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The meaning of livable streets to schoolchildren: An image mapping study of the effects of traffic on children's cognitive development of spatial knowledge

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ABSTRACT

While much focus has been placed on the physical activity and environmental benefits of providing safe and livable streets for children, few studies look at the mental health and cognitive development benefits from lowering children's exposure to threats from traffic. In response, this study uses innovative cognitive mapping methods through a series of focus-group interviews with nine and ten-year schoolchildren to uncover important ways traffic exposure limits children's cognitive development of their spatial knowledge. To test for these effects, this study focuses on schoolchildren in two similar suburban neighborhoods and schools in suburbs in the San Francisco Bay Area, but differing in the volume and speed of traffic the students are exposed to during their journeys to and from school.

The Cognitive mapping exercises and methods used in this research reveal multi-dimensional effects, including how exposure to traffic, as determined by volume, speed, and the adequacy of walking and bicycling infrastructure, limits children's progression along a cognitive development continuum of spatial knowledge. Specifically, the results show that without adequate pedestrian and bicycle facilities to provide sanctuary from automobile traffic, children are overcome by the negative senses of danger and dislike, commensurate with a limited ability to identify qualities of their neighborhood that are memorable, special, or even positive. In contrast, this study finds that children allowed to have higher levels of interaction with the environment, through independent, active travel modes improve their spatial knowledge development.

By making neighborhood streets safe, comfortable, and livable, this research establishes some key psychological cognitive benefits associated with lowering a child's exposure to automobile traffic by providing adequate pedestrian and bicycle Safe Routes to School (SR2S) infrastructure.

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1. Introduction

How do children view their world? What helps them connect with their environment and community? Or, perhaps more importantly, what gets in their way? To address this and other questions, this research examines how traffic exposure, as determined by traffic volumes and speed and the presence, or lack thereof, of proper pedestrian and bicycle facilities, influences children's progression along a development continuum of cognitive spatial knowledge (Piaget, 1956). While there is much research on the physical activity and environmental benefits of the ability of children to walk or bicycle, few studies look at the mental health benefits from the neighborhood context (Villanueva et al., 2014; Villanueva et al., 2016).

Through a series of focus-group interviews with schoolchildren, and using cognitive mapping exercises analyzed through an innovative method to compare collective results across each participant group, the effects of traffic exposure on children's cognitive development of their spatial knowledge is uncovered. As part of this exposure is due to inadequate ped/bike infrastructure, this research also helps establish how building pedestrian and bicycle facilities can improve childrens' cognitive connection with their respective communities and environment. By making neighborhood streets safe, comfortable, and inviting—in other words, livable (Appleyard et al., 1981) - this research explores the psychological benefits associated with lowering a child's exposure to automobile traffic.

This study focuses on two suburban neighborhoods in Contra Costa County in the eastern portion of the San Francisco Bay Area of California. These neighborhoods were built in the Mid-20th century and likely influenced by Clarence Perry's, 1929 Neighborhood Unit Principles recommending, among other things, that neighborhoods be built around schools "so children would not have to cross a busy street" (Perry, 1929). However, these particular neighborhoods lacked a key component of Perry's walkable, safe, and independent-mobility vision for children—they were built without sidewalks. Neighborhoods that lack this key infrastructure are referred to in this paper as Incomplete Perry Neighborhoods (IPNs). As this IPN condition can be found in many suburban US neighborhoods built around the Mid-20th Century, retrofitting them with Safe Routes to School infrastructure represents a significant opportunity for improvement and the release of a potentially large latent demand for independent walking and bicycling by children wishing to travel to school.

2. Background

2.1. Theory of children's cognitive development of spatial knowledge

The Swiss psychologist Jean Piaget (1896–1980) developed a comprehensive theory about children's development of knowledge and intelligence, known as Piaget's Theory of Cognitive Development, or Development Stage Theory (Piaget, 1956). Piaget (1956) articulated five elements of a child's cognitive development conceptions of space and spatial perceptual structuration, as follows:

1. **Proximity –** Referring to the "nearbyness of elements belong to the same perceptual field."

2. **Separation** – The means of disassociating between two neighboring elements.
3. **Spatial succession or order –** The ability to separate elements in sequence one before the other.
4. **Enclosure –** The ability to organize elements as being between or inside other elements.
5. **Continuity –** Elements can have a coordinated perceptual association.

(Piaget, 1956).

2.1.1. Piaget's cognitive, spatial, perceptual, structuration

Piaget, building on Luquet's three principal stages of children's capacity to draw spatial relationships (Piaget, 1956: 154, Fig. 85) – also theorized that school-aged children pass through three distinct developmental stages of cognitive development between age 2 and adulthood (Piaget, 1956), as follows:

- **Pre-operational Stage** (about ages 2–6) a child in this age group should be able to navigate familiar routes, but is expected to lack the ability to provide any sort of abstract representation.
- **Concrete operational stage** (about ages 7–11) where children can abstractly conceptualize and draw well-known routes, but cannot yet incorporate these routes into the context of a larger, more comprehensive map.
- **Formal operational stage** (about age 11 through adolescence and into adulthood) where children develop the ability to think about abstract concepts, as well as have the ability to completely and accurately conceptualize a large-scale map representation in relation to more well-known areas.

(Piaget, 1956; Maiss and Handy, 2011; Ward, 1978).

As this paper relies heavily on the valuable contributions of Piaget, it is important to acknowledge common criticisms (Lourenço and Machado 1996) (Matusov and Hayes 2014). Much criticism of Piaget's work revolves around his small group of research participants (which included, at one time, his own three children), all of whom were from high socioeconomic and educational backgrounds. Because of this unrepresentative sample, we should cautiously apply broad generalizations of his findings to a larger population. For example, some research has disputed Piaget's argument that all children will automatically move to the next stage of development as they mature. While other research suggests that environmental factors may also play a role in the development of formal operations (Lourenço and Machado, 1996; Matusov and Hayes, 2000), findings which are explored further by this research.

2.1.2. Importance of interaction and active travel toward improving children's cognitive development

An interesting refinement on Piaget's theory of children's spatial understanding is Gary Moore's interactionist theory, which ties a child's interaction and familiarity with the environment to their cognitive development progress along "Piaget's stages"(Maiss and Handy, 2011; Moore 1986a, 1986b). This theory is supported by the findings of other researchers as well (Biel, 1986; Southworth, 1970). Maiss and Handy (2011) further argue that active travel such as bicycling provides a more intensive interactional environmental experience than being driven, and therefore such active travel may hasten the progression from one of Piaget's development stages to the next. By extension, walking to school should offer a similar benefit.

2.2. Cognitive (image) mapping: background and methods

The practice of cognitive mapping emerged in the field of psychology, initially presented in a paper by Tolman in 1948 (Tolman, 1948), and has since been followed by an extensive literature (Kitchin and Freundschuh, 2000; Kitchin, 1994; Portugali, 1996).

Cognitive (or image mapping) was introduced to a broad audience of urban designers and planners by Kevin Lynch through his 1960 seminal work, *The Image of the City* (Banerjee, 2004; Lynch, 1960; Stea, 1973). Building on a five-year study of focused interviews and image mapping exercises with observers in Boston, Los Angeles and Jersey City in the 1950s, Lynch classified the physical, perceptible objects of an environment into five elements, as follows (Fig. 1):

- **Paths**, the channels by which people travel (streets, sidewalks, paths, canals, railroads, etc.);
- **Edges**, perceived boundaries (fences, buildings, freeways, shorelines, etc.);
- **Districts**, relatively large sections of the city distinguished by some continuity of identity or character;
- **Nodes**: Centers of attraction one can enter, and are focal points of activity and exchange (intersections, train stations, etc.);
- **Landmarks**, visible, readily identifiable objects which serve as reference points.

Lynch (1960) also developed a methodology to gather information into one collective cognitive map for a group of study participants, as also shown in Fig. 4. As will be discussed further in this paper, creating collective cognitive maps of study group participants can be useful to researchers and practitioners in helping identify important destinations, preferred routes of travel, as well as barriers, threats, and areas of danger and dislike (Travlou et al., 2008; Christensen et al., 2015; Banerjee et al., 2014; Freeman and Vass, 2010; Banerjee and Baer, 2013). Finally, as new geo-spatial and statistical modeling research shows, built environment and experiential factors encountered along people's route have a significant impact on their choice of green and active modes (walking, bicycling, etc.) (Appleyard, 2012, 2016) Fig. 5.

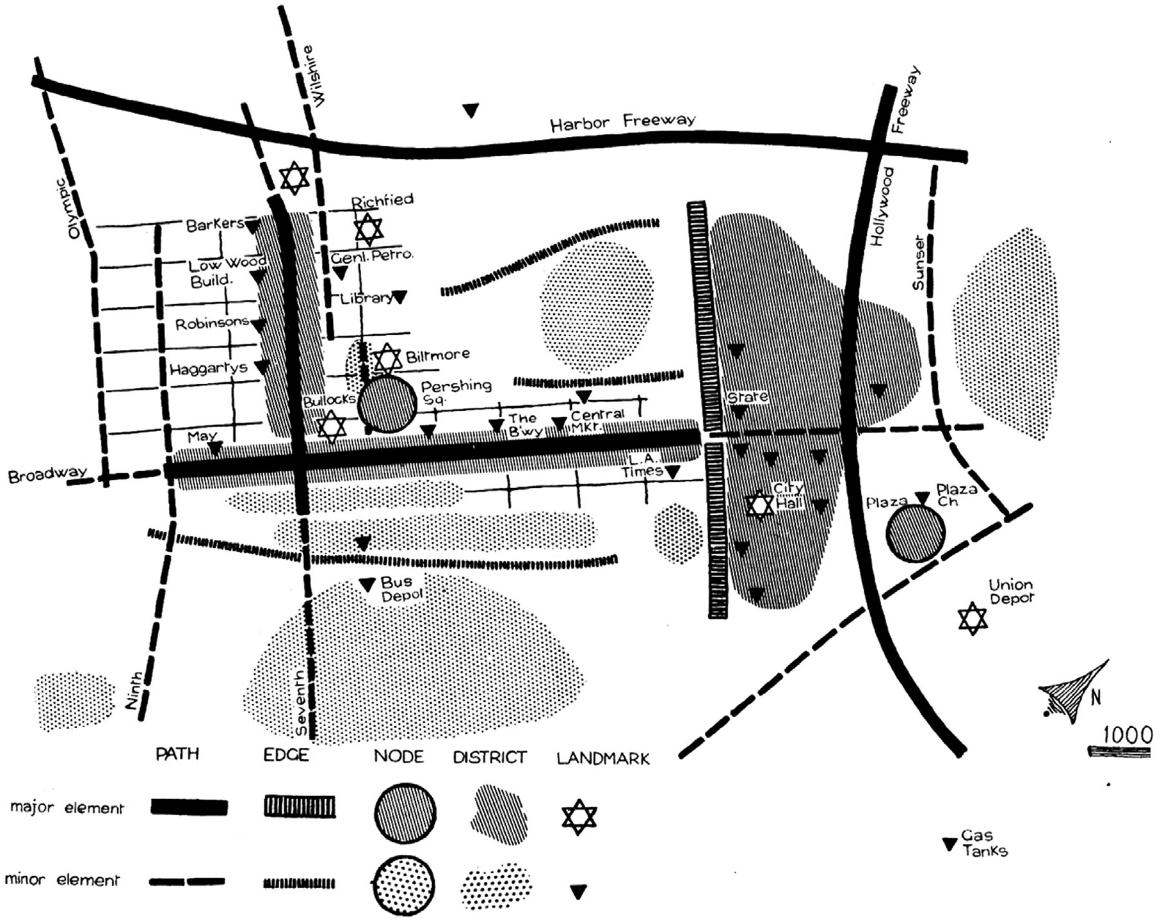

Fig. 1. One of Lynch's Collective Cognitive Maps, with legend for his five elements.

2.2.1. Cognitive mapping methods used toward understanding the impacts of traffic on community members and their neighborhood experiences

In the 1960s and 1970s Appleyard et al. (1981) used a modified version of Lynch's image mapping exercises to conduct a renowned study on the impacts of traffic on street and community satisfaction or, as the research called it, livability. Rather than giving people blank pieces of paper, as Lynch (1960) had done, Donald Appleyard captured participant responses on tracing paper overlaying a map of their street, surrounded by photos. As such, the collective maps are more spatially constrained than those gathered by Lynch (1960). A term for this type of spatially constrained map could be an *annotative cognitive map.* One of the main benefits of this annotative approach is that it helps researchers more precisely locate on a collective map the individual elements drawn by each study participant, as shown in Fig. 6.

This graphic representation of the collective response of participants proved to be an effective medium for conveying study findings regarding the cognitive/perceptual impacts of traffic volume and speed on people in communities. For example, Fig. 2a shows one of the more notable graphics of how neighbors' social ties (shown by the lines across the streets) are negatively impacted by vehicular traffic (Appleyard, et al 1981 p. 22 Fig. 2: Location of Friends and Acquaintances). In the top street, where there is light vehicular traffic, there are many social connections and an active street-life. Whereas in the bottom street, the reverse can be seen—people confronted with heavy traffic on their street have fewer social ties. In sum, this image shows how community ties can be knit together by a street that is livable and inviting, or alternatively, they can be torn apart when auto traffic noise, pollution, and threats dominate the street environment.

Another effective graphic conveying collective participant responses from *Livable Streets* shows how residents' sense of their home territories shrinks as traffic grows heavier and faster (Appleyard, et al. 1981 p. 23 Fig. 4: Home Territory). In sum, heavy traffic forces residents to retreat into the backs of their homes and away from the street. Therefore, the areas in front of homes — that could be vibrant places for children to play and neighbors to socialize — are left empty of street-life. As a result, few "watchful eyes" (Jacobs, 1961) are left to enhance neighborhood safety (Appleyard, et al. 1981).

Of particular interest to this article, is Fig. 2 below, which shows how people's ability to recall details of their street environment are negatively impacted by vehicular traffic and speed (Appleyard, et al. 1981 p. 25 Fig. 6: Environmental Awareness). This finding supports the theory that such exposure to traffic threats could have a similarly limiting effect on

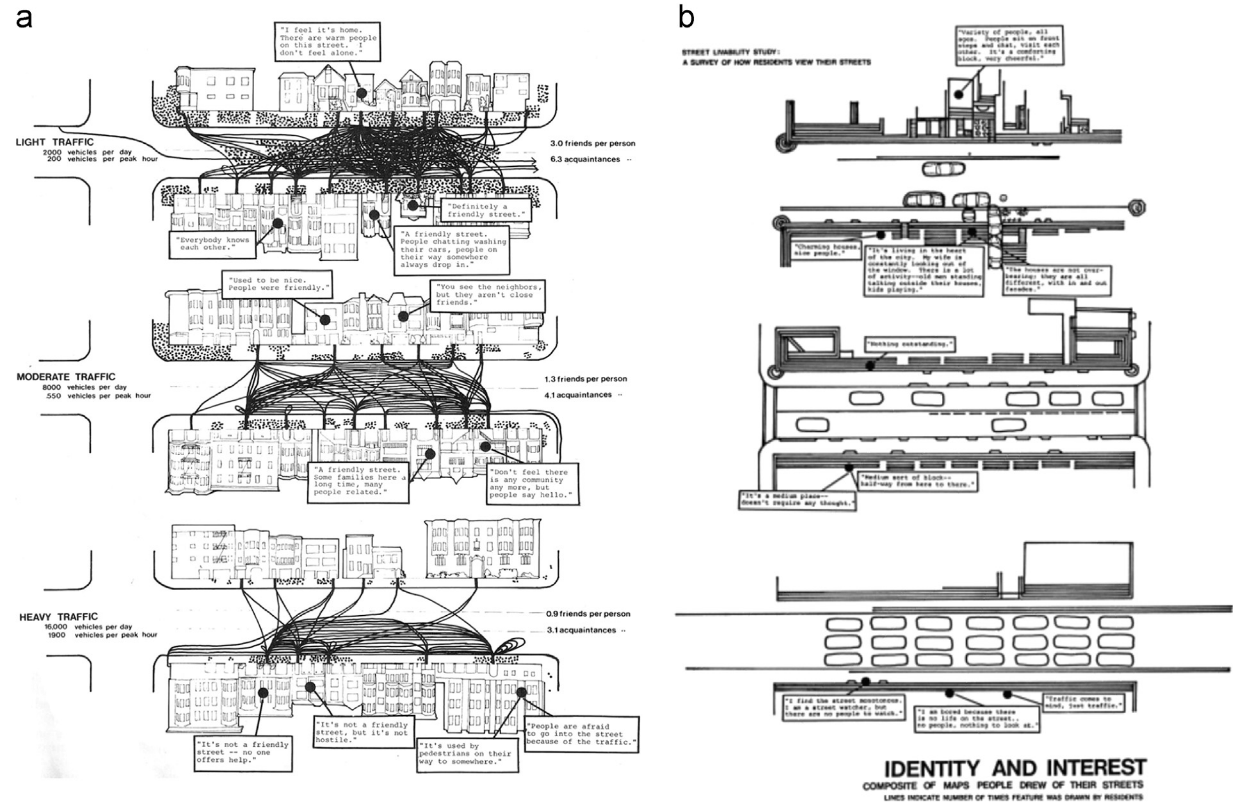

Fig. 2. (a) Location of friends and acquaintances. (b) Environmental awareness. Appleyard et al. (1981) (pp. 22, 25).

children's cognitive ability to recall memorable elements in their community.

In sum, by comparing three residential streets in San Francisco, similar in many respects, except for their traffic volumes and speed levels, Donald Appleyard was able to show that important quality of life factors, such as social connections, people's perception of the size of their home territory, neighborhood pride and property values, a significantly harmed by the exposure to traffic. Furthermore, he found that residents would adapt to these traffic impacts by withdrawing and retreating into the backs of their homes and away from the street and, consequently, their community. He also outlined how children and the elderly could be particularly vulnerable to the negative effects of traffic exposure (Appleyard, et al. 1981). To determine the impacts of the exposure to traffic, as well as a child's feelings of their own safety and comfort related to their walk to school, the cognitive/image mapping methods outlined in this combined the free-form mapping methods developed by Lynch (1960), with the research design and the line of inquiry developed by Appleyard et al. (1981).

3. Research approach

Drawing on an extensive literature, but primarily Lynch (1960) and Appleyard et al. (1981), this research developed new cognitive mapping methods to reveal the combined impacts of traffic exposure on schoolchildren's cognitive development.

3.1. Hypothesis

The main hypothesis tested in this research is as follows:

> *Increasing exposure to higher automobile traffic volumes and speeds, exacerbated by inadequate walking and bicycling infrastructure along the routes to school, limits children's spatial knowledge along a cognitive development continuum.*

To test this hypothesis, and to gauge the influence of varying volumes of traffic and speed, cognitive mapping exercises were conducted in two neighborhoods, similar in many respects (school located in the middle of the neighborhood, few off-street ped/bike pathways, socio-economic characteristics of community members, etc.), but differing primarily in the level of children's exposure to traffic, as determined primarily by volume and speed.

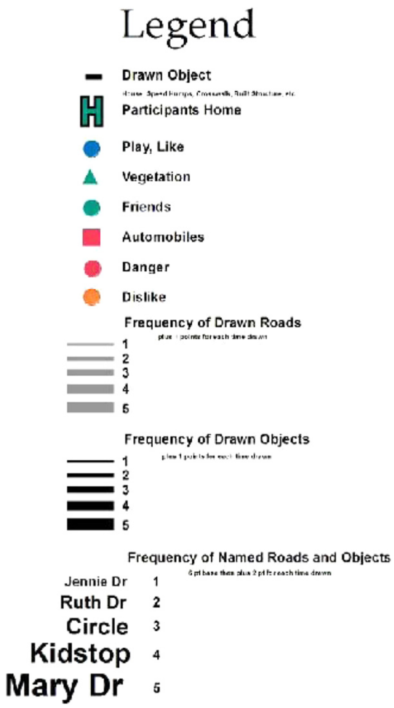

Fig. 4. This legend shows how the children's mapped responses were recorded on the collective cognitive maps (Fig. 5). For example, cool colors were designated for positive elements (green for homes of friends and acquaintances, blue for places they like to play), and warm colors for negative elements (red circles for danger, orange circles for dislike, and red squares for automobiles). For environmental awareness, if, for example, a single house or section of fence was drawn by a participant, then a line was placed in that approximate location. If a long series of houses were drawn, then a long line was placed on the map. The second manner in which the participan's environmental awareness was captured and then represented in a collective cognitive map was to scale-up line weights and type faces in proportion to the frequency in which the elements were drawn. For example, each time the same element was drawn (or labeled) in the same location by multiple participants, a line was drawn and then scaled thicker in proportion to the frequency in which it was drawn.

3.2. Study neighborhoods

To measure the effects of traffic and inadequate infrastructure along the routes to school in Incomplete Perry Neighborhoods (IPNs), two residential suburban neighborhoods, built around elementary schools within an easy walking distance of the schoolchildren, but lacking sidewalks, were chosen for comparison. Building on methods in the original *Livable Streets* study (Appleyard, et al. 1981), the communities were similar in most respects (income, race, education of parents, according to census data), but differ on the amount of exposure to traffic volumes and speed.

The two neighborhoods were Gregory Gardens (light-traffic-exposure, or Light TE) and Parkmead (heavy-traffic exposure, or Heavy TE). As shown in Fig. 3a and b, the light traffic-exposure (Light TE) neighborhood, had about half the amount of traffic around the morning school drop-off period as the Heavy-traffic-exposure (Heavy TE) neighborhood. In addition, the traffic in the Light TE neighborhood traveled at lower speeds (because of informal traffic calming provided by drainage swales). The traffic was also not as centrally located between the neighborhood and school, and thereby lessening overall exposure to traffic.

3.3. Recruitment of mapping participants

Following approved Institutional Board Review (IRB) protocols, and with assistance from the Principals at both schools, nine- and ten-year-olds who lived within walking distance to these schools were recruited for this study, with written approval from the childrens' parents and/or guardians. After these IRB requirements were met, 24 students were able to participate from the Heavy-traffic exposure neighborhood (Parkmead), and 12 were able to participate from the Light-traffic-exposure neighborhood (Gregory Gardens). In both groups there were slightly more females than males (14 in Parkmead, and 7 in Gregory Gardens). This disparity in the number of participants is addressed in the method used for creating the collective cognitive maps, discussed in more detail below. Essentially, by incorporating the frequency at which elements were drawn from individual maps, the collective cognitive maps gave the Heavy-traffic exposure (Parkmead) group an advantage over the Light-traffic-exposure neighborhood (Gregory Gardens) in terms of how they could express their development along a spatial knowledge continuum.

Children of this age were chosen in part because Piaget (1956) theorized that cognitive development for children in the

Fig. 6. This child showed a high association with the threat of traffic before improvements (e.g., see the note in the lower right, “the cars never stop and there is too much trafick.”). Note that the child’s map is oriented with south at the top.

age range evolves between his final two stages – going from Concrete to Formal. Reviewing maps of children in this age range enable the analysis of the schoolchildren's progression along Piaget's continuum of cognitive development (Piaget, 1956).

3.4. Conducting the cognitive mapping exercises

Following the same protocol and instructions for each group, the nine- and ten-year-old students were provided blank pieces of paper (18′x18′), and several black pencils. Rather than spatially constraining them with underlying pictures to orient the respondents, as done by Appleyard et al. (1981), using blank pieces of paper was similar to Lynch's method (Lynch, 1960) Fig. 1.

The instructions essentially asked the children to “draw a map of your neighborhood, between home and school, as if they were describing it to someone” (for more information see the protocol in the Appendix). The children were then asked to identify and comment on areas they liked, disliked, or felt were dangerous. They were also asked to indicate the location of their friends’ homes and places they liked to play. Each group was given the same amount of time for each task. They were also asked to indicate on the back of the map their usual travel modes to school.

4. Results

4.1. Framework for analyzing collective cognitive maps

In order to highlight the children's common themes within each group, collective cognitive maps were created using a framework and legend (Fig. 4) that would reflect the elements drawn on the maps (Fig. 5). This was a unique coding developed in this study, but guided by methods developed by Lynch (1960) and Appleyard et al. (1981).

The children's mapped responses were recorded on the collective cognitive maps (Fig. 5) in two main ways. The first was to place representative symbols in the approximate location elements were drawn by the participants. This was the process used for feelings (places disliked, expressions of danger, places liked and played in), of identifications (houses of their friends and people they know), and objects (vegetation, cars, etc.). As shown in the legend (Fig. 4) cool colors were designated for positive elements (green for homes of friends and acquaintances, blue for places they like to play), and warm colors for negative elements (red circles for danger, orange circles for dislike, and red squares for automobiles).

For capturing environmental awareness, a similar approach to what D. Appleyard used in *Livable Streets* was followed (Appleyard D. et al. 1981 p. 25 Fig. 6: Environmental Awareness). For example, if a single house or section of fence was drawn by a participant, then a line was placed in that approximate location. If a long series of houses were drawn, then a long line was placed on the map.

The second manner in which the participant's environmental awareness was captured and then represented in a collective cognitive map was to scale-up line weights and type faces in proportion to the frequency in which the elements were drawn. For example, each time the same element was drawn (or labeled) in the same location by multiple participants, a line was drawn and then scaled thicker in proportion to the frequency in which it was drawn. This was the same process used for recording the frequency of which roads were drawn.

A similar practice was used to record the frequency elements were labeled by participants. For example, for a map on an 8.5×11-inch piece of paper, each element mentioned was initially represented by 6 point type. With each successive time the element was labeled, it was enlarged another 2 points. For example, participants in the high-traffic exposure (HTE) group mentioned Parkmead School twenty times, hence it was represented at 44 points.

The resulting maps provide an effective graphic depiction of the schoolchildren's collective ability to identify physical features in their environment, as well as their spatial association between activities, feelings, preferences, etc. in their neighborhood.

5. Discussion

Graphic comparison of the children's collective cognitive maps illustrates the inverse correlation between their exposure to traffic and the quality of their neighborhood experience. In the Heavy Traffic Exposure (TE) neighborhood (Parkmead), the children frequently expressed feelings of dislike and danger when exposed to higher traffic volumes and speeds. Furthermore, schoolchildren exposed to such threats collectively expressed a limited ability to represent any detail of the surrounding environment. This finding is made even more significant given the fact that Newell Avenue, the main road in front of the school in the High Traffic neighborhood is a tree-lined street, and yet few of the trees were drawn. Instead, representations of danger and cars (red) and dislike (orange) dominated. These results are consistent with findings in *Livable Streets* (Appleyard D. et al. 1981 p. 25).

In contrast, participants from the Light TE neighborhood (Gregory Gardens), demonstrated a much richer sense of their environment, drawing more of the streets, houses, trees, and other objects, and including fewer signs of danger, or dislike, and fewer cars. The children also drew many more places in the street where they liked to play – identifying 43 percent more play-space locations in their streets – compared to the children in the heavy-traffic-exposure neighborhood.

Children rely on play and education for their mental and social development, and when they face greater threats from their environment their ability to explore independently is significantly limited (Kitchin, 1994). By extension, we might want to consider literature on children's cognitive impairments due to other nuisances, such as warfare, which similarly may limit children's ability to recall details of their environment (Levy, 1997; Evans et al., 2001; Tranter, 2015; Tranter, 1996).

In sum, alleviating the exposure to threats posed by automobiles appears to significantly improve children's ability to recall characteristics of the neighborhood, suggesting an increased ability of children to develop further along Piaget's stages of cognitive spatial intelligence, discussed earlier (Piaget, 1956).

5.1. Examination of individual maps

This pattern of limited spatial knowledge is also apparent from a review of some of the individual maps drawn by children. In Fig. 6, a child from the Heavy TE neighborhood expresses how they are threatened by traffic as the note in the lower right states, "the cars never stop and there is too much trafick (sic)." Furthermore, the busy, dangerous street between home and school is significantly constrained spatially, as it is relegated to the bottom right corner of the map.

In contrast, evidence of how lowering a child's exposure to traffic threats can enhance a their cognitive development can be found in Fig. 7a, where a ten-year-old child from the Light Traffic Exposure school and neighborhood was able to draw a highly accurate map that would rate high along all five of Piaget's elements of a child's cognitive spatial perceptual structuration. Furthermore, as shown in Fig. 7b, this child expressed a positive overall image of his neighborhood, as manifest in their testimonial.

As shown in Fig. 7a, a child from the same Light Traffic Exposure group who was able to bicycle and walk everywhere was able to express a much richer sense of their environment, drawing a very spatially accurate and detailed map of the streets, houses, trees, and other objects, and including fewer signs of danger or dislike, and fewer cars.

In comparison with the child from the Heavy Traffic Exposure Neighborhood (Fig. 6), this child from the Light TE neighborhood appears to rate higher on all of Piaget's (1956) five elements of a child's *cognitive, spatial, perceptual, structuration* (proximity, separation, spatial succession/order, enclosure, and continuity). In sum, the child from the Heavy Traffic Exposure Neighborhood (Fig. 6) appears to remain in Piaget's **Concrete operational stage**—where children can abstractly conceptualize, but cannot yet incorporate these routes into the larger context. In contrast, when compared to a child from the Light TE neighborhood (Fig. 7a), we see how a child of this age range can express further progression along Piaget's cognitive development continuum to the **Formal operational stage** by demonstrating their ability to completely and accurately conceptualize a large-scale map of his/her community (Piaget, 1956). Furthermore, the child from the Light TE neighborhood drew many more places in the street where they enjoyed playing, as well as areas they just simply liked. Finally, testimonial (Fig. 7b) which this child volunteered, is a powerful statement to how lower exposure to traffic can a

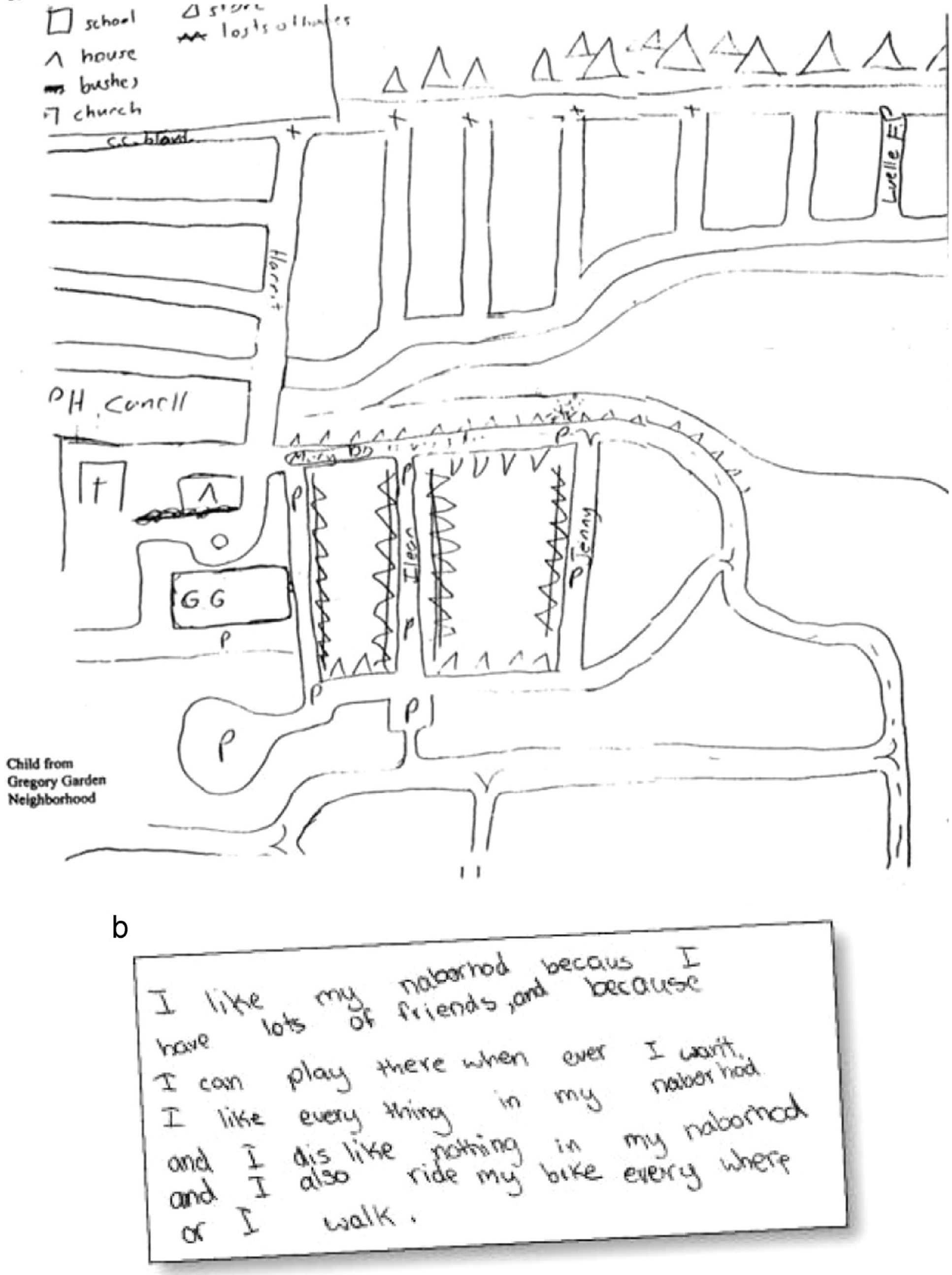

Fig. 7. a This child from the Light-traffic-exposure neighborhood, who was able to bicycle and walk everywhere in their neighborhood, was able to draw a highly accurate map of their neighborhood. 7b: The child from the light-traffic-exposure neighborhood who was able to bicycle and walk everywhere in their neighborhood offered this highly positive testimonial about their neighborhood.

elevate the quality of their experiences in their neighborhood.

5.1.1. Additional findings: active independent (walking and bicycling) versus dependent and captive mobility

While several studies have shown a relationship between children's independent travel and the potential for their improved spatial awareness and knowledge (Southworth, 1970; Hart, 1979; Rissotto and Tonucci, 2002; Mackett et al. 2007; Gale et al., 1985), according to Maiss and Handy (2011), few studies have, however, examined the effect of active versus passive (or captive) travel modes on the development of children's spatial knowledge of their communities. However, it should be noted that other research suggests that various transport modes used by children outside the journey to school is also significant factor likely influencing their maps (Panter et al. 2016). To examine whether travel by active modes leads to

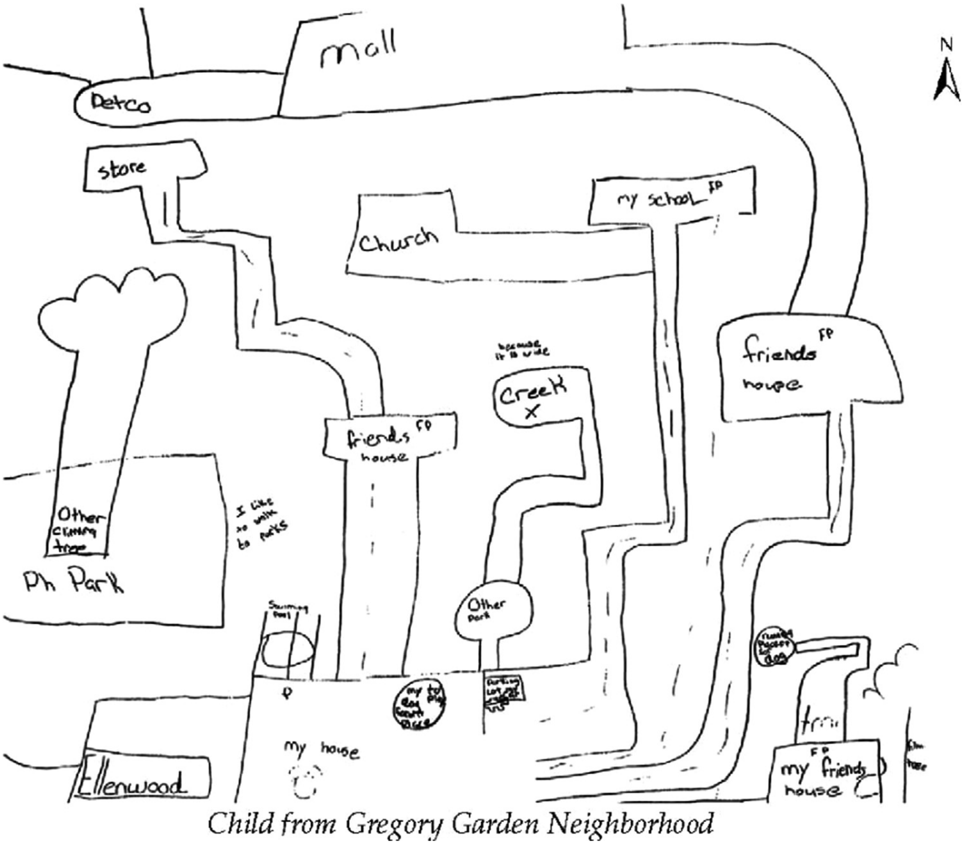

Fig. 8. A map drawn by a 10-year old child from the Light Traffic Exposure neighborhood, but who was driven everywhere. The result was a series of disconnected paths that led separately from home to school, friends, or the mall, with little detail or connection with the community within which s/he lived.

further development of community spatial knowledge than children who are typically driven everywhere, a comparison of maps drawn by children who traveled by different modes is conducted. Fig. 8 shows a child's view of his/her world from the back-seat of a car. This ten-year-old child, who was driven everywhere, was asked to draw a map of his neighborhood, and could only represent it as a series of unlinked paths.

Another participant who was also driven everywhere was so severely unable to make any connection with the area between home and school that s/he resorted to striking a line across the middle of the paper, and then drawing an image of the schoolyard above, and his/her home below. Piaget would likely the remark at the *linear* and *succession/order* elements of this child's map at the expense of accuracy in *proximity, continuity* or *enclosure* (Piaget, 1956).

These findings are consistent with other studies showing (1) children's ability to independent travel improves their spatial awareness and knowledge (Southworth, 1970; Hart, 1979; Rissotto and Tonucci, 2002; Mackett et al. 2007; Gale et al., 1985; Freeman and Vass, 2010), and (2) Maiss and Handy (2011) suggesting that children who are able to actively travel and explore their community by bicycle are able to draw more comprehensive maps of their neighborhoods than those who do not.

In combination, all of these study findings support Moore's Interactionist Theory (Moore 1986a, 1986b), and further suggesting that children who are able to actively and independently interact and experience their neighborhood via walking and/or bicycling, as opposed to those who are mostly driven, are able to draw more sophisticated cognitive maps of their community, and thus manifesting their progression along Piaget's continuum of cognitive spatial development (Piaget, 1956).

6. Conclusions

Overall the findings of this research support the hypothesis that traffic-threat-exposure (volume and speed), exacerbated by inadequate pedestrian and walking and bicycling infrastructure along the routes to school, limits children's progression along Piaget's developmental stages for spatial knowledge (Piaget, 1956). Furthermore, this study finds that higher levels of interaction with the environment, through independent and active travel, may indeed improve children's spatial knowledge development. These results are consistent with Moore's interactionist theory that interaction with the environment and cognitive spatial development may be related (Moore 1986a, 1986b).

These results are consistent with several additional studies finding that traffic can impose further negative impacts on children's cognitive development, as follows:

- Opportunities and locations for spontaneous, non-structured play are severely restricted by traffic (Hillman an Adams, 1992).
- Chronic traffic noise can stress children and raise their blood pressure, heart rates, and levels of stress hormones (Evans et al., 2001).
- In neighborhoods where traffic is a nuisance and a threat, children have a limited range of play activities and spend less time outside (Tranter, 2015; Tranter, 1996).
- Children who live in neighborhoods not dominated by traffic have a wider circle of friends, and so do their parents ("Kids on the Move.", 2002, 18).
- Many other physical benefits of active travel to school have been established by McDonald (2007).

Given its small sample and exploratory approach, the conclusions of this study should probably be viewed as more inferential than definitive, and the testing and the methods presented in this paper should continue. Furthermore, we should also look to the emergence of new technologies (touch screen pad computers, GIS, etc.) to more dynamically capture and analyze these maps drawn by children, which provide us invaluable insight on how they view their world (Freeman and Vass, 2010). Furthermore, additional research should test the relationships between all forms of active travel, in combination with a greater variety of neighborhood types and counter-measures to make them more inviting for walking and bicycling. Nevertheless, this study does provide important insights both for future research and for urban planners and urban designers.

Safe Routes to School Programs are examples of how improved opportunities for active travel among children have successfully been implemented by planners and activists on a local level (Staunton et al., 2003). Engineering improvements, encouragement programs, such as group cycling programs to school, and extracurricular activities can also effectively encourage active travel among children (Tal and Handy, 2008). Such programs, when paired with good land-use and transportation planning practices, can be an effective way to foster active travel among children. In addition, we should look toward combining these programs with more comprehensive land-use and transportation planning, which should include better coordination of siting school facilities (Appleyard, 2003; Appleyard and Torma, 2006).

6.1. Closing remarks

Cognitive mapping exercises, like the one presented in this study, provide useful tools for understanding how children view their world. The individual and collective maps created through this research show that as exposure to auto traffic volumes and speed decreases, a child's sense of threat goes down, and his/her ability to establish a richer cognitive connection with their community rises. Without pedestrian and bicycle facilities to provide sanctuary for a child from automobile traffic, the negative senses of danger and dislike appear to limit children's ability to identify the qualities of their neighborhood that are memorable, special, or even positive.

Finally, cognitive mapping exercises like this provide a valuable way for children to express their views of the world, and for identifying and assessing the problems and opportunities experienced by children along the routes to school (e.g., important destinations, secret paths, preferred travel routes, and existing barriers). In turn, they can help community members, public staff and policymakers identify and articulate the most cost-effective solutions to making neighborhoods and streets safer and more livable for the children.

Appendix A. Cognitive mapping protocol

Hello, my name is Bruce; I'd like you to meet my classmates/colleagues _____and ____.

We are from ____, and like you we also have homework assignments.

One of our homework assignments is to understand how people of your age view the world around you. You can help us by drawing a map of your neighborhood, between your home and school.

First, we would like to organize you all into equally sized groups.

7.1. Organize the children into groups of about 3–5, depending on tables and overall size of group

We are particularly interested in how you view the neighborhood between your home and school, and the other areas you may go.

You can really help us with our homework if you draw a simple map of your neighborhood for us.

Nothing fancy, just a simple map of the area between your home and school and the other areas in your neighborhood that are important to you.