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Understanding Physical Activity through Interactions between the Built Environment and Social Cognition: A Systematic Review

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Abstract

Background: Few people in most developed nations engage in regular physical activity (PA), despite its well-established health benefits. Socioecological models highlight the potential interaction of multiple factors from policy and the built environment to individual social cognition in explaining PA. **Objective:** The purpose of this review was to appraise this interaction tenet of the socio ecological model between the built environment and social cognition to predict PA. **Methods:** Eligible studies were published in peer-reviewed journals in the English language that included any tests of interaction between social cognition and the built environment with PA. Literature searches were concluded in October 2017 using five common databases. Findings were grouped by type of PA outcomes (leisure, transportation, total PA and total moderate-vigorous PA), then grouped by the type of interactions between social cognitive and built environment constructs. **Results:** The initial search yielded 308 hits initially, which was reduced to 22 independent studies of primarily high to medium quality after screening for eligibility criteria. The interaction tenet of the socioecological model was not supported for overall moderate-to-vigorous PA and total PA. By contrast, while there was heterogeneity of findings for leisure-time PA, environmental accessibility/convenience interacted with intention and environmental aesthetics interacted with affective judgments to predict leisure time PA. Interactions between the built environment and social cognition in PA for transport are limited, with current results failing to support an effect. **Conclusions:** The results provide some support for interactive aspects of the built environment and social cognition in leisure-time PA and thus highlight potential areas for integrated intervention of individual and environmental change.

Key Points

-This is the first review of the interaction tenet of the socioecological model between individual social cognition and the built environment in the physical activity domain.

- The interaction tenet of the socioecological model was not supported for overall moderate-to-vigorous physical activity, total physical activity or transport physical activity.

- Environmental accessibility/convenience positively interacted with physical activity intention and environmental aesthetics negatively interacted with affective judgments to predict leisure time physical activity. This supports a multi-level intervention approach to some aspects of leisure-time physical activity.

1. Introduction

Regular physical activity (PA) has been established as critical in the primary prevention and rehabilitation of most major chronic diseases in adults such as heart disease, type 2 diabetes, several cancers and musculoskeletal disorders as well major psychological disorders such as anxiety and depression (1, 2). Among children, regular PA and high physical fitness protect against high blood pressure, high blood cholesterol, metabolic syndrome, low bone density, depression, and obesity (3) and help form the behavioral patterns necessary to maintain physical health into adulthood. In adulthood, PA consistently shows a positive association with broader constructs such as perceived quality of life and feelings of wellbeing(4). Unfortunately, few people in most developed nations engage in regular PA (5). For example, in North America, it has been estimated that less than 20% of the population are meeting PA guidelines recommended for these health benefits (6, 7). Furthermore, a growing body of literature contends that participating in PA even at half the recommended guidelines can reduce mortality and increase health related fitness (8). A sound understanding of the antecedents of regular PA at all levels of intensity is needed to inform effective promotion policies (9).

Theoretical frameworks are useful organizing structures to understand and identify the antecedents to health behaviors (10). A socioecological approach to understanding PA has proven very helpful over the last two decades (11). Socioecological models posit that behavior is influenced by multiple levels of different aspects ranging from higher-level policy and built environment (e.g., characteristics of the neighborhood in which an individual resides, works, or otherwise spends time) to individual motivations, demographic, and biological factors (12, 13). This approach also allows for a broad understanding of PA which often occurs even within a single individual across several contexts such as occupation/work, transport and leisure (14).

Application of the social ecological approach to PA has highlighted several key environmental correlates such as land-mix use, street or pedestrian network connectivity, safety, quality of PA infrastructure, and aesthetics (15-19). Similarly, social cognitive constructs at the individual level, such as self-efficacy, intention, and affective judgments have amassed considerable support as reliable correlates of PA (2, 20-23).

While this broad scope of potential antecedents is a strength of the socioecological approach, the framework also includes some tenets for how these various factors may affect PA (24). The influence of the built environment on PA may be indirect, through individual-level cognitions (25, 26), whereby perceptions of built environment are related to social cognitive factors which in turn are related to PA. For example, Fleig et al. (27) showed that the effects of street connectivity and land-mix use on PA were mediated completely through perceptions of behavioral control in a sample of older adults. The influence of the environment on PA may also be direct and independent of social cognitions, which may be indicative of more automatic activations such as habits (28). For example, Rhodes et al. (29) showed that land mix use in the form of convenient access to retail shops predicted walking behavior independent of walking intentions.

One of the lesser examined tenets of socioecological models, however, is the potential for interactions across multiple levels of influence on behavior (24). There may be interplay between individual-level factors and the environment and understanding interactive effects is important especially for intervention development and implementation. For example, an individual's self-efficacy for PA may have limited association with PA among individuals living in low walkable neighborhoods, but individuals residing in high walkable neighborhoods with high self-efficacy might be significantly more active than those with low self-efficacy (see Figure 1 hypothesis A).

It could be that interventions to enhance social cognition will be more effective among people located in physical settings that enable rather than restrict PA (30). Given the synchronous nature of interactions, interventions improving the built environment could be more effective when supported by promotion efforts that also seek to improve an individual's social cognitions around PA (e.g., increase motivation). Alternately, individuals with lower levels of PA motivation may benefit from the presence of settings that better enable PA more than their counterparts because the former would have fewer environmental barriers to overcome (see Figure 1 hypothesis B) (31). Then the interaction between the environment and social cognition would be negative, whereby those with lower positive social cognitions would benefit from more supportive environmental attributes, with limited effect among those with more positive social cognitions around PA.

Despite the burgeoning research using the socio-ecological model to understand PA, and several separate reviews on the built environment (15, 17-19) and social cognitive (2, 20, 21, 23) levels of the framework, we are not aware of any review of the evidence for the interaction between these levels. Therefore, the purpose of this review was to collect and appraise all studies, among all age groups, where the interaction between social cognition and the built environment has been investigated regarding PA behavior.

2. Methods

We followed the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) guidelines when conducting and reporting this systematic review. The review was conducted between January 2017 and October, 2017.

2.1 Eligibility criteria

Eligible studies included the following characteristics: a) a measure of the built environment (perceived or objective) and b) an social cognition of PA with c) a dependent variable of PA (self-report or objective). Reports had to be published in English language peer review journals to be eligible. No specific restrictions on population, types of environments, or duration of study were imposed.

2.2 Information sources, search strategy and study selection

Articles for the present review were identified in five databases: PubMed, PsycINFO, SPORTDiscus, TRID, and MEDLINE using keywords and phrases associated with social cognitive and environmental constructs in PA (Electronic Supplementary Material Appendix S1). Limits were applied for English language. In addition, a manual cross-referencing of bibliographies was also completed. The search strategy was developed by all authors.

2.3 Data collection process and data items

Reports were exported to a dedicated EndNote database during the search process. Extracted data included authors, sample size and population, and study design. As well, data items specifically sought were 1) built environmental attributes, 2) social cognitive constructs, 3) type of PA behavior assessed, simplified to total moderate-vigorous PA (MVPA), leisure-time PA, and transportation PA, and 4) interaction findings.

2.4 Risk of bias assessment

An assessment of variability in study reports was conducted to gauge risk of bias and complete reporting in the included studies (Electronic Supplementary Material Appendix S2). To ascertain the validity, a 6-criteria methodological quality assessment based on the STROBE statement (32) was conducted for each study by CSM and RER, with any differences in scores reconciled. The instrument included six criteria answered with a yes (1) or no (0) format (i.e., did

the study report the sources and details of PA assessment and did the instruments have acceptable reliability for the specific age group?). High quality (low risk of bias) was considered with a score of five or six, moderate quality was considered with scores of three or four, and low quality (high risk of bias) was considered with scores of zero to two.

2.5 Analysis

Following initial read-throughs of the studies, themes for the types of interactions were developed. Themes were created where at least three studies had investigated a similar interaction (i.e., similar environment and social cognitive factor). This approach has been used previously in reviews (33, 34). Interaction findings were then grouped by type of PA outcomes which included activities performed for leisure, activities performed for transport, total moderate-vigorous PA, and total PA (14). This categorization approach has been performed in prior reviews with the built environment (17, 35). Among social cognitive constructs, themes were developed using the basic categorizations by Fishbein et al. (36). This included perceived benefits/attitude, enjoyment/affective judgments, perceived barriers, subjective norm, social support, self-efficacy/perceived control, and intention. Finally, categorization of the built environment constructs followed the taxonomy proposed by Alfonso (37), which included accessibility/convenience (land-mix use, connectivity, walkability, etc.), safety (crime, traffic), comfort/quality (infrastructure quality), and aesthetics/pleasurability (neighborhood greenery, interesting views, etc.). For most of the studies reviewed, environment was operationalized, either through objective measures or perceptions, as the neighborhood or area around respondents' residence.

Given that many studies use multiple indicators of a particular environmental category (e.g., objective and self-reported measures of accessibility/convenience), we compiled all tests

within each study and used the reliability of these tests to determine whether the study should be flagged as a significant interaction/no interaction in the comparisons across studies (see Table 1). Keeping with the exploratory nature of this review, we made the decision that if 50% or more of the tests in a given category (e.g., several tests of safety) within a study were significant, the paper was flagged as significant for comparisons across other studies.

Our analysis across studies collated the results of each social cognition x environmental category interaction by type of PA. Studies were coded as meeting 1) interaction hypothesis A (see Figure 1), 2) interaction hypothesis B (see Figure 1), 3) an unexpected interaction, or 4) no significant interaction. An overall assessment of the results was adapted from Sallis et al.'s (38) rubric for determining valence and consistency of findings. A particular interaction was considered to be supported if greater than 59% of studies were congruent with any given finding. No interaction was similarly supported when more than 59% of studies reported null findings. The results were considered inconclusive if less than 59% of studies aligned with any particular finding. Statistical significance ($p < 0.05$) needed to be present to conclude there was a positive or negative interaction.

Meta-analysis was precluded for two main reasons. First, there was extensive heterogeneity in the measures (e.g., format of measurement, mode), statistical tests employed, definitions of predictors (e.g., baseline, change), and study designs (e.g., cross-sectional, longitudinal), all of which impact the ability to accurately pool the studies for quantitative synthesis (39). Second, a descriptive synthesis is most appropriate when there are caveats or other idiosyncrasies specific to some studies that could change the outcome in a meta-analysis.

3. Results

3.1 Study Selection

The electronic database search and manual back-search of reference lists identified 308 potentially relevant records. The flow of papers through the subsequent screening process and reasons for exclusion according to PRISMA guidelines are outlined in Figure 2. CSM identified 245 potentially relevant publications after the removal of duplicates and any titles obviously not related to the topic. A record was excluded if it was a) a qualitative study (N = 26), b) a book review, poster abstract or dissertation (N = 8), c) in a language other than English (N = 1). Of these sources assessed for inclusion, 198 papers were excluded because they did not include a social cognitive variable (N = 149), an environmental variable (N = 29), a PA variable (N = 11), or a test of interaction (N = 9).

Potential sources were thus reduced to 47, which were reviewed by RER. Sources were further excluded if they had no test of interaction (N = 22), no built environment variable (N = 1), or if there was no clear delineation of individual and environmental variables (N = 2). If there was any doubt regarding the relevance of a paper, the full text was discussed among authors. A total of 22 papers were included in the review for analysis (Electronic Supplementary Material Appendix S3).

3.2 Study Characteristics and Measures

Table 1 describes the characteristics of the 22 studies included. The studies represented a total of 24,375 unique participants, with the sample sizes ranging from 71 to 6,014. The majority of studies comprised of adult populations (n = 15), with two specifically addressing older adults and five representing findings in youth. The majority included both males and females (n = 21). Geographical representation was broad: USA (n = 7), Belgium (n = 6), Netherlands (n = 3), Canada (3), Australia (n = 2), and one study including data from USA, Belgium, and Australia. Three studies included longitudinal designs and 20 were cross-sectional. Risk of bias analyses

showed that 13 studies could be considered medium quality, eight studies were high quality and one study was rated as low quality (see Electronic Supplementary Material Appendix S2).

Assessments of PA included self-reported measures on overall activity and walking (n = 5), accelerometer data (n = 9) and questionnaires such as the Flemish PA Questionnaire (n = 4), Godin Leisure Time Exercise Questionnaire (n = 3), International PA Questionnaire (n = 5), and Short Questionnaire to Assess Health Enhancing PA (n = 2). This breakdown of objective and self-reported measures differed by total MVPA (objective n = 7; self-reported = 2), total PA (objective n = 2; self-reported = 1), leisure-time PA (objective n = 0; self-reported = 17), and transport PA (objective n = 0; self-reported = 8). Environmental data were measured through tools such as spatial measures derived from Geographic Information Systems databases (n = 9), International PA Prevalence Study Environmental Survey Module (n = 2), the Neighborhood Environmental Walkability Survey (n = 7), and questionnaires developed for one-time use (n = 6). The breakdown of these objective and self-reported instruments was relatively similar across total MVPA (objective n = 5; self-reported = 4), total PA (objective n = 2; self-reported = 1), leisure-time PA (objective n = 6; self-reported = 11), and transport PA (objective n = 6; self-reported = 5), with some studies providing estimates using both kinds. Similarly, a large number of social cognitive theories, apart from socioecological models, were represented, such as the Attitude Social Influence Efficacy model (n = 3), Social Cognitive Theory (n = 11), Self Determination Theory (n = 2), and Theory of Planned Behaviour/Theory of Reasoned Action (n = 9).

3.3 Total Moderate and Vigorous Intensity Physical Activity

Nine studies included tests of interactions between social cognitive constructs and built environment variables to predict assessments of total MVPA (see Table 2).

Accessibility/convenience did not moderate associations between MVPA and perceived benefits (40-45), perceived barriers (30, 40-44, 46), affective judgments (42, 43), subjective norm (40, 41, 44, 45), self-efficacy (30, 40-45), intention (45), or social support (30, 40-44). There were no differences in these findings by whether the built environment measures were self-reported or objectively assessed. Taken together, there is convincing evidence that built environment aspects of accessibility/convenience do not interact with social cognition factors to explain estimates of total MVPA.

Less research on interaction tests between other built environment factors and social cognitive constructs to explain total MVPA has been conducted when compared to accessibility/convenience. Still, similar null findings are present for *PA infrastructure quality* interactions with perceived benefits (43, 45), perceived barriers (30, 43), affective judgments (43), subjective norm (45), social support (30, 43, 47), self-efficacy (30, 43, 45), and intention (45) when predicting MVPA. No interaction between *environmental aesthetics* and perceived benefits/attitude (43, 45), affective judgments (43), subjective norm (45), social support (30, 43), self-efficacy/perceived behavioral control (30, 43, 45), and intention (45) was identified. The two studies that have examined the interaction between perceived barriers and environmental aesthetics are mixed, despite similar samples of adults and accelerometry-based MVPA. One study showed no interaction (43), while the other study found an interaction in support of hypothesis A wherein participants with few perceived barriers to PA had more PA than those with more perceived barriers among residents in high aesthetics areas, but perceived barriers was less related to total MPVA in low aesthetics area residents (30). Only one study has explored *environmental safety* and interactions with social cognition. This study showed no interaction between perceived barriers and safety (46).

3.4 Leisure-Time Physical Activity

Tests of interactions between social cognitive constructs and built environment variables to predict leisure-time PA have been conducted in 17 studies (see Table 3). *Accessibility/convenience* showed a significant interaction supporting hypothesis A with intention in three (29, 48, 49) of four studies (50) . In all cases, higher accessibility to recreation facilities interacted positively with intention to predict greater PA than where recreation facility access was lower. The interaction was present for both self-reported (29, 48) and objective (49) assessments of accessibility/convenience.

There was considerable heterogeneity among the 12 studies testing interactions between self-efficacy/perceived behavioral control and environmental accessibility/convenience on leisure-time PA. Six studies, ranging from adolescents to older adults found no interaction (30, 31, 42, 48, 50, 51), while three studies had an interaction supporting hypothesis A in samples of children (41), adults (52), and older adults (44). These studies showed positive relationships between self-efficacy and leisure-time PA under conditions of higher accessibility/convenience (i.e., walkability). By contrast, two studies among adult samples reported interactions supporting hypothesis B (43, 53). In these studies, accessibility/convenience had a larger relationship with leisure-time PA under conditions of those reporting lower self-efficacy compared to higher self-efficacy. One study had an unexpected interaction where those with high self-efficacy showed a negative relationship with leisure-time PA under positive accessibility/convenience compared to those with lower self-efficacy and accessibility/convenience (54). Interestingly, this interaction with self-efficacy may be associated with whether accessibility/convenience was measured by self-reported or objective means. Seven (30, 31, 42, 48, 50, 51, 53) of the nine studies that assessed accessibility/convenience with self-report showed no interaction with self-efficacy. By

contrast, all four studies that assessed accessibility/convenience via objective means showed significant interactions; however, these had high heterogeneity and ranged from supporting hypothesis A (41, 44) and B (30) to an unexpected interaction direction (54) (i.e., those with lower self-efficacy and lower accessibility/convenience reported more leisure-time PA than those with higher values of these attributes).

Several studies showed no interaction between accessibility/convenience and perceived benefits/attitude (41, 42, 44, 48, 50, 54), perceived barriers (30, 41, 42, 44, 53, 54), affective judgments (31, 42, 43, 48), subjective norm (41, 44, 48, 54) , and social support (30, 42-44, 54) to explain leisure-time PA, but there were some discrepant findings. Ding et al. (43) showed support for interaction hypothesis B between the distance to recreation facilities/public parks and perceived benefits, where those who perceived fewer PA benefits had larger associations between convenience of these recreation facilities/parks and leisure-time walking. On the other hand, two studies (53, 55) found that accessibility/convenience moderated perceived benefits and leisure-time PA only for those higher in perceived PA benefits, and thus supported hypothesis A. One study each for perceived barriers and affective judgment found support for hypothesis B where higher levels of accessibility/convenience was associated positively with an indicator of leisure-time PA for only those low on enjoyment (53) or high on barriers (43). The discrepant subjective norm study (50) showed support for hypothesis A, as the association between accessibility and sufficient leisure-time walking was more positive in those who perceived more normative influence toward PA than those who perceived less normative influence. Finally, two studies showed evidence for interaction hypothesis B with social support, where those reporting lower social support had a larger relationship between accessibility and leisure-time PA than those who reported higher social support (41, 53). On the other hand, Gay

et al. (52) showed evidence for interaction hypothesis A between social support (i.e., relatedness) and perceived convenience of PA facilities on leisure-time PA among adults, where those with more convenient facilities reported a larger social support and PA relationship than those with less convenient facilities. No marked differences in perceived benefits, barriers, subjective norm, and social support were present by the objective or self-reported measurement of accessibility/convenience.

There was no evidence for an interaction between *environmental safety* and perceived benefits (48, 50, 53, 55, 56), perceived barriers (53), affective judgments (48, 53), subjective norm (48, 50, 56), social support (52, 53), self-efficacy/perceived behavioral control (48, 50-53, 56), and intention (29, 48, 50) to explain leisure-time PA. Indeed, there was only one study finding a significant interaction for safety and social cognitive factors. Beenackers et al. (56) found an unexpected interaction, where those who felt unsafe in their neighborhood had a larger intention-behavior relationship compared to those who felt safe.

The interaction between social cognitive factors and *PA infrastructure quality* was not significant for perceived benefits/attitude (43, 48, 53), perceived barriers [1, 2, 10] affective judgments (43, 48, 53), subjective norm (48, 50), self-efficacy (30, 43, 48, 50, 51, 53) or intention (29, 48, 50) when predicting leisure-time PA. The only significant finding, supportive of interaction hypothesis B, where the association between infrastructure quality and sufficient leisure-time walking was more positive for those with a less positive attitude toward PA (50). Social support had mixed results. Specifically, two studies found no interaction between social support and the quality of recreation infrastructure (30, 53), while two studies showed evidence for interaction hypothesis B (43, 47). This interaction identified a larger social support and

leisure-time PA relationship under conditions of lower quality infrastructure compared to when the quality of the infrastructure was high.

Results of the interaction between social cognitive factors and *environmental aesthetics* showed heterogeneity in predicting leisure-time PA. Perceived environmental aesthetics interacted with affective judgments of PA in two (43, 53) of three (48) studies. The two significant studies showed support for interaction hypothesis B, where higher levels of perceived aesthetics were associated positively with an indicator of leisure-time PA for those low on enjoyment compared to those reporting high enjoyment. Mixed results were evident in studies exploring the interaction between social support and environmental aesthetics. Two studies showed no interaction (43, 53), while one study found evidence for interaction hypothesis A (52) and another study found evidence for interaction hypothesis B (30).

There was evidence for no interaction between environmental aesthetics and perceived benefits/attitude (43, 48, 50, 53, 55) , perceived barriers (30, 43), subjective norm (48, 50), self-efficacy (30, 43, 48, 50, 51) and intention (29, 48, 50) when predicting leisure-time PA. Indeed, there were only a handful of discrepant studies showing interaction effects. Van Dyck et al. (53), when explaining overall leisure-time PA, showed that perceived barriers moderated aesthetics in support of interaction hypothesis A with an environment-PA relationship stronger among those lower on barriers. For self-efficacy/perceived behavioral control, Gay et al. (52) showed support for hypothesis A among an adult sample, where a larger self-efficacy (competence) and leisure-time PA relationship was found under higher levels of aesthetics than lower. By contrast, Van Dyck et al. (53) found neighborhood aesthetics had a larger positive relationship with leisure-time PA under conditions of adults reporting lower self-efficacy compared to higher self-efficacy, thus supporting interaction hypothesis B.

3.5 Physical Activity for Transportation

Eight studies included tests of interactions between social cognitive constructs and built environment variables to predict PA for transport (see Table 4). The majority of studies exploring *environmental accessibility/convenience* and its interaction with perceived benefits/attitude (41, 44, 54, 57), perceived barriers (30, 41, 43, 44, 54, 57), affective judgments (43, 57), subjective norm (41, 44, 54), self-efficacy (30, 41, 43, 44, 54) and social support (30, 41, 43, 44, 54, 57) showed no effects. Still, there was some heterogeneity in the findings. Yang and Diez-Roux (55) showed support for interaction hypothesis A, as a higher walkability score and perceived convenience were associated with more transport walking in people with positive PA attitudes than negative attitudes. By contrast, Ding et al. (43) showed evidence for interaction hypothesis B between perceived benefits of walking and walkability on walking for transport. Wang et al. (57) found that adolescents showed a larger self-efficacy and self-reported PA for transportation relationship under conditions of higher walkability compared to lower walkability, supporting interaction hypothesis A. On the other hand, Deforche et al. (51) showed that land use mix diversity was negatively associated with active transportation among adolescents with high self-efficacy but positively associated among those with low self-efficacy. Further, they reported a positive association between access to recreational facilities and active transport only for those with low self-efficacy, supportive of interaction hypothesis B. There was no notable difference in these findings by objective or self-reported assessment of the environment.

Studies have been too limited to appraise an interaction between social cognitive factors and *neighborhood safety* or *environmental aesthetics* when predicting PA for transport. There is also relatively limited research about social cognition and *environmental infrastructure quality* but perceived benefits/attitude (43), affective judgments (43) , perceived barriers (30, 43), social

support (30, 43) and self-efficacy (30, 43, 51) have shown no interaction. Finally, perceived benefits/attitude (55), affective judgments (43) , perceived barriers (30)

3.6 Total Physical Activity

Three studies included tests of interactions between social cognitive constructs and built environment variables to predict assessments of total PA (see Table 5). Given such a small number of studies, there is limited evidence available to examine these relationships. All tests explored whether *accessibility/convenience* moderated associations between total PA and social cognition (40, 54, 58). Thus far, there appears to be no evidence for moderation in the directions proposed using hypotheses A and B, although one study (54) showed an unexpected interaction where individuals lower in subjective norm/higher barriers reported more PA under less accessible/convenient environmental conditions compared to those reporting higher subjective norms/lower barriers. There was no notable difference in these early findings by objective or self-reported assessment of the environment.

4.0 Discussion

One of the tenets of socioecological models is the interaction between multiple levels of influence on behavior (24), including an interplay between individual characteristics and the environment to which individuals are exposed. The purpose of this review was to collect and appraise all studies, among all age groups, where the interaction between social cognition and the built environment in relation to PA has been investigated. To help organize our results, we investigated whether the results could be explained by two a priori hypothesized interactions (see Figure 1). To this end, 22 studies (15 focused on adults; 7 focused on youth) were reviewed that met inclusion criteria. We proposed two potential hypotheses for social cognitive and

environmental interactions. We proposed an “augmenting” hypothesis (hypothesis A) when the environment was augmenting some already high social cognitive factor to enable even more physical activity. By contrast, we also proposed an “overcoming” hypothesis (hypothesis B) when a supportive environment helped those with lower levels of social cognitive factors have greater physical activity. The interaction tenet of the socioecological model was not supported for overall moderate-to-vigorous PA and total PA. By contrast, there was heterogeneity of findings for leisure-time PA. Environmental accessibility/convenience interacted with intention in an augmenting hypothesis (hypothesis A) and environmental aesthetics interacted with affective judgments in an overcoming hypothesis (hypothesis B) to predict leisure time PA.

The reports collectively represented over 24,000 participants from five countries with most studies showing medium to high quality due to key study aspects (e.g., power to detect interactions, reliable measurement, random samples). The studies were extremely heterogeneous in their assessments of PA ranging from active transportation to leisure time PA, as well as in their appraisals of built environment constructs. For example, sources of environmental measures ranged from the use of self-report surveys, to Geographic Information Systems (GIS) surveys and open source tools to evaluate various aspects of the environment. The frequency of explored social cognition and built environment interactions was also not equal across these 22 studies. Specifically, the built environment factor of accessibility/convenience was the most frequent among interaction tests; this is likely due in part to the higher frequency with which accessibility/convenience is examined relative to other built environment constructs as well as the higher consistency of evidence supporting a direct link between accessibility/convenience and PA (59, 60). Another noteworthy limitation of this literature at present is the abundance of cross-sectional designs which allow for only a descriptive assessment of PA and not how social

cognition and the built environment (or changes in social cognition factors or changes in the built environment) may contribute to PA change. Still, we were able to examine whether interactions differed between different types of PA (total MVPA, total PA, leisure-time PA, PA for transport), many highly researched social cognitive variables (perceived benefits/attitudes, perceived barriers, affective judgments, subjective norm, social support, self-efficacy/perceived behavioral control, and intention) and a sensible taxonomy of built environment characteristics (accessibility/convenience, safety, comfort/quality aesthetics/pleasurability). Thus, the available sample of studies represents a rich data-set to appraise the state of current evidence and propose areas for future research.

Our overall analyses of the results yielded an interesting profile among the 22 studies across the different types of PA. Specifically, the outcomes of total MVPA and total PA, almost exclusively derived through accelerometry alone, were rarely explained by interactions between the built environment and social cognition. By contrast, there were considerable interaction findings for leisure-time PA and some heterogeneity of findings in PA for transportation. The results are concordant with the relationship between the built environment and types of PA (19), where specific types of PA, leisure (e.g., walking) and active transport, have more consistent and larger associations with built environment factors than general estimates of total PA. Similarly, purposeful PA, such as leisure-time exercise, typically has larger correlations with social cognition than overall PA (23, 61). The finding highlights the importance of purpose (i.e., what is the PA being performed and for what reason) when understanding PA. In any case, the results of our review suggest that the interaction tenet of the socio ecological model is not supported by general estimates of total MVPA. While evidence for total PA was limited to three studies and

only the exploration of accessibility/convenience as a moderator, the null findings were similar to total MVPA and did not support the interaction tenet of the socio ecological model.

In contrast to total MVPA and total PA, there was substantial heterogeneity of findings from our analysis of leisure-time PA, which was measured exclusively via self-report. In particular, the built environment aspects comprising accessibility/convenience and aesthetics had several studies with environment and social cognition interactions compared to those studies examining interactions with environmental safety and infrastructure quality. This is interesting because these two former aspects of the built environment, and particularly accessibility/convenience, typically have more consistent and larger bivariate correlations with PA than environmental safety/quality (59, 60), complementing past evidence for the important role these aspects may have as antecedents of PA. The most consistent evidence at this time is for the positive interaction between accessibility/convenience of recreation facilities and intention on leisure-time PA. Specifically, those people who reported having more access to recreation facilities and with better objectively assessed access to recreation facilities had a larger intention-behavior relationship than those who reported less access. Given that intention is often considered the proximal determinant of behavior (36), support for this socio ecological interaction is important information from a theoretical and practical standpoint. From a theoretical view, this suggests that the built environment may play a critical role in action control – the translation of intentions into behavior (62). The PA intention-behavior gap is considered one of the major limitations of social cognitive approaches (63) so our understanding of moderators of this gap is useful for augmenting theory (64, 65). From a practical perspective, this positive interaction highlights how augmenting individual PA motivation and environmental

PA accessibility/convenience may influence PA and supports the basic premise of socioecological models (24).

The other interaction between social cognition and the built environment with some convincing evidence was a negative relationship between affective judgments and aesthetics for leisure-time PA. Specifically, individuals with lower affective judgments (i.e., PA is not enjoyable) had a larger aesthetic and leisure-time PA relationship than individuals with high affective judgments. The finding is interesting for several reasons. First, it demonstrates the importance of separating affective aspects of an outcome expectation from perceived benefit outcome expectations, as that type of outcome expectation had no interaction with the built environment and often has a much lower bivariate association with PA (66, 67). Second, it demonstrates that the interaction tenet of the socioecological model can also be in a negative direction where individuals with lower levels of a PA motive, like enjoyment, may be the beneficiaries of the presence of settings that better enable PA. Finally, the finding may provide potentially helpful information for PA promotion. Affective judgments are likely more difficult to promote in individual-level intervention than perceived benefits or instrumental outcome expectations given they are less about hypothetical future benefits than past affective experiences (68). A focus on improving the aesthetics of the built environment offers a complementary approach to augmenting PA beyond merely working at the individual level.

Several other potential interactions between the built environment and social cognition to predict leisure-time PA remain unclear at present. These include interactions between environmental accessibility/convenience and perceived barriers and self-efficacy/perceived behavioral control, between environmental infrastructure quality and social support, and between environmental aesthetics and social support. The differences in these findings were not easily

explained by variation in geography, sample demographics or measurement of the built environment and social cognition. There was one exception. The interaction for leisure-time PA between environment and self-efficacy, however, showed more heterogeneity in findings when accessibility/convenience was measured via objective means and was null when measured with self-report. Such differences are perhaps not surprising given that perceived and objective measures of seemingly similar environment factors are often not concordant between themselves or how they related to physical activity (69). Thus, future research focused on these factors would be prudent to help clarify the conditions under which they interact. By contrast, environmental safety does not appear to interact with the social cognition-PA relationship and there is limited evidence that the quality of environmental infrastructure is a robust moderator of social cognition for any type of PA. From an individual perspective, perceived benefits and subjective norm also do not appear to interact with any conditions of the built environment to predict PA of any type, so sustained interaction research using these constructs seems unwarranted.

The results of our analysis of PA for transport, measured exclusively via self-report, are preliminary, as fewer studies have examined the interaction tenet of the socio ecological model for this outcome. Still, this limited research did not show much support for a social cognition and built environment interactions. The greatest heterogeneity in our findings was in accessibility/convenience and social cognitive interactions. Overall, our recommendation is for sustained research in social cognitive and built environment interactions, and particularly to expand the variety of built environment characteristics included, to explain PA for transport in order to yield more definitive future conclusions. However, it could be that transport PA operates differently and is much more subject to environmental factors alone, as transport PA is often

more utilitarian (for purposes other than being active for health or leisure purposes) and non-discretionary relative to leisure-time PA. Current evidence suggests that leisure-time PA is the domain where individual level motivation and the built environment interact to yield differences in behavior.

Despite notable findings in this review, there are additional limitations to our evidence base at present. First, the available studies are primarily samples of adults. We noted no differences between adult and youth samples in our analyses but future research testing this interaction tenet of the socio ecological theory should continue with youth samples to provide evidence that is more conclusive. To the extent possible, deriving built environment measures with the same approach and obtaining social cognitive values from both youth and adults in the same studies could improve the ability to make comparisons in interactive processes by age group. Second, our review focused on the available literature of individual factors that could interact with the built environment and this was social cognitive in nature. Social cognitive approaches rely on volitional and conscious processes but dual process approaches (70) suggest that some behaviors may be the result of nonconscious processes from cues (e.g., habits shaped by environments). Our failure to initially locate studies of nonconscious processes and environmental interactions seems like a limitation of the literature at present and an important area for future research. Clearly more evidence is needed to examine whether and how built environment and social cognitive factors interact to impact light intensity physical activity.

There were also some limitations of the review methods. This literature review is limited by the search terms and search engines employed as well as studies in English, and that initial screening of the abstracts was conducted by one author (CSM) which may have implications for internal validity of our review process. Furthermore, our reviewed literature is limited to

published work which has strengths in the base level of quality that accompanies the peer review process and the reliability of search access on the topic, yet is limited because of the potential positivity bias/aversion to the null that results from the peer-review system (71). Our analysis methods were also biased toward flagging significant interaction effects within a category of the built environment. We believe this is an appropriate first assessment of the interaction tenet of the socio ecological model but many of the studies included had large sample sizes and statistical significance may not be equivalent to clinical significance. Future work in this area should include effect sizes of these interactions as a matter of transparency for readers. Finally, although not a limitation of this review per se, most studies included only assessments (and thus tested interactions) of objective or perceived built environment around respondents' homes or within their home neighborhood. It could be that other environments (e.g., work) in which individuals spend time interact with social cognitive factors to promote or discourage PA.

5.0 Conclusions

In summary, to our knowledge, this is the first review examining evidence for the interaction hypothesis of the socio ecological model between the built environment and social cognition in the PA domain. Our results of 22 studies showed limited support for this hypothesis in relation to total MVPA, total PA and PA for transport but two noteworthy interactions in leisure-time PA. Specifically, environmental accessibility/convenience positively interacted with intention and environmental aesthetics negatively interacted with affective judgments to predict leisure time PA. There were also several inconclusive findings including interactions between environmental accessibility/convenience and perceived barriers and self-efficacy/perceived behavioral control, environmental infrastructure quality and social support, and environmental aesthetics and social support. The results fail to provide comprehensive support for interactions

between the home neighborhood built environment and all social cognitive factors, but do provide some support for aspects of socio ecological and social cognitive approaches that highlight potential areas for integrated intervention of individual and environmental change interventions to increase leisure-time PA.

Figure Caption:

Fig 1. Hypothesized interactions between social cognition (motivation) and the built environment when predicting physical activity

Figure 2. PRISMA study selection flow chart (72).

Physical activity (PA).

Compliance with Ethical Standards

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Conflicts of Interest
Ryan Rhodes, Brian Saelens and Claire Sauvage-Mar declare that they have no conflicts of interest relevant to the content of this review.

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Table 1. Study characteristics: overview of studies included in this review

Study	Country	Population	Study design	PA measures	Source of environment measures	Social cognitive theory and measures	Tests conducted	Significant interactions
Beenackers et al.(56)	Netherlands	4395 Adults	Cross-sectional	SQUASH (leisure-time walking)	Questionnaire developed (safety)	TPB, SCT (attitude, subjective norm, self-efficacy, intention)	4 (social cognition) x 1(environment) = 4 tests	Intention x safety (1/1 test; unexpected direction)
Beenackers et al.(50)	Netherlands	736 Adults	Cross-sectional	SQUASH (leisure-time walking)	Questionnaire developed (accessibility, safety, quality, aesthetics)	TPB, SCT, ASE (attitude, subjective norm, self-efficacy, intention)	4(social cognition) x 4 (environment) = 16 tests	Subjective norm x accessibility (1/1 tests; hypothesis A) Attitude x quality (1/1 tests; hypothesis B)
Carlson et al. (30)	USA	719 Older Adults	Cross-sectional	Accelerometer (MVPA), CHAMPS (walking for leisure, walking for transport)	NEWS, GIS (3 x accessibility, quality, aesthetics)	SCT (perceived barriers, self-efficacy, social support)	3 (social cognition) x 5 (environment) x 3 (PA) = 45 tests	<u>MVPA</u> Social support x accessibility (1/3 tests; hypothesis A) Perceived barriers x aesthetics (1/1 tests; hypothesis A) <u>Walking for leisure</u> Self-efficacy x accessibility (1/3 tests; hypothesis B) Social support x aesthetics (1/1 tests; hypothesis B) <u>Walking for transport</u> Barriers, social support, self-efficacy x accessibility (1/3 tests; hypothesis A)
Cerin et al. (31)	Australia	2650 Adults	Cross-sectional	IPAQ (leisure-time walking, leisure-time MPA, leisure-time VPA)	Questionnaire developed (5 x accessibility)	SCT (affective judgments, self-efficacy)	2 (social cognition) x 5 (environment) x 3 (PA) = 30 tests	<u>Leisure time VPA</u> Affective judgments x accessibility (1/5 tests; hypothesis B) Self-efficacy x accessibility (1/5 tests hypothesis B)
De Meester et al. (40)	Belgium	637 Adolescents	Cross-sectional	Accelerometer (MPA, VPA, Total PA)	GIS (accessibility)	HBM, SCT, TRA (perceived benefits/attitude, perceived barriers, subjective norm, social support, self-efficacy)	5 (social cognition) x 1 (environment) x 2 (PA) = 10 tests	None
D'Haese et al. (41)	Belgium	494 Children	Cross-sectional	Accelerometer (MVPA) and FPAQ (parent proxy walking,	GIS (accessibility)	ASE (parent proxy attitude/perceived benefits,	5 (social cognition) x 1 (environment)	<u>Leisure-time walking</u> Self-efficacy x accessibility (1/1 test; hypothesis A)

				cycling, sports for leisure, active transport)		perceived barriers, subjective norm, social support, self-efficacy)	x 5 (PA) = 25 tests	Leisure-time Sports Social support x accessibility (1/1 test; hypothesis B)
Deforche et al. (51)	Belgium	1445 Adolescents	Cross-sectional	FPAQ (leisure-time sports, active transportation)	NEWS (4 x accessibility, 2 x safety, 2 x quality, aesthetics)	SCT (self-efficacy)	1 (social cognition) x 9 (environment) x 2 (PA) = 18 tests	Active transportation Self-efficacy x accessibility (3/4 tests; hypothesis B) Self-efficacy x safety (2/2 tests; hypothesis B) Self-efficacy x aesthetics (1/1 test; hypothesis A)
Ding et al. (43)	USA	2199 Adults	Cross-sectional	Accelerometer (MVPA), IPAQ (leisure time walking, transport walking)	NEWS (3x accessibility, quality, aesthetics)	SCT (perceived benefits/attitude, perceived barriers, affective judgments, social support, self-efficacy)	MVPA 5 (social cognition) x 5 (environment) = 25 tests Transport Walking 5 (social cognition) x 2 (environment) = 10 tests Leisure Walking 5 (social cognition) x 4 (environment) = 20 tests	Transport Walking Benefits x accessibility (1/1 test; hypothesis B) Leisure Walking Benefits x accessibility (2/2 tests; hypothesis B) Barriers x accessibility (2/2 tests; hypothesis B) Self-efficacy x accessibility (1/2 tests; hypothesis B) Social support x quality (1/1 test; hypothesis B) Affective judgments x aesthetics (1/1 test; hypothesis B)
Gay et al. (52)	USA	477 Adults	Cross-sectional	GLTEQ (leisure-time PA)	Questionnaire developed (accessibility x 2, safety, aesthetics)	SDT (social support, self-efficacy)	2 (social cognition) x 4 (environment) = 8 tests	Social support x accessibility (1/2 tests; hypothesis A) Self-efficacy x accessibility (1/2 tests; hypothesis A) Social support x aesthetics (1/1 test; hypothesis A) Self-efficacy x aesthetics (1/1 test; hypothesis A)
Giles-Corti & Donovan (45)	Australia	1803 Adults	Cross-sectional	Self-report (MVPA)	GIS and assessor observation (accessibility x 2, quality, aesthetics)	TPB, TRA (attitude, subjective norm, self-efficacy, intention)	4 (social cognition) x 4 (environment) = 16 tests	None

Haerens et al. (42)	Belgium	523 Adolescents	Cross-sectional	Accelerometer (MVPA), FPAQ (leisure-time PA)	Questionnaire developed (accessibility)	SCT (perceived benefits/attitude, perceived barriers, affective judgments, social support, self-efficacy)	5 (social cognition) x 1 (environment) x 2 (PA) = 10 tests	None
Kaczynski et al. (58)	Canada	585 Adults	Cross-sectional	Self-report (Total PA)	NEWS (accessibility)	SCT (self-efficacy)	1 (social cognition) x 1 (environment) = 1 test	None
Kepper et al. (47)	USA	71 Adolescents	Cross-sectional	Accelerometer (MVPA), Self-Report PA (Parent proxy leisure time PA)	GIS (quality)	SDT; NCEM (parent proxy social support)	1 (social cognition) x 1 (environment) x 2 (PA) = 2 tests	Leisure-time PA Social support x quality (1/1 test; hypothesis B)
Prins et al. (49)	Netherlands	488 Adolescents	Longitudinal	AQUAA (leisure time sports participation)	GIS (accessibility)	TPB (intention)	1 (social cognition) x 1 (environment)	Intention x accessibility (1/1 test; hypothesis A)
Rhodes et al. (48)	Canada	351 Adults	Cross-sectional	GLTEQ (leisure-time walking)	NEWS, IPAPSEM (accessibility x 2, safety x 2, quality, aesthetics)	TPB (attitude/perceived benefits, affective judgments, subjective norm, self-efficacy, intention)	5 (social cognition) x 6 (environment) = 30 tests	Intention x accessibility (1/2 tests; hypothesis A)
Rhodes et al. (29)	Canada	358 Adults	Longitudinal	GLTEQ (leisure-time walking)	NEWS, IPAPSEM (accessibility)	TPB (intention)	1 (social cognition) x 1 (environment) = 1 test	Intention x accessibility (1/1 test; hypothesis A)
Van Dyck et al. (54)	Belgium	350 Adults	Cross-sectional	Pedometer (Total PA), IPAQ (leisure-time walking and cycling in neighborhood, cycling and walking for transport in neighborhood)	Urban/Rural (accessibility)	SCT (perceived benefits/attitude, perceived barriers, subjective norm, social support, self-efficacy)	5 (social cognitive) x 1 (environmental) x 6 (PA) = 30 tests	Total Physical Activity Subjective norm x accessibility (1/1 test) Barriers x accessibility (1/1 test) Leisure-Time Cycling/Walking Self-efficacy x accessibility (1/2/tests)
Van Dyck et al. (53)	USA, Australia, Belgium	6014 Adults	Cross-sectional	IPAQ (Leisure-Time MVPA, recreational walking)	NEWS (accessibility x 2, quality, safety x 2, aesthetics)	SCT (perceived benefits/attitude, perceived barriers, affective judgments, social support, self-efficacy)	5 (social cognition) x 6 (environment) x 2 (PA) = 60 tests	Recreational Walking Affective judgment x accessibility (1/2 tests; hypothesis B) Social support x accessibility (1/2 tests; hypothesis B) Self-efficacy x accessibility (1/2 tests; hypothesis B)

								Leisure-Time MVPA Benefits x accessibility (1/2 tests; hypothesis A) Affective judgment x aesthetics (1/1 test; hypothesis B) Barriers x aesthetics (1/1 test; hypothesis A) Self-efficacy x aesthetics (1/1 test; hypothesis B)
Van Holle et al. (44)	Belgium	433 Older Adults	Cross-sectional	Accelerometer (MVPA), IPAQ (leisure-time walking, walking for transport)	GIS (accessibility)	ASE (perceived benefits/attitude, perceived barriers, subjective norm, social support, self-efficacy)	5 (social cognition) x 1 (environment) x 3 (PA) = 15 tests	Leisure-Time Walking Self-efficacy x accessibility (1/1 test; hypothesis A)
Wang et al. (57)	USA	928 Adolescents	Cross-sectional	ATSS (self-reported active transportation)	GIS (accessibility x 2) Independent audit assessment (quality)	SCT (perceived benefits – decisional balance, perceived barriers, affective judgments,, social support, self-efficacy)	5 (social cognition) x 3 (environment) = 15 tests	Self-efficacy x accessibility (2/2 tests; hypothesis A) Barriers x quality (1/1 test; hypothesis A)
Yang & Diez-Roux (55)	USA	2621 Adults	Cross-sectional	Self-report (walking for travel and leisure)	GIS (accessibility) self-report (accessibility, safety, aesthetics)	TRA (attitude/perceived benefit)	1 (social cognition) x 4 (environment) x 2 (PA) = 8 tests	Walking for Leisure Attitude x accessibility (1/2 tests; hypothesis A) Walking for Transport Attitude x accessibility (2/2 tests; hypothesis A)
Zenk et al. (46)	USA	97 African American women	Cross-sectional	Accelerometer (MVPA)	Questionnaire developed (accessibility, safety)	n/a (perceived barriers)	1 (social cognition) x 2 (environment) = 2 tests	None

Activity QUestionnaire for Adolescents and Adults (AQUAA); Active Transportation to School Scale (ATSS); Basic Social Needs in Exercise Scale (BPNES); Community Healthy Activities Model Program for Seniors (CHAMPS) Flemish Physical Activity Questionnaire (FPAQ); Godin Leisure Time Exercise Questionnaire (GLTEQ); International Physical Activity Questionnaire (IPAQ); Short QUestionnaire to ASsess Health-Enhancing physical activity (SQUASH); Physical activity (PA); Moderate to vigorous physical activity (MVPA); Not applicable (NA)

Geographic Information Systems Databases (GIS); International Physical Activity Prevalence Study Environmental Survey Module (IPAPSEM); Neighborhood Environmental Walkability Survey (NEWS); Neighborhood Physical Activity Questionnaire (NPAQ)

Attitude Social influence Efficacy Model (ASE); Health Belief Model (HBM); Norms and Collective Efficacy Model (NCEM); Social Cognitive Theory (SCT); Social Disorganization Theory (SDT); Theory of Planned Behaviour (TPB); Theory of Reasoned Action (TRA)

Table 2. Interactions between environment and social cognition for total moderate-vigorous intensity physical activity.

Correlate	Studies with an interaction supporting hypothesis A	Studies with an interaction supporting hypothesis B	Studies with an unexpected interaction direction	Studies with no interaction	Overall association[a]
Accessibility/convenience					
Perceived benefits/attitude				(40-45)	0
Perceived barriers				(30, 40-44, 46)	0
Affective judgements				(42, 43)	NA
Subjective norm				(40, 41, 44, 45)	0
Social support				(30, 40-44)	0
Self-efficacy				(30, 40-45)	0
Intention				(45)	NA
Safety					
Perceived benefits/attitude					NA
Perceived barriers				(46)	NA
Affective judgments					NA
Subjective norm					NA
Social support					NA
Self-efficacy					NA
Intention					NA
Quality					
Perceived benefits/attitude				(43, 45)	NA
Perceived barriers				(30, 43)	NA
Affective judgments				(43)	NA
Subjective norm				(45)	NA
Social support				(30, 43, 47)	0
Self-efficacy				(30, 43, 45)	0
Intention				(45)	NA
Pleasurability/aesthetics					
Perceived benefits/attitude				(43, 45)	NA
Perceived barriers	(30)			(43)	NA

Affective judgements	(43)	NA
Subjective norm	(45)	NA
Social support	(30, 43)	NA
Self-efficacy	(30, 43, 45)	0
Intention	(45)	NA

[a] At least three studies were required for a theme and an estimate of strength behavior. A = supportive of hypothesis A in Figure 1 (>59% of studies), B = supportive of hypothesis B in Figure 1, 0 = no association (>59% of studies) ? = indeterminate (<60% of studies showing an association in any other category); NA = not enough studies to render a judgment.

Table 3. Interactions between environment, social cognition, and leisure-time physical activity.

Correlate	Studies with an interaction supporting hypothesis A	Studies with an interaction supporting hypothesis B	Studies with an unexpected interaction direction	Studies with no interaction	Overall association[a]
Accessibility/convenience					
Perceived benefits/attitude	(53, 55)	(43)		(41, 42, 44, 48, 50, 54)	0
Perceived barriers		(43)		(30, 41, 42, 44, 53, 54)	0
Affective judgments		(53)		(31, 42, 43, 48)	0
Subjective norm	(50)			(41, 44, 48, 54)	0
Social support	(52)	(41, 53)		(30, 42-44, 54)	0
Self-efficacy	(41, 44, 52)	(43, 53)	(54)	(30, 31, 42, 48, 50, 51)	?
Intention	(29, 48, 49)			(50)	A
Safety					
Perceived benefits/attitude				(48, 50, 53, 55, 56)	0
Perceived barriers				(53)	NA
Affective judgments				(48, 53)	NA
Subjective norm				(48, 50, 56)	0
Social support				(52, 53)	NA
Self-efficacy				(48, 50-53, 56)	0
Intention			(56)	(29, 48, 50)	0
Quality					
Perceived benefits/attitude		(50)		(43, 48, 53)	0
Perceived barriers				(30, 43, 53)	0
Affective judgments				(43, 48, 53)	0
Subjective norm				(48, 50)	NA
Social support		(43, 47)		(30, 53)	?
Self-efficacy				(30, 43, 48, 50, 51, 53)	0
Intention				(29, 48, 50)	0
Pleasurability/aesthetics					
Perceived Benefits/Attitude				(43, 48, 50, 53, 55)	0
Perceived Barriers	(53)			(30, 43)	0

Affective Judgments		(43, 53)	(48)	B
Subjective Norm			(48, 50)	NA
Social Support	(52)	(30)	(43, 53)	?
Self-Efficacy	(52)	(53)	(30, 43, 48, 50, 51)	0
Intention			(29, 48, 50)	0

[a] At least three studies were required for a theme and an estimate of strength behavior. A = supportive of hypothesis A in Figure 1 (>59% of studies), B = supportive of hypothesis B in Figure 1, 0 = no association (>59% of studies),? = indeterminate (<60% of studies showing an association in any other category); NA = not enough studies to render a judgment.

Table 4. Interactions between environment, social cognition, and transportation physical activity.

Correlate	Studies with an interaction supporting hypothesis A	Studies with an interaction supporting hypothesis B	Studies with an unexpected interaction direction	Studies with no interaction	Overall association[a]
Accessibility/convenience					
Perceived benefits/attitude	(55)	(43)		(41, 44, 54, 57)	0
Perceived barriers				(30, 41, 43, 44, 54, 57)	0
Affective judgments				(43, 57)	NA
Subjective norm				(41, 44, 54)	0
Social support				(30, 41, 43, 44, 54, 57)	0
Self-efficacy	(57)	(51)		(30, 41, 43, 44, 54)	0
Intention					NA
Safety					
Perceived benefits/attitude				(55)	NA
Perceived barriers					NA
Affective judgments					NA
Subjective norm					NA
Social support		(51)			NA
Self-efficacy					NA
Intention					NA
Quality					
Perceived benefits/attitude				(43, 57)	NA
Perceived barriers	(57)			(30, 43)	0
Affective judgments				(43, 57)	NA
Subjective norm					NA
Social support				(30, 43, 57)	0
Self-efficacy				(30, 43, 51, 57)	0
Intention					NA
Pleasurability/aesthetics					
Perceived benefits/attitude				(55)	NA
Perceived barriers				(30)	NA

			NA
Affective judgments			NA
Subjective norm		(30)	NA
Social support	(51)	(30)	NA
Self-efficacy			NA
Intention			

[a] At least three studies were required for a theme and an estimate of strength behavior. A = supportive of hypothesis A in Figure 1 (>59% of studies), B = supportive of hypothesis B in Figure 1, 0 = no association (>59% of studies) ? = indeterminate (<60% of studies showing an association in any other category); NA = not enough studies to render a judgment.

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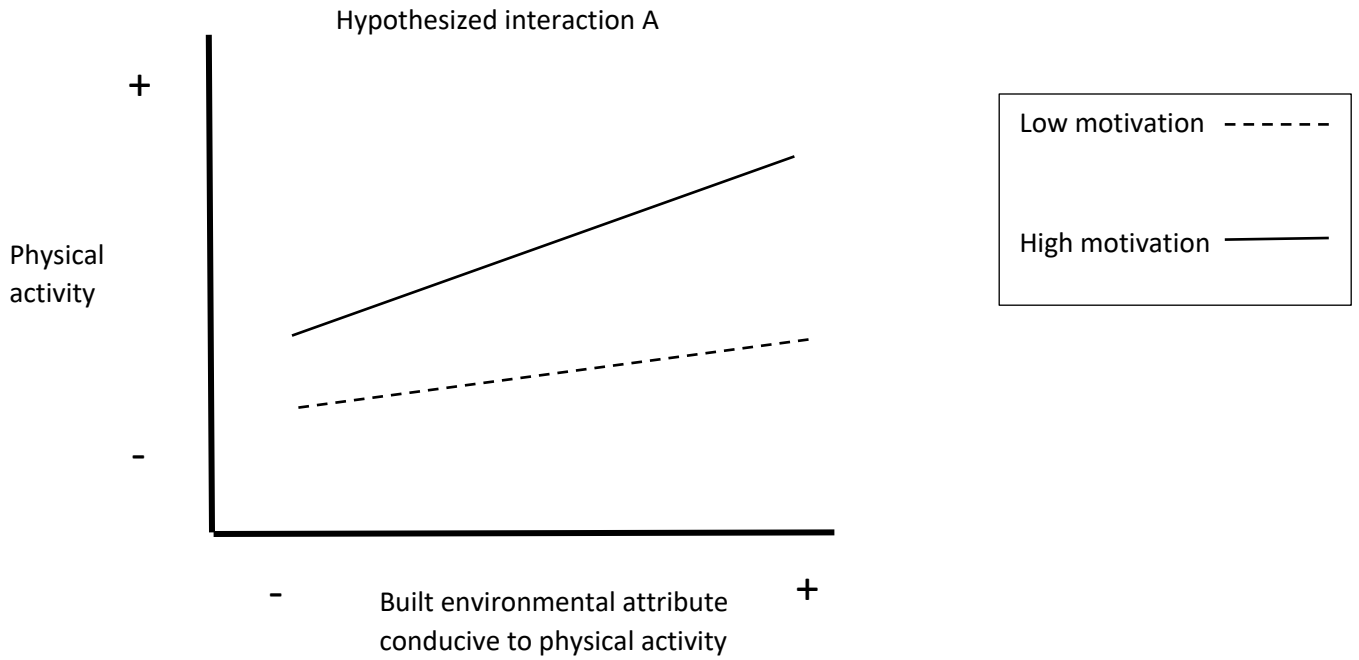
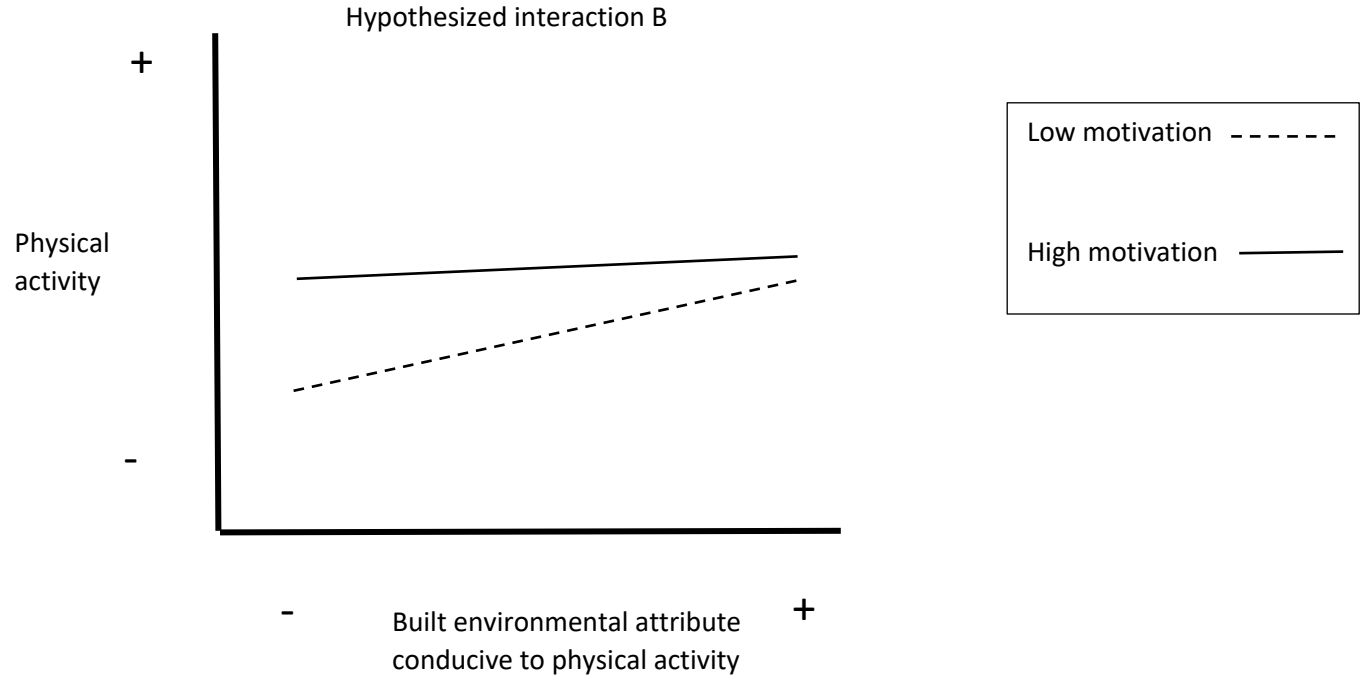
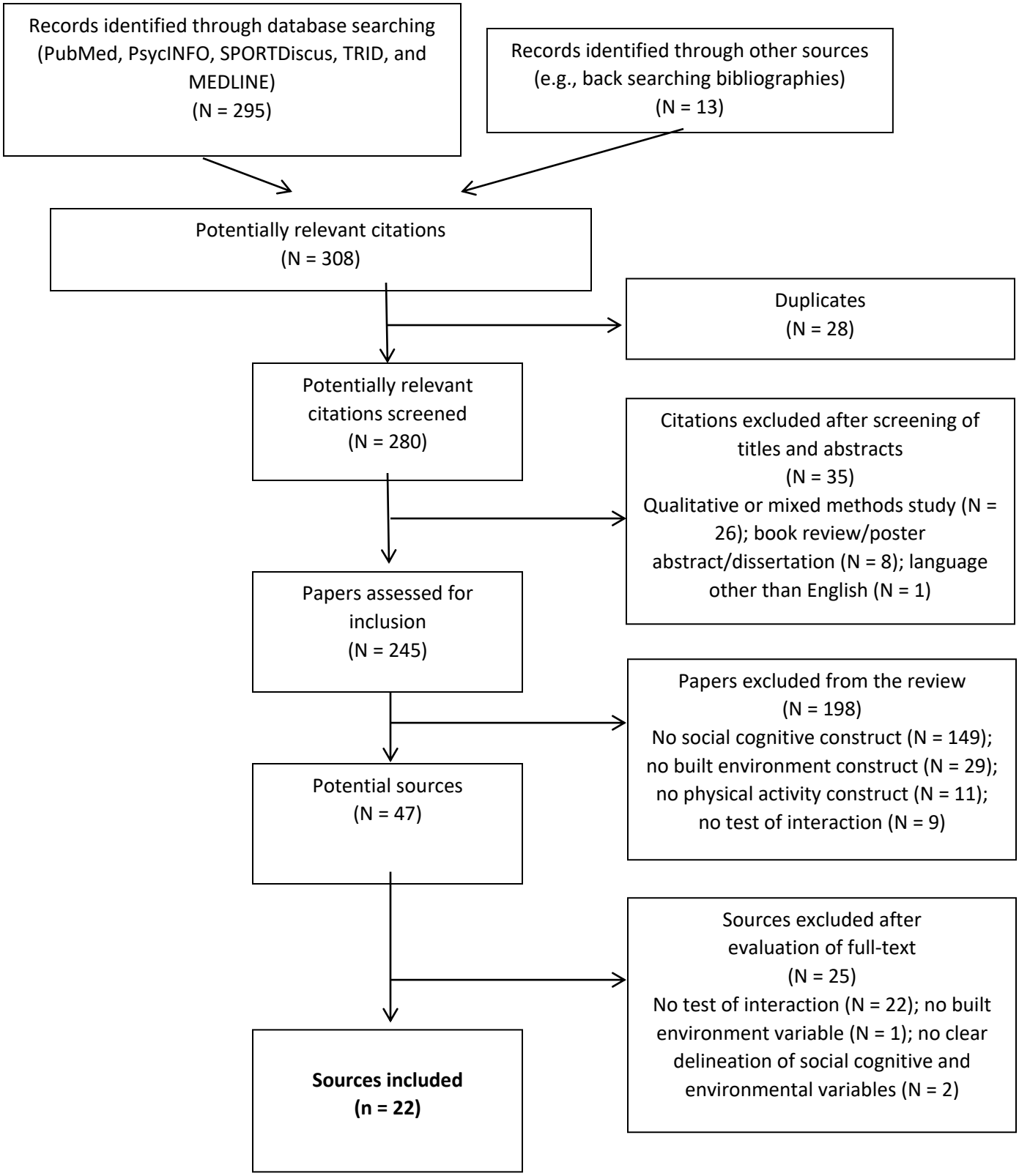
Table 5. Interactions between environment, social cognition, and total physical activity.

Correlate	Studies with an interaction supporting hypothesis A	Studies with an interaction supporting hypothesis B	Studies with an unexpected interaction direction	Studies with no interaction	Overall association[a]
Accessibility/convenience					
Perceived benefits/attitude				(40, 54)	NA
Perceived barriers			(54)	(40)	NA
Affective judgments					
Subjective norm			(54)	(40)	NA
Social support				(40, 54)	NA
Self-efficacy				(40, 54, 58)	0
Intention					

[a] At least three studies were required for a theme and an estimate of strength behavior. A = supportive of hypothesis A in Figure 1 (>59% of studies), B = supportive of hypothesis B in Figure 1, 0 = no association (>59% of studies) ? = indeterminate (<60% of studies showing an association in any other category); NA = not enough studies to render a judgment.


Hypothesized interaction A
+
Physical activity
-
Low motivation
High motivation
-
Built environmental attribute conducive to physical activity
+


Hypothesized interaction B
+
Physical activity
-
Low motivation
High motivation
-
Built environmental attribute conducive to physical activity
+


Records identified through database searching (PubMed, PsycINFO, SPORTDiscus, TRID, and MEDLINE) (N = 295)
Records identified through other sources (e.g., back searching bibliographies) (N = 13)
Potentially relevant citations (N = 308)
Duplicates (N = 28)
Potentially relevant citations screened (N = 280)
Citations excluded after screening of titles and abstracts (N = 35) Qualitative or mixed methods study (N = 26); book review/poster abstract/dissertation (N = 8); language other than English (N = 1)
Papers assessed for inclusion (N = 245)
Papers excluded from the review (N = 198) No social cognitive construct (N = 149); no built environment construct (N = 29); no physical activity construct (N = 11); no test of interaction (N = 9)
Potential sources (N = 47)
Sources excluded after evaluation of full-text (N = 25) No test of interaction (N = 22); no built environment variable (N = 1); no clear delineation of social cognitive and environmental variables (N = 2)
Sources included (n = 22)