ACTIVE TRANSPORTATION ON A COMPLETE STREET: OBJECTIVE AND SUBJECTIVE WALKABILITY CORRELATES

by

Wyatt Jensen

A thesis submitted to the faculty of
The University of Utah
in partial fulfillment of the requirements for the degree of

Master of Science

in

Human Development and Social Policy

Department of Family and Consumer Studies

The University of Utah

August 2016

The University of Utah Graduate School

STATEMENT OF THESIS APPROVAL

The thesis of **Wyatt Jensen**

has been approved by the following supervisory committee members:

Barbara B Brown	, Chair	**04/22/2016** Date Approved
Ken R Smith	, Member	**04/22/2016** Date Approved
Brett McIff	, Member	**04/22/2016** Date Approved

and by **Lori Kowaleski-Jones**, Chair/Dean of

the Department/College/School of **Family and Consumer Studies**

and by David B. Kieda, Dean of The Graduate School.

ABSTRACT

United States residents achieve insufficient amounts of physical activity. Insufficient physical activity has been linked to a number of poor health outcomes. Community improvements, such as the provision of a new light rail service as part of a complete street construction project, might encourage more physical activity through active transportation. Past research is divided as to whether active transportation is related to walkability measured objectively by trained raters, or to subjectively perceived walkability, or both.

This study uses data from the Moving Across Places Study (MAPS) to assess both objective and subjective walkability in relation to active travel to a complete street across two time points. MAPS is an evaluation of a complete street intervention in which a street received a renovation to serve more than just cars in Salt Lake City, Utah. Participants (N=536) were recruited if they lived within 2 km of the new complete street. Physical activity data were measured objectively with GPS and accelerometer units.

Objective and subjective measures of walkability were assessed at both times and across two levels of geographic analysis: neighborhood-wide, and route-specific walkability.

Results from data analyses of the data show objective measures of walkability were more strongly related to active transportation on the complete street than subjective measures. Objective measures of aesthetics, pedestrian infrastructure, and pedestrian accessibility were all significantly and negatively associated with active transportation on the complete street. Additionally, neighborhood-wide analyses were better at estimating active transportation on the complete street than route-specific walkability.

TABLE OF CONTENTS

LIST OF TABLES

Tables

INTRODUCTION

Insufficient physical activity is a growing health concern linked to poor health outcomes like obesity, heart disease, diabetes, stroke, and some types of cancers (Barnes, 2012; Manson, Skerrett, Greenland, & VanItallie, 2004; Must et al., 1999; Patterson, Frank, Kristal, & White, 2004; U.S. Department of Health and Human Services, 2000). Research has shown that fewer than 5% of adults achieve adequate amounts of physical activity when objective measures of physical activity are taken, and that objective measures show much less physical activity than self-reports (Troiano et al., 2008). One way insufficient physical activity can be combatted is to increase amounts of physical activity through neighborhood walking. Walking is the most popular form of physical activity in neighborhoods across genders, age groups, and fitness levels (Giles-Corti et al., 2008; Mathews, Colabianchi, Hutto, Pluto, & Hooker, 2009). It is well known that walking and moderately vigorous physical activity levels are healthy behaviors associated with many positive health outcomes (Warburton, Nicol, & Bredin, 2006), which makes it important to know what encourages walking in one's neighborhood.

One way to encourage active transportation, defined as any mode of transportation that involves physical activity as a means of travel, may be to provide more walkable neighborhoods with good transit options. Past research has typically focused on either objectively rated or subjectively perceived measured neighborhood walkability. Objective measures often include four broad classes of physical environmental features that are thought to support active transportation. Good pedestrian accessibility provides access along sidewalks and supports for crossing roads, such as crosswalks or pedestrian signals. Pleasant aesthetics includes good views and comfortable facilities for pedestrians, such as street trees, historic buildings, and fewer car-oriented features such as driveways. Traffic hazards that impede walkability include features that create physical and/or psychological barriers to active transportation, such as high speed limits, angled parked cars, absence of bike lanes, and many lanes of traffic. Crime indicators include features such as graffiti, poor street lighting, and blank walls that reduce informal surveillance of pedestrians (Day, Boarnet, Alfonzo, & Forsyth, 2006).

Subjective measures are those that residents themselves provide on surveys, but address many of the same features as objective measures. For example, the widely used survey employed in this study, the Neighborhood Environment Walkability Scale-abbreviated (NEWS-A), includes items that assess ease of walking to transit stops, good-quality sidewalks and bike paths, interesting neighborhood sights, traffic hazards, and crime perceptions (Cerin, Saelens, Sallis, & Frank, 2006; Saelens, Sallis, Black, & Chen, 2003).

Research on walkability is voluminous. For objective measures of walkability, past reviews provide strongest support for density and land use mix, both of which may indicate that walkable destinations exist in the neighborhood. They also include pedestrian infrastructure (e.g., sidewalks in good conditions, presence of street trees), proximity to destinations, and crime safety as objective factors related to walking (Dunton, Kaplan, Wolch, Jerrett, & Reynolds, 2009; Saelens & Handy, 2008; Werner, Brown, & Gallimore, 2010). Another review found utilitarian walking (walking to destinations) was consistently associated with the presence and proximity of utilitarian destinations, such as local shops, services, and transit stops, in 80% of studies examined (24 of 30). Street connectivity was associated with utilitarian walking in 58% of the studies and the presence and maintenance of sidewalks in 42% of the studies (Sugiyama, Neuhaus, Cole, Giles-Corti, & Owen, 2012).

Past reviews of subjective qualities associated with walking suggest that perceived traffic safety, crime safety, land use mix, pleasantness of walking (e.g., lots of shade from trees on paths, sidewalks in good condition), and attractiveness (Saelens & Handy, 2008; Van Cauwenberg et al., 2011) are the most consistent correlates. Another review found that subjective factors such as nearby facilities to engage in physical activity, sidewalks, shops, services, and ratings that traffic was not a problem were all positively associated with physical activity (Duncan, Spence, & Mummery, 2005).

When examining specific objectively measured walkability features, physical activity was significantly correlated with only a few objectively rated environmental indicators. One study assessed 162 walkability features, but found objectively measured physical activity or walking associated with only 16 items. These include the presence of sidewalks, and street characteristics such as pedestrian crossings (Boarnet, Forsyth, Day, & Oakes, 2011). Another study found that if an area had more positive pedestrian safety features, like pedestrian crosswalks, a sample of young girls was more likely to choose that area for a walking route (Rodriguez et al., 2014). Other research has found that when a route to a park scored higher on trained rater measured pedestrian-friendly traffic (e.g., few lanes for vehicle travel), beauty, crime safety, street maintenance, and neighborhood maintenance residents were more likely to be users of the park (Dills, Rutt, & Mumford, 2012). In contrast, streets with unfavorable walkability, such as streets with more automotive traffic, sidewalk defects, graffiti, litter, and poor aesthetics, related to the presence of more pedestrians counted by raters (Suminski, Heinrich, Poston, Hyder, & Pyle, 2008). Another study found that lower density, which is usually considered a deterrent to walking, and better sidewalk conditions associated with more physical activity among residents in higher density areas (Schulz et al., 2013). Another study also found that residents living in more urban inner city areas with very high street connectivity (e.g., streets that intersect and are almost universally lined with sidewalks) had lower level of physical activity than residents living in suburban areas with lower density and poor street connectivity (Lopez & Hynes, 2006). These mixed results suggest that the objective walkability of a neighborhood may provide an incomplete understanding of active travel.

Other studies have found that neighborhood walking was significantly correlated with residents' perceptions of walkability. One study of two neighborhoods chosen to represent high and low levels of objectively measured walkability found that the highly walkable neighborhood was perceived by residents to have more residential density, land use mix, street connectivity, attractiveness, and traffic safety than the less walkable neighborhood. Residents of the objectively walkable neighborhood also achieved more minutes of physical activity than residents who rated their neighborhood as low on these key elements (Saelens et al., 2003). Another study found that perceived access to public transit, bike lanes, and a variety of destinations was significantly associated with reported physical activity (Hoehner, Ramirez, Elliott, Handy, & Brownson, 2005).

Similarly, perceived land use mix, residential density, ease of walking to public transportation, and street connectivity were also significantly correlated with self-reported physical activity (De Bourdeaudhuij, Teixeira, Cardon, & Deforche, 2005). The findings of these studies demonstrate that subjective walkability appears to be consistently associated with physical activity. However, a limitation to these studies is that they typically do not include both objective and subjective indicators of walkability. Sometimes the studies do not include objective measures of physical activity and they do not connect objective measures of activity to particular places walked.

It is not clear from many of the studies reviewed so far whether objectively rated walkability is expected to be reflected in residents' perceptions of walkability. The literature is divided as to whether subjective perceptions mirror objectively rated conditions or if the two forms of measurement represent different phenomena. To fully understand neighborhood walkability, research is needed on both objective and subjective measurements of walkability. Few studies have combined both types of measurement (Adams et al., 2009). Of studies that included both, some find concordance and some find discordance between objective and subjective walkability (Arvidsson, Kawakami, Ohlsson, & Sundquist, 2012; Ball et al., 2008; Gebel, Bauman, & Owen, 2009; Leslie, Sugiyama, Ierodiaconou, & Kremer, 2010; Macintyre, Macdonald, & Ellaway, 2008).

Research that has found concordance between objective and subjective walkability shows that the majority of respondents' self-rated measures of perceived walkability agreed with objective measures of walkability (Arvidsson et al., 2012). Arvidsson et al. measured objective walkability using Geographic Information Systems (GIS) to assess residential density, land use mix, and street connectivity. In comparison, they measured perceived neighborhood walkability by using the NEWS to assess perceived residential density, land use mix, and street connectivity. Measures for both objective and subjective neighborhood walkability were z-scored and then dichotomized using median splits to create four concordance categories: high objective/high perceived, high objective/low perceived, low objective/high perceived, and low objective/low perceived walkability. Results indicated that approximately 70% of participants' objective and perceived ratings matched for residential density and land use mix, and 60% matched for street connectivity. Another study, also using the same technique, found that approximately 70% of participants achieved concordance between the measures of objective and perceived neighborhood density, street connectivity, land use mix, and retail density (Gebel et al., 2009).

Some research has found discordance between objective and subjective measures that includes differences in perception of access to facilities such as walking/bicycling tracks and tennis courts (Ball et al., 2008), amount of green space in the neighborhood (Leslie et al., 2010), and distance to destinations (Macintyre et al., 2008). These studies have found that environmental perceptions are not significantly correlated with the actual environment. This could be a concern because many studies rely on participant environmental perceptions rather than objectively measured environments.

One possible reason for poor correspondence between objective and subjective walkability measures is that they could be measuring different parts of the neighborhood. Objective neighborhood walkability measures may be examining a larger or smaller area than the residents' subjective perception of their neighborhood. If this poor correspondence is caused by differences in objective and subjective neighborhood boundaries, correspondence should improve if objective and subjective walkability are focused on a more narrowly defined route. If this is true, stronger correlations should emerge for route-specific objective and subjective measures of walkability than for neighborhood-wide measures.

Another possible reason for poor correspondence between objective and subjective walkability may be that subjective measures of walkability might be influenced by factors apart from the physical environment, such as the purpose for walking. Research has identified that leisure walking occurs in places that are more attractive or pleasant and that utilitarian walking (e.g., walking to get some place) is typically not as strongly related to attractiveness and pleasantness (Saelens & Handy, 2008). This research suggests that walking for pleasure/leisure could be more strongly associated with subjective walkability (pleasantness and attractiveness) whereas instrumental walking for active transportation could be more strongly associated with some indicators of objective walkability (e.g., presence of physical infrastructure), if not others (e.g., pleasant aesthetics). The purpose that residents have for walking may heavily influence their perceptions of neighborhood walkability. Walking to a busy urban street that offers light rail stops may be instrumental walking, so that residents may be less attuned to walkability features or may walk despite poor walkability features. In fact, the Suminski et al. study found more walking in less objectively walkable areas for a busy urban street with many instrumental destinations. Thus, the walk to the complete street may occur regardless of objective walkability (Suminski et al., 2008).

As the research has shown, it is unclear whether objectively and subjectively measured walkability relate to active transportation when both measures are included in the model. Relatively few studies have assessed both objective and subjective neighborhood walkability, and of those that have, many do not assess associations between the two types of measures. The present study examined both objective and subjective neighborhood walkability along a corridor in Salt Lake City, Utah that recently received a complete street renovation that included a light-rail transit line. Objective neighborhood walkability was measured by using the Irvine Minnesota Inventory (IMI) to assess the walkability of participant's home block as well as a ¼ mile street network buffer around the participant's home. Subjective walkability was measured by using the NEWS-A to measure perceived neighborhood walkability as well as route-specific perceived walkability to the nearest light rail transit stop on the new complete street. This study aimed to answer the following research questions:

1. Do objectively measured and subjectively perceived walkability correlate over time and with each other?
2. Prior to complete street improvements, do objectively measured and subjectively perceived walkability features relate to active transportation on the complete street?
3. After the complete street improvements, do objectively measured and subjectively perceived walkability features relate to active transportation on the complete street?
4. Are relationships between walkability and active travel to the complete street found for both neighborhood and route-specific measures of walkability?

5. Do walkability indicators at time 1 predict active travel on the complete street at time 2?

METHODS

Data

The data for this project come from the Moving Across Places Study (MAPS). MAPS is an evaluation of a complete street intervention in which a street received a renovation to serve more than just cars in Salt Lake City, Utah, USA. The main goals of this intervention were to add in a light rail transit line and five new rail stops, bike lanes, and improved sidewalks. MAPS has collected data from adult residents (*N*=536) living within 2 kilometers of the new complete street in 2012 and 2013. Time 1 data were collected between March and December of 2012, prior to the light rail construction completion. Time 2 data were collected between May and November of 2013 after light rail opened in April 2013. Participants were recruited to wear accelerometers (Actigraph GT3X+) and GPS loggers (GlobalSat DG-100 data loggers) for approximately 1 week for each year. Participants had two scheduled visits each year, one at the beginning of the week in which they completed surveys and were fitted for the devices and one at the end of the week when devices were collected from participants and more surveys were conducted.

Sample

Participants were recruited door-to-door and were selected if they: were over 18, able to walk a few blocks, intended to stay in the neighborhood for more than 1 year, were not pregnant, were able to speak in Spanish or English, and agreed to wear devices and fill out the surveys. Informed consent procedures were approved by the University of Utah Institutional Review Board. The data for this project were from a subsample of 536 participants who had worn accelerometers in 2012 for at least 3 days with 10 hours or more of wear, and who had GPS data and who were available for follow-up data collection in 2013. Participants were 51% female, 25% were of Hispanic ethnicity, and the mean age was 42 years old.

Measures

The Irvine Minnesota Inventory (IMI) was used to measure objective walkability in the study area. The IMI includes 162 items and the scale authors suggested they could be organized into four conceptually distinct domains: accessibility, pleasurability, perceived safety from traffic, and perceived safety from crime (Day et al., 2006). This project used a modified version of the IMI to capture objective walkability for both the participant's home block and for a ¼ mile street network buffer around each participant's home to capture narrowly defined route walkability and neighborhood walkability, respectively. Items were chosen when they were similar in content to the perceived walkability subscales below, given the more extensive validation history of the perceived scores. Following methods used by other research, this study uses a subset of 40 IMI items have been dichotomized to represent the presence or absence of any feature (e.g., some/few vs. none) (Boarnet et al., 2011; Gasevic et al., 2011). The modified version of the IMI used in this study consists of five domains of measurement that have been identified using theory and exploratory factor analysis to create new factors of: crime indicators, traffic hazards, aesthetics, pedestrian infrastructure, and pedestrian accessibility. Interrater reliabilities for the IMI scales were acceptable across both time points for crime indicators, traffic hazards, aesthetics, pedestrian infrastructure, and pedestrian accessibility (see Table 1). Home block IMI ratings consist of audit ratings for only the block face where the participant's home is located. The ¼ mile buffers used for the neighborhood-level analysis were calculated by averaging length-weighted IMI scores for each street segment in a ¼ mile around each participants' home using street network distance.

The Neighborhood Walkability Scale-Abbreviated (NEWS-A) was used to measure participants' perceptions of neighborhood walkability. The NEWS-A is a survey of 62 items aimed at capturing respondent perceptions across a variety of neighborhood walkability factors, including residential density, land use mix-diversity, street connectivity, walking/cycling facilities, aesthetics, traffic safety, and crime safety (Cerin et al., 2006; Saelens et al., 2003). Additionally, a modified version of the NEWS-A was used to capture perceptions of route-specific walkability for a particular route of interest. In both 2012 and 2013, a subset of 43 NEWS-A items was used to assess subjectively perceived walkability along a route to a light rail stop on the complete street. This subset of NEWS-A items was modified to capture subjectively perceived walkability on a specific route to the nearest light rail stop. In 2012, prior to construction of the new light rail stops, participants were asked to respond to perceived walkability questions as if they were to walk to the location of the future nearest light rail stop from their home, which was provided to them on a map. After the light rail service opened in 2013, participants were asked to respond to perceived walkability questions as if they were to walk to the nearest light rail stop from their home, with maps again provided.

GPS and accelerometer devices were used to identify trips of physical activity and active transportation on the complete street. The company Geostats (now Westat) identified all trip stages that involved active travel. A trip involving active travel, defined as walking, biking, running, using bus, or using rail transit, was considered to be on the complete street if the trip had any GPS points registering on or along the complete street within a 40-meter buffer from the street centerline.

The following variables were used as control variables: gender, Hispanic ethnicity, having access to a car, and household income. If a participant had missing data on household income, it was imputed using a regression imputation. Age was initially included as control variable for conceptual reasons; however, multicollinearity checks revealed that it was collinear with having access to a car. Having a car also had a significant Spearman correlation with the outcome of active travel to the complete street (r = -.17 p<.01 for having a car, r = .05 for age) so it was retained.

Finally, the dependent variable was a dummy variable computed to indicate the use of any method of active transportation on the complete street (walking, biking, running, using bus, or using rail transit).

Data analysis procedures

In order to explore factors that are comparable between the neighborhood-level NEWS-A and the route-specific-level NEWS-A at both time points of 2012 and 2013, this study replicated then adapted the confirmatory factor analysis (CFA) of the NEWS-A items by Cerin et al. using IBM's SPSS AMOS version 22 (Cerin, Conway, Saelens, Frank, & Sallis, 2009). Cerin et al. created factors across 6 domains: accessibility (3 items), street connectivity (2 items), infrastructure for walking/bicycling (6 items), aesthetics (4 items), traffic hazards (3 items), and crime (4 single-items recommended instead of one scale). After the CFA was conducted for this study, correlations of the same scale over time and between NEWS-A and IMI scales were calculated.

Correspondence between objective and subjective measures across time points was assessed with Pearson correlation coefficients. These statistics also described the stability of measures over time.

Logistic regression (SPSS v22) was used to estimate active transportation use on the complete street for both 2012 and 2013 as a function of objectively and subjectively rated walkability measures and key control variables. Collinearity tests revealed that there were unacceptable levels of collinearity (condition index greater than 5 in a model without the constant with two individual coefficients greater than 0.5) (Belsley, Kuh, & Welsch, 1980). To reduce collinearity without collapsing across factors, separate analysis of each of the five walkability factors were conducted with Bonferroni-corrected significance levels (0.05/5 = .01). In order to clarify their separate and combined contributions to active travel, each walkability factor was entered into its own logistic regression along with control variables, then entered into a model with its corresponding counterpart (for example, NEWS-A crime was entered into a model with IMI crime).

In order to assess similarities and differences between measures of IMI and NEWS-A scales, standardized versions of the scales were entered into logistic regression models constraining the IMI and NEWS-A scales to be equal using a test statement in

SAS (v9.4). For example, IMI crime indicators were constrained to be equal to NEWS-A crime indicators and a test statement was run to examine if the coefficients of the two scales are significantly different from one another. Each of the logistic regressions controlled for gender, Hispanic ethnicity, having access to a car, and household income.

To assess if time 1 walkability indicators predict time 2 active transportation on the complete street, a series of logistic regressions were performed to see whether time 1 walkability indicators significantly predicted time 2 active transportation. Similarly to the logistic regressions mentioned above, each walkability factor was entered into its own logistic regression then into a model with its corresponding counterpart.

Table 1.
Interrater Reliability for IMI Scales

	2012		
	Cohen's kappa	Pearson's *r*	Cronbach's Alpha
Access	0.36	0.84	0.91
Infrastructure	0.50	0.73	0.84
Aesthetics	0.37	0.83	0.91
Traffic Hazards	0.11	0.70	0.80
Crime	0.34	0.65	0.78
	2013		
	Cohen's kappa	Pearson's *r*	Cronbach's Alpha
Access	0.31	0.48	0.60
Infrastructure	0.67	0.88	0.94
Aesthetics	0.09	0.69	0.82
Traffic Hazards	0.25	0.78	0.87
Crime	0.01	0.46	0.63

RESULTS

Scale creation

To develop perceived walkability scales, a confirmatory factor analysis was used to replicate and extend the work of Cerin et al. Table 2 shows the model fit statistics for the CFA when a direct replication of the Cerin model was used. A CFI of 0.66 and a RMSEA of 0.06 indicated poor model fit (Schumacker & Lomax, 2016; Widaman & Reise, 1997). Another limitation of Cerin's CFA was that it did not contain a multi-item crime factor, a factor believed to be important for walkability (Brown, Werner, Smith, Tribby, & Miller, 2014; Foster & Giles-Corti, 2008; Foster, Knuiman, Hooper, Christian, & Giles-Corti, 2014; Kim, Ulfarsson, & Todd Hennessy, 2007; McDonald, 2008). Consequently, a modified version of a CFA was conducted for this study that added additional perceived crime items available in the survey.

Table 3 shows the current CFA factors and the individual items that went into each factor. Model fit for the current CFA is acceptable with CFI of .91 and a RMSEA of 0.04 for the neighborhood-level analysis and a CFI of 0.95 and a RMSEA of 0.04 for the path-level analysis (see Table 4). The CFA for the NEWS-A identified a 6-factor structure for neighborhood walkability: crime indicators, traffic hazards, aesthetics, pedestrian infrastructure, street connectivity, and pedestrian accessibility; a 5-factor structure was identified for route-specific walkability: crime indicators, traffic hazards, aesthetics, infrastructure, and accessibility. Street connectivity was not relevant to the route-specific walkability because street connectivity refers to the overall street network and is not computed for particular routes. By design, the IMI only captures walkability at the block face level and a route-specific-level summary score does not include scores from the broader area needed to define area walkability.

Once acceptable model fit had been achieved for the CFA for both neighborhood and path-level NEWS-A factors at both time points, similar subscales for the IMI items were created. Initially, a confirmatory factor analysis was attempted for the IMI; however, adequate model fit could not be achieved using the dichotomized IMI variables. A theory-driven exploratory factor analysis, informed by the NEWS-A factors, led to a 5-factor IMI model consisting of summed scales of crime indicators, traffic hazards, aesthetics, pedestrian infrastructure, and pedestrian accessibility. These scales were created for both 2012 and 2013 for closely matched items on the NEWS-A as listed in Table 5. Following methods used in previous research, the IMI scales were computed by summing the dichotomized items within each scale (Boarnet et al., 2011; Gasevic et al., 2011). Higher values in the sum indicate a greater number of items that indicate the scale name. For example, the higher the crime indicators score, the more indicators of crime had been captured. For three scales, aesthetics, pedestrian infrastructure, and pedestrian accessibility, higher scores indicate hypothetically more walkable conditions; for crime indicators and traffic hazards, higher scores indicate hypothetically less walkable conditions.

Objective and subjective walkability stability and associations

To assess how stable the measures are over time and to examine direct relationships between NEWS-A and IMI scales, Pearson's correlations were performed for time 1 and time 2 scales with each other and NEWS-A scales were correlated with the corresponding IMI scale (see Table 6). When correlating each scale with itself over time (2012 to 2013), most correlations were positive and significant ranging from 0.46 to 0.87. The only exception was IMI crime indicators on the home block (r = .08, not significant). When correlating NEWS-A scales with their corresponding IMI scales, crime indicators, traffic hazards, aesthetics, infrastructure, and accessibility were all significantly correlated with each other for the neighborhood-level analysis in 2012. However, in 2013, only crime indicators and accessibility remained significant for the neighborhood-level analysis. Although five of seven of the time 1 correlations between IMI indicators and NEWS-A perceptions were positive, crime indicators and traffic hazards both had significant negative correlations. The greater the physical evidence of crime and traffic problems, the lower the residents' perceptions of these problems.

The strength of the positive significant correlations between IMI and NEWS-A scales ranged from r = 0.12 to r = 0.29. These significant but modest correlations indicate that objectively rated and resident-perceived walkability are not redundant measures. This suggestion can be tested systematically in the multivariate analyses that follow.

Neighborhood analysis of active transportation 2012

Prior to the complete street improvements, three of five features of objectively measured and none of five features of subjectively perceived walkability were significantly related to active transportation on the complete street at the neighborhood-level of analysis. Table 7 shows the results for the logistic regressions for 2012 for the neighborhood-level analysis. In the IMI-only models, greater aesthetics, more pedestrian infrastructure, and more pedestrian accessibility were all negatively and significantly related to active transportation on the complete street. For each unit decrease of the aesthetics scale, the likelihood of using the complete street increased (OR = 0.58). Lower pedestrian infrastructure and accessibility scores were associated with an increased likelihood of using the complete street (OR = 0.65, 0.62, respectively). In the NEWS-A only models, none of the walkability factors were significantly related to active transportation on the complete street. When combining the NEWS-A and IMI into single models, all three IMI scales that were significant in single analyses retained their significance (ORs from 0.58 to 0.64). Greater IMI aesthetics, more IMI pedestrian infrastructure, and more IMI pedestrian accessibility were all negatively and significantly related to the likelihood of active transportation on the complete street.

<u>Route analysis of active transportation 2012</u>

Prior to the complete street improvements, one of five features of objectively rated and none of five features of subjectively perceived walkability were significantly related to active transportation on the complete street at the route-specific-level analysis. Table 8 shows the results for the logistic regressions for 2012 for the route-specific-level analysis. In the IMI-only models, higher aesthetics scores were negatively and significantly related to active transportation on the complete street. For each unit decrease in the aesthetics scale, the likelihood of using the complete street increased (OR = 0.70).

In the NEWS-A only models, none of the walkability factors was significantly related to active transportation on the complete street. When combining the NEWS-A and IMI into single models, the relationship between poor aesthetics and more walking retained its significance.

Neighborhood analysis of active transportation 2013

After the complete street improvement, three of five features of objectively rated and none of five features of subjectively perceived walkability were significantly related to active transportation on the complete street at the neighborhood-level analysis. The right side columns in Table 7 show that in the IMI-only models and in the combined models, higher IMI aesthetics scores and more IMI pedestrian accessibility were both negatively and significantly related to active transportation on the complete street. For each unit decrease in the aesthetics scale, the likelihood of using the complete street increased (OR = 0.56 for IMI-only and OR = 0.54 for combined). Lower pedestrian accessibility scores were associated with an increased likelihood of using the complete street (both OR = 0.53). When combining the NEWS-A and the IMI models, higher IMI crime indicators were also positively and significantly related to the greater likelihood of active transportation on the complete street (OR = 1.23). Additionally, the relationship between poor IMI aesthetics and higher IMI pedestrian accessibility retained their significance.

Route analysis of active transportation 2013

After the complete street improvement, four of five features of objectively rated and none of five features of subjectively perceived walkability were significantly related to active transportation on the complete street at the route-specific-level analysis, as shown in Table 8. In the IMI-only models, better pedestrian infrastructure (OR = 1.28) was positively and significantly related to the likelihood of active transportation on the complete street. In contrast, more traffic hazards (OR = 1.28), lower aesthetics (OR = 0.68), and lower pedestrian accessibility (OR = 0.73) scores were all related to greater likelihood of active transportation. When combining the NEWS-A and the IMI into single models, significant IMI predictors from the individual models retain their significance.

Tests of differences between objective and perceived measures

Above logistic analyses all showed that objective and subjective walkability indicators were not redundant, given that significant predictors in single models retained significance in combined models. Additional analyses were conducted to determine whether objective or subjective indicators were more powerful than their counterparts.

The test combined logistic regression equations where each scale coefficient was constrained to be equal to its counterpart (e.g., IMI crime indicators = NEWS-A crime indicators). For the neighborhood analyses for 2012, aesthetics ($\chi 2\ (1) = 6.32$, $p = .01$), pedestrian infrastructure ($\chi 2(1) = 6.18$, $p = .01$), and pedestrian accessibility ($\chi 2(1) = 14.02$, $p < .001$) were all significantly different from one another based on Wald chi-square tests. Models above indicated that the objective measures were more significant than subjective ones. For the route-specific analyses for 2012, none of the scales was significantly different from one another. For the neighborhood analyses for 2013, aesthetics (G2(1) = 23.67, p < .0001), pedestrian infrastructure (G2(1) = 5.72, p = .02), and pedestrian accessibility (χ2(1) = 26.09, *p* < .0001) were significantly different from one another. For the route-specific analyses for 2013, aesthetics (χ2(1) = 11.03, *p* = .001) and pedestrian accessibility (χ2 (1) = 9.11, *p* = .003) were significantly different from one another. Across these tests, the IMI measures had stronger association with the odds of active transportation for all but one comparison. For the 2013 neighborhood pedestrian infrastructure test, the NEWS-A (χ2 = 3.40, df = 1, *p* = 0.06) had a stronger but nonsignificant association with active transportation than the IMI (χ2 = 2.56, df = 1, *p* = 0.11).

<u>Time 1 walkability indicators predicting time 2 active transportation use on the complete street</u>

When examining whether time 1 walkability indicators predict time 2 active transportation use on the complete street at the neighborhood-level, three out of five features of walkability from 2012 predict active transportation in 2013 (see Table 9). In the IMI-only models, time 1 poor aesthetics (OR = 0.73), less pedestrian infrastructure (OR = 0.73), and less pedestrian accessibility (OR = 0.66) were related to greater likelihood of active transportation on the complete street. When combining the NEWS-A and IMI into single models, significant IMI predictors from the individual models retain their significance.

When examining whether time 1 walkability indicators predict time 2 active transportation use on the complete street at the route-specific-level, one out of five features of walkability from 2012 significantly predict use in 2013 (see the right side of Table 9). In the IMI only models, poor aesthetics (OR = 0.66) was related to greater likelihood of active transportation on the complete street. When combining the NEWS-A and IMI into single models, the IMI aesthetics retained significance.

Examining logistic regression equations controlling for distance from the complete street

The results for these logistic regressions indicate that distance may play an important role in active transportation use on the complete street. For the neighborhood-level analysis in 2012, IMI aesthetics and pedestrian accessibility were no longer significant, while poorer pedestrian infrastructure remained associated with greater likelihood of active transportation use on the complete street. For the route-specific-level analysis in 2012, IMI aesthetics was no longer significant when distance was controlled. In the neighborhood-level analysis in 2013, IMI aesthetics and pedestrian infrastructure remained significant. For the route-specific-level analysis in 2013, none of the previously significant IMI scales of traffic hazards, aesthetics, pedestrian infrastructure, or pedestrian accessibility remained significantly related to active transportation on the complete street.

When IMI scales retained their significance, the directions were still negative with low walkability associating with more likelihood of walking. This prompted an examination of the means for each of the IMI scales comparing participants' block-level IMI scores for those who lived near (within 1 km) or far (farther than 1 km) from the complete street. A series of independent-samples *t*-tests demonstrated that areas near the complete street typically had better pedestrian infrastructure, fewer crime indicators, more traffic hazards, and lower levels of pedestrian accessibility.

For the neighborhood-level analysis in 2012, the area near the complete street had fewer crime indicators, more traffic hazards, greater pedestrian infrastructure, and less pedestrian accessibility than the far area. For the route-specific analysis in 2012 the area near the complete street had fewer crime indicators, greater pedestrian infrastructure, and lower pedestrian accessibility than the far area. For the neighborhood-level analysis in 2013, the area near the complete street had more crime indicators, less aesthetics, greater pedestrian infrastructure, and lower pedestrian accessibility than the far area. For the route-specific-level analysis in 2013, the area near the complete street had greater pedestrian infrastructure and less pedestrian accessibility than the far area.

Table 2.
Fit Statistics for Current Replication of Cerin NEWS-A CFA

Model	χ^2	*df*	χ^2/df	CFI	RMSEA
Neighborhood NEWS-A	2906.86**	364	7.98	0.66	0.06

Note. CFI = comparative fit index; RMSEA = root mean square error of approximation. $^{**}p<.001$

Table 3.
NEWS-A Descriptive Statistics of Variables Used to Create New 6-Factor Model

	Time 1			Time 2		
Neighborhood Environment Walkability Scale- Abbreviated (NEWS-A) Items and Item Numbers	*M*	*SD*	Factor loading	*M*	*SD*	Factor loading
Access						
1. Stores are within easy walking distance of my home	3.13	0.88	0.59	3.24	0.82	0.61
2. There are many places to go within easy walking distance of my home	3.12	0.92	0.91	3.11	0.91	0.85
3. It is easy to walk to a transit stop (bus, light rail) from my home	3.49	0.83	0.32	3.60	0.71	0.36
Street Connectivity						
4. The distance between intersections in my neighborhood is usually short (100 yards or less; the length of a football field or less)	2.86	0.97	0.40	2.82	0.93	0.45
5. There are many alternative routes for getting from place to place in my neighborhood. (I don't have to go the same way every time)	3.22	0.88	0.55	3.20	0.84	0.60
6. The streets in my neighborhood have few if any, cul-de-sacs (dead-end streets)	2.88	1.05	0.29	2.80	1.05	0.31
Infrastructure						
7. My neighborhood streets are well lit at night	2.67	0.98	0.69	2.69	0.92	0.77
8. Walkers and bikers on my neighborhood streets can be easily seen by people in their homes	3.03	0.84	0.62	2.99	0.82	0.67
9. There are crosswalks and pdesestrian signals to help walkers cross busy streets in my neighborhood.	3.03	0.95	0.46	3.09	0.89	0.51
Aesthetics						
10. There are many interesting things to look at while walking in my neighborhood	2.86	0.92	0.78	2.90	0.89	0.81
11. There are many attractive natural sights in my neighborhood (such as landscaping, scenic views)	2.55	0.97	0.85	2.63	0.93	0.85
12. There are attractive buildings/homes in my neighborhood	2.63	0.94	0.74	2.66	0.90	0.78
Traffic Hazards						
13. There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood	2.21	0.89	0.61	2.19	0.84	0.60
14. The speed of traffic on most nearby streets is usually slow (30 mph or less) (reversed)	2.17	0.97	0.40	2.17	0.93	0.38
15. Most drivers exceed the psoted speed limits while driving in my neighborhood	2.84	0.91	0.39	2.83	0.87	0.38
Crime						
16. There is a high crime rate in my neighborhood	2.42	0.89	0.66	2.41	0.89	0.68
17. The crime rate in my neighborhood makes it unsafe to go on walks at night	2.40	0.99	0.61	2.43	0.98	0.64
18. Gang activity	0.00	1.00	0.79	0.00	1.00	0.82
19. Groups of teenagers or adults hanging out in the neighborhood causing trouble	0.00	1.00	0.79	0.00	1.00	0.81
20. House or place you suspect drug dealing occurs	0.00	1.00	0.77	0.00	1.00	0.78

Note: NEWS-A = Neighborhood Environment Walkability Scale Abbreviated. *N*=536. Response choices for items 1-17: (1) strongly disagree (2) somewhat disagree (3) somewhat agree (4) strongly agree. Z-scores were used for items 18-20. Instructions for responding to items 18-20: "Please rate the following problems you might have seen in this area in the last 12 months" ratings ranged 1=no problem 10=big problem. Factor loadings are standardized and were determined using AMOS Graphics version 22.

Table 4.
Fit Statistics for Current NEWS-A and Route-Specific NEWS-A CFA

Model	χ^2	*df*	χ^2/df	CFI	RMSEA
Neighborhood NEWS-A	845.37**	339	2.49	0.91	0.04
Route-Specific NEWS-A	526.90**	230	2.29	0.95	0.04

Note. CFI = comparative fit index; RMSEA = root mean square error of approximation. ***p*<.001

Table 5.

Variables Used to Create IMI and NEWS-A Factors

IMI Items:	NEWS-A Items:
Access	**Access**
1. Presence of sidewalk buffer	1. Stores are within easy walking distance of my home
2. Presence of sidewalk	2. There are many places to go within easy walking distance of my home
3. Presence of curbcut	3. It is easy to walk to a transit stop (bus, light rail) from my home
4. Are sidewalks shaded by trees?	
Infrastructure	**Infrastructure**
5. Are crosswalks present?	7. My neighborhood streets are well lit at night
6. Presence of white painted lines at crosswalk	8. Walkers and bikers on my neighborhood streets can be easily seen by people in their homes
7. Presence of yellow pedestrian crossing sign	9. There are crosswalks and pdesestrian signals to help walkers cross busy streets in my neighborhood.
8. Presence of zebra striping at crosswalk	
9. Presence of a pedestrian walk signal	
10. Presence of a median	
11. At least 50% of block has buildings	
12. Presence of different road surface or paving	
13. Presence of a traffic signal	
Aesthetics	**Aesthetics**
14. Presence of a front porch	10. There are many interesting things to look at while walking in my neighborhood
15. Presence of a detached single family home	11. There are many attractive natural sights in my neighborhood (such as landscaping, scenic views)
16. Presence of flowers	12. There are attractive buildings/homes in my neighborhood
18. Absense of predominant driveways	
20. Presence of street trees	
21. Presence of historic buildings	
22. Presence of decorative/unique sidewalk	
23. Presence of Townhome/condo with 3 units or more	
Traffic Hazards	**Traffic Hazards**
24. Speed limit above 25 mph	13. There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood
25. Presence of three or more lanes of traffic	14. The speed of traffic on most nearby streets is usually slow (30 mph or less) (reversed)
26. Absence of a speed bump	15. Most drivers exceed the psoted speed limits while driving in my neighborhood
27. Presence of a parking lot	
28. Block is inconvenient to cross	
29. Block is unsafe to cross	
30. Low amount of parked vehicles along street	
31. No bike lanes present	
32. Absence of street and traffic signs	
33. Absence of traffic/pedestrian signals	
Crime indicators	**Crime indicators**
34. Blank walls are present on block	16. There is a high crime rate in my neighborhood
35. Closed view	17. The crime rate in my neighborhood makes it unsafe to go on walks at night
36. Presence of litter	18. Gang activity
37. Presence of bars on windows	19. Groups of teenagers or adults hanging out in the neighborhood causing trouble
38. Presence of graffiti	20. House or place you suspect drug dealing occurs
39. Absence of outdoor lighting	
40. Presence of freeway/overpa	

Table 6.
Correlations of Scales Between 2012 and 2013 and NEWS-A with IMI Scale Correlations

	Scale correlations from 2012 to 2013	NEWS-A with IMI scale correlations	
		2012 *r*	2013 *r*
Neighborhood NEWS-A			
Crime Indicators	0.68**	0.16**	0.27**
Traffic Hazards	0.60**	0.18**	0.07
Aesthetics	0.66**	0.29**	0.23*
Infrastructure	0.55**	0.23**	0.04
Street Connectivity	0.52**	-	-
Accessibility	0.47**	0.19**	0.14**
Route-specific NEWS-A			
Crime Indicators	0.63**	-0.16**	-0.16**
Traffic Hazards	0.63*	-0.12**	-0.07
Aesthetics	0.65**	0.24**	0.12**
Infrastructure	0.60**	0.15**	0.01
Accessibility	0.63**	-0.07	-0.05
Home block IMI			
Crime Indicators	0.08		
Traffic Hazards	0.59**		
Aesthetics	0.46**		
Infrastructure	0.58**		
Accessibility	0.60**		
Neighborhood IMI			
Crime Indicators	0.46**		
Traffic Hazards	0.82**		
Aesthetics	0.86**		
Infrastructure	0.81**		
Accessibility	0.87**		

Note. ** indicates correlation is significant at the .01 level (2-tailed). *N*=536. Correlations are Pearson's Correlations

Table 7.

Logistic Regression Results for Neighborhood Level Analysis of Active Transportation on the Complete Street in 2012 and 2013

	2012				2013			
	OR	95% CI	*p*	Nagelkerke R^2	OR	95% CI	*p*	Nagelkerke R^2
IMI Crime Indicators	0.96	(0.77, 1.20)	0.72	0.08	1.27	(1.05, 1.54)	0.02	0.08
NEWS-A Crime Indicators	1.19	(0.97, 1.46)	0.09	0.09	1.02	(0.84, 1.23)	0.86	0.07
Combined IMI and NEWS-A Crime Indicators				0.09				0.08
IMI	0.93	(0.74, 1.16)	0.52		1.23	(1.05, 1.59)	0.01	
NEWS-A	1.21	(0.98, 1.48)	0.08		0.95	(0.77, 1.15)	0.58	
IMI Traffic Hazards	1.17	(0.95, 1.44)	0.15	0.09	1.05	(0.87, 1.27)	0.60	0.07
NEWS-A Traffic Hazards	1.14	(0.93, 1.40)	0.22	0.08	0.94	(0.77, 1.13)	0.50	0.07
Combined IMI and NEWS-A Traffic Hazards				0.09				0.07
IMI	1.15	(0.93, 1.42)	0.21		1.06	(0.88, 1.28)	0.56	
NEWS-A	1.11	(0.90, 1.37)	0.32		0.93	(0.77, 1.13)	0.47	
IMI Aesthetics	0.63	(0.51, 0.79)	0.001	0.13	0.56	(0.46, 0.70)	0.001	0.15
NEWS-A Aesthetics	0.89	(0.72, 1.10)	0.26	0.08	1.07	(0.89, 1.30)	0.50	0.07
Combined IMI and NEWS-A Aesthetics				0.15				0.15
IMI	0.58	(0.46, 0.73)	0.001		0.54	(0.44, 0.67)	0.001	
NEWS-A	1.03	(0.82, 1.29)	0.75		1.20	(0.98, 1.47)	0.08	
IMI Infrastructure	0.65	(0.51, 0.82)	0.001	0.12	0.86	(0.70, 1.04)	0.12	0.07
NEWS-A Infrastructure	0.93	(0.75, 1.15)	0.48	0.08	1.19	(0.99, 1.45)	0.07	0.07
Combined IMI and NEWS-A Infrastructure				0.13				0.08
IMI	0.63	(0.50, 0.80)	0.001		0.85	(0.70, 1.04)	0.11	
NEWS-A	1.00	(0.80, 1.26)	0.97		1.20	(0.99, 1.45)	0.07	
IMI Accessibility	0.62	(0.50, 0.75)	0.001	0.14	0.53	(0.43, 0.66)	0.001	0.16
NEWS-A Accessibility	1.05	(0.86, 1.30)	0.64	0.08	1.11	(0.91, 1.34)	0.3	0.07
Combined IMI and NEWS-A Accessibility				0.14				0.17
IMI	0.61	(0.50, 0.75)	0.001		0.53	(0.43, 0.65)	0.001	
NEWS-A	1.10	(0.89, 1.40)	0.38		1.16	(0.95, 1.41)	0.15	

Note. All analyses controlled for gender, Hispanic ethnicity, car access, and household income.

Table 8.

Logistic Regression Results for Route-Specific Level Analysis of Active Transportation on the Complete Street in 2012 and 2013

	2012				2013			
	OR	95% CI	*p*	*Nagelkerke* R^2	OR	95% CI	p	*Nagelkerke* R^2
IMI Crime Indicators	0.85	(0.68, 1.06)	0.14	0.09	1.08	(0.89, 1.31)	0.42	0.07
NEWS-A Crime Indicators	0.96	(0.78, 1.18)	0.68	0.08	0.99	(0.82, 1.21)	0.95	0.07
Combined IMI and NEWS-A Crime Indicators				0.09				0.07
IMI	0.84	(0.70, 1.05)	0.12		1.08	(0.89, 1.31)	0.42	
NEWS-A	0.93	(0.76, 1.15)	0.52		1.01	(0.83, 1.22)	0.95	
IMI Traffic Hazards	1.21	(0.99, 1.48)	0.06	0.09	1.28	(1.06, 1.56)	0.01	0.09
NEWS-A Traffic Hazards	0.99	(0.80, 1.21)	0.89	0.08	1.20	(0.99, 1.46)	0.07	0.08
Combined IMI and NEWS-A Traffic Hazards				0.09				0.1
IMI	1.22	(0.99, 1.49)	0.06		1.30	(1.07, 1.58)	0.008	
NEWS-A	1.01	(0.82, 1.25)	0.92		1.24	(1.00, 1.52)	0.05	
IMI Aesthetics	0.70	(0.57, 0.87)	0.001	0.11	0.68	(0.56, 0.83)	0.001	0.1
NEWS-A Aesthetics	0.81	(0.65, 1.01)	0.06	0.09	1.12	(0.92, 1.35)	0.26	0.07
Combined IMI and NEWS-A Aesthetics				0.11				0.1
IMI	0.72	(0.58, 0.89)	0.003		0.67	(0.55, 0.82)	0.001	
NEWS-A	0.87	(0.70, 1.10)	0.24		1.16	(0.95, 1.40)	0.14	
IMI Infrastructure	0.91	(0.73, 1.13)	0.40	0.08	1.28	(1.06, 1.55)	0.01	0.09
NEWS-A Infrastructure	0.94	(0.76, 1.16)	0.57	0.08	1.20	(0.98, 1.46)	0.07	0.07
Combined IMI and NEWS-A Infrastructure				0.09				0.1
IMI	0.92	(0.73, 1.14)	0.44		1.29	(1.06, 1.55)	0.009	
NEWS-A	0.96	(0.77, 1.18)	0.67		1.18	(0.97, 1.44)	0.10	
IMI Accessibility	0.85	(0.70, 1.02)	0.08	0.09	0.73	(0.61, 0.88)	0.001	0.1
NEWS-A Accessibility	1.01	(0.82, 1.25)	0.91	0.08	1.21	(0.99, 1.47)	0.06	0.08
Combined IMI and NEWS-A Accessibility				0.09				0.1
IMI	0.84	(0.70, 1.02)	0.08		0.74	(0.62, 0.88)	0.001	
NEWS-A	0.98	(0.81, 1.23)	0.98		1.19	(0.98, 1.45)	0.09	

Note. All analyses controlled for gender, Hispanic ethnicity, car access, and household income.

Table 9.
Logistic Regression Results for 2012 Walkability Indicators Predicting Active Transportation on the Complete Street in 2013

	Neighborhood Level Indicators				Route-Specific Indicators			
	OR	95% CI	*p*	Nagelkerke R^2	OR	95% CI	*p*	Nagelkerke R^2
IMI Crime Indicators	0.96	(0.80, 1.17)	0.70	0.08	0.96	(0.79, 1.16)	0.66	0.08
NEWS-A Crime Indicators	1.00	(0.81, 1.18)	0.83	0.08	1.02	(0.84, 1.23)	0.88	0.08
Combined IMI and NEWS-A Crime Indicators				0.08				0.08
IMI	0.97	(0.80, 1.18)	0.73		0.96	(0.79, 1.17)	0.68	
NEWS-A	0.99	(0.81, 1.19)	0.88		1.01	(0.83, 1.23)	0.93	
IMI Traffic Hazards	1.05	(0.87, 1.28)	0.59	0.08	1.15	(0.95, 1.38)	0.15	0.09
NEWS-A Traffic Hazards	1.06	(0.88, 1.28)	0.56	0.08	1.14	(0.94, 1.38)	0.19	0.09
Combined IMI and NEWS-A Traffic Hazards				0.08				0.09
IMI	1.04	(0.86, 1.27)	0.65		1.16	(0.97, 1.41)	0.11	
NEWS-A	1.05	(0.87, 1.27)	0.62		1.16	(0.96, 1.41)	0.13	
IMI Aesthetics	0.73	(0.60, 0.90)	0.002	0.11	0.66	(0.54, 0.81)	0.001	0.12
NEWS-A Aesthetics	0.91	(0.75, 1.10)	0.31	0.08	0.93	(0.76, 1.13)	0.44	0.08
Combined IMI and NEWS-A Aesthetics				0.105				0.12
IMI	0.74	(0.60, 0.91)	0.004		0.66	(0.54, 0.81)	0.001	
NEWS-A	0.98	(0.80, 1.20)	0.83		1.02	(0.83, 1.25)	0.87	
IMI Infrastructure	0.73	(0.60, 0.90)	0.003	0.10	0.94	(0.77, 1.15)	0.55	0.08
NEWS-A Infrastructure	1.07	(0.88, 1.30)	0.49	0.08	0.99	(0.82, 1.20)	0.90	0.08
Combined IMI and NEWS-A Infrastructure				0.11				0.08
IMI	0.71	(0.57, 0.86)	0.001		0.94	(0.77, 1.15)	0.56	
NEWS-A	1.16	(0.95, 1.41)	0.15		1.00	(0.82, 1.21)	0.98	
IMI Accessibility	0.66	(0.55, 0.80)	0.001	0.13	0.83	(0.70, 0.99)	0.05	0.09
NEWS-A Accessibility	0.84	(0.70, 1.01)	0.06	0.09	1.19	(0.98, 1.44)	0.09	0.09
Combined IMI and NEWS-A Accessibility				0.133				0.1
IMI	0.67	(0.55, 0.81)	0.001		0.84	(0.70, 1.01)	0.07	
NEWS-A	0.85	(0.71, 1.03)	0.10		1.17	(0.96, 1.43)	0.12	

Note. All analyses controlled for gender, Hispanic ethnicity, car access, and household income.

DISCUSSION

The measures of both the perceived walkability measured with NEWS-A and objectively rated walkability measured with IMI have been thoroughly examined and tested in this study and these measures have been reliably rated, and are fairly consistent in their outcomes. An interesting trend was that even though the NEWS-A subjective measures and the IMI objectively rated measures are often significantly and positively correlated (see Table 6), active transportation to the complete street is only significantly related to objective measures. As summarized below, the objective features of poor walkability are often key predictors of active transportation use on the complete street.

Perceived walkability, measured by NEWS-A, was never significantly related to active transportation on the complete street. However, an interesting trend emerged in the data for this study. NEWS-A predictors, across both neighborhood and route-specific measures, tended to be positively but insignificantly associated with the likelihood of active transportation to the complete street. In contrast, IMI predictors tended to be negatively and significantly associated with the likelihood of active transportation on the complete street. The only exceptions to this were the IMI scales of crime indicators and traffic hazards; they tended to have positive but insignificant relationships with the likelihood of active transportation on the complete street. In reviewing prior research on concordance or discordance between objective and subjective measures of walkability, none of the studies identified discussed the direction of relationships between objective and subjective measures of walkability and physical activity or active transportation (Arvidsson et al., 2012; Ball et al., 2008; Gebel et al., 2009; Leslie et al., 2010; Macintyre et al., 2008). Future research is needed to determine whether residents tend to be more positive in evaluations of perceived walkability despite some negative objectively assessed walkability measures.

The results of this study indicate that when conditions offer poor aesthetics, less pedestrian infrastructure, and less pedestrian accessibility, the more likely it is that a participant would use active transportation on the complete street. Other research has also found that IMI scales did not show expected relationships with walking behavior (Schopflocher, VanSpronsen, & Nykiforuk, 2014). These unexpected relationships may be caused by purpose of walking, for example instrumental walking (e.g., walking for transportation compared to walking for leisure). Some research has found evidence that walking for transportation was observed more in places that were rated as having more sidewalk defects, graffiti, and litter (Suminski et al., 2008). Suminski et al. also mention that this is likely caused by the pull of destinations and state that walking for transport is positively associated with the presence of destinations. This research could indicate that people may be willing to walk through unfavorable areas (such as those with poor aesthetics, less pedestrian infrastructure, and less pedestrian accessibility) if their destination is on a street that offers multiple means of transportation or several different destination types. The complete street offered a major transportation and retail/service corridor that may have had sufficiently attractive destinations and transit options to draw residents despite their less ideal walking supports.

In order to illustrate how each IMI scale is associated with the likelihood of active transportation on the complete street, a series of probabilities were calculated that represent three different walkability scenarios as measured by the IMI: low walkability, average walkability, and high walkability. Each of the IMI scales used in these predictions was standardized with z-score transformations, and low walkability was calculated at one standard deviation below the mean, average walkability was calculated at the mean, and high walkability was calculated one standard deviation above the mean. Once the predicted probabilities were calculated, the results were graphed. Figures 1 and 2 graph the predicted probability of active transportation on the complete street across these three walkability scenarios in 2012 and 2013, respectively. In 2012, walking was more likely when IMI scales indicated poorer aesthetics, less pedestrian infrastructure, and lower pedestrian accessibility. In 2013, walking was more likely when IMI scales indicated poorer aesthetics and less pedestrian accessibility. Results show that poor accessibility and aesthetics double the probability of active transportation on the complete street compared to when the neighborhood offers good pedestrian accessibility and aesthetics in 2012. These probabilities get slightly stronger in 2013. For more detailed information, Table 10 indicates the direction of relationship for IMI items that are significantly related to active transportation on the complete street.

It was hypothesized that creating smaller, more route-specific measures of walkability would lead to more powerful correlations between objective and subjective measures of walkability. This hypothesis was not supported by the data for this study. When examining the correlations between objective and subjective measures of walkability, neighborhood-level measures had more powerful relationships with each other than the route-specific measures had with each other. Perhaps residents develop neighborhood-wide perceptions that correspond to neighborhood features better than the more microlevel features associated with routes. In addition, residents might have greater familiarity with the neighborhood than with the specific route about which they were questioned. Future research might compare neighborhood and route-level perceptions and objectively rated measures for routes that are most frequently taken.

Study strengths and limitations

Few studies have compared objectively rated and subjectively perceived predictors of walkability as this study does. Additionally, this study uses objectively rated physical activity and use of the complete street, which has been shown to be more accurate than self-reported amounts of physical activity or self-reported trips of physical activity. However, the study is limited by the lack of an entire route of objective walkability measures for the route-specific analysis. This study relied on the IMI ratings of a participants' home block face instead of having composite scores of IMI ratings that trace the route that a participant may take to a light rail stop on the complete street. Future research should examine an entire rating of route-specific objective walkability as this may help strengthen the route-specific-level of analysis and may lead to interesting comparisons with neighborhood-level features.

The results of this study should not be used to recommend that poor walkability design features encourage walking to transit. It is not known how many people failed to walk due to these conditions of poor aesthetics, less pedestrian infrastructure, and less pedestrian accessibility. Urban designers may need to acknowledge that where many people converge on transit lines is where the physical supports for walking may not be ideal, as in the aim of the complete street renovation to include better sidewalks complete with large buffers to separate pedestrians from traffic. Although such improvements occur along the complete street itself, the improvements do not extend to the surrounding neighborhood from which residents access the complete street. The improvements and diversity of destinations on the complete street may be attractive enough to draw nearby residents to the complete street, even if they have to walk through unfavorable areas to get there.

It is also interesting that perceived walkability measured with the NEWS-A and objectively rated walkability measured with the IMI were often significantly and positively correlated (see Table 6) but active transportation on the complete street was only significantly related to objective conditions. There are many psychological or cultural factors that might mean that residents do not “read” the physical conditions in the same way that IMI raters did. This may also explain why some research finds discordance between perceived walkability and objectively measured walkability. Perhaps walking purpose makes people more comfortable with or accommodated to less than ideal environmental walking conditions.

It is recommended that future research examines the route-specific analysis more in-depth. It could be that the use of only the IMI ratings of a participant’s home block face weakened the results of the route-specific analysis. Future research should also include objective and subjective types of measures for walkability. Studies that have examined concordance or discordance between objective and subjective measures note the potential importance of both types of scales if researchers wish to more completely understand motivations and barriers to neighborhood physical activity (Arvidsson et al., 2012; Ball et al., 2008).

The findings in this study clearly indicate that there are connections between the environment and active transportation. However, more research is needed for urban planners and transportation engineers to find better ways to support and encourage active transportation in urban settings, especially when relationships may seem counter-intuitive as the results of this study and other studies have shown (Lopez & Hynes, 2006; Schulz et al., 2013; Suminski et al., 2008). As our society becomes more physically inactive, the importance of this work grows. Physical inactivity has been linked to a number of poor health outcomes like obesity, heart disease, diabetes, stroke, and some types of cancers (Barnes, 2012; Manson et al., 2004; Must et al., 1999; Patterson et al., 2004; U.S. Department of Health and Human Services, 2000). To combat these risks, other research has shown that increased levels of active transportation have been linked to better health outcomes like lower BMI and more cardio-respiratory benefits (De Nazelle et al., 2011; Frank et al., 2006; Shephard, 2008). The more we understand the relationships between the environment and physical activity, the more we can promote healthy living with increased amounts of physical activity and active transportation.

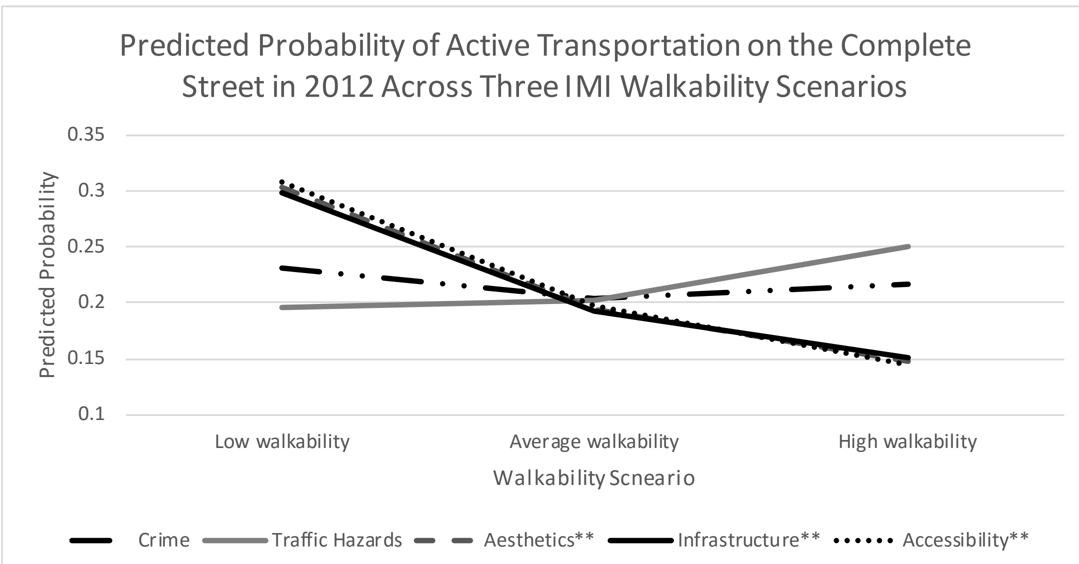

Figure 1 . ** Indicates significantly related to active transportation on the complete street.

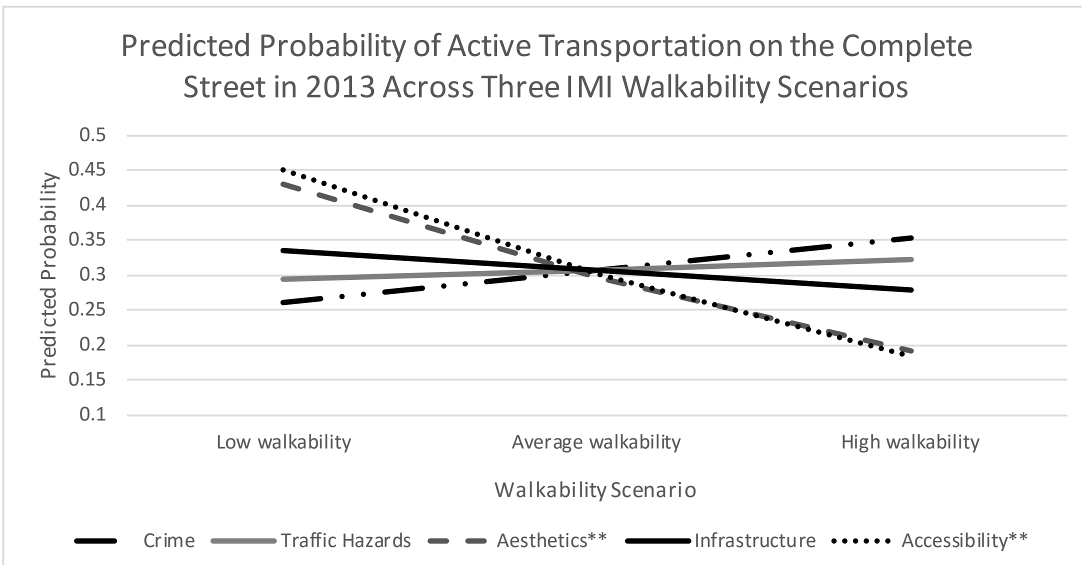

Figure 2 . ** Indicates significantly related to active transportation on the complete street.

Table 10.
Relationships Between Active Transportation on the Complete Street and Individual IMI Items From Significant Summary Scores: Logistic Coefficients and Spearman Correlations

2012 Neighborhood			2013 Neighborhood		
	Coefficient	***r***		**Coefficient**	***r***
Pedestrian Accessibility			**Pedestrian Accessibility**		
Presence of sidewalk buffer	7.44	-0.17**	Presence of sidewalk	-4.48	-0.06
Presence of sidewalk	-5.89	-0.25**			
Are sidewalks shaded by trees?	-5.51	-0.23**			
Pedestrian Infrastructure			**Pedestrian Infrastructure**		
Presence of white painted lines at crosswalk	-11.60	-0.12**	Presence of zebra striping at crosswalk	4.5	0
Presence of different road surface or paving	-8.20	-0.11*	At least 50% of block has buildings	-4.48	-0.20**
Presence of a traffic signal	8.87	0.10*			
Aesthetics			**Aesthetics**		
Presence of flowers	6.52	-0.13**	Absense of predominant driveways	-1.63	-0.09*
Absense of predominant driveways	0.88	0.14**	Presence of street trees	-1.81	-0.12**
Presence of street trees	-7.59	-0.21**			
2012 Route-Specific			**2013 Route-Specific**		
Pedestrian Accessibility			**Pedestrian Accessibility**		
Presence of curbcut	-0.91	-0.11**	Presence of sidewalk buffer	-0.65	-0.10*
			Are sidewalks shaded by trees?	-0.83	-0.17**
Pedestrian Infrastructure			**Pedestrian Infrastructure**		
Presence of white painted lines at crosswalk	-1.87	-0.08	No individual items were significant		
At least 50% of block has buildings	1.11	0.11*			
Presence of a traffic signal	2.13	0.18**			
Aesthetics			**Aesthetics**		
Presence of historic buildings	-0.97	-0.12**	Presence of flowers	0.76	0.03
			Presence of Townhome/condo with 3 units or more	-0.57	-0.06

Note. All IMI coefficients are significant at the .05 level. Spearman correlations significance levels are shown as * = .05 and ** = .01

REFERENCES

Adams, M. A., Ryan, S., Kerr, J., Sallis, J. F., Patrick, K., Frank, L. D., & Norman, G. J. (2009). Validation of the Neighborhood Environment Walkability Scale (NEWS) items using geographic information systems. *Journal of Physical Activity and Health, 6*(SUPPL. 1), S113-S123.

Arvidsson, D., Kawakami, N., Ohlsson, H., & Sundquist, K. (2012). Physical activity and concordance between objective and perceived walkability. *Medicine and Science in Sports and Exercise, 44*(2), 280-287. doi:10.1249/MSS.0b013e31822a9289

Ball, K., Jeffery, R. W., Crawford, D. A., Roberts, R. J., Salmon, J., & Timperio, A. F. (2008). Mismatch between perceived and objective measures of physical activity environments. *Preventive Medicine, 47*(3), 294-298.

Barnes, A. S. (2012). Obesity and sedentary lifestyles: Risk for cardiovascular disease in women. *Texas Heart Institute Journal, 39*(2), 224.

Belsley, D. A., Kuh, E., & Welsch, R. E. (1980). *Regression diagnostics: Identifying influential data and sources of collinearity*. New York: Wiley.

Boarnet, M. G., Forsyth, A., Day, K., & Oakes, J. M. (2011). The street level built environment and physical activity and walking: Results of a predictive validity study for the Irvine Minnesota Inventory. *Environment and Behavior, 43*(6), 735-775.

Brown, B. B., Werner, C. M., Smith, K. R., Tribby, C. P., & Miller, H. J. (2014). Physical activity mediates the relationship between perceived crime safety and obesity. *Preventive Medicine, 66*, 140-144.

Cerin, E., Conway, T. L., Saelens, B. E., Frank, L. D., & Sallis, J. F. (2009). Cross-validation of the factorial structure of the Neighborhood Environment Walkability Scale (NEWS) and its abbreviated form (NEWS-A). *International Journal of Behavioral Nutrition and Physical Activity, 6*. doi:10.1186/1479-5868-6-32

Cerin, E., Saelens, B. E., Sallis, J. F., & Frank, L. D. (2006). Neighborhood environment walkability scale: Validity and development of a short form. *Medicine and Science in Sports and Exercise, 38*(9), 1682-1691. doi:10.1249/01.mss.0000227639.83607.4d

Day, K., Boarnet, M., Alfonzo, M., & Forsyth, A. (2006). The Irvine–Minnesota inventory to measure built environments: development. *American Journal of Preventive Medicine, 30*(2), 144-152.

De Bourdeaudhuij, I., Teixeira, P. J., Cardon, G., & Deforche, B. (2005). Environmental and psychosocial correlates of physical activity in Portuguese and Belgian adults. *Public Health Nutrition, 8*(7), 886-895. doi:10.1079/PHN2005735

De Nazelle, A., Nieuwenhuijsen, M. J., Antó, J. M., Brauer, M., Briggs, D., Braun-Fahrlander, C., . . . Fruin, S. (2011). Improving health through policies that promote active travel: A review of evidence to support integrated health impact assessment. *Environment International, 37*(4), 766-777.

Dills, J. E., Rutt, C. D., & Mumford, K. G. (2012). Objectively measuring route-to-park walkability in Atlanta, Georgia. *Environment and Behavior, 44*(6), 841-860.

Duncan, M. J., Spence, J. C., & Mummery, W. K. (2005). Perceived environment and physical activity: A meta-analysis of selected environmental characteristics. *International Journal of Behavioral Nutrition and Physical Activity, 2*(1), 11.

Dunton, G. F., Kaplan, J., Wolch, J., Jerrett, M., & Reynolds, K. D. (2009). Physical environmental correlates of childhood obesity: A systematic review. *Obesity Reviews, 10*(4), 393-402.

Foster, S., & Giles-Corti, B. (2008). The built environment, neighborhood crime and constrained physical activity: An exploration of inconsistent findings. *Preventive Medicine, 47*(3), 241-251. doi:10.1016/j.ypmed.2008.03.017

Foster, S., Knuiman, M., Hooper, P., Christian, H., & Giles-Corti, B. (2014). Do changes in residents' fear of crime impact their walking? Longitudinal results from RESIDE. *Preventive Medicine, 62*, 161-166.

Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. (2006). Many pathways from land use to health: Associations between neighborhood walkability and active transportation, body mass index, and air quality. *Journal of the American Planning Association, 72*(1), 75-87.

Gasevic, D., Vukmirovich, I., Yusuf, S., Teo, K., Chow, C., Dagenais, G., & Lear, S. A. (2011). A direct assessment of "Obesogenic" built environments: Challenges and recommendations. *Journal of Environmental and Public Health, 2011*. doi:10.1155/2011/161574

Gebel, K., Bauman, A., & Owen, N. (2009). Correlates of non-concordance between perceived and objective measures of walkability. *Annals of Behavioral Medicine, 37*(2), 228-238.

Giles-Corti, B., Knuiman, M., Timperio, A., Van Niel, K., Pikora, T. J., Bull, F. C. L., . . . Bulsara, M. (2008). Evaluation of the implementation of a state government community design policy aimed at increasing local walking: Design issues and baseline results from RESIDE, Perth Western Australia. *Preventive Medicine, 46*(1), 46-54. doi:10.1016/j.ypmed.2007.08.002

Hoehner, C. M., Ramirez, L. K. B., Elliott, M. B., Handy, S. L., & Brownson, R. C. (2005). Perceived and objective environmental measures and physical activity among urban adults. *American Journal of Preventive Medicine, 28*(2), 105-116.

Kim, S., Ulfarsson, G. F., & Todd Hennessy, J. (2007). Analysis of light rail rider travel behavior: Impacts of individual, built environment, and crime characteristics on transit access. *Transportation Research Part A: Policy and Practice, 41*(6), 511-522. doi:10.1016/j.tra.2006.11.001

Leslie, E., Sugiyama, T., Ierodiaconou, D., & Kremer, P. (2010). Perceived and objectively measured greenness of neighbourhoods: Are they measuring the same thing? *Landscape and Urban Planning, 95*(1), 28-33.

Lopez, R. P., & Hynes, H. P. (2006). Obesity, physical activity, and the urban environment: Public health research needs. *Environmental Health, 5*(1), 25.

Macintyre, S., Macdonald, L., & Ellaway, A. (2008). Lack of agreement between measured and self-reported distance from public green parks in Glasgow, Scotland. *International Journal of Behavioral Nutrition and Physical Activity, 5*(1), 26.

Manson, J. E., Skerrett, P. J., Greenland, P., & VanItallie, T. B. (2004). The escalating pandemics of obesity and sedentary lifestyle: A call to action for clinicians. *Archives of Internal Medicine, 164*(3), 249-258.

Mathews, A. E., Colabianchi, N., Hutto, B., Pluto, D. M., & Hooker, S. P. (2009). Pedestrian activity among California adults. *Journal of Physical Activity & Health, 6*(1), 15.

McDonald, N. C. (2008). The effect of objectively measured crime on walking in minority adults. *American Journal of Health Promotion, 22*(6), 433-436.

Must, A., Spadano, J., Coakley, E. H., Field, A. E., Colditz, G., & Dietz, W. H. (1999). The disease burden associated with overweight and obesity. *Journal of the American Medical Association, 282*(16), 1523-1529.

Patterson, R. E., Frank, L. L., Kristal, A. R., & White, E. (2004). A comprehensive examination of health conditions associated with obesity in older adults. *American Journal of Preventive Medicine, 27*(5), 385-390.

Rodriguez, D. A., Merlin, L., Prato, C. G., Conway, T. L., Cohen, D., Elder, J. P., . . . Veblen-Mortenson, S. (2014). Influence of the built environment on pedestrian route choices of adolescent girls. *Environment and Behavior, 47*(4), 359-394.

Saelens, B. E., & Handy, S. L. (2008). Built environment correlates of walking: A review. *Medicine and Science in Sports and Exercise, 40*(7 Suppl), S550.

Saelens, B. E., Sallis, J. F., Black, J. B., & Chen, D. (2003). Neighborhood-based differences in physical activity: An environment scale evaluation. *American Journal of Public Health, 93*(9), 1552-1558.

Schopflocher, D., VanSpronsen, E., & Nykiforuk, C. I. (2014). Relating built environment to physical activity: Two failures to validate. *International Journal of Environmental Research and Public Health, 11*(2), 1233-1249.

Schulz, A., Mentz, G., Johnson-Lawrence, V., Israel, B. A., Max, P., Zenk, S. N., . . . Marans, R. W. (2013). Independent and joint associations between multiple measures of the built and social environment and physical activity in a multi-ethnic urban community. *Journal of Urban Health, 90*(5), 872-887.

Schumacker, R. E., & Lomax, R. G. (2016). *A beginner's guide to structural equation modeling* (4th ed. New York): Routledge Taylor & Francis Group.

Shephard, R. J. (2008). Is active commuting the answer to population health? *Sports Medicine, 38*(9), 751-758.

Sugiyama, T., Neuhaus, M., Cole, R., Giles-Corti, B., & Owen, N. (2012). Destination and route attributes associated with adults' walking: A review. *Medicine and Science in Sports and Exercise, 44*(7), 1275-1286. doi:10.1249/MSS.0b013e318247d286

Suminski, R. R., Heinrich, K. M., Poston, W. S., Hyder, M., & Pyle, S. (2008). Characteristics of urban sidewalks/streets and objectively measured physical activity. *Journal of Urban Health, 85*(2), 178-190.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine and Science in Sports and Exercise, 40*(1), 181.

U.S. Department of Health and Human Services. (2000). *The practical guide: Identification, evaluation, and treatment of overweight and obesity in adults*: Washington, DC. National Institutes of Health, National Heart, Lung, and Blood Institute, NHLBI Obesity Education Initiative, North American Association for the Study of Obesity.

Van Cauwenberg, J., De Bourdeaudhuij, I., De Meester, F., Van Dyck, D., Salmon, J., Clarys, P., & Deforche, B. (2011). Relationship between the physical environment and physical activity in older adults: A systematic review. *Health & Place, 17*(2), 458-469.

Warburton, D. E., Nicol, C. W., & Bredin, S. S. (2006). Health benefits of physical activity: The evidence. *Canadian Medical Association Journal, 174*(6), 801-809.

Werner, C. M., Brown, B. B., & Gallimore, J. (2010). Light rail use is more likely on "walkable" blocks: Further support for using micro-level environmental audit measures. *Journal of Environmental Psychology, 30*(2), 206-214. doi:10.1016/j.jenvp.2009.11.003

Widaman, K. F., & Reise, S. P. (1997). Exploring the measurement invariance of psychological instruments: Applications in the substance use domain. In *The science of prevention: Methodological advances from alcohol and substance abuse research* (pp. 281-324). Washington, DC, US: American Psychological Association