



Redesigning the Built Environment

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Introduction

During the past century, human life expectancy at birth has increased more than 30 years (Wang, et al, 2016). Continuous efforts to reduce mortality and morbidity have led to such exceptional human achievement. In the United States, however, life expectancy varies widely across geographical regions, neighborhoods, and even city blocks. Children in the South and Appalachian regions of the country are born expecting to live twenty years less than those in other parts of the country (Dwyer-Lindgren et al, 2017). Yet, disparities are evident even on more local scales. In New York City, for example, children who live just ten miles from one another can anticipate differences of up to five years in life expectancy (Tavernise, & Sun, 2015). These life-span disparities across even small geographical areas underscore the importance of the environment on long term mental and physical health.

Built environments encompass risk factors and potential benefits for longevity, including the depletion or boost of physical activity, sense of community, social interaction, respiratory and cardiovascular morbidity, and cognitive health (Wang et al, *In Press*). Among the physical environment, some prominent high-risk factors associated with health in the long term include proximity to traffic-related air pollution, lead exposure, lack of access to healthy food supply, lack of access to green spaces and less walkable neighborhoods. While hazardous exposures have significant direct effects on overall health, exposure to supportive environments have also shown to influence behaviors, such as walking routines and social interaction, and consequently health outcomes, like lower risk of cardiovascular and respiratory diseases, impaired brain and nerve functioning, obesity and stress (Lee & Maheswaran, 2011; Freeman, Neckerman & Schwartz-



Soicher, 2013; Larson, Story & Nelson, 2009). For example, people living in more walkable neighborhoods are less likely to be obese (Rundel et al., 2008) and lack of access to a park can slow down cognitive development by up to 12 months (Dadvand et al, 2015). In the past few decades, research has started to uncover the complexity, magnitude and lifelong impact of these factors. The deeper effects of the environment may be evidenced in a study conducted in 2010, where researchers scanned and compared the entire genome. Surprisingly, 50% of the differentially expressed genes could be attributed to living in urban versus rural areas, whereas only 5% could be attributed to ancestry and gender (Idaghdour et al., 2010).

Even more, the effects of the environment are not only deeply entrenched in our biological selves, but they also follow individuals over the life course. Most of these exposures to physical environments exist and persist throughout the lifetime of an individual. For example, access to green spaces is predictive of lower obesity for both children and older adults, independently. Not only are these environments predictive of outcomes at every stage of life, but they act as cumulative factors over time. For example, lead exposure through paint in an unrenovated household is predictive of slower brain development in children, and neurodegenerative disease in adults, such as dementia and Alzheimer (Needleman, 2004). Because lead accumulates in the body by being stored in bones along calcium, developmental exposure has compounded effects when reaching older age. Such cumulative effect of exposure to adverse environments calls for a lifecourse approach in order to support individuals to successfully transition through life stages to live healthier and longer lives.

From cities to neighborhoods, homes and workplaces, the settings we are exposed to have a remarkable lifelong impact on our wellbeing - including the economic, psychological, mental



and even physical domains. Designing physical environments that support successful aging is of paramount importance for healthy, productive, and equitable societies. This is particularly true for Americans living in poverty, who experience the biggest difference in life expectancy based on where they live. As an example, individuals in the highest income bracket from both New York City and Detroit have the same average life expectancy. However, individuals in the lowest income bracket in Detroit live five years less than similar New York City residents (Chetty et al, 2016). To underscore the magnitude of this disparity, eliminating cardiovascular disease, the leading cause of death in the U.S., would only increase overall U.S. life expectancy seven years (American Heart Association, 2000). Optimizing the built environments, in which children grow up and adults grow old is of paramount importance as we strive for healthier and more equitable societies in the era of 100-year lives.

The Built Environment in the United States

Despite the importance of household, neighborhood, and community characteristics in the built environment for emotional well-being, preventing cardiovascular and respiratory diseases, accelerated neurodegeneration and consequently life expectancy, access to such environments varies widely across the United States. From an equity perspective, neighborhoods are especially relevant, since they represent the social and material resources needed for a community to thrive, and disadvantaged ones rely more on these resources. A recent study showed life expectancy varies widely across the US, where men with the highest income in the US live 15 years longer than those who earn the least, and women with the highest level of income live 10 years longer than the poorest ones. (Chetty et al, 2016). Higher income individuals benefited from the increase in life expectancy, regardless of their geographical location. However, for lower income individuals life



expectancy depends on the local area where they live. Those with the lowest income could expect to live 4.5 years more, depending on their location.

Access to green space and walkable neighborhoods.

Beyond the overall disparity in life expectancy, the United States shows consistent disparities of the different aspects of the built environment that influence human health and behavior, such as green spaces, places for social gathering, transportation and housing. Access to green spaces and walkability of the neighborhood have been consistently associated with better physical and mental health for both children and older adults, including increased physical activity, lower obesity, reduced stress and improved cognition (Kondo, Fluehr, McKeon & Branas, 2018; Lee & Maheswaran, 2011). However, only 10% of the nation's 500 largest cities are rated as very walkable where most errands can be accomplished on foot (City Health Dashboard, 2018) and 100 millions of Americans don't have access to a nearby green space (Trust for Public Land, 2020). Regionally, data from the National Environmental Public Health Tracking Network shows residents living without close proximity to a park in metropolitan areas are strongly concentrated in the south east, in states like Georgia, Alabama and Tennessee (Kane & Timer, 2019). Gaps in access to urban green areas increase for lower income populations. In a recent study, researchers examined 10 metro areas, including New York, Los Angeles, Chicago, Houston, Seattle, Phoenix, Indianapolis, Jacksonville, Portland, and St. Louis, using high resolution land cover data and census data. They found that access to urban vegetation is strongly associated with both higher education and higher income levels, meaning lower income individuals across urban areas are less likely to live near urban green space (Nesbitt, Meitner, Girling, Sheppard & Lu, 2019). Similarly,



more advantaged neighborhoods are not only associated with greater access to green spaces, but also with lower incidence of pedestrian accidents (Noland, Klein, Tulach, 2013; Yu, 2014).

Access to places to gather and engage with others

Neighborhood environments also provide the spaces for us to be socially active and engaged. Preventing social isolation is critical for longer and healthier lives, since it has shown to be associated with adverse physical and mental health consequences, such as depression, impaired executive function, accelerated cognitive decline, poor cardiovascular function, impaired immunity and, most strikingly, all-cause premature death (Alcaraz et al, 2019; Hawkey & Capitano, 2015). Unfortunately, neighborhoods are growing less connected over time and the average household has been reduced to half its size over the last century (Sims et al, 2016). Evidence from a nationally representative survey suggests that from 1985 to 2004, the number of people saying there is no one with whom they discuss important matters nearly tripled. The most common response on how many confidants they had (e.g. people you would talk about your important matters) was three in 1985, and by 2004 it was zero, with the largest drop of social ties through neighborhoods and voluntary associations (McPherson, Smith-Lovin & Brashears, 2006).

Exposure to pollution sources

Another important factor of the built environment is living next to a source of traffic-related air pollution (e.g. highways and major roads), since it has been extensively associated with childhood asthma, impaired lung function, premature death and death from cardiovascular diseases and cardiovascular morbidity (American Lung Association, 2021). According to the American Lung Association, only 4 in 10 Americans live in areas with recommended levels of air quality



(American Lung Association, 2019). Similarly, it is estimated that 30 to 45 percent of Americans live 300 to 500 meters from a highway or a major road, the most highly affected by traffic emissions (Health Effects Institute, 2010). Across the country, the most polluted states are California, Pennsylvania, Washington, Oregon and Alaska (American Lung Association, 2019), significantly impacted by motor vehicles, but also by wildfires and industrial pollution (American Lung Association, 2001). Across states, ample evidence has shown that lower socioeconomic status is associated with both higher exposure to air pollution and greater harm from air pollution (Hajat, Hsia & O'Neill, 2015; Finkelstein et al, 2003; O'Neill et al, 2003). Similarly, nonwhite populations, particularly African Americans, face the highest risk of particle pollution in the air (American Lung Association, 2001). Race is not only a predictor of higher air particle pollution, but also a predictor of lower production of pollution. For example, one study found that in the United States, on average, whites experience approximately 17% less air pollution exposure than is caused by their consumption. In contrast, African American and Hispanics, on average, bear 56% and 63% more air pollution exposure, relative to their consumption (Tessum et al, 2019).

Indoor pollution is also a strong contributor for air quality. For example, household solid fuel burning for cooking and keeping warm temperatures during winter, such as wood, crop waste and coal, is estimated to be responsible for 1.6 million deaths annually across the world (World Health Organization, 2002). In this case, as in the previous one, lack of access to clean fuels for indoor use has been extensively associated with poverty, contributing to the increased pollution exposure to poor inhabitants (Masozera, Bailey, & Kerchner, 2007). This is the case of Alaska, for example, where two of the top 25 most polluted cities in the United States are located, according to the last “State of the Air” report by the American Lung Association (2019). This occurs in large part because of solid fuel burning, like wood, during low temperature seasons. Climate change is



another strong predictor of increased air pollution, which is more extensively covered in the climate report of the New Map of Life initiative (Wang, C. 2021).

Exposure to unrenovated housing and contaminated water systems

Beyond neighborhood conditions, household settings strongly influence life expectancy from early ages, and follow individuals until they grow older. For example, lead exposure, a common material used for water system pipelines and paint, has been extensively linked with slower neurological development in children and an increased difficulty learning to read in school (Vivier, Hauptman, Weitzen, Bell, Quilliam & Logan, 2011), and most recently with intergenerational transmissions from in-utero exposure. This means that mothers who live in houses with residual lead-based paint or pipelines will transmit ingested lead to the fetus, and therefore change its aging trajectory even before they are even born. In 1978, the federal government banned consumer uses of lead-based paint. According to the American Housing Survey, a nationally representative sample, the median year homes were built in the United States is 1974 (US Census Bureau, 2013). Today, it is estimated one in every three households with children six years or younger has a high risk of lead exposure because of old paint (Benfer, 2017). Such risk is mostly associated with low-income households who struggle with older housing conditions and less capacity for housing maintenance. Not only socioeconomic status, but also race and residential segregation have shown to be associated with higher likelihood to be exposed to lead. In Detroit, for example, one study found racial minority children face a disproportionate burden of lead exposure (Moody, Darden & Pigozzi, 2016). More recently, the COVID pandemic made household conditions become even more of a pressing need for lower income populations,



since children and mothers increased their indoor time, and consequently increasing their potential exposure to lead (Anthes, 2021).

Such contamination crisis extends to tap-water sources. According to a recent study, more than 77 million Americans live in areas where violations of the Safe Drinking Water Act on water systems were reported (Fedinick, Wu, Panditharatne, Olson, 2017). Around 12,000 health-standards were violated in around five thousand community water systems. Pollutants coming from industrial manufacturing, farming and water plant and pipes deterioration range include lead, nitrates, arsenic, radium, fluoride and fecal matter. Drinking water crises got nationwide attention in places such as Flint, Michigan, Toledo, Ohio, Yonkers, New York and Wilmington, North Carolina (Fedinick, Wu, Panditharatne, Olson, 2017), but unfortunately it is further spread across the country. Disparities are strongly evidenced in access to safe water systems. Poverty, indigeneity, education, and rurality are predictors of lower access to safe water and highlight the injustice of those who have faced historical disadvantage are disproportionately impacted by industrial dumping contaminants (Mueller, & Gasteyer, 2021). Despite it being a nationwide crisis, some states have been hit the most. Some of them because of natural disasters damaging water systems, such as Puerto Rico, whereas others have been mostly impacted by radiation pollutants, such as Texas, and legacy effects of the coal-mining industry, such as Pennsylvania.

Access to healthy whole food stores

Access to healthy food outlets also plays a fundamental role in living healthier and longer lives, because of the strong influence of obesity and other cardiovascular diseases in reduced life expectancy in the United States. Within this domain, healthier diets depend most fundamentally on having access to affordable and wholesome food stores. Unfortunately, food deserts, where



access to healthy food supplies is lower, make it nearly impossible for many Americans to improve their diets. According to the United States Department of Agriculture, 17.7 percent of the population, that is 54.4 million people, live in low-income neighborhoods with low access to a supermarket, supercenter, or large grocery store (USDA, 2019). This measure considers low access as more than 33% of the neighborhood living far away from a supermarket. Namely, more than half a mile for urban areas, and 10 miles for a rural area. Studies have found these gaps increase for racial minorities and rural communities (Karpyn et al, 2010). For example, a multistate study found that ninety two percent of African Americans do not live in a census tract with a supermarket, compared to sixty nine percent of whites (Morland, Wing & Roux, 2002). In another nationwide analysis, researchers suggested that 20 percent of rural counties lived in a food desert (Treuhaft & Karpyn, 2010). Given the large and wide coverage of fast food stores, high-fat and high-sugar diets are the most available and affordable options for lower income families. Some evidence suggests mothers who are exposed to such diets unintentionally predispose multiple generations to metabolic problems linked to obesity and diabetes (Ferey et al, 2019). It is important to highlight, however, that mere access to healthy food stores has proven not to be effective by itself (Abeykoon, Engler-Stringer, & Muhajarine, 2017). Both affordability and education are important mechanisms that will be explained in the next sections.

The consequences of disparities in access to supportive environments

Overall, differences in built environments affect disadvantaged populations the most dramatically, which might partially explain the life expectancy disparities between socioeconomic status, and the predictive power of the neighborhood on average life expectancy of the most economically disadvantaged. This occurs not only because of higher exposure to unhealthy or non-



supportive environments as we have evidenced above, but also because non-white and poorer populations are subject to greater harm from such exposures. In the case of air quality, for example, a large study on fine particle pollution-related mortality of 13.2 million medicare recipients found low socioeconomic status significantly increased the risk of premature death related to such exposure (Zeger, Dominici, McDermott, & Samet, 2008). Similar evidence has been found for non-whites. A study of New Jersey residents found that early mortality from long-term exposure to particle pollution was higher for neighborhoods with a larger proportion of African Americans, lower home values and lower median income (Bell & Dominici, 2008). The consequences of disparities in access to healthy environments are of utmost importance to the United States since it presents a strong risk of reduced physical health, reduced mental health, decreased productivity and increasing inequality across the country.

Generalized reduced physical health

First, lack of access to healthy and safe built environments increases the risk of physical health morbidities associated with early mortality, such as cardiovascular and respiratory diseases. For example, access to green spaces has been shown to promote physical health, through the increase of physical activity in daily life as well as leisure time (Kondo, Fluehr, McKeon & Branas, 2018; Abraham, Sommerhalder & Abel, 2010; Twohig-Bennett & Jones, 2018). Further research has also evidenced the causal effect of green spaces on decreased respiratory illness (Russel et al, 2013). One study exploited the natural experiment of one hundred thousand trees lost due to an invasive pest - the emerald ash borer in the United States. Researchers found that areas that experienced loss of trees due to the emerald ash borer showed an additional 6 thousand deaths



related to respiratory illness and 15 thousand due to cardiovascular related disease (Donovan et al, 2013).

Generalized reduced mental health

Second, lack of access to such environments potentially reduces mental health, through increased loneliness and depression throughout the lifecourse, and higher likelihood of neurodegenerative diseases like dementia and Alzheimer, which in turn affect both early mortality and quality of life (Hawkey & Capitanio, 2015). Loneliness can be partially prevented through built environments where individuals can socialize with others. For example, quasi-experimental evidence suggests that access to safe and maintained green spaces is associated with more social contacts. (Kuo, Sullivan, Coley, Brunson, 1998). Decreasing feelings of loneliness in society is critical because they have been extensively associated with impaired executive control and poorer general health in children (Diamond, & Lee, 2011; Harris, Qualter & Robinson, 2013), impaired control over eating behavior and obesity in teenagers (Salvy et al, 2011), higher incidence of immune & inflammatory diseases in adults (Slavich & Cole, 2013; Glaser, Kiecolt-Glaser, Speicher & Holliday, 1985; Kiecolt-Glaser et al, 1984) and accelerated cognitive decline and all-cause mortality in later adulthood (Tilvis et al, 2004; Alcaraz et al, 2019; Shankar, Hamer, McMunn & Steptoe, 2013) Overall, experiencing feelings of loneliness independently impacts several life stages that, if accumulated, exponentially increases the likelihood of morbidities related to early mortality, such as obesity, inflammatory diseases and impaired immunity.

Decreased economic productivity and income opportunities

Third, increased exposure to harmful environments will potentially decrease both the economic productivity of society and the income opportunities for individuals, since decreased mental and physical health leads to disability and lower productivity in the workplace. For example, environmental hazards like lead, and air quality, have consistently shown to be associated with accelerated brain aging, leading to cognitive decline and dementia (Finch & Morgan, 2020). Increased dementia rates in a society aging at an accelerated rate would increase the costs of direct medical, social and informal care costs. In fact, it is estimated that the total worldwide cost of Dementia in 2015 reached 818 billion USD, or 1.1% of the global gross domestic product. Similarly, depression is as of today the leading cause of disability across the world (Friedrich, 2017). A recent study analyzing the American Productivity Audit estimated that US workers with depression cost employers approximately \$31 billion USD more per year, compared to peers without depression (Stewart, Ricci, Chee, Hahn & Morganstein, 2003)

Increased cumulative inequality

The fourth consequence is that such disparities might increase inequality gaps in society, through two main mechanisms. On one side, the inequalities that are experienced during childhood have long term and cumulative effects throughout the lifespan, reducing the likelihood of social mobility. For example, children who grow up further away from a green space have been shown to be delayed twelve months in cognitive development, pulling back opportunities for higher education and income opportunities in later life (Dadvand et al, 2015). On the other side, many of these exposures and consequences of harmful environments have been shown to be transmitted intergenerationally, further preventing intergenerational mobility. The intergenerational



transmission of disadvantage has been shown by pioneer research in the last decade, showing three potential mechanisms through which it operates: biological motherhood and structural discrimination and learning of unhealthy food selection patterns and preferences.

Some of the built environment hazards disadvantaged mothers are exposed to are transmitted to children from in-utero transmission. For example, recent evidence shows mothers who are exposed to higher levels of pollution by inhaling more urban black carbon particles experience shortening of placental telomere length, suggesting accelerated aging of their offspring (Ladd-Acosta et al. 2019; Saenen et al. 2016, 2019). Similarly, lead ingested through household environments (such as unrenovated housing and pipelines) accumulates in the bones over the lifespan, and later on is released during pregnancy as maternal calcium to the fetus and through breast milk feeding (Ettinger et al, 2004)

Similarly, disadvantage can be transmitted to children through historical discrimination and lower access to economic resources that consequently lead to growing up in lower opportunity neighborhoods with higher exposure to toxic environments. Decades of discriminatory practices have burdened black communities with increased poverty and residential segregation, later on reflected on substandard housing and increased environmental toxic hazards. As of today, the effects of historical discrimination fall on children of color. Black children in the United States have nearly three times higher risk to have elevated lead levels in their blood, compared to white children (Jones et al, 2009), and similar evidence supports differential levels of access to green spaces (Nesbitt, 2019), and overexposure to lower air quality (Tessum et al, 2021)

Lastly, the compounded disparities that experience disadvantaged populations may also be intergenerationally transmitted through learning of inadequate behaviors, a consequence of

developmental lack of access to supportive environments during earlier stages of life. For example, some evidence shows that dietary choices and behaviors in children can be predicted by parental dietary behaviors (Rimal, 2003). In this case, families who grew up without the economic resources and the physical proximity to buy healthy foods, may unintentionally expose children to unhealthy patterns of preferences and food selection, and therefore lead to morbidities associated with lower life quality and life expectancy, such as obesity (Birch & Davison, 2001).

Evidence-based interventions

Because of the high costs and scales associated with built environment interventions, most of the available evidence is cross-sectional, which prevents time-based variation in order to understand the changes in health outcomes because of specific built environments exposures. However, existing evidence using natural experiments, government programs and quasi-experimental approaches have shed light on some of the mechanisms and settings that enable or prevent built environment interventions to improve outcomes.

Improving access to urban green areas

Providing access to green space has been extensively associated with decreased cardiovascular and respiratory disease, increased mental health, increased social engagement and higher cognitive function; four pillars that across different life stages, from childhood to late adulthood, cumulatively support overall health in the long term. The first mechanism through which green areas improve overall health is associated with reduced cardiovascular and respiratory disease. One natural experiment found that in counties where the emerald ash borer pest reduced the number of trees, such county dwellers experienced a higher mortality related to cardiovascular

and lower-respiratory-tract disease, compared to those where the emerald ash borer was not present, and therefore canopy tree vegetation remained intact (Donovan et al, 2013). Despite this study not measuring specific mechanisms, it contributes to the plausibility of the causal effects of green space on cardiovascular and respiratory health. However, experimental and non-experimental evidence on lower scales sheds more light into the potential mechanisms. Green spaces have been shown to improve air quality (Nowak, Crane & Stevens, 2006), which has strongly been associated with lower incidence of mortality due to respiratory and cardiovascular disease (Lelieveld, 2020). Similarly, green spaces have been shown to increase physical activity (James, Banay, Hart &Laden, 2015), which in turn decreases risk of cardiovascular disease (Myers, 2003)

Green spaces and nature have also consistently shown positive effects on mental health. For example, it has been extensively shown that exposure to nature is effective in reducing stress and promoting positive emotions (Russel, 2013). Even more, in order to disentangle the independent effects of nature and exercising, it has been shown that when randomly assigning participants to a walk in a green space or in an urban environment, those who took a walk in a green space showed higher decrease of negative emotions, like anxiety and rumination, and higher positive emotions and cognitive performance, compared to those who took a walk in the urban environment (Bratman, Daily, Levy & Gross, 2015). Likewise, reductions in air pollution through green spaces have been shown to accelerate cognitive development in children, particularly increased working memory and decreased inattentiveness (Dadvand, 2015), and, in contrast, to slow down cognitive decline in late adulthood (Cherrie, 2018). Finally, green spaces can also act as places for social gathering. A study using quasi-random assignment of public housing residents in Chicago to residential areas with varying amounts of vegetation, suggested that presence of trees



and grass promoted the use of common spaces and therefore building informal relationships with neighbors (Kuo, Sullivan, Coley, Brunson, 1998).

Improving access to healthy food outlets.

Healthy diets are a cornerstone of successful aging, since obesity is a direct cause of chronic diseases and disability (Bales & Buhr, 2008) (Starr, McDonald & Bales, 2014). Even more, evidence suggests that diets including 5 portions of fruit and vegetables a day increases life expectancy and reduces accelerated cognitive aging (Khaw et al, 2008; Ngandu et al, 2015). Despite the wide evidence of disparities in access to healthy food stores in the United States, evidence about interventions that have successfully improved healthy eating habits through built environment interventions are less evident.

An influential study found that neighborhoods where a new supermarket enters has small effects on increased grocery purchases (Allcott et al, 2019). Similarly, they found that families that moved to areas where neighbors eat healthier had little effect on eating patterns. They conclude using an economic model that equalizing access to healthy food stores would reduce the difference in healthy eating between low income and high income households by only ten percent. Dietary choices are a complex phenomenon, where multiple context and individual factors might explain the reduced effectiveness of bare access interventions to lower income households.

The same study suggests education explains 20 percent of healthy diet preferences variation between socioeconomic status and 14 percent are explained by nutrition knowledge. Some evidence shows nutrition education might be successful interventions to improve health choices (Anderson et al, 1998) and reduce obesity (Da Silveira, Taddei, Guerra, & Nobre, 2013).



Another important mechanism is affordability. Increasing food affordability has proven to be effective in improving health outcomes. For example, supplemental nutrition programs have shown to have positive effects on lowering body-mass index (Nguyen, Shuval, Bertmann & Yaroch, 2015) and improved birth weight (Almond, Hoynes & Schanzenbach, 2011).

An additional explanation of why improved access does not lead to improved dietary habits lies in reduced self-control. This is a plausible reason, given evidence suggests that adults who grew up in poverty are more likely to value the present over the future when making decisions, because of the effect of uncertainty and resource scarcity (Bernheim, Ray & Yeltekin, 2015; Mani, Mullainathan, Shafir & Zhao, 2013; Griskevicius, Tybur, Delton & Robertson, 2011), and even because of the cumulative effect of stress on self-regulatory brain function (Kim et al, 2013). Further research is needed to understand how improving access to healthy food stores can more effectively improve healthy dietary behaviors.

Improving access to higher opportunity neighborhoods

Because of the strong influence of neighborhood conditions on long term wellbeing, researchers have also explored the possibility of providing incentives to help families move into different neighborhoods with more favorable conditions. When a neighborhood's levels of poverty are high, the increased concentrated disadvantage leads to increased incidence of crime and violence and lower quality schools. The effects of moving out of such environments positively impacts adults' mental and physical health, including lower incidence of major depression, improved well-being and lower levels of obesity and diabetes (Ludwig, 2013). Consequently, research has shown that children that move out of these environments improve their income and likelihood to attend higher education by adulthood. Similarly to environmental hazards,



neighborhood exposure is cumulative over childhood development, since children's outcomes have been shown to be proportional to the time they spent growing up in these environments (Chetty & Hendren, 2018)

Nevertheless, evidence suggests that incentives alone are insufficient to significantly increase the likelihood to move to higher opportunity neighborhoods. Traditionally, it was suggested the mechanism underlying the modest effectiveness was that lower income families prefer to live in lower opportunity neighborhoods. Further research has shown that additional barriers during the house search process, and not preferences, hinder families to move to better neighborhoods. A strong body of evidence suggests these barriers in the housing search process, beyond mere access, can effectively be addressed through modest program modifications (Bergman et al, 2019). Namely, customized assistance, such as motivational guidance, emotional support and financial assistance. The striking effectiveness of robust randomized controlled trials using such methodology provides evidence that housing programs can be more effective by identifying underlying hardship that comes with poverty, and providing interventions that promote agency and and consequently lead to better choices. Although such evidence is related to higher upward mobility neighborhoods, this might apply to further cases of environmental exposures (e.g. high air-pollution neighborhoods). In short, efforts to increase access to better environments can incorporate incentives and furthermore they should include educational, motivational and emotional factors that underlie household choices.

Lessons on the effectiveness of built environment interventions

As mentioned above, environmental conditions are predictors of health and wellbeing outcomes throughout the life-course. Most of these physical factors are especially challenging for



low-income communities since their living areas and infrastructure tend to have lower levels of investment. Based on the evidence, two types of interventions and mechanisms are mentioned. The first group of interventions are related to the reduction of exposure to hazardous built environments, such as households with lead-based paint or higher levels of air pollution. Such interventions have shown to be effective in improving health outcomes over the lifespan, suggesting they are promising pathways to increase healthy aging.

Comparatively, the second group of interventions are related to built environments that enable positive behaviors, such as exercising and increasing healthy food intake. However, an increasing amount of evidence suggests increasing access to environments that might prompt positive behaviors alone does not drive outcomes, but it also requires opportunities to enact agency. Taking as an example healthy food consumption and food stores, improving access to grocery stores alone has not shown to improve grocery intake (Elbel, 2015). Similarly, housing-vouchers given to households to move to high-opportunity neighborhoods have smaller effect sizes than those that incorporate emotional support and assistance brokering with landlords (Bergman et. Al, 2019). Consequently, a higher predictor of healthy food consumption is educational attainment among families (Handbury, Rahkovsky, & Schnell, 2015), and cash-benefits showed to be more effective with housing choice guidance (Bergman et. Al, 2019). Access alone is not the solution. In order to effectively empower equitable and healthy long lives, making good environments available is as important as increasing households and individual opportunities to enact agency through education and empowerment.

Recommendations



Rethinking the built environment has not been a new endeavour in the United States. By 1900, urban dwellers faced what was called the “urban penalty”. Inhabitants of cities could expect to live a decade less than rural dwellers. Records from the Death Registration Area suggest that the life expectancy at birth of the urban white population was 46 years, while it was roughly 55 for their rural counterpart (Haines, 2001). Back then, the rapid urbanization and flourishing industrialization turned cities into hazardous environments. Lack of sewage and water disposal systems led to higher degree of water contamination and dissemination of bacterial diseases like Cholera. Overly crowded dwells and high migration flows contributed to accelerated spread of infections like tuberculosis and typhoid. In fact, county level data from the Census of 1850 shows that counties where households had access to water systems and railroad transportation had a death rate of 20.5 deaths per thousand inhabitants, compared to 15.6 in counties that did not have access to these facilities (Haines, Craig & Weiss, 2000). Because of the incidence of infectious diseases, larger cities were usually related to decreased longevity. Similarly, racial disparities during early 1900 were equally striking, both before and after the abolition of slavery. Data from the Death Registration Area shows life expectancy at birth of blacks was 41.8 years. Ironically, since 80% of the African American population was rural, compared to 60% of whites, they were partially protected from the negative effects of hazardous urban environments (Preston & Haines, 1991). Nowadays, that trend has turned and Black Americans face a disproportionate burden of environmental exposures across the United States.

Nevertheless, by 1940, the mortality gap between urban and rural areas had almost disappeared (Preston & Haines, 1991). Emerging knowledge of bacteria impulsed better informed public infrastructure planning. Clean water and adequate sewage disposal systems allowed for reduction of infectious diseases, while other measures like vaccines, air pollution initiatives, health



education and further household improvements to manage heat and ventilation allowed to improve living standards and therefore to alleviate urban mortality (Haines, 2001). Further improvements in increased life expectancy after 1940 were mostly related to middle and older age, such as medical advances and changing health behaviors (e.g. smoking) that significantly reduced chronic cardiovascular and respiratory disease.

Fast forward a century and cities nowadays provide a better environment than their rural counterparts, reflected in increased longevity and healthspan for city dwellers. Contemporary urban environments provide better quality of life, opportunities to socialize, increased food availability and higher access to health and educational services, even offsetting the potential risk of increased disease spread in densely populated areas. A good example of the health benefits of urban living is evidenced after the coronavirus pandemic. Densely populated areas, such as urban centers, that would supposedly pose higher risk of infectious disease, showed surprising benefits and decreased vulnerability to the virus. Rural dwellers in the United States faced a higher risk of infection and death due to coronavirus than their urban counterparts (McGranahan & Dobis, 2021). This is partly because rural communities have higher incidences of existing health preconditions, and lower likelihood to live in close proximity to a healthcare center. The U.S. Department of Agriculture estimates that during the last 3 weeks of October, rural areas had 14% of the population, but accounted for 27% of deaths due to COVID-19 (Cromartie, Dobis, Krumel, McGranahan & Pender, 2020)

Rethinking the built environment strongly contributed to improving life expectancy by reducing infectious disease. Nowadays, the challenge is different. By 2013, 95% of children born in high-income countries are already born expecting to live at least 50 years (Deaton, 2013) while,



in contrast, decreased fertility is expected to accelerate population aging. How well inhabitants do in life will no longer be determined by staving off death during childhood, but instead by the life course exposures that will adequately prepare them for increased longevity. The built environment that was once designed to prevent child mortality has, once again, the opportunity to support not only longer but also healthier lives. Urban environments designed to support children to develop healthy habits throughout the lifecourse, to grow older in a supportive community, and to reduce exposure to pollutants that, even from childhood, impair brain functioning and increase the risk of heart disease and cancer.

Overarching Lessons for Built Environment Interventions

The built environment has been proven to be influential across different stages of life in determinant factors for healthy aging. Evidence on such interventions lead to three overarching lessons moving forward. First, built environment legacy comes with toxic exposures to pollutants that independently and cumulatively affect life course outcomes. Minimizing exposure to such environments will have an exponential effect in improving childhood development and minimizing chronic diseases.

Second, access to supportive environments is not enough for changing behavior. Access interventions must be complemented with programs that empower individuals to make better decisions and change their behavior. This is particularly important for closing inequality gaps, given the structural burden of poverty and disadvantage on having access to information and knowledge, and better exercising faculties to make decisions for the long term.

Third, community and social engagement is central to any built environment intervention that aims to promote positive behaviors. Social engagement reduces risk of all-cause death and



decreases vulnerability to other diseases. Similarly, being socially engaged also contributes to improved mental health, and reduces accelerated brain aging. Social engagement is both a mechanism and an outcome for healthier aging.

Designing environments for improved nutrition and healthy food access.

As mentioned before, one of the main constraints towards environments that promote healthier aging is access to healthy food outlets, because of the immediate, cumulative and even intergenerational effects of the most affordable food option across the country - high-fat and high-sugar diets. Therefore, urban environments designed for improved longevity should enable households of any level of income to acquire healthy foods, such as vegetables and fruits, in an accessible and affordable manner. Food programs that have improved affordability have shown outstanding results, and should continue to build the basis for a more equitable distribution of the longevity benefits, including not only a longer but also a healthier and more fulfilling life, where both obesity and cardiovascular disease do not disproportionately impact lower income and minorities.

Despite mere access to healthy food outlets in local food deserts has not proven to increase healthy food choices, further research needs to be pursued in order to understand the conditions under which healthy food choices can be developed. Following the example from neighborhood choice studies (Bergman et al, 2019) where research should study the specific barriers for neighborhood choice, similar approaches should aim to understand the independent and codependent role of built environment, educational and community aspects of barriers for positive nutritional choices.



Similarly, in order to overcome the distribution and effectiveness challenges of designing neighborhoods with healthy food outlets that effectively change diets, community involvement is of paramount importance. Health and diet behavior research indicates that social engagement is a powerful lever to sustain healthier behaviors. Local initiatives like community-owned stores and community gardening in vacant lots and parks pose promising pathways to reduce both increasing loneliness in neighborhoods and increase access to healthy foods like vegetables and fruits. In Tucson, Arizona, for example, the Food Conspiracy Co-Op not only provides healthy food options to the local community, but it also comprises a place for gathering, engagement of local schools and intergenerational learning opportunities through urban gardening. Similarly, in southwest Wisconsin, an association of neighbors in Viroqua, a town of less than five thousand inhabitants, owns the Viroqua Food Co-Op, where they provide opportunities to volunteer while learning about natural food and affordable, yet nutritious, recipes. In fact, not only are community-owned stores more likely to develop local distribution systems that could improve the resilience of these neighborhoods, but they also seem to be more resilient themselves than supermarket chains. For example, a study analyzing 71 healthy food store interventions found that none of the community-owned stores have closed, compared to half of the commercial stores (Brinkley, Glennie, Chrisinger & Flores, 2019).

Designing environments to promote physical activity and prevent sedentary behavior.

Another big predictor of long term life outcomes is physical activity, not only because of its effect on reducing cardiovascular disease, but also because of its strong influence on improved mental health in the long term. Since early engagement in exercise is supportive of childhood development and protective of chronic disease, neighborhood environments that provide



opportunities for regular physical activity and reduce sedentary behavior across generations are a critical component for improving extended healthspan, beyond mere lifespan (Owen et al, 2020). Even more, the prevalence of insufficient physical activity due to increased sedentary behavior at work, at home, during commutes, and during leisure time has become a global crisis. According to a study by the CDC in 2019, about 25% of Americans spend more than eight hours a day sitting (Sturm & Cohen, 2019)

At a local level, neighborhoods have the opportunity to redefine physical activity not as a leisure activity, but as part of the everyday activities throughout the life course. Improving the connectivity of neighborhoods through availability of services, food outlets, schools and opportunities to socialize and meet others, could significantly improve daily physical activity. For example, in Australia, 10-minute cities are urban environments that have been proposed with the purpose to make most daily life errands accessible for their residents in a walkable radius. Such environments where services are available at a local level would not only promote physical activity for young and old alike, but it would also reduce traffic and improve air quality. Children growing up in these environments will benefit from the protective effect of exercise during childhood to grow older, healthier, and prevent neurodegenerative and respiratory disease incidence during their late adulthood. Nevertheless, existing infrastructure across the United States poses a challenge to redesign neighborhoods, for which renovating existing environments is equally important.

One striking challenge that prevents local physical activity is decreased safety. Neighborhoods that have been long neglected can be revitalized as well in order to drive long-term outcomes. Planting grass, removing trash and planting trees in long neglected areas has been shown to be effective to improve residents' quality of life, by replacing vacant lots with green areas



where different generations can engage in play, exercise and learning. For example, randomized trials restoring vacant land by cleaning and greening previously abandoned areas in Philadelphia have shown to be effective to reduce crime and improve perceived safety, two major predictors of reduced physical activity in place (Branas et al, 2018). Similar results show improved mental health, by reducing the incidence of depression in the residents of such neighborhoods. This is particularly relevant in order to tackle the historical burden of residential segregation that has led to structural inequalities in access to supportive environments.

Reshaping hazardous environments for longer and healthier aging.

Given the strong effects contaminants associated with the built environment have on children and their long-term consequences, it is imperative to remove such hazards nationwide. Households where children are environmentally supported for healthier longevity can be achieved by either renovating hazardous environments or providing the appropriate opportunities for families to move out of such poisonous environments. Rehabilitating and retrofitting housing, schools, and water systems to prevent exposure to contaminants such as lead and arsenic are of critical importance. Government programs aimed at reducing poisoning risk, such as renovation and repair initiatives have to be adequately funded to prevent lead to systematically impair child development and increase late adulthood disability in lower income and non-white communities.

Similarly, in order to better provide opportunities for healthy longevity there needs to be significant investment to renovate the deteriorated water infrastructure, prioritizing rural and low-income communities, where industrial, farming and agricultural pollutants, as suggested by the National Environmental Justice Advisory Council (2018). However, monitoring and renovating the water distribution and treatment systems is a capital-intensive task, while citizen reporting



services are not always efficient. It is estimated the cost of maintaining the current drinking water system during the next 20 years to be higher than 400 million, and the lead-pipe removal across the country at 60 million dollars (Maher, 2021). We need to further invest in technology that can reduce the cost of renovating infrastructure and detecting contaminants, and more efficient and inclusive pathways for citizens to report water complaints. For example, researchers from University of Oxford are working on nanotechnology devices that will drop the cost of finding chemical pollution caused by toxic, heavy metals dissolved in water (The Engineer, 2020). Similarly, in Canada, an open access interactive site of community-based monitoring technology that allows for communities in the Mackenzie river to monitor the water quality of the river in Canada, and provide them more readily opportunities to engage in environmental reports to local governments (The Gordon Foundation, 2020).

Unfortunately, certain environments have suffered from either irreversible pollution, the cost of removing it might be economically unfeasible or social mobility might be higher in a different area. Options to move out of such poisonous environments would also provide families the possibility to decrease their exposure to toxic environments. Housing-assistance programs like the Housing Choice Voucher program provide the financial support to help families move to higher socio-economic opportunity neighborhoods. However, federally assisted housing options and voucher housing programs are currently concentrated in areas with high levels of lead poisoning risk (Benfer, 2019). Federal housing programs could incorporate built environment and environmental hazard criteria to define their housing options. Previous evidence of the Moving To Opportunity Project shows that, under the right conditions, families can effectively make the decision and move out of disadvantaged environments.

Designing environments for social engagement across the life course

Finally, in order for the benefits of longevity to be fully experienced, the built environment needs to be designed to allow us to meet and engage with others. Recent evidence has shown the stark effect of loneliness on several aspects of health and even premature death. This is even a more pressing endeavour given the cultural shift of living preferences and household composition. Solo-housing has been rising as a preferred living setting (Jack, Ivanova, Gram-Hanssen & Buchs, 2021), and older adults are increasingly living more lonely - either through assisted living facilities, hospice care, or personal choice (Stapler, 2016). Similarly, families are shrinking in size, and it is more common now for children to live apart from their parents as they grow older, while the number of potential adults taking care of parents has decreased, given the reduced number of children per couple. More than ever, we are uniquely positioned to rethink how our structures can help us to navigate these cultural shifts while ensuring we prevent a crisis of loneliness and therefore, of lower quality of life.

As the household composition changes, traditional approaches to both rentals and home construction are oriented towards family-based groups. Nevertheless, we can proactively provide more options to think of communities beyond family ties. Building and enabling housing options that support community-based housing could allow the creation of social support networks among individuals who are not necessarily related to each other, which are critical for household resilience and critical functions like childcare. In order for this to happen, we need to further invest in technologies that might enable such flexible arrangements: modern technologies to effectively construct affordable and flexible homes, house-sharing and matching platforms to allow those in search of living partners to find each other, and financial options to flexibilize housing conditions above and beyond the inflexibility of ownership of a home with a predesigned arrangement that



might not fit current needs. For example, startups like Diamond Age are investigating the use of 3d-printing technologies to provide more affordable and flexible housing that can more readily and affordably fit different household needs. On the other hand, companies like Figure are leveraging blockchain technologies to flexibilize home-ownership assets in order to allow individuals to transition into retirement with more flexibility, while startups like SilverNest are allowing aging adults to find others considering home sharing as an option to improve finances and prevent isolation.

Transportation is another area that is in ripe need of innovation in order to support healthier and longer lives. Particularly, social isolation increases as individuals become less willing and/or capable of driving as they enter late adulthood and face increasing challenges of minimal access to public transport networks in the United States. A study estimated that in 2015 16 million older adults were living in places without access to public transportation. Meanwhile, another study found that the number of licensed drivers 70 and older has increased more than 50 per cent from 1997 to 2017, and the accident rates are higher for this population, compared to their younger counterparts (Institute for Highway Safety, 2021). In this area, we need to invest in technology that will transform transportation systems to enable individuals to maintain autonomy in an affordable and accessible manner as we age, further reducing isolation and access to critical services such as healthcare. One of the potential pathways is the massification of autonomous-driving as an affordable and accessible choice for those growing older and struggling to maintain a safe lifestyle while still commuting to meet others.

In the domain of autonomous driving, two barriers will need to be overcome in order to adequately support healthier longevity. The first barrier is affordability. As of today, those who



face the most challenges finding transportation options are those in rural areas or lower-income inhabitants. In order for autonomous driving to make a meaningful change, it will be needed to invest and scale this technology to reduce costs up to a point where those who are in most need of this service can effectively make use of it. Secondly, autonomous driving would be required to be accessible for older adults facing different cognitive and motor performance needs. The Society of Automotive Engineers divides automation into six levels, based on the need for driver intervention and attentiveness (SAE, 2021). Level four is the one that would be able to respond even if a request for intervention from the driver does not happen promptly - which is the scenario needed for aging populations. Investment in both driving the level of automation to support cognitive and motor needs, and reducing the overall cost are required for autonomous driving to support healthier longevity. Some companies have already started incorporating older adults in their design process for self-driving cars. For example, the autonomous driving company Waymo has partnered with the Foundation for Senior Living, testing these services with adults facing disability from chronic and degenerative disease, such as loss of vision due to macular degeneration.

Conclusion

The built environment, composed of the places where we live, commute, work and learn, has a strong influence on physical and mental health, through both hazardous exposures or environments that prevent healthier behaviors. Such exposures follow individuals over a lifecourse even predicting chronic degenerative disease and early mortality, therefore influencing how much and how well someone gets to live. More concerningly, lower-income and racially diverse communities are disproportionately exposed and affected by both lack of supportive environments and more highly polluted environments, creating a compounded disadvantage that creates and will



further increase inequities in healthy longevity. If we don't intervene, the economic and social cost of unhealthy built environments will lead to long-term decreases in population physical and mental health, and economic productivity.

There is a unique opportunity to plan for longevity by adapting, renovating and designing built environments that are focused on outcomes, rather than structures. In this report we outlined four goals for designing environments: improve nutrition and healthy food access, promote physical activity and prevent sedentary behavior, enhance social engagement across the life course, and reshape hazardous environments for longer and healthier aging. Creating supportive environments is crucial for healthy, productive, and equitable societies. This is particularly true for Americans living in poverty, who experience the biggest difference in life expectancy based on where they live. We need to design environments that provide equitable opportunities for everyone, regardless of where they are born, to have healthy century-long lives.

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