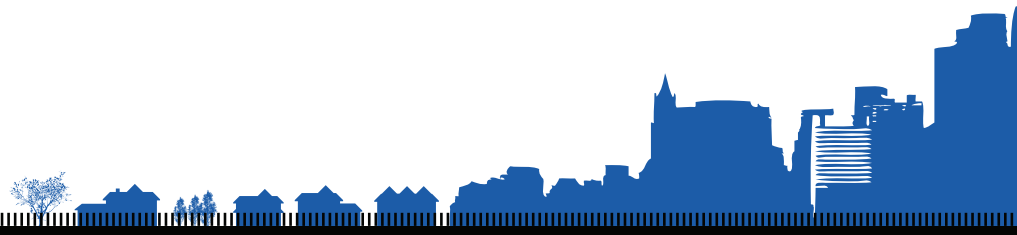
HOUSING AND CHILDREN'S HEALTHY DEVELOPMENT

Research Design, Data Collection, and Analysis Plan



U.S. Department of Housing and Urban Development | Office of Policy Development and Research

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Submitted to:

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Office of Policy Development and Research

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Introduction

A family's decision about where to live determines not only the characteristics of their dwelling (for example, size, physical adequacy, and cost) but also other aspects of their residential context, such as the safety of a neighborhood and access to high-quality resources for children, including schools, suitable neighborhood playmates, and role models. A child's home, neighborhood, schools, peers, role models, and family define the residential context, both physical and social, in which one grows up. Social and physical environments strongly influence children's development.

Because lower-income families usually have limited choices about where to live, they face difficult tradeoffs among these different residential features. The Housing and Children's Healthy Development (HCHD) Study was designed to advance the understanding of how children's residential context contributes to their well-being. Insights into low-income parents' location decisions and tradeoffs; what effects these decisions have on children's cognitive, social, emotional and health outcomes; and how these effects occur hold promise for developing more effective policies to foster healthy child development.

The HCHD study emanates from a multiyear effort of the John D. And Catherine T. MacArthur Foundation Research Network on How Housing Matters for Families with Children (hereafter, the Network). Following the long tradition of MacArthur Research Networks, the prominent social scientists and policy experts composing the Network developed a consensus about the gaps in the research on housing and children and the best approach to fill them.[1]

After reviewing the most rigorous recent research, such as the Moving to Opportunity Demonstration (MTO) and studies conducted by the Chicago Public Housing Authority, the Network identified the need for a new study to address the basic questions of whether and how housing affects children's healthy development. It recommended the collection of systematic survey data measuring and tracking children's housing, neighborhoods, families, and schools, along with child and family outcomes. This recommendation addressed the lack of any existing longitudinal data set that measures these domains from a child development perspective. The Network recommended a housing voucher experiment to achieve the goal of estimating causal effects of a child's residential context.

The HCHD study is designed to address the gaps and issues identified by the Network. Distinct from MTO—in which volunteering households living in public housing in high-poverty neighborhoods in the mid-1990s were randomly given housing vouchers to move to lower-poverty neighborhoods—this experiment is not restricted to households living in public housing (Sanbonmatsu et al., 2011). In addition, the HCHD study is being implemented in more than one location,[2] unlike the natural experiments in Chicago, where residents in poorly maintained public

[1] Network members were T. Cook (chair), D. Acevedo-Garcia, S. DeLuca, G. Duncan, K. Edin, T. Leventhal, J. Lubell, J. Ludwig, S. Newman, M. Pattillo, and S. Raudenbush. Project officers E. Poethig and I. Kachoris and Vice President for Housing at the MacArthur Foundation, M. Stegman played major roles in the initiation and success of the Network.

[2] The Welfare to Work Voucher Demonstration (for example, Mills et al., 2006) achieved these goals but did not collect survey data on all domains over time.

housing buildings were offered vouchers when the Chicago Public Housing Authority demolished those buildings while leaving better-maintained buildings untouched (Jacob, 2004; Jacob, Kapustin, and Ludwig, 2015).

Research Goals

The HCHD study will answer several research questions:

1. **How does housing affect children net of the other important influences on children's lives, including their families, neighborhoods, and schools?** Until solid evidence exists demonstrating that children's well-being is (or is not) affected by housing per se—distinct from the effects of other aspects of children's physical and social world—researchers are not equipped to debate the value of housing policies from a child perspective. Previous studies have not adequately answered this question because they have not isolated the effect of housing on family, neighborhood, and school factors typically associated with it. The HCHD study is designed to do this, with better measures of housing and child development than in previous studies.
2. **What are the features of housing that matter most?** Assuming that housing affects children, sound policy requires explicit targets specifying what aspects of housing are key. Therefore, the HCHD study has developed a comprehensive set of housing measures that pertain directly to children's development. These new measures will isolate the aspect(s) of housing that make a difference in children's outcomes.
3. **For whom and in what circumstances does housing matter?** The policy also needs population targets, primarily the demographic and socioeconomic groups most affected by housing or benefitting most from policy intervention. Low-income families with children—the focus of this study—are highly heterogeneous along multiple dimensions, ranging from family structure to neighborhood attributes.
4. **How do families with children make housing, neighborhood, and school choices, what are the effects of these choices, and how would these effects change if their choices changed?** It is difficult to design effective policies without understanding how families make decisions about housing, neighborhoods, and schools. This study will be the first to offer insights into why families make the choices they do along with the effects of these choices.

Understanding the tradeoffs parents must make in choosing where to live has important implications for policy. Multiple studies, including MTO (Orr et al., 2003), the Welfare to Work Voucher Demonstration (Mills et al., 2006), and the Chicago voucher experiments (Jacob and Ludwig, 2012), found that families did not use their housing vouchers to upgrade their neighborhoods significantly. If researchers and policy officials incorrectly expected that voucher holders would move to higher-income neighborhoods, how can one expect to design effective mobility-oriented housing programs in the future?

These questions will be answered by investigating specific associations of housing choice voucher receipt, housing conditions (including housing quality, neighborhoods, and schools), and measures of family context (e.g., parenting, routines), parental health, and children's cognitive, emotional, and physical development. The research design includes random assignment so that changes in selected outcomes can be attributed more confidently to the impact of the housing choice voucher. However, because little is known about these processes and interactions, the lack

of commonly accepted measures of many of these items (for example, housing control), and the complex interactions to be examined, this part of the study is best seen as exploratory.

Main Study Design

Exhibit 5 provides an overview of key features of the HCHD study, including the sites, number of data collection waves, and child target samples, along with a summary of Wave 1, or baseline, data collection.

Study Sites

Including a housing voucher experiment required conducting the study in particular cities or metropolitan areas served by a public housing authority (PHA) that uses a random lottery to allocate its vouchers. Financial constraints drove the decision to focus on only two study sites: the Cleveland and Dallas metropolitan areas.[3]

Criteria for Site Selection

Beyond a voucher lottery, the three additional criteria for selecting the study sites were the metropolitan areas having variation in geographic location, housing market characteristics, and racial and ethnic population, and the PHAs being considered high performers based on the U.S. Department of Housing and Urban Development's (HUD) assessment of PHA management and reputation in the field and being committed to participating in the HCHD study.

Cleveland metropolitan area. Located in the Midwest, the Cuyahoga Metropolitan Housing Authority (CMHA) serves all of Cuyahoga County, which includes the city of Cleveland, Ohio, and its inner suburbs. It is a relatively soft housing market, with an estimated 2016 rental vacancy rate in the metropolitan area of about 9 percent.[4] CMHA's portfolio includes 25,729 assisted housing units comprising 9,284 public housing units, 15,269 Section 8 vouchers, and 1,176 multifamily units, representing several different HUD project-based assisted housing programs. CMHA's tenant population includes 33.4 percent of family households with one or more children younger than 18, 27.4 percent of households headed by a person aged 62 or older, and 36.2 percent who are physically or mentally disabled.[5] The majority of tenants, 89.2 percent, are Black; 8.4 percent are White, and 2.4 percent are other races. Roughly 7 percent report being Hispanic, and 93 percent report being non-Hispanic.

Dallas metropolitan area. Located in the southwest, the Dallas Housing Authority (DHA) serves the city of Dallas and counties across north Texas. This rental market is relatively tight, with an estimated 2017 rental vacancy rate in the housing market area of about 6 percent.[6] DHA's

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[3] More precisely, the Cleveland sample area includes all of Cuyahoga County, which covers Cleveland and its suburbs. This area comprises 43 ZIP codes. The Dallas sample area includes seven counties encompassing 120 ZIP codes in and around the city of Dallas. These are roughly equivalent to the metropolitan areas, so the two samples are referred to as metropolitan areas for simplicity.

[4] See https://www.huduser.gov/portal/publications/pdf/ClevelandOH-comp-16.pdf.

[5] Categories are not mutually exclusive.

[6] See https://www.huduser.gov/portal/publications/pdf/DallasTX-comp-17.pdf.

portfolio includes nearly 22,000 assisted housing units comprising 17,000 in which the tenant is using a housing choice voucher, 1,800 multifamily units, and 3,000 public housing units. The geographic area under DHA's purview includes seven counties: Collin, Dallas, Denton, Ellis, Kaufman, Rockwall, and Tarrant. Roughly 50 percent of households are families with one or more children younger than 18 years old, 21 percent are headed by someone aged 62 or older, and about 24 percent are headed by a nonelderly person who is disabled. The majority of tenants are Black (85.3 percent); 8.6 percent are White, and the remaining 6.1 percent are other races (including 2 percent who are Asian). In addition, 6.2 percent report being Hispanic, and 92.3 percent report being non-Hispanic. Some tenants (1.5 percent) declined to report any race.

PHA liaison. Quadel Consulting & Training, LLC, a well-known assisted housing consulting firm that has worked with numerous PHAs, has been the liaison between the research team and CMHA and DHA. Quadel maintains regular communications with each PHA, assisted with the development of the Memorandum of Agreement covering the PHAs' participation in the study and data sharing, oversaw waiting list randomization, helped to develop a protocol to track voucher recipients using administrative data, and continues to assist with general troubleshooting.

Study Design

Timing. The study is currently designed to collect two waves of data. Wave 1, or baseline data collection, began in May 2017 and ended in September 2018. The timing of Wave 2 was based on the desire to ensure that households in the voucher treatment group (described in the following section) would have sufficient time to find, lease, and live in assisted housing. The spring of 2019 was initially thought to be sufficient time for this to occur, but for various reasons, it will be too soon for most voucher treatment households, particularly in Dallas. The timing of Wave 2, therefore, is currently still being determined.

Samples. The study has a dual-frame sample design consisting of a sample of voucher applicants (the *voucher sample*) and a probability sample of modest and low-income households (the *population sample*). The voucher sample is further divided into a randomly assigned treatment group of households who are offered a housing assistance voucher and a control group. Both the voucher and probability samples share three main eligibility criteria in Wave 1: (1) the household has at least one child between the ages of 3 and 10; (2) the child spends at least 3 nights per week on average in this household; and (3) the interview can be conducted in either English or Spanish.

Voucher Sample

The voucher sample consists of randomly chosen voucher applicants, some of whom will be offered a voucher and others who will not be offered a voucher. This rigorous research design of random variation in who receives a housing voucher supports the examination of the causal effects of housing on children. Some examples of such effects include how the offer and use of a voucher affect parents' choices about where to live; the kinds of housing and neighborhood quality tradeoffs low-income families make; how these choices affect their children's development; the effects of housing on health and other child development outcomes; and how stress, parenting, and stability may transmit the effects of housing and affect children's healthy development.

As noted, the voucher sample consists of applicants for housing vouchers who were randomly assigned to the voucher waiting lists in the CMHA and DHA. The treatment group sample was selected from the randomly sorted applicants on the waiting list who were likely to be offered a voucher within approximately 1 year of the start of data collection. The control group was selected from the randomly sorted applicants who were unlikely to be offered a voucher within this time frame. Both housing authorities included a brief description of the HCHD study on their voucher application form. Applicants who did not want to participate in the study checked an opt-out box and were not contacted.

The study team aimed for equal sample sizes in the two sites, with equal numbers of treatment and control samples. Data were collected from the child's primary caregiver (PCG) and up to two randomly chosen children in the household between 3 and 10 years of age. The goal was to interview 848 households and 1,170 children (that is, 424 households in each site comprising 212 treatment and 212 control households). As shown in exhibit 5 (and in more detail in exhibit 1), the goal was exceeded; 907 households and 1,202 children were interviewed.

Population Sample

The population sample design was developed in collaboration with the sampling division of the Survey Research Center (SRC) at the University of Michigan and under the direction of T. Raghunathan, director of SRC.[7] It is a stratified, random sample of households in the Cleveland and Dallas metropolitan areas. The population sample was generated through a multistage procedure using several sources of external data: the American Community Survey (ACS) 2010-2014 5-year summary file, 2016 Census planning data, household roster data from the National Survey of Family Growth (NSFG, a study also being conducted by SRC), and a commercial database purchased from Marketing Systems Group. In the first stage, all U.S. Census block groups at each site were stratified into three groups (low, medium, and high) based on their median family income, according to the 2015 ACS.[8] Block groups were also ranked for their likelihood of containing households with children eligible for this study. To obtain this measure, SRC used household-level eligibility data from the NSFG study to examine the percentage of households with age-eligible children in 1,909 urban and suburban block groups. Next, SRC modeled the percentage of households with age-eligible children in each block group using 160 ACS variables.

The final model, which included 63 components and 155 interaction terms, provided a fair fit to the NSFG data. This estimated grouped logit model was then fitted to the 988 block groups in the Cleveland and Dallas sample frame to develop a measure of size (MoS) estimate for each block group. Using MoS and income data, block groups were then sampled, with the goal of oversampling low-income block groups using a ratio of 3:2:1 for low-income, middle-income, and high-income block groups, respectively, to create the primary sampled units (PSUs). Once

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[7] HCHD Study coprincipal investigators G. Duncan and S. Raudenbush were also actively involved in the sample design.

[8] Cutoff values differed between Cleveland and Dallas due to differences in income distributions between the two areas. See exhibit 7 for details. Stratification of block groups at the first stage also incorporated the estimated number of eligible households (that is, children aged 3 to 10 and English- or Spanish-speaking) based on multiple data sources.

the PSUs were identified, SRC acquired lists of every valid residential postal address (for example, delivery sequence files, or DSF) in the specified PSUs. The DSF data include household income (imputed when missing), which was used to group the units into low-, middle-, and high-income addresses.[9] Once this stratification was completed, SRC selected addresses from each block group using a ratio of three low-income addresses, two middle-income addresses, and one high-income address. Attempting to identify household income before being contacted by an interviewer creates an oversample of lower-income households without requiring the interviewers to screen income at the doorstep. The target sample sizes were similar to the voucher sample: 868 households divided evenly across the two sites (see exhibit 2). This goal was also exceeded; 894 households and 1,194 children were interviewed.

Data Collection

Protocol Development and Pilot Study

Data collection instruments include a combination of established, tested questions (for example, cognitive achievement and Patient Reported Outcomes Measurement Information System [PROMIS] measures of health[10]) and newly developed questions that address the key issues motivating the study (for example, preferences and tradeoffs, child-relevant housing features, biomarker measures of healthy child development). Input was sought from subject experts either individually or, in the case of housing, through a "thinkers' session." The draft protocol underwent multiple iterations. As with all surveys, the final instrument represents a balance between including all essential measures and available funding.

In the fall of 2016, the draft protocol was pilot-tested in Dallas with 50 modest-income households having at least one child in the 3–10 age range. The protocol was revised based on the pilot experience, and the Wave 1 baseline field work was launched in late May 2017 and completed in September 2018.

Main protocol. SRC at the University of Michigan is the survey contractor for the HCHD study. SRC's highly trained interviewers typically collected Wave 1 baseline data in the PCG's home. Data were gathered using multiple methods and procedures:

1. Interviewers conducted personal interviews with PCGs, usually mothers, using Computer-Assisted Personal Interviewing (CAPI).
2. Mothers also completed a short, self-administered questionnaire.
3. Interviewers collected physical measures of mothers and children (for example, height and weight) and blood biomarkers for the voucher sample (explained below).
4. Children were administered standardized reading and math achievement tests and a computerized task evaluating executive functioning, a key component of self-regulation.
5. Interviewers collected systematic observations of the home environment, using both established subscales of the Home Observation for Measurement of the Environment, better known as HOME (Caldwell and Bradley, 1984), and other measures, including

[9] See exhibit 7 for the household income cutoffs used in each site.

[10] PROMIS measures were developed by a National Institutes of Health (NIH) committee as part of the NIH Roadmap (https://commonfund.nih.gov/promis/index).

using a laser tape measure to obtain the physical dimensions of each room in the unit to be an objective measure of the housing unit's square footage. This information will be useful when analyzing subjective assessments of crowding, privacy, and clutter.
6. Interviewers made systematic observations of the neighborhood environment, defined as the blocks surrounding the households' housing units.
7. Interviewers conducted systematic observations of parent-child interactions.

All instruments and measures, including CAPI and self-administered forms, are available in English and Spanish.

Respondents were compensated separately for completing the PCG and child interviews (see exhibit 7 for details). PCGs and children in the voucher sample were also compensated if they agreed to have their blood sampled. Exhibit 6 provides an overview of the topics covered in the study. Exhibit 7 provides more details about key measures, including child outcomes and housing, neighborhood, and school measures.

Along with the information collected during the interviews, additional neighborhood and school measures being collected include:

1. Census tract-level measures from the American Community Survey.
2. Crime-rate measures using common Federal Bureau of Investigation (FBI) definitions made available by the National Neighborhood Indicators Partnership.
3. Administrative school quality measures, including information from the Common Core of Data, a federal program that annually collects data about all U.S. public schools, and from the Education Data Exchange Network and the Department of Education EDFacts initiative, which contain student achievement and accountability data mandated by No Child Left Behind. These data are being collected by NORC at the University of Chicago, based on the schools identified in the interviews with the PCGs.

Three Branches

As noted earlier, the HCHD study is designed to advance the understanding of how children's residential context contributes to their well-being. The study has three branches—tradeoffs, child development, and biology and health—each with its own specific research questions, significance, and innovations.

A. Tradeoffs

Aims

Low-income parents face serious constraints when seeking housing, which can lead them to live in places that undermine their children's development. Scarce resources for housing can constrain not only the size and physical quality of the dwelling units in which children grow up but also the quality of their neighborhoods and local schools. In many cases, low-income parents will face tradeoffs between dwelling unit quality, neighborhood quality, and school quality—money spent on one aspect of quality will leave less to spend on other aspects. Larger family sizes, lower family incomes, and more expensive local housing markets tend to make these tradeoffs more severe. The scientific literature provides little guidance on how housing attributes that matter for children are priced in the market. Federal policy is designed to improve parents' housing options, but its success depends strongly on how parents understand their housing

options and how they make housing choices. Yet, too little is known about the information parents have regarding their options and how they use this information to make housing choices. This branch of the HCHD project, therefore, seeks to accomplish four aims:

Aim 1. Clarify how aspects of dwelling unit quality, neighborhood quality, and local school quality combine to influence the cost of housing accessible to families of below-median income.

Aim 2. Assess how qualities of dwelling units, neighborhoods, and schools combine to contribute to key cognitive, socioemotional, and health outcomes among children.

Aim 3. Learn how parents make choices about where to live.

Achieving these three aims allows this branch of the study to achieve a fourth aim:

Aim 4. Enhance the study of child development through theoretical and methodological advances in the study of housing and other related social contexts.

Significance

This branch of the HCHD study is animated by the search for a deeper understanding of how housing conditions influence children and requires two new ways of thinking. First, a child-centric conception of housing quality is needed because past housing measures were not developed to reflect the features of homes most likely to help children's development. Therefore, new measures were created that focus on the spaces available to children to read, work, and play and information on the room where the child sleeps. Second, and more fundamentally, the effect of housing should be conceptualized as depending not just on child-relevant features of the physical dwelling unit but also on the unit's inevitable links to the broader residential environment, specifically to local neighborhoods and their preschools and schools.

For a given level of spending on housing, prospective homebuyers and renters see tradeoffs between dwelling unit quality, neighborhood quality, and school quality. Spending more on one desirable attribute usually means spending less on other attributes. The qualities that make a dwelling unit, neighborhood, or school attractive in the housing market are plausibly the same qualities that foster child development. If this is the case, when parents with constrained housing resources are forced to tradeoff between housing, neighborhood, and school quality, how they manage and resolve this tradeoff has implications for how their children develop. For low-income families, the tradeoffs can be stark. If they seek to maximize the size and quality of their unit, families will likely have to accept a more dangerous neighborhood environment and less effective local schools.

If, on the other hand, they limit their housing search to comparatively favorable neighborhoods, families are likely to find only marginally acceptable housing units at a rent they can afford. Although this logic is compelling, little is known about the magnitudes of these tradeoffs and how the magnitudes change with family size and housing rents or prices. The first two aims of this branch focus on overcoming these gaps in knowledge. Aim 1 considers how the three sources of environmental quality influence rental and house prices. Using hedonic modeling, a widely-used technique in public finance and urban economics (for example, Brown and Uyar, 2004), regression models will be estimated to predict the rent or purchase price of a unit based on housing, neighborhood, and school characteristics, a broader set of measures than in the typical hedonic model. Aim 2 considers the impact of these environments on child development.

Understanding these tradeoffs has potentially important policy implications. If more were known about the tradeoffs between dwelling unit quality, neighborhood quality, and school quality, housing policies could presumably be crafted to serve children better. However, knowing about these tradeoffs is insufficient—how parent preferences influence their search for housing units also must be known. These preferences may or may not be aligned with what research suggests are the best choices for child development.

The tradeoff between housing, neighborhood, and school quality generates a fundamental question for housing policy: How do parents seek housing options, and how do they react to constraints and manage tradeoffs? In the largest-ever mobility study among HUD-assisted households (Ludwig et al., 2011), researchers and policy officials incorrectly expected higher rates of moving to low-poverty neighborhoods than happened and fewer subsequent moves to lower-income neighborhoods, which illustrates this knowledge gap. Aim 3 focuses on learning how parents understand and weigh their housing options and how they use new resources to enact their preferences. On the one hand, research may find that parents rationally maximize their children's outcomes when selecting housing units under sharp constraints. On the other hand, research may find that parents lack the knowledge needed to do so or that considerations other than child development loom large in their housing preferences.

Innovations

Theoretical innovations. This branch of the HCHD study expands theories of how housing choices influence children by incorporating the reality that the qualities of a dwelling unit are tied to the qualities of neighborhoods and schools. In the study's conceptual frame, for any aspect of child development (for example, verbal skill or aggressive behavior), each child possesses a potential outcome associated with each dwelling unit a parent might afford and select. Each potential outcome depends on dwelling unit quality, neighborhood quality, and local school quality. In this frame, the causal effect on the child of selecting one dwelling versus another depends not only on the qualities of the dwelling unit's size, structure, and condition but also on the qualities of the associated environments. At the same time, the rent or price of the unit is also a function of these qualities.

This scenario presents a hypothetical rational parent seeking to maximize child outcomes with a constrained optimization problem—the task is to select the dwelling unit with the best potential outcome for the child, subject to the constraint that the relevant aspects of quality contribute differentially to the rent. This theoretical frame provides a basis for evaluating the potential of alternative housing policies to promote child development.

Analytic innovations. The study team's view, in the spirit of Heckman (1979) and Rubin (1978), is that children possess potential outcomes under alternative housing choices and that the causal effects of housing choice are comparisons between these potential outcomes. This framework helps clarify the assumptions required to make valid causal inferences. Specifically, potential outcomes must be independent of housing choice, given relevant baseline covariates.

Measurement innovations. This study will, for the first time, integrate new measures of dwelling unit quality theoretically linked to child development with state-of-the art measures of neighborhood quality and school quality to provide a comprehensive analysis of their association with parental preferences and child outcomes. Also, the study will develop the first detailed assessments of housing tradeoffs using regular survey questions.

Measures

Meeting the research objectives requires collecting housing, neighborhood, and school data. As shown in exhibit 7, housing is examined along a number of dimensions, including the physical condition of the unit, housing quality, cost, and size.

Crucial to aim 3 are measures of the housing preferences and choices of families. These measures will be revealed for the treatment group families in the voucher experiment by the choices they make about where to live, given the new resources made available by the voucher. Additional assessments of preferences and choices are, in some ways, richer and more general. One assessment is through the use of vignettes, in which each respondent is asked how much they would be willing to pay (in rent) for "a home in good physical condition, in a safe neighborhood, with schools that have well-behaved children?" Respondents are then asked how much they would be willing to pay in rent for a similar unit where the school has discipline problems, the neighborhood is unsafe, or the home is in poor physical condition. Pilot tests with 16 low-income Baltimore mothers similar to respondents in HCHD found that they had no problems understanding the vignette questions. Respondents are also asked questions about what they like most and least about their current living situation and the reason(s) why they last moved.

PCGs will also be asked what they consider to be the most important features of a good home, a good neighborhood, and a good school; what is most and least important to them: a nice home, good neighborhood, or good schools; and how much more they would be willing to pay to live in (or near) each feature.

B. Child Development

Aims

The study team hypothesizes that the unaffordable, crowded, and poor-quality housing of many low-income families induces high levels of family stress, instability, and conflict, which, in turn, compromise children's development. The HCHD voucher study tests whether supplying low-income families with more resources for housing enables them to live in more affordable and better units, with favorable consequences for child and family well-being. In addition, the stratified population sample allows the team to examine how naturally occurring changes in housing affect a broader population of families. This branch of the HCHD study has four specific aims.

Aim 1. Test how housing, assessed by crowding, physical quality, and affordability, affects family processes central to children's development (stability, stress, and support).

Aim 2. Learn how housing directly affects children's behavior problems (internalizing and externalizing), self-regulation (executive function and effortful control), and cognitive achievement.

Aim 3. Assess how housing indirectly affects children's development through its more proximal effects on family processes.

Aim 4. Test how such housing effects vary by race.

Significance

Risks associated with children's socioeconomic status are channeled through social contexts in which they are embedded, including the contexts of family (Conger and Donnellan, 2007), neighborhood (Leventhal and Brooks-Gunn, 2000), preschool and school (Barnett and Belfield, 2006; Rouse and Barrow, 2006). Across these contexts, exposure to less supportive, responsive, and resourced settings during early childhood may be critical for setting problematic life-long trajectories (Duncan, Ziol-Guest, and Kalil, 2010; Heckman, 2006; Wheaton and Clarke, 2003). However, housing has been largely absent from discussions relating social contexts to inequality (Farkas, 2003) and child development (Bronfenbrenner and Morris, 2006). This omission is surprising, given that housing is linked to the more frequently studied family, neighborhood, and school contexts.

The study's conceptual model for linking housing crowding, quality, and affordability to child development draws from two theories of family resources, suggesting that housing effects on children's development are likely to be both indirect and direct and operate through processes related to family stability, support, and stress. From a demographic perspective, the *family stability model* suggests that crowded, physically inadequate, and unaffordable housing can contribute to a parent's decision to move out of a given unit and into another one. Housing units of low quality or taxing a family's budget also may have implications for the stability of children's daily experiences within that unit and whether families must share housing with others (for example, doubling up) to lower costs (Auh et al., 2006). Such family instability is consistently linked with children's risk of behavior difficulty, adjustment problems, and compromised achievement (Cavanaugh and Huston, 2006; Fomby and Cherlin, 2007). In short, initial support exists for the premise that greater crowding, a lower quality unit, and less affordable housing may cause higher family instability (daily and more generally), which, in turn, may adversely affect children's development.

From a perspective primarily growing out of psychology, the *family stress model* posits that economic hardship and negative financial events are associated with higher parental stress, depression, and conflict with partners, which, in turn, are associated with lower-quality parenting characterized by inconsistent, unsupportive, harsh, and punitive parenting behavior (Conger and Donnellan, 2007). These compromised parenting processes impede children's development. According to the family stress model, housing attributes would indirectly affect children's development via parental stress that undercuts supportive and otherwise effective parenting.

Finally, from a broader perspective, the model in this study acknowledges several selection realities. For one, families self-select into different types of housing conditions based on observed (for example, sociodemographic) and unobserved (for example, preferences) characteristics (Duncan et al., 2004) that may underlie any observed associations between housing conditions and children's development (Leventhal and Newman, 2010) and have to be part of any modeling. For another, the model also draws from ecological models of child development (Bronfenbrenner and Morris, 2006). These realities account for the interrelation between housing and children's other social contexts, especially neighborhoods, preschools, and schools (Cook et al., 2002), including processes of selection into these other contexts with which housing is linked (Duncan and Raudenbush, 2001). By randomly providing people with more affordable housing, the housing voucher experiment will get a better handle on addressing these selection processes than is possible in other kinds of research.

Innovations

Conceptual innovations. This study deepens our understanding of the role of social contexts in children's development by investigating an understudied context—housing. The study's approach focuses on conceptually compelling and policy-relevant dimensions of housing—crowding, physical quality, and affordability—that have not been incorporated into any existing representative, longitudinal studies of U.S. children and families. Moreover, the joint focus on children's cognitive achievement, behavioral problems, and especially their self-regulation is novel. These outcomes have not been the foci of prior housing research despite their associations with environmental stressors and importance for social and economic outcomes in later adult life (Raver, 2004).

The study employs an innovative, multidisciplinary model of how housing influences child development, both directly and indirectly, via its effects on family processes (stability, stress, and support).

The study's findings will have more generalizability than other studies because the sample in each city includes one stratum of families eligible for housing vouchers and another stratum of families representative of each city but over-representative of lower-income families, who are the focus of most housing policy (aside from the mortgage-interest deduction). The HCHD study will provide researchers with new data on a wider range of housing characteristics, family processes, and child outcomes than previously and a more diverse sample.

Methodological innovations. The research design embeds a randomized housing voucher lottery experiment (that will affect crowding, housing quality, and affordability) within a longitudinal survey of a representative population in two cities.

The study will make major contributions to the measurement of processes and mechanisms that link environmental conditions (in this case, housing, neighborhoods, and schools) with children's development.

Policy innovations. This study will help the housing policy community determine which features of housing matter most for child and family well-being. Housing policy has been dominated by affordability issues and bricks and mortar rather than an understanding of the housing-related features (for example, unit size) that may be consequential for children's behavioral, emotional, and cognitive needs (Leventhal and Newman, 2010). This study's findings will help place housing policy into the context of the more general set of other in-kind (for example, food stamps) and income support policies that are recognized as not only addressing immediate needs but also having a longer-term impact on children. In addition, the findings on the effects of housing on family processes may help the targeting of resources—for example, helping to identify which families may most need assistance and the type(s) of family stress that have the biggest effect on child development—toward supportive services that mitigate family stress and foster stability and support (Popkin, Cunningham, and Burt, 2005).

Measures

This branch of the HCHD study again utilizes the broad array of collected housing measures (see exhibit 7), including the physical condition, size, quality, and costs. In addition, three primary dimensions of family processes, stress, stability, and support, are assessed. Family stress is assessed by the Parent-Child Conflict Tactics Scale-Short Form (Straus, et al., 1998) and

Challenges to Parenting (Hofferth et al., 1997; Huston et al., 2003). The PROMIS measures capture parental anxiety and depressive symptoms. Family stability is assessed by the Family Routines Inventory and the Home Observation for Measurement of the Environment (HOME) (Caldwell and Bradley, 1984; Leventhal et al., 2004). The Thin-Slice Observation of Cognitive Sensitivity and HOME evaluate family support. These two dimensions of family processes are also captured in the *Daily Diary,* a time diary included in Wave 1 that PCGs were asked to complete.

Children's socioemotional adjustment. The study assesses children's socioemotional adjustment in two domains: behavior problems and self-regulation. The Behavior Problems Index (BPI) (Zill and Peterson, 1986) is a widely used, 28-item parent-report questionnaire designed to assess *behavior problems*. The BPI yields psychometrically robust scores of externalizing (for example, argues too much) and internalizing (for example, too fearful or anxious) problems, as well as subproblem scores for antisocial, anxious/depressed, headstrong, hyperactive, immature/dependency, and peer conflict/social withdrawal. Because *self-regulation* is a multidimensional construct and an important predictor of later conduct disorders and mental health, it is examined along several dimensions related to executive function (attention, memory, and cognitive flexibility) and effortful control (behavioral and emotional control). Specifically, the Hearts and Flowers task, a computerized direct assessment, is used to examine children's inhibitory control, working memory, and cognitive flexibility (Davidson et al., 2006); previous work demonstrated this task is appropriate for children aged 4 and older, but piloting indicated it can be successfully administered to children as young as 3 years old. After completion of direct tasks, interviewers complete a 28-item Preschool Self-Regulation Assessment-Assessor Report (PSRA) for all children interviewed (Raver et al., 2011), scoring children's emotional and behavioral regulatory behavior throughout the assessor-child interaction.

Children's cognitive achievement. Children's achievement is assessed by two subtests of the Woodcock-Johnson Psycho-Educational Battery-III and Extended Battery-III (Woodcock et al., 1989, 2001). This standardized test, available in English and Spanish, is widely used in national studies, and selected subtests are applicable for children aged 2 and older. The Letter-Word subtest evaluates children's reading ability, and the Applied Problems subtest evaluates children's math.

C. Biology and Health

Aims

Randomized control trials of vouchers and health exist but have mostly involved special-population-issued vouchers outside of the voucher lottery (O'Connell, Kasprow, and Rosenheck, 2008; Buchanan et al., 2009; Mills et al., 2006; Ludwig et al., 2011). Thus, it is unknown how the standard voucher program affects health. This branch of the HCHD study is prompted by (1) the absence of any health study of the standard voucher population; (2) the relatively clear findings for depression in MTO, in which moving to better neighborhoods led to lower levels of depression and psychological distress (Ludwig et al., 2011), and other voucher and income studies, which found that offering subsidized rents to homeless veterans reduced drug and alcohol use but had no significant effect on other physical or mental health symptoms (O'Connell, Kasprow, and Rosenheck, 2008); and (3) the less clear physical health findings (except extreme obesity). This branch of the HCHD study has two main aims.

Aim 1. Replicate and extend previous voucher findings with families in the voucher housing program.

Aim 2. Test how four distinct social processes mediate health effects[11].

Significance

This part of the HCHD study seeks to test social explanations of how an exogenous family income supplement (one component of socioeconomic status, or SES) affects health, using a housing voucher as the income supplement.

The study extends past findings in several ways. First, it focuses on young children (ages 3-10 at baseline) , who spend considerable time in and immediately around the home and interact more with caregivers than do children 11 and older. Moreover, young children are particularly susceptible to many pathogens, and SES differences in their biology emerge very early. Social contexts are associated with the regulation of cortisol, for instance. Cortisol is associated with changes in important mediators of immune response that directly influence inflammation, which, in turn, leads to alterations in cellular processes and the regulation of cytokine production, including the production of Interleukin-6 (IL-6) that then induces the production of acute phase reactants such as C-reactive protein (CRP).

The main significance of the study is to understand the social mechanisms through which an income subsidy like a voucher affects health—that is, to identify which causal processes entailed by vouchers are responsible for health benefits. The study team postulates that a housing voucher will increase disposable income and the quality of neighborhoods and housing units they encompass. These housing features should reduce the level of psychological stress in a caregiver's and even a child's life. So, too, should be having more disposable income: the extra cash allows debts to be paid, basic needs to be met, and fewer conflicts about money to arise (Furstenberg et al., 1999). If vouchers reduce stress, there should then be less dysregulation in nearly all stress-related biological systems, including inflammation, as indexed by Interleukin 6 (IL-6) and CRP; metabolic glucose regulation, as indexed by HbA1c; and brain changes temporally related to depression and cognitive functioning loss (McEwen and Gianaros, 2010).[12] No study has tested the causal links from a stress antecedent like a housing voucher to changes in a sequence of impacts from stress levels to biomarkers and health.

Most families who apply for a voucher are in the private market and paying rent that exceeds 30 percent of their income. When these families get a voucher, they can use it more flexibly than other families. In theory, they can use all of its value either to pay rent in a very different neighborhood or to increase discretionary income by remaining in place, ensuring that their unit meets standards and substituting the voucher subsidy for their prior rental expenses. The higher these expenses, the greater the share they can claim as new disposable income. In practice, Jacob and Ludwig (2012) found that nearly all families blend an upgraded neighborhood with some

[11] That is, the voucher program may affect housing because it has an effect on intermediate characteristics, such as increasing disposable income or reducing parental stress, which, in turn, have an effect on child health.

[12] HbA1c refers to the hemoglobin A1C test, which is a simple blood test that measures average blood sugar levels over the past 3 months.

additional cash, on average, gaining more of the voucher's value as cash. In short, it is unclear how well MTO's health results generalize to the national Section 8 program, in which few families are initially as low-income or as unhealthy as MTO families (Cook and Wing, 2012). The proposed study will fill this important gap.

Furthermore, although MTO treatment families agreed to move as part of their participation in the experiment, 53 percent did not move. Of those who did move, most moved locally to settings almost as racially segregated as those they had left and, after staying for the required year in their new neighborhood, most moved again to neighborhoods even more like those they had originally left, although somewhat less low-income and crime-ridden. This mobility pattern suggests that low-income voucher holders may be unable to move to communities that are considerably more affluent or whose racial mix leaves them in the numerical minority. There is, therefore, greater leverage for current policy by studying the housing voucher population as a whole and not constraining the affluence of the receiving neighborhood. Researchers can then test whether the increased disposable income from the voucher makes up for the lesser neighborhood upgrades that spontaneously occur because increases in income—not only improvements in neighborhood quality—can affect health. Policymakers need to know whether health is affected by combining the lesser neighborhood change and the greater disposable income that the majority of voucher holders experience. This knowledge speaks to the effectiveness of the nation's largest rental housing assistance program.

Innovations

Conceptual innovations. The HCHD study involves the same nominal "voucher" cause as in prior studies and similar biological and health outcomes as in MTO. However, it is unique in the social mediating processes, biological pathways, total health outcomes studied, and inclusion of young children and regular voucher families who already rent in the private market when they get a voucher.

Perhaps the most innovative element is the analysis of how vouchers impact health through effects on social mediators such as family, neighborhood, and schools. Nearly all past studies of vouchers and income supplements constructed their designs around demonstrating health effects rather than explaining them.

Methodological innovations. This study is the first natural experiment to test how housing vouchers issued to the general population of voucher-eligible families affect both the biology and health of adults and young children.

The emphasis on children ages 3–10 is also noteworthy. Children so young were not included in MTO or other voucher studies, except in Mills et al. (2006), in which individual health was not a focus.

Policy innovations. The sampling design involves two cities: Cleveland and Dallas. These cities were chosen partly because of their racial and ethnic diversity, allowing us to study Black, White, and Hispanic families. These cities were also selected because they are more similar to other cities in the United States than cities like New York City, Los Angeles, or Chicago, permitting a purposive generalization to a new set of cities.

Measures

A key innovation for this part of the HCHD study is the collection of biomarkers. Interviewers measure height, weight, and waist-to-hip ratios for both the PCG and child(ren) to measure obesity and extreme obesity using standard cutoff values. Interviewers also assess the systolic and diastolic blood pressure of PCG using standard survey procedures that SRC has used many times before. Disrupted or improved *sleep patterns* are also important in affecting health. The PROMIS measure of sleep disturbance is used for caregivers, and caregiver responses to items adapted from the Children's Sleep Habits Questionnaire are used for children. The final focus is on *diabetes, asthma*, and *allergies* (respiratory and skin), for which relevant items from the National Health Interview Survey were used.

Dried blood spot (DBS) collection was successful in the baseline data collection, with strong cooperation from both adults and children. A problem with the blotting paper used for heavy metals (arsenic, mercury, and lead), along with a financial conflict of interest regarding the Northwestern University laboratory handling the DBS, raised concerns by the Johns Hopkins Institutional Review Board, which led to terminating the collection of heavy metal testing after roughly 350 children had contributed DBS for lead testing. Dried blood spots will be collected from caregivers and children in the voucher sample in Wave 2. As in Wave 1, the specimen will be taken from a finger, but the data collection protocol will follow Specimen Collection Instructions and filter paper procedural guidelines for practitioners of the Michigan Department of Community Health (MDCH, 2011).

Dried blood spots provide valid data on metabolic and inflammatory markers and are quite stable during repeat measures and long periods in frozen serum storage (Aziz et al., 2003; Breen et al., 2000; Macy, Hayes, and Tracy, 1997; Ockene, et al., 2001; Rao et al., 1994; Rosa-Fraile et al., 2004). The study team will test how children are affected by vouchers with respect to IL-6 and CRP, biological markers that have been shown to be affected by stress (Glaser and Kiecolt-Glaser, 2005; Soderberg-Naucler, 2006; Vedhara, Fox, and Wang, 1999).

In addition to the biomarker measures, the study will also examine whether and how various housing, neighborhood, and family process features act as possible mediators—for example, characteristics or factors that are affected by vouchers and, in turn, affect other outcomes or moderators, such as when the effect of vouchers varies based on another characteristic, such as race or gender. As already discussed, living in better neighborhoods, better housing units, more affordable housing units, etc., could lower stress levels and, therefore, improve the health of caregivers and children. The wide range of measures outlined in exhibit 7 will be used to explore these possible pathways.

Analyses

Two major design elements influence all of the analytic choices:

1. The random assignment used to provide housing assistance for the housing voucher sample.
2. Repeated observations with two waves of data for both the voucher and population samples.

The random assignment of housing assistance to the voucher sample is a major methodological strength of the HCHD study. Randomly selecting who among the eligible households is offered a housing voucher is the best way to create two similar groups, if not identical, in both observed

and unobserved characteristics. Comparing outcomes between two randomly assigned groups indicates that any observed differences are due to the intervention, and, in this case, the receipt or use of a housing voucher, rather than any differences between the two groups.

Confirmatory analyses that build off prior research findings will examine whether receiving a housing voucher affects children's cognitive, emotional, and physical development. In particular, the analyses will determine how much housing choice vouchers affect children's development as indicated by:

1. Physical health: measured by IL-6, a biomarker for infection and inflammation, and CRP, a biomarker for stress.
2. Emotional development, examining executive functioning with the Hearts and Flowers test along with self-regulation using the PSRA.
3. Cognitive achievement using the Woodcock-Johnson Letter-Word and Applied Problems tests.

The random assignment of housing choice vouchers means that any observed differences in these outcomes can be causally attributed to the impact of the voucher.

The study will estimate the effects of randomly assigned vouchers on six primary outcomes—IL-6, CRP, executive functioning (Hearts and Flowers), self-regulation (Preschool Self-Regulation Assessment), reading achievement, and math achievement (Woodcock-Johnson test)—reporting both intent-to-treat (ITT) and treatment-on-treated (TOT) effects. The ITT analyses will test the effects of a voucher *offer*, and the standard TOT analyses will test the effects of actual voucher *use*.

In addition, the availability of two waves of outcome observations means that standard panel data fixed effects models can be used to account for unobserved family characteristics. In these sorts of models, causal inferences are supported by *within-family changes* in housing characteristics rather than simple cross-sectional comparisons. The key assumption is that the most important unobservable confounders—for example, differences between those receiving a housing voucher and those who do not receive housing assistance—are invariant at some level of aggregation. The use of fixed effects will further strengthen analyses of the randomized voucher sample and be used to estimate models with the population sample.

Despite their strengths, however, fixed effects models can produce misleading causal inferences. For example, linear models make it easy to extrapolate beyond the support of the data. The study will estimate models using propensity score matching with difference-in-difference (DiD) regressions to reduce this potential problem. Propensity scores will be used to create a group of changers and nonchangers for various treatments. In the primary analyses, for instance, propensity models will be used to predict who receives housing assistance. For additional child development analyses, for instance, propensity models will be used to examine changes in crowding, physical housing quality, and affordability, then matching cases based on their propensity scores. For the tradeoff analyses, propensity models will be used to examine changes in unit, neighborhood, and school quality.

Even after matching on rich covariates and lagged outcomes, families who do and do not reduce crowding, housing quality, etc., might differ in unobserved ways. Therefore, to strengthen the analyses using matched samples, the study team will combine matching with DiD regressions

using the outcomes measured in Wave 1 as baselines, thereby reducing the effect of unobserved family characteristics similar to what is done in fixed effect models. Note that DiD-matching does not require as many assumptions as cross-sectional matching. In DiD-matching, the propensity score must only account for time-varying sources of confounding. Any remaining time-invariant differences will be identified in the model by the person/household-level fixed effect.

To ensure the analyses are not affected by selection bias, baseline differences between treatment and control groups and any differential attrition effects will be examined. Propensity models can be combined with ITT and TOT models further to ensure a balance between the treatment and control groups. Whatever selection bias remains will be further controlled by including numerous heterogeneous covariates, especially the inclusion of Wave 1 outcome measures.

The study team will also use *subgroup methods* to identify the mediating effects of housing measures. Understanding the effects of mediators is complicated because a voucher can change crowding, physical quality, neighborhood, school, and affordability. At first glance, randomly assigned vouchers do not provide the leverage to separate these effects. However, previous research identifies subpopulations that respond to receiving a voucher in ways that emphasize each specific mediator. These subpopulations provide a way to learn how each mediator affects family processes, child development, and outcomes. For example, the effect of vouchers in subgroups who experienced larger than usual voucher-induced doses of crowding will inform about the effects of crowding. The key to this quasi-experimental approach is identifying varying subgroups: a group who differentially changes affordability; a group who differentially changes crowding; a group who differentially changes neighborhoods, and so on.

Despite the complexities of implementation, the basic form of the analyses follows a two-stage least squares framework. In the first stage, mediators are regressed on exogenous covariates, indicators for the responder subpopulation, an indicator for voucher receipt, and the interaction of voucher receipt and responder subpopulation. In the second stage, the voucher receipt and voucher-by-responder interactions serve as excluded instrumental variables to identify the effects of the mediators on outcomes.

Finally, several complications need to be addressed in all of the analyses. First, because data are collected from up to two eligible children per household, child observations are clustered within a family. Thus, the regression models will estimate all standard errors using a cluster robust variance matrix.

Special Features of the Tradeoff Analysis

The tradeoff study requires some more specialized analyses. First, hedonic models will be used to understand how qualities of dwelling units, neighborhoods, and schools combine to influence rents. Hedonic modeling is a widely used technique in public finance and urban economics that regresses the price (or rent) of the housing unit against an array of attributes of the *full housing bundle,* including characteristics of the surrounding neighborhoods and local schools. Thus, the model expresses how buyers weigh aspects of housing quality (HQ), neighborhood quality (NQ), and school quality (SQ) in their housing expenditures.

The other special feature of the tradeoff analysis is to develop insights into how parents make decisions about where to live. One aspect of this analysis is asking parents to answer vignette

questions that probe along multiple dimensions. Using appropriate statistical methods (for example, ordinal regressions that allow one to assume that choices can be ranked but do not require one to assume that the differences between choices are the same) will provide good causal information on the relative impact of each type of quality (HQ, NQ, and SQ) on parents' valuation of the housing option described in the vignette. Survey- and vignette-based analyses will then be compared by assessing the extent to which survey-based measures predict vignette effects. These analyses of parent choice will help assess the extent to which parents have and use information about the likely impact of residential choices on their children. The experimental impact of voucher availability will be analyzed, as well as the qualities of dwelling units, neighborhoods, and schools to which children are exposed, to study the revealed preferences. As described earlier, both ITT and TOT effects will be estimated. The ITT analyses will inform about the capacity of housing voucher policies to achieve the goal of enhancing child development, and the TOT analyses will estimate the impact of using the voucher on dwelling unit, neighborhood, and school quality associated with a child's residence.

Handling Multiple Comparisons

Because the confirmatory analyses focus on more than one outcome, inflated errors may be a problem. That is, because there is the possibility of detecting a statistically significant effect just by chance, examining more than one outcome increases the likelihood of detecting a chance finding beyond the specified *p*-value.

Steps recommended by Schochet (2009; Orr & Maynard, 2015) are followed to address this issue. First, *confirmatory* analyses designed to assess the effects of housing assistance on prespecified outcomes are distinguished from *exploratory* analyses designed to identify hypotheses that could require additional analyses (Schochet, 2009). As described earlier, the confirmatory analyses examine how much the receipt of a housing voucher affects children's development in three domains—physical health, emotional development, and cognitive achievement—and seek to understand the tradeoffs parents make in choosing where to live.

Further, two specific outcomes were identified to examine in all three domains used in the confirmatory analyses: IL-6 and CRP for physical health; executive functioning and self-regulation for emotional development; and reading and math assessments for cognitive achievement. However, Schochet (2009) recommends that domain-specific hypothesis testing should be done for each domain as a group. That is, instead of examining the impact of vouchers on IL-6 and CRP separately, a composite t-test is conducted to examine the global hypothesis about this domain. If the effect of vouchers on the overall domain is found to be statistically significant, models are then estimated for each measure using *unadjusted p*-values. As Schochet explains (2009), "the significance of a particular outcome does *not* provide confirmatory evidence about the domain as a whole but provides information that could be used to help interpret the global findings."

However, identifying the three domains that will be examined in the confirmatory analyses still does not eliminate concerns about inflated errors because more than one hypothesis is being tested. Therefore, the Benjamini-Hochberg "step-up" procedure (1995) will be used to compute adjusted p-values for composite t-tests. The Benjamini-Hochberg procedure is designed to adjust the false discovery rate—for example, the expected fraction of statistically significant tests that are false discoveries (Schochet, 2009). The procedure begins by ranking the p-values from the three composite tests. For any given significance level, α (typically set at 0.05 or 0.10), an

adjusted significance level is computed by multiplying it by 1/N, where N is the number of possible tests. Thus, the significance level required for the smallest p-value if α equals 0.05 is 0.016 (0.05 * 1/3), the significance level required for the second smallest p-value is 0.025 (0.05 * 1/2), and the significance level required for the largest p-value is 0.05 (0.05 * 1/1). No adjustments need to be made for exploratory analyses, but the results from these analyses will be appropriately qualified in all reports and papers to alert readers that these results should be treated cautiously.

Power Analysis

Exhibit 3 reports power analyses for the voucher sample.[13] Two factors are especially important for the power analyses: (1) a rich array of covariates will be used in the multivariate models, and (2) the two-wave pre-post design means that baseline measures of outcome variables can be used as additional covariates in the multivariate outcome models. One the one hand, by reducing unexplained variance, these research design factors improve the statistical power of the samples. On the other hand, statistical power declines when there are missing data, either because some questions are not answered or due to attrition between Waves 1 and 2.

The top panel of exhibit 3 presents power analyses using observations from Wave 1. The table shows the minimum detectable effect (MDE) that the study team will have at least an 80-percent chance of detecting (for example, power = 0.80). The difference in the MDEs is only due to the different rates of missing data in Wave I. Dried blood spots, for example, were obtained from 80 percent of the 1,202 children in the treatment and control groups of the voucher sample, and nearly all (98 percent) children completed the Woodcock-Johnson Letter-Word (reading) test. Exhibit 3, therefore, shows results using the smaller number of cases with dried blood spots as well as those who completed the Hearts and Flowers test of executive functioning (97 percent) and the Woodcock-Johnson Letter-Word test. The power analyses also use the adjusted *p*-values (α) based on the Benjamini-Hochberg procedure described previously. That is, α values of 0.016 and 0.033 were tested in place of the standard 0.05 and 0.10 values.

The first column shows the MDE when no adjustments are made for any multivariate correlations (for example, $R^2 = 0$). The next three columns show the revised MDEs based on three estimates of the overall correlation (R^2) between all covariates and baseline measures of outcome variables with the Wave 2 outcomes: 0.3, 0.5 and 0.7. The results show that accounting for these research design factors improves (that is, reduces) the minimum effect sizes that can be detected between 15 to nearly 50 percent, depending upon the expected correlation between baseline covariates and Wave 2 outcomes.

To be conservative—but also expecting baseline outcome measures to be correlated with Wave 2 outcome measures—the midrange estimate of $R^2 = 0.5$ was adopted. For example, the Woodcock-Johnson tests are designed to have a standard deviation (SD) of 15 points. The top panel of exhibit 3 shows that, without taking into account any design effects with the voucher children's sample of 1,180 cases who completed the Woodcock-Johnson Letter-Word test, one

[13] Power analyses conducted using *Optimal Design Plus Empirical Evidence: Documentation for the "Optimal Design" Software*, developed by Jessaca Spybrook, Howard Bloom, Richard Congdon, Carolyn Hill, Andres Martinez, and Stephen Raudenbush. https://websites.umich.edu/~amzzz/od/od-manual-20111016-v300.pdf.

would be able to detect a difference of 2.6 (15 * 0.175 when $\alpha = 0.033$) to 2.9 points (15 * 0.190 when $\alpha = 0.016$). However, with the design effects factored in, the MDE difference shrinks approximately 30 percent to 1.9 (15 * 0.124 when $\alpha = 0.033$) to 2.0 points (15 * 0.135 when $\alpha = 0.016$).

The bottom panel of exhibit 3 shows the estimated MDEs if assuming an attrition rate of 10 percent from Wave 1 to Wave 2. The MDE values increase but not substantially. Again, using the Woodcock-Johnson Letter-Word test SD of 15 points, the revised MDE ranges between 2.7 and 3.0 when assuming no design effects and 1.9 to 2.1 with a design effect of $R^2 = 0.5$.

The effect of these design factors is illustrated further by looking at key outcomes from the biology and health component of the study, which examines whether the receipt of a housing voucher will have beneficial effects on children's health. Three important indicators of healthy development examined are levels of IL-6, a biomarker for infection and inflammation; CRP, a biomarker for stress; and self-regulation (for example, executive functioning and impulse control).

Because the HCHD Study will be the first research to be able to test these effects, one cannot compare MDEs from the HCHD study with similar results from previous studies. Instead, the research relies on studies of the effect of income on these three outcomes, which provides a reasonable approximation because housing vouchers have an income effect. Also included is one study of the effect of residential moves on self-regulation because receipt of a housing voucher is likely to increase residential stability.

The top row of exhibit 4 displays the MDE for the HCHD of receiving a housing voucher on the three child outcomes: CRP, IL-6, and self-regulation. Using the results from the bottom panel of exhibit 3 for dried blood spots and assuming a design factor of $R^2 = 0.5$ shows an MDE of 0.144 to 0.157 for all three outcomes. For CRP, where the mean level for children is 1.22 mg/L with a standard deviation of 5.11 (Dowd et al., 2010), the HCHD study will be able to detect statistically significant differences of 0.7 to 0.8 mg/L.[14]

The bottom three rows of exhibit 4 show the effect sizes for impacts of income increases on CRP, IL-6, and self-regulation in three recent studies (Evans and Garthwaite, 2014; Petersen et al., 2008; and Roy and Raver, 2014). The last row in the table shows the effect size in a recent study of the impact of residential stability on self-regulation (Roy et al., 2014). It is reasonable to hypothesize effects of the size that HCHD can detect, based on previous studies. In particular, Evans et al. (2014) found that a $1,000 average increase in annual income was associated with a 19-percent decrease of standard deviation in the level of CRP, and a housing voucher is worth roughly $8,000/year to a recipient household.

In an observational study examining the relationship between socioeconomic status (SES) and IL-6, Petersen et al. (2008) found individuals with higher SES, measured as a combination of household income and education, had lower IL-6 levels, with a one-standard-deviation change in SES lowering the IL-6 level by 13 percent of a standard deviation.

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[14] The 0.5–0.6 range is arrived at as follows: 5.11 * 0.144, which is the effect size for HCHD at the 0.05 level of significance = 0.5; 5.11 * 0.157, the effect size for HCHD at the 0.10 level of significance = 0.8.

A longitudinal study by Roy and Raver (2014) found that children in deep poverty, defined as below 50 percent of the federal poverty level (FPL), were 15 percent more likely to have poor self-regulation than children not as deeply impoverished. HCHD should be able to detect an effect of at least this size because, again, housing vouchers are worth an average of $8,000/year, which should move all but the very lowest-income households above 50 percent of the FPL.

Another longitudinal study, Roy et al. (2014) found that among low-income children, those who did not move scored at least 6 points higher—or nearly one-quarter of a standard deviation—on a measure of self-regulation. HCHD should plausibly observe a similar effect size because families with children receiving housing vouchers are expected to be more residentially stable than control families.

Overall, these illustrative power results show that the HCHD study's design will detect effects as small or smaller than those found in other studies when examining the various research questions.

Exhibit 1: Completed Wave 1 Interviews

	Cleveland	Dallas	Total
Household/Primary Caregiver			
Voucher—Treatment	225	238	463
Voucher—Control	219	225	444
Total Voucher Sample	444	463	907
Total Population Sample	447	447	894
Children			
Voucher—Treatment	301	317	618
Voucher—Control	283	301	584
Total Voucher Sample	584	618	1,202
Total Population Sample	610	584	1,194

Source: HCHD data files

Exhibit 2: Design of Population Sample

Primary Block Group Strata	Sampling Rate	Number of Households		
		Cleveland	Dallas	Total
Low-Income	0.50	217	217	434
Middle-Income	0.33	145	145	289
High-Income	0.17	72	72	145
Total	1.0	434	434	868

Source: Survey Research Center Sampling Group, March 2017

Exhibit 3. Minimum Detectable Effect Sizes for Housing and Children's Healthy Development Study

			Estimated Total Correlation between Baseline Covariates and Wave 2 Outcomes			
Outcome	N	**Adjusted Significance Level**	**0.0**	**0.3**	**0.5**	**0.7**
Wave 1 Samples						
Dried Blood Spots	968	0.016	0.210	0.176	0.148	0.116
		0.033	0.193	0.162	0.137	0.102
Hearts and Flowers	1,168	0.016	0.191	0.161	0.136	0.105
		0.033	0.176	0.147	0.125	0.097
W-J Letter-Word	1,180	0.016	0.190	0.160	0.135	0.105
		0.033	0.175	0.146	0.124	0.097
With 10% Attrition						
Dried Blood Spots	871	0.016	0.220	0.185	0.157	0.122
		0.033	0.203	0.169	0.144	0.111
Hearts and Flowers	1,051	0.016	0.202	0.168	0.143	0.110
		0.033	0.184	0.154	0.131	0.101
W-J Letter-Word	1,062	0.016	0.201	0.168	0.141	0.110
		0.033	0.183	0.154	0.130	0.100

W-J = Woodcock-Johnson.

Notes: Significance levels are adjusted using the Benjamini-Hochberg procedure. With three main outcome domains, a significance level of 0.05 becomes 0.016 (0.05 * 1/3), and a significance level of 0.10 becomes 0.033 (0.10 * 1/.3). Power = 0.80 for all analyses. Top panel N is based on the actual number of children in the voucher sample who answered the question(s) in Wave 1. Bottom panel N based on 10-percent attrition from Wave 1 N.

Source: HCHD data files

Exhibit 4. Power Analysis of the Effects of Income or Residential Stability on C-reactive protein, Interleukin 6, and Self-Regulation: Housing and Children's Healthy Development Compared to Illustrative Studies

(effect sizes in percent of a standard deviation)

	CRP	IL-6	Self-Regulation
HCHD	0.144–0.157	0.144–0.157	0.144–0.157
Evans et al. (2014)	0.190		
Petersen et al. (2008)		0.135	
Roy and Raver (2014)			0.148
Roy et al. (2014)			0.240

CRP = C-reactive protein. IL-6 = Interleukin 6. HCHD = Housing and Children's Healthy Development.

Source: HCHD data files

Exhibit 5: Study Overview

Number of Sites	2: Cleveland, Dallas
Number of Study Waves	2
Timing	Wave 1: May 2017–September 2018 Wave 2: to be determined
Study Design	Dual-frame sampling design: - Sample of voucher applicants - Stratified, random population sample
Voucher Sample	Randomly selected households with 1 or more children aged 3–10 from Public Housing Authority applicant pool: - Treatment group offered housing assistance - Control not offered assistance at this time
Population Sample	Multistage selection based on U.S. Census blocks groups: **Stage 1**: Block groups (BG) stratified based on 2015 American Community Survey median family income into three groups: Cleveland: Low BG: 62.1%+ households earn < $35K

	Medium BG: 38.7% to 62.1% households earn < $35K High BG: < 38.7% households earn < $35K Dallas: Low BG: 51%+ households earn < $35K Medium BG: 27% to 51% households earn < $35K High BG: < 27% households earn < $35K - Block groups sampled using ratio of 3 low-income: 2 medium-income: 1 high-income to create Primary Sample Unit (PSU) **Stage 2:** Obtained household incomes of all housing units in PSU and used this data to stratify addresses into three groups: Cleveland: Low-income addresses: Average income $14,682 Middle-income addresses: Average income $37,498 High-income addresses: Average income $73,396 Dallas: Low-income addresses: Average income $21,282 Middle-income addresses: Average income $45,585 High-income addresses: Average income $93,592 - Addresses selected within each BG at a 3:2:1 (low-, middle-high-income, respectively) address ratio Cleveland: 8,258 addresses selected from 54 BG Dallas: 5,844 addresses selected from 54 BG
Child Selection Criteria	- 3 to 10 years of age (Wave 1) - Spends at least 3 nights per week in the household
Survey Assessment Methods	- Computer-assisted personal interviews (CAPI) - Self-administered questionnaires (SAQ) - Child assessments - Physical measurements (e.g., height, weight) - Blood draws: HbA1c, IL-6, CRP, heavy metals: arsenic, lead, mercury

	- Laser tape room measurements - Interviewer neighborhood observations
Wave 1 Interviews	*Household/Primary Caregiver (PCG)* Total 1,801 Voucher Treatment 463 Control 444 Total 907 Population 894 *Children* Total 2,396 Voucher Treatment 618 Control 584 Total 1,202 Population 1,194
Payments	$50 – PCG interview $25 – PCG blood spot (voucher only) $25 – Child interview (per child) $25 – Child blood spot (voucher only) $25 – Diary Additional payments provided during “endgame” to boost recruitment/participation: $25 – PCG interview $15 – Child interview
Languages	Protocols developed and administered in English and Spanish

Funders	- John D. and Catherine T. MacArthur Foundation - Eunice Kennedy Shriver National Institute of Child Health and Human Development - U.S. Department of Housing and Urban Development - Robert Wood Johnson Foundation

HbA1c = hemoglobin A1C. CRP = C-reactive protein. IL-6 = Interleukin 6.

Note: Details on the selection of the population sample taken from "Sample Selection in the Housing Study" prepared by the SRC team, March 28, 2017.

Source: Numerical estimates from HCHD data files

Exhibit 6: Topics Covered in Housing and Children's Healthy Development Study Protocols

Adult Interview and Assessments	Child Interview and Assessments	Additional Assessments and Observations
- Residential mobility, crowding, privacy, space - Housing quality - Other housing features - Housing costs - Public Housing Authority applicant questions - Preferences and tradeoffs - Neighborhood - Neighborhood vignettes - Respondent general information - Employment information - Spouse/partner/other parent information - Household income, assets, debts - Mental health - Health - Physical measures (height, weight, blood pressure) - Blood spot collection - Challenges to parenting - Family environment and routines - Home Observation for Measurement of the Environment (HOME) - Discipline of child	- Hearts and Flowers executive function task - Preschool Self-Regulation Assessment - Woodcock-Johnson (Applied Problems) - Woodcock-Johnson (Letter-Word identification) - Physical measurements (height, weight, waist, hips) - Blood spot collection - Thin-slice observation of cognitive sensitivity/Lego activity	- Neighborhood observations - Physical environment of home - Square footage of living space in the dwelling (by laser tape)

Adult Interview and Assessments	Child Interview and Assessments	Additional Assessments and Observations
- Child demographics - Child's room - Child's residential background - Childcare and preschool - School - Child's behavior - Child health		

Source: HCHD protocol

Exhibit 7: Key Housing and Children's Healthy Development Measures

Domain	***Measures***	***Description***
Child Outcomes		
Cognitive	Woodcock-Johnson Letter-Word (reading)	Widely used tests of achievement
	Woodcock-Johnson Applied Problems (math)	
Socioemotional	Behavior problems (Child Behavior Checklist)	Widely used, validated instrument assessing socioemotional behavior problems
	Executive functioning (Hearts and Flowers)	Children must respond quickly to images of hearts and flowers in different ways; tests inhibitory control, working memory, and cognitive flexibility
	Cognitive sensitivity (Thin-slice)/Lego activity	Recently developed measures of how PCG identifies, interprets, and responds to child's cognitive needs when engaged in a joint task.
	Self-Regulation	Preschool Self-Regulation Assessment-Assessor Report (PSRA)
Health	Biomarkers: height, weight, waist-to-hip ratio	Used to assess child obesity, a key indicator of a child's health
	PCG overall assessment of child's health	Widely used health measure
	Physical limitations	Used to assess severity of any physical or mental health issues that limit play or school
	Specific health issues: asthma, allergies (respiratory, skin), headaches, diabetes	PCG asked if a doctor ever said child had each specific illness/health issue
	Child's sleep patterns/problems	Sleep Disorders Inventory for Students (SDIS) for children 2 and older, used to determine if a child is likely to have a sleep disorder

Domain	***Measures***	***Description***
	Dried blood spots: HBA1c, IL-6, CRP	Collected ONLY for the voucher sample—measures of stress
	Dried blood spots—heavy metals (lead, mercury)	Collected ONLY for the voucher sample—measures exposure to heavy metals
Housing		
Size and Crowding	Number of bedrooms, bathrooms, other rooms	Used as objective measures of physical space
	Place for child to read, work, do homework?	Measure of child's privacy
	Identify room where respondent child sleeps	Measure of child's privacy
	Place for child to play outdoors?	Measure of personal space
	Interviewer laser tape measure of rooms in unit	Objective measure of unit size
	PCG: Do you have enough space?	Subjective report of personal space and crowding
Costs	Tenure (own or rent)	Required to assess housing costs for the population sample
	Monthly payments (rent or mortgage)	Primary housing cost
	Other costs (e.g., taxes, insurance, gas, electric, water)	Additional housing costs are sometimes included with rent
Quality	Broken windows; cracks/holes in walls; peeling paint; rats/mice/roaches; kitchen sink, refrigerator, stove, heat working; mold	Standard measures of housing quality used in the American Housing Survey
Safety	PCG: How safe do you feel in your neighborhood?	Asked in both the PCG interview and SAQ
	PCG: How safe do you feel in the immediate area right outside your home?	Asked in PCG interview

Domain	***Measures***	***Description***
Preferences	PCG: What do you consider the most important features of a nice apartment or house? PCG: What do you consider the most important features of a good neighborhood? PCG ratings: What do you like most about the place where you live now for your child? What do you like least about the place where you live now for your child? Which features are most/least important: nice home, good neighborhood, good schools? Questions that assess how much the PCG would be willing to pay for each feature Vignettes that ask about the importance (how much willing to pay in rent) of physical condition, neighborhood safety, and schools	PCG and SAQ questions designed to elicit information about the types of tradeoffs households say they consider when deciding where to live, which can be compared to the characteristics of the housing units and neighborhoods where households actually choose to live
Mobility	Number of years in current home	SAQ measure of tenure
	Reason(s) for moving	SAQ measure
Neighborhood Measures		
Interviewer Observations	8 block faces—physical condition of buildings, roads; physical disorder (garbage, graffiti, abandoned cars, drug/alcohol/ cigarette litter); social disorder (drugs, alcohol, litter; land uses	Questions modified from the Move to Opportunity (MTO) study
PCG Rating	How would you rate your neighborhood as a place to live?	Scale of 1 “Very Satisfied” to 4 “Very Dissatisfied”
School		
Preferences	PCG: What do you consider the most important features of a good school?	Options include: 1. Children are getting a good education 2. Children are well-behaved 3. High test scores 4. Teachers care about the children 5. School is safe

Domain	***Measures***	***Description***
Location	Name, address of child's school	Links CCD and Eden/EDFacts data for specific schools
School Features	Common Core of Data (CCD) measures: number of students, teacher/student ratio, percent students receiving free or reduced price lunch7	CCD provides administrative data about schools
	EDEN/EDFacts: Student achievement	EDEN/EDFacts provides performance data about school systems and individual schools
Covariates/Mediators/Moderators		
Child's Background	Child's gender, age, race, ethnicity	Child-level covariates used to remove bias in outcome models
PCG's Background	PCG gender, age, race, ethnicity	PCG-level covariates used to remove bias in outcome models
	PCG's education, occupation, employment earnings, debts and assets, marital status	
Household Composition	Household composition: number of people and relationships of them to the PCG and to the child	
PCG Socioemotional	PCG's mental health	PROMIS: measures PCG's physical, mental, and social health
	Parenting stress	1. Parent-Child Conflict Tactics Scale-Short Form (Strauss et al., 1998): measures maltreatment and neglect of children by PCG 2. Challenges to Parenting (Hofferth et al., 1997)
PCG Health	PCG self-report of overall health	Widely used health measure
	Specific health issues (asthma, diabetes, hypertension, heart condition)	Has doctor ever told PCG he/she had each specific illness/health issue
	Physical limitations (e.g., walking, climbing stairs, two hours of physical activities)	Used to assess severity of any physical or mental health issues that limit play or school
	PCG's sleep pattern/problems	Pittsburgh Sleep Quality Index (PSQI)

Domain	***Measures***	***Description***
	PCG dried blood spots: HbA1c, IL-6, CRP	Measures of stress
	PCG's cigarette and alcohol use	
	PCG blood pressure	
Family Processes	Family routine	The Family Routines Inventory (Jensen et al., 1983) measures how much parent's organize children's daily life
	Parent support	Home Observation for Measurement of the Environment (HOME)
Household Expenditures	Household expenditures on children (e.g., how much spent last month on medical and dental; childcare and schooling; clothes and shoes; toys, games, and presents; camps and lessons)	SAQ questions
	General household expenditures (e.g., how much spent last month on food and transportation)	

PCG = primary caregiver. HbA1c = hemoglobin A1C. CRP = C-reactive protein. IL-6 = Interleukin 6. SAQ = Self-Assessment Questionnaire

Source: HCHD study protocol

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