.

Fig. 1. Locations of study sites within UK.

4.1. Site selection and types of intervention

We worked in partnership with Sustrans to identify sites for the study where pilot DIY Streets interventions were likely to take place within an appropriate time period. Sites were selected pragmatically on the basis of the likelihood of interventions being completed with the project timescales. We covered a range of geographical areas, with sites in England, Scotland and Wales (Fig. 1). Area-level poverty and deprivation is measured by Indices of Multiple Deprivation (IMD) which are calculated in similar but not identical ways in England, Wales and Scotland (Communities and Local Government, 2007; Scottish Government, 2009; Welsh Assembly Government 2005). The intervention sites chosen by Sustrans were targeted towards areas of relatively high deprivation, with all but Oxford falling into the top 40% of most deprived areas for their country.

Interventions at two sites (Bridgend and one London site) had not been completed in time for our post-intervention study, so these have not been included in this aggregate analysis presented here. The results in this paper thus relate to 7 sites.

In each location a nearby comparison neighbourhood where no changes were occurring was selected so that any changes detected in outcome measures could be attributed with greater confidence to the intervention. Although comparison sites were matched as closely as possible to intervention sites, the deprivation levels (IMD) of each pair of sites was not always identical. However, non-parametric tests showed no significant difference between comparison and intervention sites on IMD when considering matched pairs by location (Wilcoxon $z = -1.46$ and $p = 0.14$).

As shown in Fig. 2, the interventions we evaluated ranged from more comprehensive transformations to what Biddulph described as "glorified traffic calming projects" (Biddulph, 2010, p. 203).

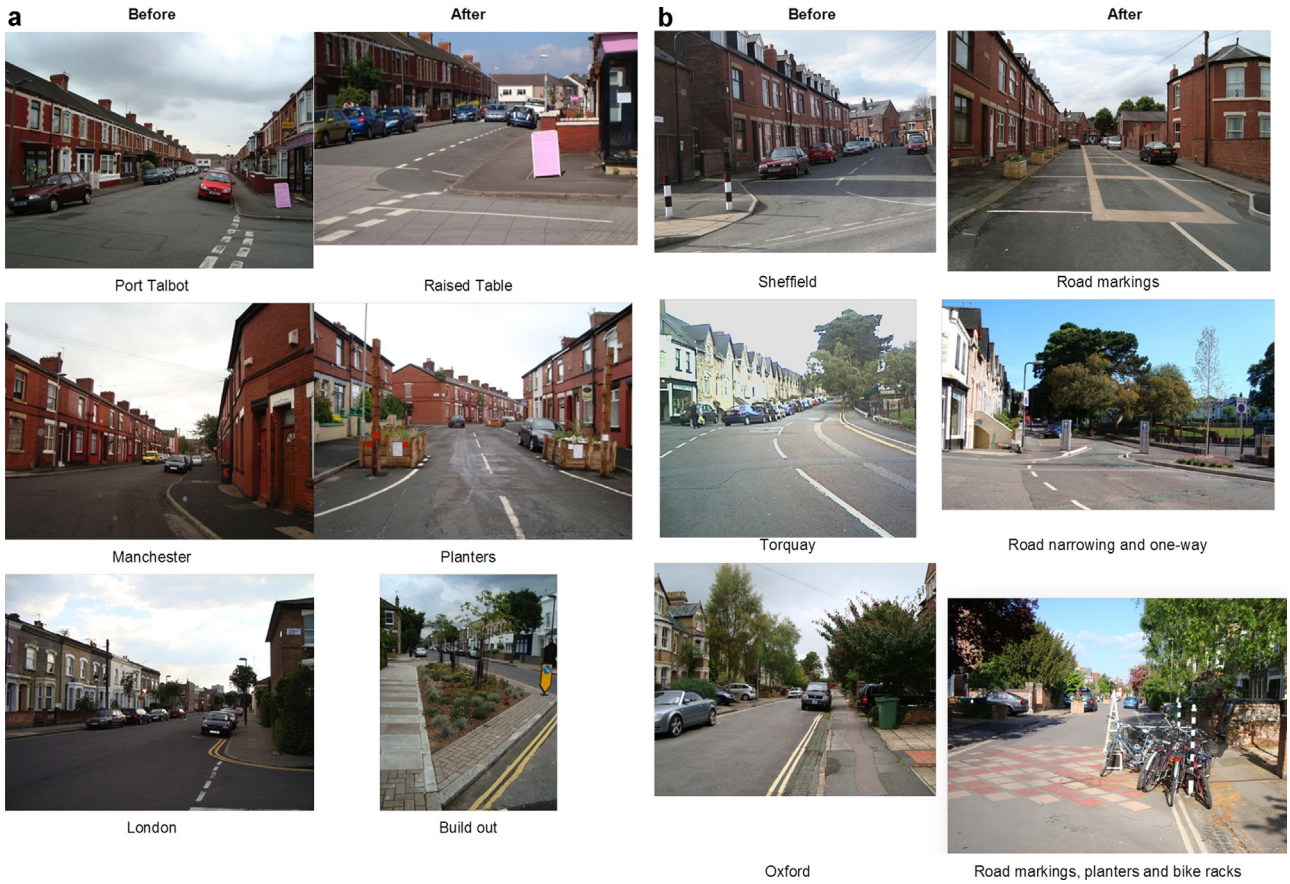

Fig. 2. Images showing streets we surveyed before and after 'DIY Streets' interventions.

4.2. Sample design

The longitudinal cohort which is the focus of this paper is a subsample of the repeat, cross-sectional sample undertaken pre- and post-intervention. The impact of change on individuals' behaviour and wellbeing from a longitudinal sample is appropriate for the research questions asked in this study and provides a more robust indication of any effects of environmental change than population level changes measured through repeated cross-sectional design.

We aimed to contact all people over the age of 65 resident in the sampled streets. A variety of methods were employed, including door-to-door leafleting, community meetings and information sessions facilitated by Sustrans. In total, 96 questionnaire surveys by interview were undertaken in 2008 and 61 in 2010/11. Surveys were undertaken during the summer months (May–October) when the weather is likely to be most supportive of outdoor activities. The date of the post-intervention survey for each site was at the same time of year as the pre-intervention survey and a minimum of three months after completion of any environmental changes. This was summer 2010 for all but one pair of sites (Oxford), where a delayed intervention meant the post-intervention survey was undertaken in 2011. Of the total sample, 36 were a true longitudinal cohort (20 in intervention sites, 16 in comparison sites), whereby the same respondents completed the interview in both years. This sample is used in the analyses presented here. The attrition is likely to be due to changes in the residents over time, which is particularly to be expected amongst a deprived and elderly population, as well as the result of survey fatigue.

4.3. Measures

A range of measures were used in the questionnaire tool, relating to perceptions of the outdoor environment, outdoor activity and health and wellbeing. Respondents rated 38 statements relating to perceptions of the neighbourhood environment on a 5-point Likert scale, from 'strongly disagree' to 'strongly agree'. These statements covered aspects of places in and around the home, the local street environment, local open space and the neighbourhood in general. The statements were developed from previous work using focus groups to determine important factors in local and neighbourhood perception (Sugiyama, Ward Thompson, & Alves, 2008). Appendix A gives the full set of environmental variables used in the questionnaire.

The questionnaire used self-report measures of time spent outdoors and the frequency of going outdoors in summer and winter as indicators of levels of outdoor activity.

In order to measure health and wellbeing EUROQOL and CASP-19, well-established scales, were used. The EUROQOL (EQ-5D) is a self-rated health scale, assessing five aspects of health; mobility, self-care, usual activities, pain/discomfort; and anxiety/depression. In addition, the EQ visual analogue scale (VAS) allows participants to rate their health state on 100 point scale from worst imaginable (0) to best imaginable (100). CASP-19 (Hyde et al., 2003) is a subjective psychological measure of quality of life (QoL) in older age based on a model of needs satisfaction and comprises four domains: Comparison, Autonomy, Pleasure and Self-Realisation, assessed through 19 statements. In addition, as a measure of general health, we asked participants to state on how many days in the previous month they

Table 1
Characteristics of the longitudinal cohort sample.

	2008		2010/11	
	Intervention group, $n = 20$	Comparison group, $n = 16$	Intervention group, $n = 20$	Comparison group, $n = 16$
Age: mean (SD)	73.8 (7.49)	70.9 (4.83)	76.3 (7.59)	73.18 (4.94)
Sex (% male)	36.8%	31.3%		
Functional capability: mean (SD)[a]	1.90 (0.84)	1.84 (1.03)	1.84 (0.78)	1.92 (0.97)
Living arrangement				
At home alone	55%	37.5%	50%	37.5%
At home with other(s)	45%	50%	50%	50%
Sheltered housing alone	–	12.5%	–	12.5%

[a] IADL measure has a range of 1–5 with higher levels associated with lower functional ability.

were unhealthy, defined as being too unwell to look after themselves or leave the house.

In order to measure local social networks, we included a number of the environmental perception statements related to knowing neighbours. We also included a loneliness scale, asking how often people felt isolated, left out or lacking companionship. Furthermore, post-intervention we asked whether respondents knew their neighbours better or worse than two years previously.

We also collected demographic data relating to age, sex and functional status measured using and Instrumental Activities of Daily Living (IADL) scale, adapted from Jette et al. (1986).

We used the same questionnaire before and after the intervention. In the post-intervention survey respondents were also asked about their engagement with the DIY Street community process (for intervention sites only) and whether they perceived that they were more active and had more contact with neighbours compared with two years previously.

4.4. Demographic characteristics

The mean age of the sample was 73.8 for the intervention group, with the comparison group having a slighter younger mean age of 70.9 in 2008. The majority of respondents were female, 63.2% in the intervention group and 68.8% in the comparison group. Whilst the mean functional capability of the intervention group declined over time, the opposite was true for our comparison group. Characteristics of the longitudinal cohort sample are summarised in Table 1.

4.5. Analysis

Differences (t-test) pre- and post-intervention, were examined for each variable, both overall and split by intervention and comparison site. The difference in the degree of change over time (t-test) between intervention and comparison groups was also examined for each variable

The data were then subjected to regression modelling in order to explore which variables best predicted change over time, i.e. that distinguished between the participants before and after the intervention. The small sample size available for the longitudinal cohort ($n = 36$) and the ratio of this to the large number of potential predictors fails to meet criteria recommended for stable regression analysis (e.g. Tabachnick and Fidell, 2007). In addition, the presence of multi-collinearity in the data – i.e. many predictors with moderate or high correlations (as is the case here), has been shown to lead to: unstable model coefficients; model overfit; inflated values of R^2; and poor out-of-sample prediction (Magidson, 2013). However with recent developments in high dimensional data analysis, it is now possible to carry out regressions on small sample sizes in which the number of predictors (p) in regression can be

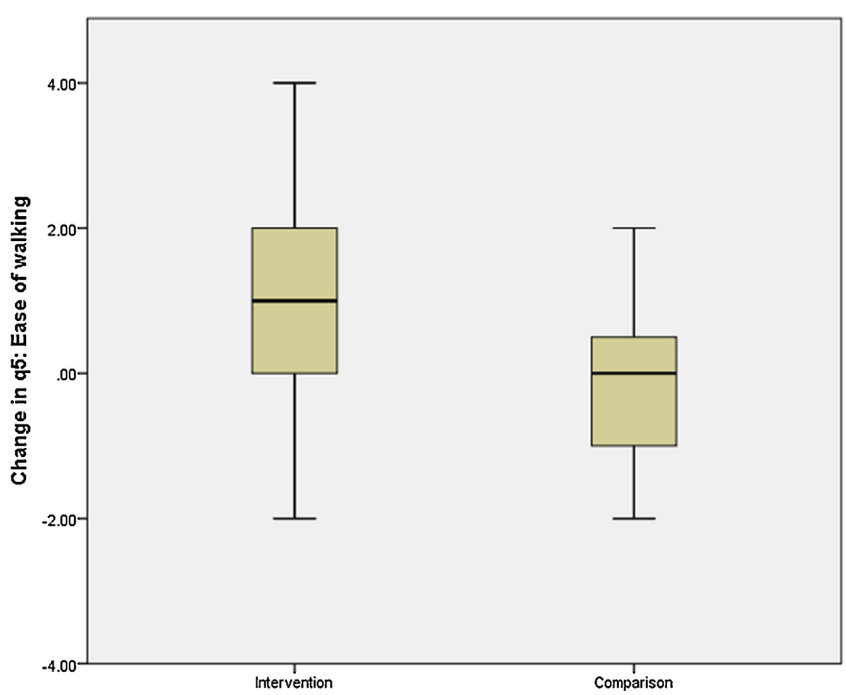

Fig. 3. Change in responses to Q5 by site, pre–post-intervention (difference in change between comparison and intervention groups is significant at $p = 0.03$).

greater than the number of cases (n). The particular form of this type of analysis used here was correlated component regression (CCR) using the COREXpress statistical package with M-fold cross validation (Magidson, 2013). The analysis has several benefits in addition to its capacity to deal with small sample sizes, multiple records per case and multi-collinearity. These are its ability to identify suppressors and, through its regularisation process, to prevent model over-fit whilst delivering better out-of-sample prediction.

CCR models are unique in that they are based on two tuning parameters. The first is K, the number of correlated components (each a linear combination of the predictors), and the second is P, the number of predictors. Tuning is done through a process of regularisation which imposes model restrictions to reduce predictor error variance and leads to simpler models for the validation sample. For example, a conventional 'saturated' regression model can be run within CCR and corresponds to the option in which K can be set equal to P. However, practice shows that R squared values are usually found to be optimised under regularisation (and therefore the model fit improved) when $K < P$. The program therefore initially optimises for K, and then for P given that particular value of K. Magidson (2010) has shown that, when applied to test data sets of different sample sizes, CCR not only outperforms conventional regression but also a number of other regularisation models.

In the first round of M-fold cross validation the sample is randomly divided into M equal sized folds (say 5 folds, M1–M5). M5 is then set aside for validation testing and the model trained on M1–M4. This is then repeated with M4 set aside for validation and the model trained on M1, M2, M3, and M5. In the second round of M-fold validation the sample undergoes new randomisation and the process is repeated. Assessment of the final model is therefore based entirely on out-of-sample performance which addresses a general concern over poor levels of replication from published models (e.g. Nuzzo, 2014). This dependence on cross validation of how the model performs on new cases means that the regression model does not require the traditional sampling assumptions underpinning conventional hypothesis testing. The expectation is that the power is higher (and therefore the required sample size lower) than more traditional approaches due to the regularisation provided by CCR. However, because it is a new technique, there are not yet tools available to provide standard power calculations.

In order to assess the impact of environmental change in the intervention and comparison sites, a logistic regression was run using the site type (intervention or comparator) as the dependent variable and change (between 2008 and 20010/11) in the health-related and environmental measures (EUROQOL, CASP-19, number of unhealthy days, time outdoors and frequency of going outdoors, and the 38 environmental perception variables) as predictors. IADL was also included as a potential confounder at the individual level. The dependent variable was deliberately chosen as the site condition, so that we would be able to identify all the predictor variables which were associated with change between the two sites. As the sample size was $n = 36$, the division of folds was set at 6 folds of 6, and 200 rounds of regressions were run, giving a total of 1200 out of sample regression runs.

5. Results

Independent t-test results showed that participants in both the intervention and comparison groups perceived that they were more active post-intervention than two years previously. However the level of agreement with this statement is significantly different ($p = 0.04$) between the intervention and comparison groups, with those in the intervention groups more likely to have reported that they are more active. Responses to Q5 (it is easy for me to walk on my street) also showed a significant difference in change between the intervention group vs the comparison group ($p = 0.03$). Fig. 3 shows the difference in change over time in responses to Q5 by site (intervention or comparison), indicating that responses remained broadly the same for the comparison group but improved for the intervention group by c. one point on the 5-point Likert scale.

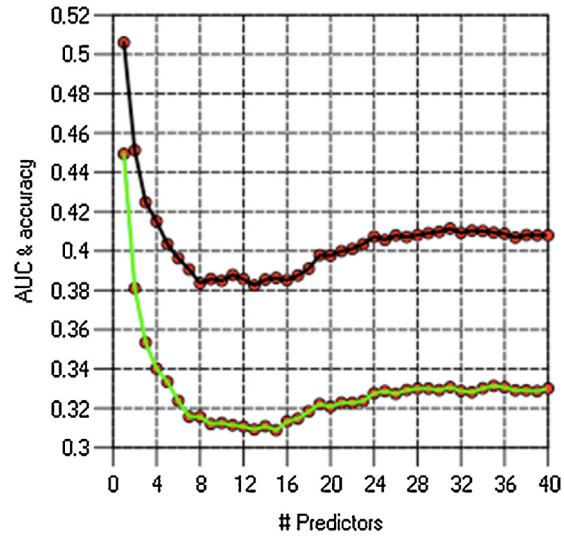

Fig. 4. CCR model showing regression optimised with 1 predictor.

Overall, taking the sample as a whole, paired t-tests showed a significant decline in quality of life measured by CASP-19 ($p = 0.04$) and an increase in the reported number of unhealthy days, i.e. when a respondent felt unable to get out of the house or look after themselves ($p = 0.006$). These measures of change over time did not differ significantly between intervention and comparison groups. The self-report frequency of going outdoors in winter, but not in summer, significantly decreased over the two to three year period ($p = 0.05$). Self-report levels of outdoor activity in summer did not change significantly.

There was no significant change, or significant difference between sites over time, in the EQ5D scale or the EUROQOL Visual Analogue Scale (VAS).

Some environmental perceptions increased significantly across the whole sample: Q15 (the paths to get to the local open space are easy to walk on) ($p = 0.02$) and Q26 (there is an attractive fountain or water feature in the local open space) ($p = 0.05$). On variables used to measure social networks and community engagement, there was no significant change over time or between intervention and comparison sites.

5.1. Correlated component regression results

CCR results, to indicate which variables' change over time best predict the sample from the intervention vs comparison site, are shown in Fig. 4 and Tables 2a and 2b. Fig. 4 shows that the accuracy of prediction (dark line) is maximised by a one predictor solution; in other words, the addition of other predictors to the model

Table 2a
CCR model fit and standard coefficients.

Model fit	Training	Cross validation	Standard error
R^2	0.127	0.041	0.038
AUC	0.718	0.453	0.083
Accuracy	0.694	0.528	0.061

Predictor variable	Standard co-efficient	CC1
Change_q5 (easy to walk)	1.759	1.000

Table 2b
Predictor table.

Predictor	Frequency of occurrence in 1200 out of sample regression runs
Q5_change (easy to walk)	791
Change in unhealthy days	412
EUROQOL Visual Analogue Scale	336

reduces the strength of prediction, as the black line shows. This single predictor is identified as Q5 (it is easy for me to walk on my street) under 'standard coefficient' and 'predictor table'. The 'fit' table (Table 2a) shows R-squared is small at 0.04 (Cohen effect size) and accuracy is 53%. The standard coefficient is positive, indicating a higher positive change score on Q5 for the intervention cf the comparison site. Finally, the predictor table (Table 2b) shows the single item predictor (Q5) present on 791 out of 1200 regression runs. The next two predictors in rank order of 'out of sample' predictions are also shown in the table, although it must be stressed that they are not contributing to this model.

Although the measures of number of unhealthy days and health measured by the EUROQOL Visual Analogue Scale (VAS) are the next best predictors after Q5, they do not enhance the model and, furthermore, neither changes in measures of quality of life (CASP-19) nor of outdoor activity discriminate between the two groups. In summary the results of the CCR support the findings of *t*-tests of change over time amongst the variables that best discriminate the intervention from comparison sites, with change in the statement "it is easy for me to walk on my street" showing a significant difference in change over time between intervention and comparison sites.

6. Discussion

We set out to understand whether an environmental intervention such as street design contributes to the quality of life, health, getting outdoors and social networks of an elderly population, in order to contribute to knowledge on age-friendly design. Using Sustrans' 'DIY Streets' interventions as a case study, we undertook a natural experiment, conducting a questionnaire survey with a cohort of older residents both before and after the intervention took place, and with a cohort of older residents of a nearby comparison street with no intervention.

Overall, there were comparatively few changes observed. Results suggest that, whilst some changes in outcome measures have been found in intervention streets and not their comparators, and which therefore may be attributable to the interventions, there are also changes across all sites which may be due to changes in the wider neighbourhood or because of the ageing of the sample population over time. These are discussed below in relation to the research questions set out in Section 1.

6.1. Health and quality of life

A decline in quality of life was observed across both intervention and comparison sites. Change over time in the age of cohort participants may at least partly explain this decline in quality of life over time, and the intervention did not appear to mitigate any such decline.

Across both groups, there was an increase in the number of unhealthy days reported, those in which respondents felt unable to undertake usual activities. Although the increase was greater in comparison than in intervention sites, this difference was not significant, although the Cohen effect size for this difference is 0.88, suggesting it is a large effect. Similarly, although not statistically significant, the respondents in the comparison sites reported a mean change of 7.25 points lower on the EUROQOL VAS compared with an increase of 3.82 at intervention sites. The Cohen effect size for this difference is 0.54, suggesting a medium sized effect.

Overall, the evidence is ambiguous in supporting the notion that the DIY Street interventions contributed to improved health or quality of life, or to mitigating the decline in health in an ageing population. However, the effect sizes suggest that the sample is under-powered to detect significant differences between intervention and comparison sites on these measures.

6.2. Frequency and time of outdoor visits

The frequency of going outdoors in winter significantly decreased at both comparison and interventions sites. These data may have been affected by particularly cold weather in the winter of 2009/10 and, to a lesser extent, 2010/11 and are also limited by relying on recall from several months back as surveys were only undertaken in summer months. Changes in time spent outdoors were not statistically significant or large in effect size, either across the sample or between intervention and comparison groups.

In a retrospective question, the intervention group said that they were more active than 2 years previously, significantly more so than those in comparison streets. Given, that this did not correspond to an increase in reported frequency of going outdoors amongst the intervention group, it is possible that respondents expected to have experienced an increase in going outdoors, as they were engaged in and aware of the aims of the intervention, and thus reported this. Alternatively, it could be that respondents' activity levels increased without there being an increase in frequency of going outdoors or of time spent once out, independent measures of physical activity levels would be necessary to confirm this.

Overall, the interventions seem to have had a positive effect on people's post hoc perceptions of activity levels but not on time or frequency of visits outdoors, based on repeated measures.

6.3. Social networks

There was no change in any measures of social networks and no differences between comparison and interventions groups, suggesting that social engagement was not affected by the interventions, despite community involvement being integral to the development of the improvements. This might suggest either that those who were involved with the development of the interventions were already actively engaged with their community and therefore did not feel any changes, or that any community involvement did not leave a legacy beyond the time of the development of changes.

6.4. Environmental perceptions

In addition to these broader outcome measures we analysed change in environmental perceptions, based on 38 statements about the neighbourhood environment. The key result from this suggests that the interventions have resulted in a significant improvement in perceptions of how easy it is to walk on the street near home, and this was not experienced in the comparison sites. The Cohen effect size for this difference was 0.74, confirming a medium-level effect. This is an important result in that it tallies closely with the core aims of the DIY Streets interventions, which are intended to aimed at reducing the speed and volume of traffic on the street and at encouraging residents to use their streets in different ways, such as for social activities and children's play. It is supported by the intervention groups' perception that they are more active post-intervention than prior to it. However, the data on time spent outdoors and frequency of outdoor visits raises

questions about how well these perceptions are matched by actual changes in activity.

It is also of note that there were enhanced perceptions of the wider neighbourhood environment, specifically relating to paths to the local open space and attractive water features in the local open space, found across all participants, suggesting these wider environmental improvements may mask any effect of more local changes to the residential street environment.

Considering the wider aims of the environmental improvements, our results suggest that the level of environmental intervention in the 'DIY Streets' pilot projects used in our study were sufficient to enhance older people's perceptions of street walkability, but may not have led to greater overall levels of outdoor activity and do not appear to have had a significant influence on self-report measures of health or quality of life. These findings match similar findings that have been reported on such interventions. Van Andel (1985) used a mixed methods study, consisting of interviews and observation to investigate the effects of a Dutch '*woonerven*' (home zones) on childrens' play behaviour. Whilst improvements were noted in relation to the designers' objectives, it was suggested that more fundamental changes would be needed to dramatically affect the play behaviour of children and a similar conclusion could be drawn here. In order to have significant changes on the health and wellbeing outcomes of an ageing population, there may be a need for more drastic changes to the environment. The aim of 'DIY Streets' interventions was not to improve QoL solely for older people, but for the whole population. These results do not therefore suggest that the schemes were unsuccessful in what they set out to do but, rather, that the impact on older people may be limited and more dramatic street design changes or other types of support, such as social support alongside environmental change, may be needed to effect such changes.

Furthermore, perceptions may change over time once residents have had chance to adapt to their new streetscape (Clayden, McKoy, & Wild, 2006). It is feasible that the time period of between three and six months post-intervention was not long enough for changes to high level outcomes such as those assessed here to become manifest, set in the context of other changes in individuals' lives (most notably ageing in this case) and wider neighbourhood effects. The wider, cross-sectional survey analysis results reported previously (Ward Thompson et al., 2014) showed that there was a positive change over time in perceptions of neighbourhood safety in the streets after dark. This, combined with the significant change in perceptions of home street walkability found in this study suggest that the intervention may have helped move participants from the precontemplation to the contemplation or preparation stages of the 'Transtheoretical model' of behaviour change with respect to their levels of outdoor activity (Marcus & Simkin, 1994). However, the findings of the cross-sectional analysis also point to a negative change over time in perceptions relating to outdoor facilities at home, such as gardens and car parking, which may have moderated any positive benefits of the environmental changes. In this larger, cross-sectional sample, ease of getting out and about in the neighbourhood was a significant predictor of some health and quality of life measures, as well as time outdoors, but not of activity levels, and these findings are to some extent mirrored by the direction of change (although mostly not significant) in health and wellbeing measures in the longitudinal cohort findings.

This study has limitations in terms of small sample sizes, which mean we cannot draw conclusions about the effects of specific types of changes to the street environment at each locality, but rather draw on aggregate analysis across sites with varying levels of intervention to the design of the built environment. Nonetheless, the longitudinal cohort, set in the context of a wider cross-sectional sample at each of the two time points of the study, gives some confidence in the robustness of the findings.

7. Conclusions

This paper has considered differences over time between intervention and comparator sites, following a pilot 'DIY Streets' shared space intervention, using self-report measures from a longitudinal cohort of older adult participants. The analysis of variables focused on those which differentiated between the intervention and comparator sites in change over time, before and after the intervention.

Our study showed that street design interventions led to a significant effect in a key outcome measure for the DIY streets project, i.e. that older participants report a significant improvement in how easy it is to walk on the street near home. Participants also considered that they were significantly more active post-intervention. However, the evidence is more ambiguous when considering whether the changes had subsequently resulted in benefits for health and quality of life, frequency of activities outdoors, time spent outdoors, or better social connectedness.

This paper contributes to building an evidence base on the links between the built environment, perceptions of it, and health and wellbeing outcomes in an elderly population. Most studies of transport interventions to date have focussed on traffic and accident outcomes or retrospective perceptions of residents, where we present evidence from a prospective longitudinal study.

Our results suggest that good design can lead to positive change in perceptions that may be an important early stage in behaviour change and in enabling an elderly population to maintain their outdoor activity. However, it also suggests that if wider health, quality of life or social benefits are to result, more radical changes to the local street and/or neighbourhood environment may be necessary as well as, possibly, other means of support alongside environmental support for an ageing population. The changes required to effect wider health, quality of life or social benefits might include full implementation of 'home zone' principles. This requires: a single, shared surface between buildings, without retaining distinction between pavements for pedestrians and road for vehicular traffic, but with adequate provision for blind and visually impaired people; ensuring that the design offers adequate, well designed seating at regular intervals; and greater use of planting to create a more pleasant ambience. There is a need for larger longitudinal studies to assess the health and behavioural outcomes arising from such changes to the built environment, particularly for an older population. A larger sample may enable changes to be attributed to specific interventions in order to provide more detailed design guidance. Study of the effect of street environment changes over a longer time period may also be necessary to identify an impact on health and wellbeing outcomes.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landurbplan.2015.02.019.

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