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Temporal effects of distressed housing on early childhood risk factors and kindergarten readiness☆

Claudia J. Coulton [a,*], Francisca Richter [a], Seok-Joo Kim [b], Robert Fischer [a], Youngmin Cho [a]

[a] Center on Urban Poverty and Community Development, Jack, Joseph and Morton Mandel School of Applied Social Sciences, Case Western Reserve University, 10900 Euclid Ave., Cleveland, OH 44122, United States
[b] Department of Social Welfare, Daegu University, 201 Daegudae-ro, Gyeongsan-si, Gyeongsangbuk-do 38453, South Korea

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ABSTRACT

Poor housing quality and housing crises have been linked to adverse outcomes for children. However, few studies have focused on the early childhood period or been able to pinpoint how the timing and duration of housing problems contributes to early educational success. This longitudinal study draws on linked administrative records from housing, education, social service and health agencies to examine the influence of exposure to housing neighborhood conditions since birth on school readiness of all children entering kindergarten over a four-year period in a big city school system. Using marginal structural models that properly account for dynamic housing and neighborhood selection, we find that children exposed to problematic housing and disadvantaged neighborhoods have lower kindergarten readiness scores after accounting for other factors. The negative effects of housing problems on kindergarten readiness are partially mediated by child maltreatment incidences, residential instability, and elevated blood lead levels. Communities are advised to pay more attention to distressed housing as a cause of disparities in early child development and school readiness.

1. Introduction

Socio-economic inequalities in children's cognitive skills at school entry are significantly higher in the US than in the UK, Canada or Australia (Bradbury, Corak, Waldfogel, & Washbrook, 2015). While it is generally acknowledged that the environment in which children spend their early years is crucial, little is known specifically about how housing conditions, both in children's own family homes and the immediately surrounding areas, factor into disparities in early literacy skills and kindergarten readiness. A main challenge in studying the effect of housing and neighborhoods environments on children's development is that housing and neighborhoods are not exogenously assigned to the child's family. Rather, selection into environments is influenced by household characteristics beyond those that are commonly observed by the researcher. A strength of this study is that we are able to leverage our unique longitudinal data to address selection and thus, reduce estimation bias relative to analyses based on survey or cross sectional data. This population-based study has two main purposes: (1) To examine the cumulative impact of housing distress on early literacy skills for all children entering kindergarten over a four-year period in a big city school system, and (2) To explore the influence of housing problems on selected risk factors for early development including child maltreatment, residential instability and lead exposure.

The focus of this study on housing and early literacy skills as an aspect of kindergarten readiness is justified because there is considerable evidence that exposure to stressful circumstances, environmental hazards and less than optimal early environments negatively affect early cognitive and socio-emotional development (Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005; Martin, Razza, & Brooks-Gunn, 2012), that these influences are cumulative (Appleyard, Egeland, Dulmen, & Sroufe, 2005; Evans, 2003) and that disadvantages shown at kindergarten entry tend to persist over time (Duncan et al., 2007; Hart, Petrill, Deckard, & Thompson, 2007). Children growing up in low-income households and poor neighborhoods experience these negative conditions at higher rates compared to children living in better circumstances, which contributes to well-documented disparities in educational outcomes. This study adds to our knowledge about the specific role that housing plays in early development because it examines the influence of a wide range of housing exposures on the young child, both in the residential home and from the surrounding properties. These include characteristics of the housing stock and indicators of disinvestment such as foreclosure, vacancy and abandonment. Such indicators of housing distress grew enormously following the mortgage

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* Corresponding author.
E-mail address: claudia.coulton@case.edu (C.J. Coulton).

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crisis in the late 2000's, but the effects on early childhood have yet to be examined, even though >2 million children are estimated to have been touched by foreclosure (Lovell & Isaacs, 2008).

2. Background and conceptual framework

Based on a detailed review of the literature on housing and child development, Leventhal and Newman (2010) argue that macro-level forces influence housing and neighborhood conditions, which in turn affect family processes and child outcomes. Additionally, they contend that family background factors play a role in families' selection into housing and neighborhoods and numerous child characteristics influence family processes and child development outcomes. We adapt this framework to focus on housing-related effects on early school readiness and the micro and macro processes uniquely captured in our longitudinal data on children and properties (see Fig. 1).

2.1. Housing and early school success: theory and mechanisms

From an ecological-developmental perspective (Bronfenbrenner & Evans, 2000), educational success in the early grades is influenced by a number of factors, including those emerging from the home and neighborhood environments (Duncan & Magnuson, 2011; Shonkoff & Phillips, 2000). Multiple pathways appear to account for the connection between ecological disadvantage in early childhood and markers of school achievement (Dupere, Leventhal, Crosnoe, & Dion, 2010). Of greatest relevance to the current study are those mechanisms that plausibly link the experiences of families with their housing and surrounding properties to early education success: family stress, residential instability, and toxic environmental exposures.

2.1.1. Family stress and child maltreatment

Housing problems can affect early school success through disruptions to adequate parenting (Leventhal & Newman, 2010). It is well documented that attentive, responsive and consistent parenting is critical to early learning and cognitive development (Bradley, Corwyn, Burchinal, McAdoo, & Coll, 2001), but these parental behaviors are often compromised for those in disadvantaged circumstances (Evans, 2004). Housing problems and neighborhood conditions undoubtedly bear some of the responsibility for lapses in parenting through their impact on parent's stress levels and mental health (Klebanov, Brooks-Gunn, & Duncan, 1994) and the everyday chaos that occurs in difficult housing circumstances (Evans et al., 2005). One of the few housing studies that focused on young children found that elevated levels of behavioral problems could be explained in part by the adverse influence of bad housing conditions on mother's psychological distress (Coley, Leventhal, Lynch, & Kull, 2013).

Child maltreatment, arguably an indicator of extreme parenting failure, might be an additional explanation for the link between housing problems and school readiness. Children that are the subject of child maltreatment investigations have been shown to have diminished chances of early school success (Fantuzzo & Perlman, 2007), and a number of studies demonstrate that neighborhoods with distressed housing have increased rates of child maltreatment (Coulton, Crampton, Irwin, Spilsbury, & Korbin, 2007). Housing crises may also contribute to parenting stress and child maltreatment as suggested by a recent study that found an increased risk of child maltreatment investigations in households that were in the process of mortgage foreclosures (Berger et al., 2015).

2.1.2. Residential instability

Another pathway through which housing problems can affect early learning outcomes is the disruptions associated with frequent moves. Though evidence seems to suggest that residential movement per se is not harmful once other risk factors are taken into account (Hango, 2006), frequent mobility has been shown to have negative consequences for child development (Astone & McLanahan, 1994; Pribesh & Downey, 1999; Wood, Halfon, Scarlata, Newacheck, & Nessim, 1993). One of the few studies that focused specifically on early childhood found residential instability to be inversely associated with cognitive and social development at age 5, particularly for children in low-income families (Ziol-Guest & McKenna, 2014). Additionally, research shows that residential instability in the early years has direct effects on parental behaviors that are considered abusive or neglectful and on self-reported parenting stress levels (Warren & Font, 2015).

Housing problems undoubtedly play a role in the high levels of residential instability that have been documented among poor households (Gasper, DeLuca, & Estacion, 2010; Pribesh & Downey, 1999). In particular, housing crises rather than strategic choices to relocate to better neighborhoods or employment opportunities are responsible for a

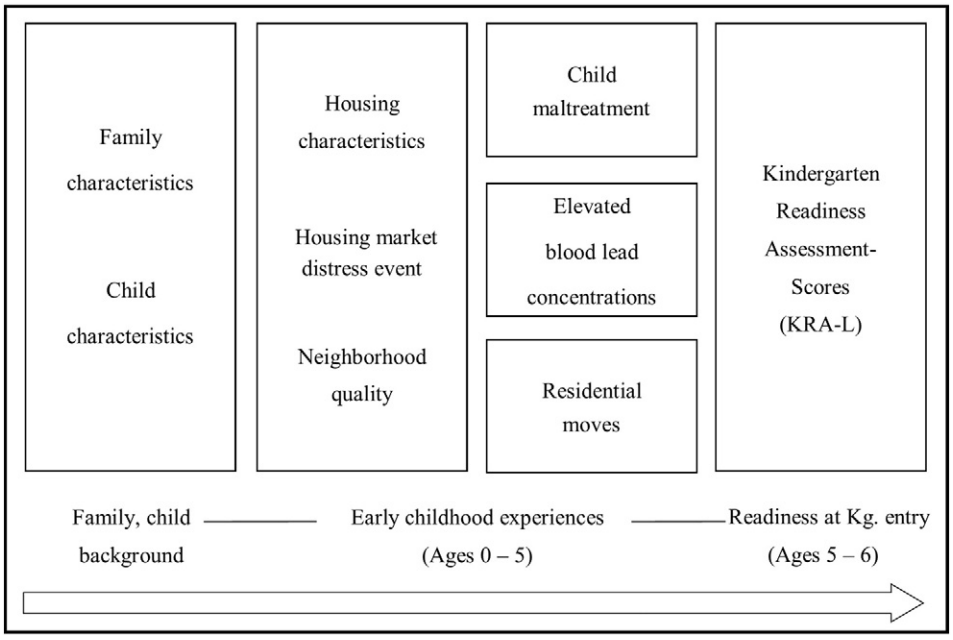

Fig. 1. Hypothesized relationships between housing, mediators, and kindergarten readiness.

large portion of moves in low-income neighborhoods (Coulton, Theodos, & Turner, 2012). For example, many families in a Baltimore study pointed to harmful housing conditions such as mold, lack of heat, crumbling walls, leaks, electrical problems, and vermin, as important reasons for relocating (DeLuca, Rosenblatt & Wood, 2011).

2.1.3. Environmental exposures

The physical deterioration of housing may affect child health and development through increasing the risk of contact with harmful substances (Breysse et al., 2004; Shaw, 2004). Housing that has been vacant or the focus of disinvestment tends to have serious maintenance deficiencies that can pose significant risk for exposure to lead and other environmental hazards in the home (Evans, 2006). The negative effects of lead exposure on early cognitive development are well established, and studies show that young children with elevated blood lead levels score lower on school readiness and developmental assessments (Dilworth-Bart & Moore, 2006; Krieger & Higgins, 2002; Lanphear et al., 2005). Although lead paint particles and dust in and around the home are a major source of lead exposure, less is known about how the risk of lead exposure relates to housing and neighborhood conditions more broadly. However, one study along these lines found that low-income children living in private market housing that was old and dilapidated had elevated blood lead levels at a significantly higher rate than children that lived in public housing (Clark et al., 1985). General trends suggest that prolonged disinvestment and lack of maintenance are key factors that persist in explaining economic disparities in deleterious environmental exposures such as lead among young children (Jacobs, Wilson, Dixon, Smith, & Evens, 2009).

2.2. Macro and market forces affecting urban housing

The concept of "housing niches" is a useful framework for thinking about the connection of macro-social and market forces to the lived experiences of families and children with housing (Saegert & Evans, 2003). Niches imply a contingent view of households being sorted into housing units and neighborhoods and the constraints this imposes on their experience in a cumulative fashion. In many metropolitan areas, persistent lines of race and class structure these niches (Sharkey, 2013) and shape the market forces that accordingly have unequal impact on the lives of household members. In recent years, the impact of the mortgage crisis has been greatest on those minority households, housing units, and neighborhoods that disproportionately received subprime and predatory loans that had a high probability of going into default (Rugh, Albright, & Massey, 2015).

At the household level, there is scant research on the effects of foreclosure on children. However, in New York City, foreclosures were found to be related to school instability (Been, Ellen, Schwartz, Stiefel, & Weinstein, 2011). Additionally, a Wisconsin study reported that children in foreclosed homes were more likely to experience child maltreatment (Berger et al., 2015). Beyond their own households, there is reason to believe that neighborhood properties that become vacant and blighted following foreclosure may have spillover effects that impact children in their vicinity (Immergluck, 2012; Immergluck & Smith, 2005a, 2005b, 2006). In the wake of the foreclosure crisis are also large numbers of housing units that are sold to investors (or speculators) at extremely low prices, and then rented out or "flipped" several times with very few improvements (Coulton, Schramm, & Hirsh, 2008; Coulton, Schramm, & Hirsh, 2010; Immergluck, 2013). Families with children that move into these homes face problems of low housing quality and instability along with the possibility of environmental hazards from the surrounding blight. These conditions correlate negatively with early child development at the neighborhood level (Kohen, Leventhal, Dahinten, & McIntosh, 2008), although the effects on children who live in these homes have yet to be fully explored.

Cleveland, the location for the current study, is a city where the macro and market forces described above have affected many homes and neighborhoods (Coulton et al., 2010; Whitaker & Fitzpatrick, 2013). Foreclose filings in the Cleveland area grew exponentially from 2003 to 2007 when they leveled off at previously unprecedented heights. REO (i.e., real estate owned by banks) inventory, vacancy and abandonment rose and sale prices fell as a result, bringing as little as 10 cents on the dollar of the market value prior to the crisis. Cleveland is also highly segregated by race (Iceland, Weinberg, & Steinmetz, 2002) and the loss of assets due to foreclosure was most severe in African American neighborhoods that were heavily leveraged with subprime mortgages. The children in this study, the majority of whom are African American and low-income, started life during this period of housing crises and rapid disinvestment, which continued unabated as they entered kindergarten.

3. The current study

The current study follows several cohorts of children from birth through kindergarten and includes a nearly continuous record of housing experiences along with markers for possible mediators of housing problems such as family stress, residential instability, and environmental exposures. It overcomes several limitations of previous research. First, few previous studies of housing have focused specifically on the early childhood period or had the ability to evaluate the sequence of housing experiences along with other circumstances and events that might also contribute to school readiness.

Second, research on housing and child development suffers from limitations in the measurement of housing. A review of early childhood studies concludes that most focus narrowly on only a few aspects of the housing context, such as neighborhood poverty rates or income levels, and make suppositions about housing problems or conditions in relation to income (Nettles, Caughy, & O'Campo, 2008). Studies that have gathered housing quality information suffer from common methods variance because they rely on self-reports of housing perceptions provided by the same individuals that self-report on parenting behaviors or child outcomes (Evans, 2003). Moreover, research has not explored how the duration of housing problems affects outcomes, a question of particular relevance for the developing child (Newman, 2008). This study overcomes these limitations by using administrative records data to capture multiple measures of housing conditions for children's residential locations over time. Thus, it avoids the problem of common methods variance and takes into account the duration of exposure on a number of dimensions of the housing experience.

Third, there is a disconnection in the literature between macro-structural and market influences and housing as experienced by families and children, even though the conceptual framework discussed earlier articulates their importance. When studies do include a broader context, it is typically represented by a limited set of static variables (e.g., home ownership rates) for fixed geographic units such as census tracts. Yet, housing markets are dynamic and operate at various geographies that cannot be assumed to follow fixed boundaries (Koschinsky, 2009). This study does not rely on fixed units of geography or estimates from a single point-in-time. Instead, we evaluate measures of quarterly housing market distress at various distances from children's homes to see where points of influence peak or recede.

Fourth, limitations on research design have made it difficult to address the endogeneity of housing and neighborhood selection when looking at effects on parents and children. Cross-sectional survey analyses face the problem of selection bias, because it is difficult to control for all of the factors that may predispose households to their housing experiences. Experimental studies, the most rigorous design for establishing causality, have been limited to housing program participants who volunteer for random assignment with the possibility that they will be relocated and do not adequately represent the large population of households that do not receive housing assistance. Acknowledging the limits of both national surveys and mobility experiments, DeLuca and Dayton (2009, p. 481) argue that one way to gain deeper understanding

of selection into housing and neighborhoods and to model impact is "to conduct single-city panel studies, because these studies reduce heterogeneity and control for some hidden bias." To address this gap in the literature, we conduct a longitudinal study of the housing and neighborhood conditions from birth to kindergarten of all children in a big city school district. Far from assuming them to be randomly assigned, this study recognizes that neighborhood and housing conditions are determined in part by household characteristics, which may be influenced by past living conditions and in turn influence family processes and child development. This process takes place over time, invalidating the use of standard regression models that are unable to handle time-varying confounders of treatment. We gain traction on the endogeneity problem by using dynamic selection methods to reduce the bias from time-varying confounders and to estimate time-varying effects of neighborhoods and housing on early literacy outcomes (Robins, Hernan, & Brumback, 2000; Wodtke, Harding, & Elwert, 2011).

The study focuses on four main hypotheses. First, cumulative exposure to poor quality housing and disadvantaged neighborhoods during early childhood negatively affect early literacy skills as assessed at kindergarten entry. Second, markers of housing market distress such as foreclosure and disinvestment are related contributors to children's performance on these assessments. Third, child maltreatment, residential instability and lead poisoning are negatively associated with early literacy. Fourth, problematic housing conditions and housing market distress dynamically contribute to the likelihood of child maltreatment, residential instability and lead poisoning in the early childhood period.

4. Methods

4.1. Study population and design

This is a retrospective longitudinal study of children that entered kindergarten for the first time in the Cleveland Metropolitan School District (CMSD) during the 2007–2010 academic years. It is a secondary analysis of administrative records. All entering students were included in the analysis ($N = 13.762$). This represents the entire student body of kindergartners in Cleveland during that 4-year period. The study data came from two integrated data systems (IDS) further described below. We compiled monthly address histories for the children in the study from birth to the date of their entrance into kindergarten using a combination of information contained in these records. The address histories allowed for the assessment of the timing and duration of measures related to their housing conditions, neighborhood context and residential mobility. Other records supplied data on maternal and child characteristics at birth, the timing of selected experiences and exposures from birth to kindergarten, and the kindergarten readiness literacy assessment. The longitudinal design permits us to model temporal effects of housing and neighborhood on school readiness and various mediating processes, and for the dynamic modeling of households' selection into housing and neighborhoods. The study was approved by the Institutional Review Board at Case Western Reserve University. As a secondary analysis of existing data, there was no requirement for individual parental consent.

4.2. Data sources and procedures

This study draws on two relatively unique data resources for Cleveland and Cuyahoga County maintained by the Center on Urban Poverty and Community Development, Case Western Reserve University. The first, the ChildHood Integrated Longitudinal Data (CHILD) system, links administrative records data at the level of the individual child from public health, public assistance and social services agencies, early childhood programs and K-12 education. The records in CHILD are linked together through probabilistic matching techniques within a highly secure research environment (Lalich, Anthony, Richter, Coulton, & Fischer, 2015). Importantly for this study, all residential addresses from the records are stored and date stamped.

The second data resource is a geographic information system (GIS) based tool that links records at the parcel level from multiple public sources as to housing type, conditions, values, land use codes, public housing and project based section 8 units, mortgage originations, sales and deed transfers, foreclosure filings and sales, vacancy status, housing code violations, demolitions, and tax delinquencies. This property integrated data system contains information on all residential and non-residential parcels in the county, along with shape files, centroids, and census geography identifiers for the parcels (Hirsh, Schramm, & Coulton, 2012).

Several of our study measures, including housing and neighborhood conditions and residential mobility require a reliable address history for the child. We used multiple records in tandem in order to obtain the most reliable address in all instances. We applied an address standardization protocol to these addresses and ran them through a geocoding program to for validation. Medicaid program records were the preferred source of addresses as these are checked and updated regularly in the process of program administration. Over 80% of the children in the study participated in Medicaid. The remainder of the addresses came from a variety of other records such as school, childcare and health records that are updated less frequently and are less complete than Medicaid. In these instances, we assumed that the child's address remained constant until a new address was encountered. This assumption introduces some error into our measurement of the duration of housing and neighborhood exposures could contribute to underestimates of residential mobility in this study.

In order to link the housing information to children's monthly residential addresses, we converted the standardized street addresses to parcel numbers for matching. We utilized a parcel-address look-up file that we built for our research. This match allowed the retrieval of parcel-based housing variables for each residential location tied to the time-period the child was at that address. For each address, we also specified a buffer of 500, 1000 and 1500 ft around the child's house to capture the housing market conditions in the surrounding area. Known as "ego-centric" or sliding neighborhood units, we chose these buffers based on previous studies that suggested a gradient of spatial influence and the need for sensitivity testing at various geographic scales (Chaix, Merlo, Subramanian, Lynch, & Chauvin, 2005; Koschinsky, 2009; Matthews, 2011). Additionally, we identified the census tract for each residential address for the purpose of obtaining demographic and socio-economic attributes of the population from census data sources.

4.3. Measures

The measures we used for this study all come from the integrated administrative records databases described above. Reliance on these existing data sources presents some limitations in that the data elements recorded by the agencies may not include the full range of measures that would be ideal for research. Nevertheless, because these records are available for the population rather than a sample, we can interpret our findings with respect to their systemic importance and demonstrate what communities and policy makers can learn from this relatively efficient method of conducting longitudinal research on existing records. The study measures and data sources are summarized in Table 1.

4.3.1. Child and family characteristics

Low birth weight is a child development risk factor that is determined from the birth certificate and defined as <2500 g. *Gender*, *race or ethnicity*, whether English is a second *language* and the child's *age at kindergarten* entry are control variables determined from school records. *Disability* status of the child is determined from a record of participation in the early intervention program for special needs children ages 0–3 (authorized under the Individuals with Disabilities Education Act, Part C).

Table 1
Study variables and measures.

Concepts	Measures (unit)	Sources
Child characteristics		
Low birth weight	<2500 g (yes = 1)[a]	S
Gender	Female (yes = 1)	E1
Race/ethnicity	Reference (yes = 1, African American), Hispanic (yes = 1), Non-Hispanic whites and other (yes = 1)	E1
Age	Age at kindergarten (month)	E1
Language	English as a second language (yes = 1)	E2
Disability	Early intervention status (yes = 1)	C1
Family characteristics		
Teen mother	Age below 18 at child birth (yes = 1)[a]	S
Mother's education	Mother has high school degree at child birth (yes = 1)[a]	S
Poverty status	Month in SNAP (month)	C2
Neighborhood quality		
Concentrated disadvantage	Factor score of six items[b] (rank, 0–100)	N
Housing characteristics		
Housing condition	Poor condition (yes = 1)	H1
Low market value	Market value below $30,000 adjusted inflation of 2010 (yes = 1)	H1
Public/subsidized housing	Public housing or project based section 8 (yes = 1)	H4,H5
Housing market distress event		
Tax delinquent	Parcel with tax delinquency	H1
Foreclosure	Parcel in foreclosure	H2
Speculator owned	Parcel owned by speculator[c]	H3
Mediators		
Child maltreatment	Child neglect/abuse investigation (yes = 1)	C1
Residential instability	Number of address changes (number)	E1,C1,C2
Elevated blood lead	Highest lead level in blood >5 μg/dL (yes, no, and no test)[a]	S
Educational outcome		
Kindergarten readiness	Kindergarten Readiness Assessment-Literacy score (0–29)	E1,E2

Sources
E1: Cleveland Metropolitan School District (CMSD).
E2: Ohio Educational Management Information System (EMIS).
C1: Cuyahoga County Department of Child and Family Services (CCDCFS).
C2: Cuyahoga County Job and Family Services (CCJFS).
S: Ohio Department of Health (ODH)[c].
H1: Cuyahoga County tax assessor H2: Cuyahoga County Sheriff's department.
H3: Cuyahoga County recorder deed transfers H4: Cuyahoga Metropolitan Housing Authority (CMHA).
H5: Department of Housing and Urban Development (HUD).
N: 2000 Decennial Census and 2009 American Community Survey (ACS)-5 year estimates (www.census.gov).

[a] Birth (and/or Lead) data provided by Ohio Department of Health (This should not be considered an endorsement of this study or these conclusions by the ODH).

[b] Variables were interpolated between 2000 and 2010. Six items are comprise of individual poverty, unemployment, children, African-American, single-householder, and welfare receipt.

[c] REO sales deeds applied text recognition to identify individuals, companies and LLCs with pattern of buying REO at low values including bulk and individual purchases. REO (Real Estate Owned), SNAP (Supplemental Nutrition Assistance Program).

We determine the *mother's age* and *education* at the time of birth from the child's birth certificate. The family's *poverty status* is determined monthly based on records of participation in the Supplemental Nutrition Assistance Program (SNAP). Households that are eligible for SNAP fall below approximately 130% of the poverty threshold set by the U.S. government. A limitation of this measure is that some low-income families may not apply for benefits, and would not be included in this administrative data set.

4.3.2. Neighborhood and housing measures

We measure the socio-economic conditions in the broader neighborhoods (i.e. census tracts) using standard US Census variables. Specifically, we rank all of the census tracts in the county on a widely used *concentrated disadvantage factor score* (Sampson, Raudenbush, & Earls, 1997), derived from a principal components factor analysis. The variables included in the factor are welfare receipt, poverty, unemployment, female-headed households, racial composition (percentage African American), and density of children (less than age 18). Since we are interested in modeling effects of severe contextual disadvantage in this study, we selected a cut point of the 70th percentile on the factor as a marker of neighborhood distress. As a robustness checks, we examined other cut points within plus or minus 10 points but found negligible differences.

Children's housing experiences are determined monthly based on their residential addresses. The housing measures are divided two groups: Indicators of housing conditions and markers of housing market distress. *Housing condition rating* is based on the classification rating system provided by the county tax assessor that grades housing from as good, fair, poor, very poor or unsound. Since we were interested in the effects of deteriorated housing as compared to adequate housing, we chose to classify housing units rated as poor, very poor or unsound as being in poor condition for our study. A limitation of reliance on the county ratings is that they come from periodic external inspections, and may miss recent changes in property conditions or damage to the inside of the houses that are not part of an overall picture of deterioration. To this, we add a second indicator of poor housing conditions, *very low-market value*, possibly reflecting market appraisals of the state of repair of the buildings. We set the threshold at $30,000 (in 2010 dollars), which represents the 30th percentile of housing unit values in our study.[1]

We also include a marker for whether housing units are in *public or project-based section 8* housing units. Public housing units are owned and operated by the government housing agency. Project-based section 8 units are privately owned buildings with government subsidy contracts. These types of units are inspected on a regular schedule, are required to meet specified standards, and fall outside the market valuation protocols that we rely on as indicators of property conditions for the private market housing in which the majority of our study population lives. Therefore, we flag units that are public or project based section 8 as a control variable to account for some measurement error. A limitation is that we did not have information on other types of subsidies that are also used for housing, such as low-income or historic tax credits.

We also developed measures for several housing market events that can destabilize housing or are markers for disinvestment in the properties. First, we demarcate *foreclosure spells* based on the date that a property went to foreclosure sale. The typical foreclosure takes about 18 months to complete in our county, so we consider the foreclosure spell to cover the 18 months prior to the sale. The foreclosure process can cause distress to the occupants of the home due to the uncertainty that is engendered and the fact that the occupants may face a residential move that is unplanned. Additionally, foreclosures may be markers for disinvestment by owner occupants or landlords. Another signal of housing distress is the acquisition of a foreclosed and vacant housing unit by a speculator (i.e., *speculator owned*). As part of a previous study, we developed a method of using patterns of grantee (buyer) and grantor (seller) names on deeds to identify property transfers that have a high likelihood of involving housing speculators. We found that most speculator owned houses were poorly maintained and rented out with few improvements (Coulton et al., 2010). *Tax delinquency* spells are a final marker of housing disinvestment (Whitaker & Fitzpatrick, 2013). We

[1] We evaluated the year that the housing unit was built as a possible indicator of housing quality for this study. However, year built was problematic for several reasons. <5 percent of our study population lived in housing built since 1978 (the year that lead was removed from paint by federal statute), and the average housing unit was approximately 80 years old. Most of the newer housing that our population lived in was concentrated in just a few census tracts, and was often in public or section 8 subsidized buildings.

define the tax delinquent spell as encompassing the period from the quarter before the arrearages were posted through the point at which they were resolved.[2] In order to capture market destabilization in the context surrounding children's houses, we calculate the number of foreclosed, speculator-owned and tax delinquent properties within 500, 1000 and 1500 ft buffers surrounding the houses ever occupied by a child in the study.

4.3.3. Mediating events

This study also includes several child-level risk factors that we hypothesize will have a negative effect on kindergarten readiness and may be influenced by housing problems. We ascertain the occurrence of *child maltreatment investigations* from the records of child abuse and neglect reports that were accepted for investigation by the County's Department of Children and Family Services. Allegations serious enough to result in acceptance for investigation have been shown to reflect serious concerns about family functioning and ability to care for children (Coulton et al., 2007; Slack, Holl, McDaniel, Yoo, & Bolger, 2004; Stith et al., 2009), and studies have shown that child maltreatment investigations are a better predictor of adverse outcomes than are substantiations (Hussey et al., 2005). However, other studies suggest that many instances of maltreatment are not reported to the child welfare authorities, so reliance on agency records is a limitation of our study (Sedlak et al., 2010). We calculate this variable based on whether or not the child was the subject of an investigation each year from birth to kindergarten. *Residential instability* is a count of the number of address changes experienced by the child each year. Due to the possibility of some address changes that were not recorded in or data, we consider this a lower bound estimate of residential mobility. We use records of lead testing from the Ohio Department of Health to determine whether the child ever had an *elevated blood lead level*. We use the threshold for concern set by the state that is defined as having a level >5 μg/dL. According to Centers for Disease Control and Prevention, this reference level is set at the 97.5th percentile of blood lead levels in U.S. children aged 1–5 years (Centers for Disease Control and Prevention, 2012; 2013).

4.3.4. School readiness-early literacy skills

The score on a test of *kindergarten readiness of literacy* is the main dependent variable for the study. During the study period, Ohio utilized the Kindergarten Readiness Assessment-Literacy (KRA-L) to evaluate children entering school. The KRA-L, developed by the Ohio Department of Education (ODE) and implemented in public school districts beginning in 2004, is a standardized screening instrument that measures early language and literacy skills (Ohio Department of Education, 2005). School districts in Ohio must administer the assessment to all children entering kindergarten within the first six weeks of school, maintain individual score sheets with the child's records, and report individual student composite scores for KRA-L via the Educational Management Information System (Ohio Department of Education, 2009). This assessment not only evaluates skill areas important to becoming a successful reader but also helps teachers plan for lessons that encourage reading (Ohio Department of Education, 2009). The KRA-L consists of 25 items that include important subsets of literacy such as oral language, phonological awareness and print awareness (Ohio Department of Education, 2005). Reading skills tapped by these subsets have been shown to be moderately to strongly related to future reading achievement (Logan, Justice, & Pentimonti, 2014; National Early Literacy Panel, 2008). According to ODE (2005, p. 11), the reliability and the validity of the KRA-L conforms to the standards jointly recommended in 1999 by the American Educational Research Association, the American Psychological Association and the National Center for Measurement in Education. Total possible scores on KRA-L range from 0 to 29 points.

4.3.5. Missing data imputation

An evaluation of missing data patterns revealed that 94% of cases have valid data on the dependent variable (KRA-L) and 90% of the cases have valid data on the key independent variables of housing and neighborhood conditions. Nevertheless, only about 70% of children have full non-missing data on all model variables including co-variates and over the entire study period. Since there was no discernable pattern in the missing data, we chose to apply multiple imputation. Specifically, we perform our analysis over 30 imputed data sets generated with a multiple imputation by chained equations algorithm in Stata (Royston & White, 2011). This algorithm allows each variable to have its own imputation model specification depending on whether variables are continuous, categorical, or discrete. We perform all analyses on these imputed data sets.

4.4. Analytic techniques

The overall goal of our analysis is to use our detailed longitudinal data to understand the influence of housing and neighborhood conditions during the entire period of early childhood development culminating in the readiness for kindergarten. Our analytic methods are designed to represent these cumulative effects while also taking into account the dynamic selection of households into housing units and neighborhoods.

4.4.1. Selection into treatment models

We aim to understand the influences of housing conditions over time on kindergarten readiness. Thus, our model needs to consider that individual covariates that influence housing choice will in turn influence subsequent housing conditions and other time-varying individual covariates. We hypothesize that cumulative exposure to housing distress derived from this dynamic process of housing selection and individual characteristics has a negative influence on kindergarten readiness as measured by the KRA-L score. However, housing choices are not made independently of neighborhood selection. Housing and neighborhoods are best seen as bundles among which individuals make selections given their past exposure to housing and neighborhood, as well as a series of other covariates. Under these assumptions, we describe the model we estimate using the directed analytic graph (DAG) shown in Fig. 2. DAGs are commonly used to represent causal relations among variables via directed arrows between nodes and to evaluate the identifiability of these relationships (Pearl, 2009). Though we have a yearly panel of children until their entry into kindergarten (five or six

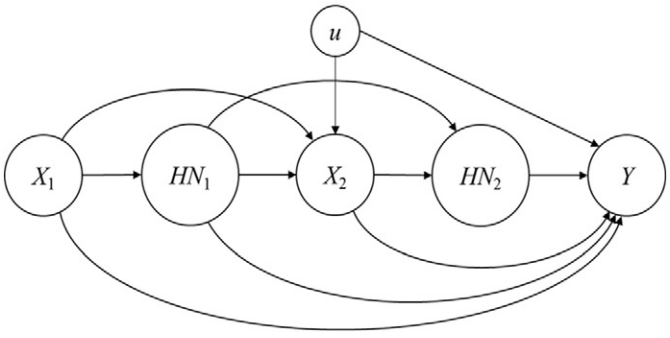

Fig. 2. A two-period model of the effect of housing and neighborhood distress on Kindergarten test scores. Past housing and neighborhood exposure (HN_1) influences future exposure (HN_2) and test scores outcome (Y). Covariates included in X are exposure to lead, mobility rate, being victim of neglect or maltreatment, u presents unobserved characteristics that influence covariates and the outcome. Time invariant characteristics such as gender, race, mother's education at birth of child and being born at low birth weight are also included as covariates.

[2] Taxes in arrearage beyond a certain point may be sold off as tax lean certificates. At that point, the taxes show as paid on county records. We used an additional data set of tax lien foreclosure to identify these instances, and were able to fill in the quarters as still involving an owner who was delinquent on the taxes.

years per child), the DAG illustrates a two-period model for simplicity. This setting is similar to the analysis of temporal neighborhood effects by Wodtke et al. (2011), although our model accounts for the simultaneous selection of housing and neighborhood by households.

In Fig. 2, we denote housing and neighborhood exposure at year t by HN_t, covariates by X_t, and test score outcome by Y. Time invariant variables in X_t include variables for mother's education, age of the mother, child's birth weight, gender, disability status, and race. Time-varying covariates include poverty status, past residential mobility and child maltreatment reports. These covariates influence all housing and neighborhood choices HN_1, and HN_2, subsequent covariates X_2, and outcome Y. Finally, u represents unobserved characteristics that influence covariates and the outcome.

As Wodtke et al. (2011) point out, typical regression models fail to identify the full effect of housing and neighborhoods on the outcome in the presence of variables that are simultaneously mediators and confounders. This is the case of X_2, which mediates the relation between HN_1 on Y but confounds the relation between HN_2 and Y. Controlling for X_2 to handle confounding will block the indirect path through which HN_1 affects Y and so we are unable to estimate the full effect of HN on Y. We address this identification problem by estimating inverse probability of treatment weights within the context of a marginal structural model (Robins et al., 2000). The selection model used to estimate the probability of treatment is a pooled multinomial regression on child-year observations. A similar selection model from birth to age three is used to estimate the effects of early housing conditions on elevated lead levels.

4.4.2. Marginal structural models of housing and neighborhood effects

We proceed to specify a multinomial logit for the selection model of neighborhood and housing conditions. For this, we need to define a categorical dependent variable of housing and neighborhood conditions, with a number of categories that clearly differentiates quality across levels, but at the same time insures convergence of algorithms used to estimate model parameters. We define "treatment" as a multilevel variable reflecting neighborhood and housing conditions. Specifically, neighborhoods are dichotomized into two levels: being above or below the 70th percentile of the concentrated disadvantage factor within the entire county. Housing is divided into three categories: (1) being deemed in poor condition, (2) not deemed in poor condition but having very low value, or (3) not deemed in poor condition and not having a very low value. This classification defines six categories of neighborhood and housing conditions that we denote by HN_{it}, where i indexes the child and t denotes the age of the child.[3] In 2006, 18% of the housing units in our data were classified as being in poor condition and another 18% were not deemed to be in poor condition but were of very low value.

Following Wodtke et al. (2011), we define the average causal effect on the outcome of a neighborhood and housing trajectory relative to another as the expected difference in test scores when children are counterfactually subject to each of the two neighborhood and housing trajectories. A trajectory is defined over the course of the five or six years in the life of a child prior to taking the KRA-L test. Therefore, if we code six possible levels of neighborhood and housing conditions in each year, we arrive at $6^5 = 7776$ possible trajectories and not enough data to estimate treatment effects for all possible pairs. Thus, we specify a more parsimonious parametric model that measures effects of cumulative exposure to housing and neighborhood conditions. In order to account for time-varying confounders that affect treatment, we estimate this model weighted by the inverse probability weights estimated through the selection model. In essence, observations so weighted form a pseudo-population in which time-varying covariates no longer confound the relationship between treatment (housing and neighborhood conditions) and tests scores. In this model of cumulative exposure, we gradually include markers of housing market distress that are also symptomatic of physical distress along with cumulative measures of the mediator variables such as lead poisoning, housing instability, and child maltreatment reports.

4.4.3. Model specification

The neighborhood and housing selection model is specified as a multinomial logit on the categorical variable HN_{it} taking values between 0 and 5, for child i in period t.

$$\frac{P(HN_{it}=k)}{P(HN_{it}=0)} = exp\left[(X_i, \overline{Z}_{it}, \overline{H}\times\overline{N}_{i(t-1)}, T_{it})\beta^{(k)}\right], \quad k=1,\ldots,5 \tag{1}$$

where,

HN_{it}: neighborhood and housing distress for child i at period t (categorical).

X_i: time-invariant characteristic for child i.

$\overline{Z}_{it}$: current and lagged time dependent characteristics.

$\overline{H}\times\overline{N}_{i(t-1)}$: lagged interaction of neighborhood distress and housing distress.

T_{it}: dummy variables indicating time period and kindergarten entry cohort.

We proceed by computing the inverse probability of treatment weights using predicted probabilities obtained from model (1). The probability of treatment refers to the likelihood that household i selected into its actual housing and neighborhood trajectory. The inverse probability weights are multiplied by a stabilizing factor as seen in Eq. (2).

$$SW_i = \prod_{t=1}^{T} \frac{P\left(HN_{it}=k_{it}\,|\overline{H}\times\overline{N}_{i(t-1)}=\overline{k}_{i(t-1)},\ Z_{i1}=z_{i1}\right)}{P\left(HN_{it}=k_{it}|\overline{H}\times\overline{N}_{i(t-1)}=\overline{k}_{i(t-1)},\ \overline{Z}_{it}=\overline{z}_{it}\right)} \tag{2}$$

where:

SW_i is the stabilized IPW for child i.

k_{it}, represent the actual values of the housing and neighborhood variable.

Z_{it} are other characteristics for child i during period t, whereas as before, $\overline{Z}_{it}$ represents current and lagged characteristics.

The probabilities in the denominator are estimated directly from Eq. (1). The numerator is meant to stabilize weights and is estimated from a model similar to model (1) with the variables $\overline{Z}_{it}$ replaced by Z_{i1}, the characteristics in period one.

Finally, we are able to estimate the following marginal structural model of cumulative exposure through a weighted OLS procedure:

$$Y_i = \sum_{j=1}^{L} X_{ij}\,\beta_j + \sum_{j=L+1}^{J} \overline{X}_{ij}\,\beta_j \tag{3}$$

$$\overline{X}_{ij} = \frac{\sum_{k=1}^{T} d_k\, x_{ijk}}{\sum_{k=1}^{K} d_t} \tag{3.1}$$

where:

i: child, j: characteristic, t: period/age of child.

d_t: fraction of year for period t.

x_{ijt}: j_{th} time-varying characteristics for child i in period t.

X_{ij}: j_{th} time-invariant characteristics for child i.

Y_i: KRA-L test score for child i.

The term $\overline{X}_{ij}$ Eq. (3.1) represents duration-weighted exposure to poverty, neighborhood and housing distress.

[3] Our specification of three levels of housing quality based on two characteristics, combined with two levels of neighborhood quality, lead to a dependent variable with six categories that is well estimated. Other specifications with a larger number of categories were attempted but convergence in estimation was not consistently achieved for the multiply-imputed data.

Table 2A
Descriptive analysis of study variables.

	Time invariant		Time variant by age											
			0–1		1–2		2–3		3–4		4–5		5-K. entry	
	M or %	(SD)	M or %	(SD)	M or %	(SD)	M or %	(SD)	M or %	(SD)	M or %	(SD)	M or %	(SD)
Child characteristics														
Low birth weight (yes = 1)	12.3%													
Gender (female = 1)	49.5%													
Race/ethnicity														
(Reference = African American)	69.0%													
(Non-Hispanic white)	18.2%													
(Hispanic)	11.7%													
(Other)	1.1%													
Age at kindergarten (months)	65.7	(3.9)												
English as a second language (yes = 1)	7.7%													
Disability (yes = 1)	10.9%													
Family characteristics														
Teen mother (yes = 1)	16.0%													
Mother has high school degree (yes = 1)	57.0%													
Family below poverty line (yes = 1)[a]			77.4%		76.9%		77.2%		77.8%		79.1%		78.9%	
Neighborhood characteristics														
Concentrated disadvantage factor score (0−100)			74.3	(18.5)	74.6	(18.6)	74.5	(18.7)	74.3	(19.1)	74.0	(19.3)	73.9	(19.8)
Housing characteristics														
Poor condition housing (yes = 1)			22.5%		21.1%		18.7%		16.4%		14.4%		11.5%	
Low value housing (<$30,000) (yes = 1)[b]			32.6%		31.2%		29.8%		29.9%		29.5%		32.0%	
Public housing or project based section 8 (yes = 1)			9.5%		10.0%		10.5%		10.6%		10.7%		9.7%	
Housing market distress events														
Parcel with tax delinquency (yes = 1)			18.9%		15.6%		13.9%		13.0%		14.0%		10.1%	
Parcel in foreclosure (yes = 1)			4.3%		6.1%		7.6%		7.9%		7.4%		5.3%	
Parcel owned by speculator (yes = 1)			2.2%		3.2%		4.6%		6.3%		8.1%		8.1%	
Any housing market distress events (yes = 1)			22.8%		21.3%		21.4%		22.0%		24.1%		19.7%	
Buffer 500 ft. - avg. number of parcels														
With tax delinquency			12.3	(9.7)	10.1	(7.8)	9.1	(6.9)	9.0	(7.0)	9.4	(7.2)	9.9	(7.9)
In foreclosure			2.4	(2.3)	3.3	(3.1)	4.0	(3.3)	4.1	(3.3)	3.8	(3.2)	3.4	(3.0)
Owned by speculator			1.0	(1.4)	1.5	(1.8)	2.1	(2.4)	2.9	(3.3)	3.8	(3.9)	4.5	(4.4)
Mediators														
Child neglect/abuse investigation (Yes = 1)			13.7%		12.1%		13.5%		13.0%		12.1%		8.0%	
Residential moves (number)			0.5	(0.7)	0.5	(0.8)	0.5	(0.8)	0.5	(0.7)	0.5	(0.7)	0.2	(0.5)
Lead level in blood >5 μg/dL														
(Yes)	38.6%													
(No)	46.7%													
(Not tested)	14.8%													
Educational outcome: KRA-L score	15.8	(7.2)												

Note. N = 13,758 (first imputation).
[a] Family below poverty line for at least halt the year.
[b] Inflation adjusted.

4.4.4. Models of the direct effect of housing on mediators

We are also interested in understanding the effects of housing and neighborhood conditions on the potential mediators of child maltreatment, residential instability and elevated blood lead levels. For the time-varying maltreatment and residential mobility outcomes, we apply child-level fixed effects panel models. These models control for unobserved heterogeneity or selection factors that are time invariant. In essence, they estimate the effect of change in housing and neighborhood conditions on change in the likelihood of these events. Fixed effects models address the problem of selection into treatment by estimating within-and not between-individual effects due to changes in the treatment. So rather than explicitly modeling selection based on observables and 'undoing' it via inverse probability of treatment weights, a fixed effects panel model differences-out unobservables that may be responsible for selecting into specific levels of treatment.

For the outcome of lead, we cannot rely on fixed effects because the underlying process of lead level elevation is cumulative in young children. Once a child tests positive, the lead elevation is known to be present and will not be reduced by change in exposure. Moreover, the time of testing does not necessarily coincide with the point of elevation but tends to be dictated by screening protocols and medical visits. Therefore, we adopt the same approach that we used to control for selection in the previous models of kindergarten readiness. We estimate the effects of early housing and neighborhood conditions – from birth to three[4] – on having a positive lead test result. As with the KRA-L model described above, we estimate inverse probability weights from a birth-to-age three-selection model, which are then used to estimate a marginal structural model of lead exposure using a multinomial logit specification on a three-leveled variable (not tested, tested negative, tested positive).

[4] Lead testing is typically done at ages 18 months through 3 years, a peak period for possible exposure because children are becoming mobile, touching many things in their environments and putting their fingers in their mouths. Children on Medicaid are required to be tested at 12 and 24 months. A minority of children are delayed in getting their screenings and are not tested until 4 or 5 years old. However, it is not possible to determine from the lead screening precisely when or where the exposure occurred. Nevertheless, it is most likely that it occurred during the peak period. Therefore, we organize our modeling to account for all of the housing and neighborhood exposures cumulatively to the 3rd year regardless of when the lead screening was completed. We made this choice to avoid erroneously attributing effects to housing conditions that occurred after children's lead levels were already elevated.

Table 2B
Descriptive analysis of average exposure from birth to kindergarten entry.

	M	(SD)
Family characteristics		
Poverty (Share of time below poverty line)	0.75	(0.35)
Neighborhood quality- Share of years exposed to		
Concentrated disadvantage score above 70p	0.66	(0.41)
Housing characteristics - share of years exposed to		
Poor condition housing	0.18	(0.29)
Low value housing (<$30,000 inflation adjusted)	0.31	(0.34)
Public housing or project based section 8	0.10	(0.25)
Housing market distress - share of years exposed to		
Parcel with tax delinquency	0.15	(0.23)
Parcel in foreclosure	0.07	(0.15)
Parcel owned by speculator	0.05	(0.15)
Buffer 500 ft. - avg. number of parcels		
With tax delinquency	9.95	(6.30)
In foreclosure	3.51	(2.17)
Owned by speculator	2.46	(2.28)
Mediators		
Child neglect/abuse investigation (share of years with investigation)	0.13	(0.19)
Residential moves (average per year)	0.46	(0.42)
Lead level in blood >5 μg/dL	0.39	(0.49)

Note. N = 13,758 (first imputation).

5. Results

5.1. Descriptive findings on study variables

The descriptive statistics for the study variables are provided in Tables 2A and 2B. Table 2A of the table displays time invariant and time varying variables. We report the time varying variables for children at yearly age intervals, from birth until kindergarten entry. It should be noted that the length of the final period varies by individual based on their age at the time they entered kindergarten. Therefore, the descriptive statistics for each interval are weighted for the number of months each child is observed. In Table 2B, we report cumulative exposures for the time varying variables.

Since this study is based on the entire population of children that entered kindergarten in Cleveland in 2007–2010, the demographic and socio-economic characteristics reflect the makeup of the student body. These entering kindergartners are predominately African-American (69%) and more than three-quarters come from low-income families. Nearly half their mothers had not graduated from high school by the time of their birth. The children spent their early childhood years in neighborhoods that are above the 75th percentile for the region on the concentrated disadvantage factor. The mean KRA-L score for the study population is 15.8 out of a possible total of 29 points. Only 18% of the study population falls into the upper score band width (24–29), the only range that is considered not to be in need of special educational attention and support (Ohio Department of Education, 2005). Thus, the study is representative of one big city school system, but not more advantaged populations or districts.

Looking at those variables that are time varying, it can be seen that most of the exposures remain relatively constant over the years from birth to kindergarten. However, there are some exceptions. The proportion of children living in bad conditions decreases over time. Cleveland demolished >10,000 substandard homes during the study period, removing some of the worst properties from the possibility of being occupied. Rates of children living in tax delinquent homes also decreases consistent with the fact that tax delinquency is typically a precursor to demolition. Residing in homes that are in foreclosure rises and then declines, consistent with the peak of the foreclosure crisis in Cleveland. Rates of occupying speculator owned homes increase in line with trends of bank's offloading properties through bulk sales (Coulton et al., 2010).

Table 3
Marginal structural models for the relationship between KRA-L and housing conditions weighted by the inverse probability of treatment.

	I			II			III		
	b	*se*		*b*	*se*		*b*	*se*	
Child characteristics									
Low birth weight (yes = 1)	−0.72	0.21	***	−0.72	0.21	***	−0.74	0.21	***
Gender (female = 1)	1.60	0.12	***	1.59	0.12	***	1.58	0.12	***
Race/ethnicity (reference = l African American)									
(White)	−0.65	0.19	***	−0.65	0.19	***	−0.45	0.19	*
(Hispanic)	−2.28	0.27	***	−2.30	0.28	***	−2.29	0.28	***
(Other)	−0.13	0.63		−0.16	0.63		−0.15	0.62	
Age at kindergarten (months)	0.27	0.02	***	0.26	0.02	***	0.26	0.02	***
English as a second language (yes = 1)	−2.42	0.32	***	−2.44	0.32	***	−2.57	0.32	***
Disability (yes = 1)	−2.47	0.21	***	−2.47	0.21	***	−2.28	0.21	***
Family characteristics									
Teen mother (yes = 1)	0.42	0.19	*	0.43	0.19	*	0.50	0.19	*
Mother has high school degree (yes = 1)	1.58	0.15	***	1.57	0.15	***	1.37	0.15	***
Poverty (share of time below poverty line)	−1.90	0.19	***	−1.80	0.19	***	−1.41	0.22	***
Neighborhood quality - share of years up to kindergarten exposed to									
Concentrated disadvantage score above 70th p.	−0.71	0.20	***	−0.77	0.22	***	−0.74	0.22	***
Housing characteristics - share of years up to kindergarten entry exposed to									
Poor condition housing	−0.43	0.23	†	−0.34	0.24		−0.13	0.24	
Low value housing (<$30,000 inflation adjusted)	−0.13	0.20		−0.33	0.20		−0.25	0.20	
Public housing or project based section 8				−0.17	0.29		−0.15	0.29	
Housing market distress - share of years up to kindergarten entry exposed to									
Parcel with tax delinquency				−0.78	0.28	**	−0.52	0.29	†
Parcel in foreclosure				−1.39	0.44	**	−1.01	0.44	*
Parcel owned by speculator				−1.54	0.39	***	−1.25	0.39	**
Buffer 500 ft. - avg. number of parcels									
With tax delinquency				0.05	0.02	**	0.05	0.02	*
In foreclosure				−0.11	0.05	*	−0.11	0.05	*
Owned by speculator				0.02	0.05		0.03	0.05	
Mediators									
Child neglect/abuse investigation (share of years up to K. with investigation)							−2.21	0.34	***
Residential moves (average per year)							−0.45	0.17	*
Lead level in blood >5 μg/dL (reference: negative)									
(Positive)							−0.84	0.14	***
(Not tested)							−0.78	0.20	***
Intercept	−1.11	1.10		−0.63	1.11		−0.38	1.11	

Note $^{\dagger}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. $N = 13{,}689$ (multiple imputation, $m = 30$). All models included a dummy variable for the year of entry into kindergarten.

Child maltreatment rates decline as children get older, consistent with research that shows the highest risk in the earliest years of life (US Department of Health and Human Services, 2014). Residential mobility drops in the year before the child enters kindergarten, possibly in anticipation of living near a neighborhood school.

Table 4
The relationship between housing and key mediators.

Fixed effects linear probability models - full panel						
	Child maltreatment			Residential moves		
	b	*se*		*b*	*se*	
Family characteristics						
Poverty (share of year below poverty)	0.054	0.005	***	0.337	0.011	***
Neighborhood quality						
Concentrated disadvantage factor score (rank 0–100)	0.002	0.004		−0.091	0.009	***
Housing characteristics						
Poor condition (yes = 1)	0.016	0.004	***	0.417	0.009	***
Low value housing (<$30,000 inflation adjusted)	−0.001	0.004		−0.092	0.007	***
Public housing or project based section 8 (yes = 1)	0.017	0.007	*	0.292	0.013	***
Housing market distress events						
Parcel with tax delinquency (yes = 1)	0.010	0.004	*	0.249	0.008	***
Parcel in foreclosure (yes = 1)	0.025	0.005	***	0.241	0.011	***
Parcel owned by speculator (yes = 1)	0.007	0.006		0.401	0.013	***
Buffer 500 ft. - avg. number of parcels						
With tax delinquency	0.000	0.000		0.000	0.001	
In foreclosure	0.001	0.000	**	0.007	0.001	***
Owned by speculator	−0.001	0.001	†	0.004	0.001	**
Intercept	0.090	0.007	***	0.106	0.012	***

Multinomial Lead Model -Inverse Probability Weighted Exposure			
Dependent variable values: tested positive, negative, not tested			
Margins for probability of testing positive	*dy/dx*	*se*	
Child characteristics			
Low birth weight (yes = 1)	−0.045	0.014	***
Gender (female = 1)	−0.022	0.008	**
Race/ethnicity (reference = African American)			
(White)	−0.010	0.012	
(Hispanic)	−0.035	0.018	*
(Other)	−0.053	0.044	
English as a second language (yes = 1)	−0.038	0.021	†
Disability (yes = 1)	0.051	0.013	***
Family characteristics			
Teen mother (yes = 1)	0.004	0.012	
Mother has high school degree (yes = 1)	−0.070	0.009	***
Poverty (share of years below poverty line up to age 3)	0.204	0.012	***
Neighborhood quality - share of years up to age 3 exposed to			
Concentrated disadvantage score above 70th p.	0.086	0.013	***
Housing characteristics - share of years up to age 3 exposed to			
Poor condition housing	0.038	0.012	**
Low value housing (<$30,000 inflation adjusted)	0.054	0.011	***
Public housing or project based section 8	−0.008	0.017	
Housing market distress - share of years up to age 3 exposed to			
Parcel with tax delinquency	0.057	0.014	***
Parcel in foreclosure	0.051	0.024	*
Parcel owned by speculator	0.046	0.027	†
Buffer 500 ft. - avg. number of parcels			
With tax delinquency	0.003	0.001	***
In foreclosure	0.010	0.003	**
Owned by speculator	0.000	0.004	

Note. $^{\dagger}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. $N = 13.758$ children over all periods for child maltreatment and residential moves panel models. $N = 13,681$ children for lead model (multiple imputation, $m = 30$). Fixed effects models include an age variable; lead model controls for year of birth.

5.2. Cumulative effects of housing, neighborhood and other risk factors on kindergarten readiness

In this section, we examine the dynamic effects of housing and neighborhood conditions on Kindergarten readiness (KRA-L). Table 3 displays the estimates of our marginal structural models that control for dynamic selection of housing and neighborhood quality each year. The coefficients for the time varying variables represent the weighted average effects over the period from birth to kindergarten entry. In order to adjust for the fact that children vary in the exact number of months in the final period before entering school, the variables are calculated as average yearly rates. Then, for example, we can think that if a child enters kindergarten the day after her fifth birthday, a 0.2 cumulative exposure to housing market distress represents exposure in a total of one out of those five years.

All models include a set of time-invariant child and family characteristics. First, looking at Model 1, we see that the cumulative exposure to household poverty and to neighborhoods of concentrated disadvantage has a negative effect on KRA-L scores. The time spent in housing units that are in poor condition has a negative effect on KRA-L scores but living in housing with a low estimated market value does not show any additional effect.

Model II adds housing market distress events to the analysis. The time spent living in housing units that are tax delinquent, in foreclosure or owned by a speculator all have significant negative effects on kindergarten readiness. The density of these distressed properties within a 500-foot buffer around the children's own houses also has a negative effect on KRA-L scores. The spillover effects of surrounding housing units (not shown) were still significant but weaker for 1000 and 1500 foot buffers. After adding these markers of housing market distress, the effect of poor housing condition, as recorded by the county, becomes weaker. The market distress indicators, which change quarterly, may be picking up deterioration in the condition of the house that may not yet figure into the tax assessor rating or the estimated market values.

Model III incorporates the direct effects of child maltreatment, residential mobility and elevated lead levels on KRA-L. These variables are risk factors for lack of school readiness, but are also potential mediators of poor housing and neighborhood conditions. All three of these factors have negative effects on KRA-L scores as predicted. Children with one or more incidents of maltreatment score lower on KRA-L than those who are not victimized. The number of residential moves is negatively related to KRA-L scores. In addition, children that have elevated blood lead levels, and those that are not tested, have lower KRA-L scores than children who test negative for lead exposure. Moreover, the incorporation of these risk factors into the models result in some reduction in the coefficients for the housing and neighborhood variables, suggesting the possibility of partial mediation.

5.3. Effects of housing and neighborhood on child maltreatment, residential mobility and elevated blood lead levels

Given the negative effects of child maltreatment, residential mobility and elevated blood levels on KRA-L scores shown in the previous models, we undertake an examination of the influence of neighborhood and housing characteristics on these risk factors. In all three models, we adopt methods to control for the effects of dynamic selection into

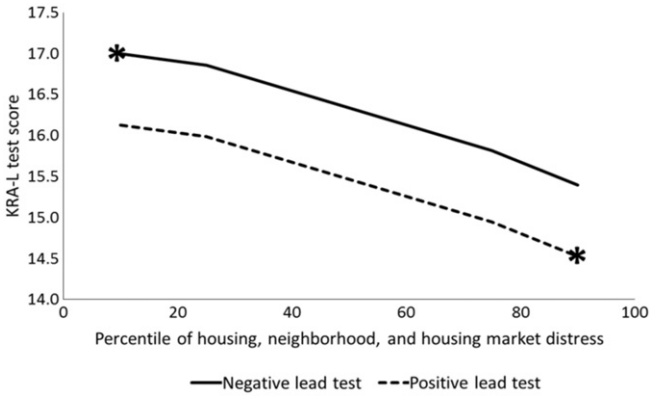

Fig. 3. Average predicted test scores for levels of housing and neighborhood distress.

housing and neighborhoods. For the time-varying child maltreatment and residential mobility outcomes, we apply fixed effects panel models. Fixed effects are at the child level. These models control for unobserved heterogeneity or selection factors that are time-invariant within the child's household during their first years in life. In essence, they estimate the effect of a change in housing and neighborhood conditions on the likelihood of child maltreatment and residential mobility events, holding constant differences among children's households that are time invariant.

The top section of Table 4 presents the fixed effects model for child maltreatment. We see that an increase in the proportion of time spent in poverty increases the likelihood of a child maltreatment report. Child maltreatment incidents are also positively related to families living in houses that are in poor condition, being in the foreclosure process, and entering public or project-based section 8 housing. Incidents of child maltreatment are not significantly related to changes in neighborhood concentrated disadvantage, low market value, tax delinquency or speculator ownership of housing.

The residential mobility fixed effects model appears in the second column of the top section of Table 4. An upturn in the share of time spent in poverty during the year increases rates of residential mobility as does living in poor housing conditions or public and project-based subsidized housing. Changes in all of the housing market distress markers add to the chances that the household will relocate within the year. Living in neighborhoods of concentrated disadvantage or in housing with low market value reduces rates of residential mobility in this population.

In the bottom section of Table 4, we display estimates from the cumulative lead poisoning models incorporating the inverse probability weights for selection into housing and neighborhoods up to the age of three. Specifically, we report the marginal effects estimates for the multinomial model of elevated lead levels. The coefficients in these models represent the change in the probability of having an elevated lead level due to a change in the independent variables. Controlling for family and child background factors, the chances of lead poisoning are higher for children that spend more time in poverty, poor housing conditions and low market value housing. Greater exposure to housing units touched by market distress such as tax delinquency, foreclosure and speculator ownership increase rates of lead poisoning in children.

5.4. Simulation of combined effects

The above summary points to several aspects of neighborhood and housing contexts that have measureable impacts on kindergarten readiness scores and other early childhood risk factors. However, in reality these attributes of the urban context do not exist in isolation. Housing crises, deterioration and devaluation can be part of a cycle of neighborhood decline. To illustrate the combination of all of these contextual effects, we calculate predicted KRA-L scores for various levels of housing and neighborhood distress with all other variables held constant at their mean. We present these estimates in Fig. 3, for children with and without lead poisoning. Children with elevated blood lead levels score lower on KRA-L assessments than other children within each level of housing and neighborhood disadvantage. We have already seen that children living with housing problems are almost twice as likely to have elevated lead levels. As can also be seen in Fig. 3, in the points designated by an asterisk (*), children with the highest exposure to problematic housing and neighborhood conditions (i.e. 90th percentile) and positive lead tests are estimated to score 15% lower on KRA-L than those living in the best conditions (10th percentile) with negative lead tests. It should be noted that poverty in this population is relatively high at all points on the continuum since children on average spent 75% of their early childhood in poverty (using the marker of SNAP participation). While poverty is strongly interrelated with housing and neighborhood conditions, our model allows us to estimate the *additional effects* of housing conditions on kindergarten readiness scores for this low-income population at varying levels of housing distress.

Although these examples are provided for children at selected levels of disadvantage, it should be kept in mind that the actual population of children entering kindergarten in this study tended to fall more toward the disadvantaged end of the housing continuum. Thus, these comparisons suggest the benefits that could be achieved if children in the worst housing and neighborhoods were instead exposed to the kinds of environments that the most fortunate children in the school system experience. This is not as big a leap as might be assumed, since the housing and neighborhoods occupied by the most advantaged students' families are still relatively affordable compared to the region.

6. Discussion

This study examined the effects of housing and neighborhood conditions on literacy skills, a key aspect of kindergarten readiness, for all of children that entered school over a four-year period in a big city school system. A unique aspect of the study is that it relies exclusively on administrative records and brings together linked records beginning at birth on children and all of the properties that they occupied before entering kindergarten. By focusing on entire kindergarten entry cohorts within one location and time period, it is able to take into account systemic and housing market factors that often vary in other kinds of longitudinal research.

At the time of this study, the entering students were similar to those in many central city public primary schools. Their scores on a kindergarten readiness literacy assessment were too low to enter kindergarten without special supports. The students were disproportionately African-American and Hispanic and members of low-income households. The children's home neighborhoods were quite disadvantaged relative to the neighborhoods in the region. Moreover, the housing units occupied by much of the study population fell at the lower end of the housing market with respect to quality and market valuation. The housing stock in Cleveland is generally old, and 90% of the kindergartners lived in privately owned housing units, most of which are one to four-family structures. Many of the dwellings they lived in were touched by the foreclosure and vacancy crisis that was in force during the study period. While children in the study relocated frequently, most of them tended to move within the same quality of neighborhoods although there was more variation in whether their moves lead to better or worse housing. Several other studies also have shown this pattern of the overall stickiness of household poverty status at both the neighborhood (Sharkey, 2013) and housing unit (Theodos, Coulton, & Pitingolo, 2015) levels.

We estimated a series of models that looked at the influence of housing and neighborhood conditions on kindergarten readiness literacy scores and potential mediators including child maltreatment, residential instability and elevated blood lead levels. In all instances, we adopted analytic methods that arguably control for dynamic selection into poor quality housing and disadvantaged neighborhoods. This allows us to have a degree of confidence that the effects we estimate in our models are less subject to bias due to time-varying confounding than standard linear models. We found that scores on kindergarten readiness literacy scores were negatively affected by children's cumulative exposure to poor quality housing and disadvantaged neighborhoods. Housing market crisis events, such as foreclosure and disinvestment, also had consistently negative effects on scores. Moreover, we identified some spillover effects from nearby distressed properties on children's kindergarten readiness literacy scores. Two of our housing quality measures, poor condition rating and low market value, became insignificant in some models that included housing market stress events. We suspect that these former metrics, which are updated only periodically, may be less sensitive than our housing market stress events to the rapidly changing conditions of properties during the economic and housing market conditions in place at the time of this study. Finally, the incidences of child maltreatment, residential

mobility and lead poisoning all had negative effects on kindergarten readiness literacy scores, after controlling for neighborhood and housing conditions.

We found a few variables in our models to have unexpected effects on kindergarten readiness literacy scores. Once exposure to neighborhood disadvantage and poor housing conditions were accounted for, African American children scored slightly higher than white children. This suggests that African American children's apparent disadvantages in school are partially due to the structural disadvantages that they face in a highly segregated metropolitan area such as Cleveland.

We also evaluated the impact of housing and neighborhood conditions on several known risk factors that we considered potential mediators of housing and neighborhood effects. In our fixed effects panel model of child maltreatment, we found that living in public or project-based section 8 housing, private market units in poor condition, or houses that were in the process of foreclosure increased the chances of a child maltreatment report in the early childhood years. Berger et al. (2015) similarly found that foreclosure increased the risk of a maltreatment report among children of all ages using administrative records data from Wisconsin. The increased risk of child maltreatment in relation to public housing might be due to lagged effects of housing problems that occurred in prior years prompting families to make application for housing assistance. Since there is often a waiting period, the move to public housing could have come after a prolonged period of family distress. Or it is possible that there is a surveillance effect with families in public housing being more likely to come into contact with mandated reporters.

Residential instability was found to increase when families lived in housing units that were in poor condition or had been through housing market dislocations such as foreclosure, vacancy and disinvestment. The results of this fixed effects model is consistent with other literature that links housing problems to frequent mobility in low- income families (DeLuca et al., 2011). Unexpectedly, we found that living in housing that was of low market value or in a neighborhood of concentrated disadvantage lowered mobility rates. Given that most of the families in our study population had low incomes but were living in private market-rate housing, they may have been reluctant to give up affordable units even when conditions were less than ideal.

Finally, we found cumulative effects of poor housing conditions and housing market stress events in children's own homes and in the surrounding area on the likelihood of children having elevated blood lead levels. This link between lead exposure and substandard housing has been documented in prior studies (Evans, 2006), but our research design has the advantage of measuring housing conditions and events continuously from birth and controlling for time-varying confounding though our dynamic selection modeling. In fact, we estimate that children that spent all of their pre-school years in poor housing and neighborhood conditions were 25% age points more likely to have an elevated lead level than those who avoided such circumstances, controlling for other factors. At the 10th and 90th percentiles of housing, neighborhood and housing disadvantage, the difference in the probability of high lead levels was 23 percentage points, at 0.28 and 0.51, respectively.

7. Conclusions

In closing, it is important to acknowledge several limitations of this study. First, because we focused on the population of school children in one large city during a particular time, the results cannot be readily generalized to other times and places. However, Cleveland shares many similarities with other northern industrial cities that have been hard hit by poverty, concentrated disadvantage and housing market dislocations. As such, it may suggest how these conditions are likely to affect children in similar school systems and cities.

Second, the study reliance on administrative records limited our choice of study variables. We were not able to incorporate subjective perceptions of housing and neighborhood quality, take into account other members of the household besides the mother and child, or to make direct observation of housing and neighborhood quality. Moreover, our direct measures of poor housing conditions relied on ratings provided by the tax assessor and estimated market values. This information is updated on a schedule driven by tax assessment purposes and may be insensitive to housing problems that are recent, temporary or not readily visible. We believe that our markers of housing market events, such as foreclosure and tax delinquency, are probably picking up deterioration in housing quality that happens quickly when houses have periods of vacancy, especially in cities with weak housing markets.

Third, several of our key outcome variables have limitations. The KRA-L test focuses on kindergarten readiness related to literacy skills. There are other aspects of early development that are also pertinent to early school success, including socio-emotional and physical development, but these were not measured. Our lead testing data provides the residential location of the child when the blood lead level was obtained, but does not definitively indicate where and when the lead exposure occurred. Additionally, the measure of child maltreatment is based on cases that are reported to the authorities and screened-in for investigation, but some maltreatment undoubtedly goes unreported.

Finally, although we used a rich set of variables and various methods to control for selection bias and confounding, we could not rule out all threats. The ideal would have been to randomly assign families to the full range of housing and neighborhood conditions available to this population and then observe the effects on outcomes. However, even with initial random assignment, subsequent moves would introduce selection effects, and it can be seen that this is a mobile population. We used inverse probability of selection methods to overcome the problem of time-varying confounders due to dynamic residential mobility and controlled for a series of variables that influence selection, but we had to establish thresholds for defining problematic housing and neighborhoods, when the reality is that these exist on a continuum. Moreover, the administrative records contained only some of the variables that would be ideal for modeling selection. In particular, we did not know whether the family owned their home, was renting or whether they were using a housing choice voucher, and this could be an important aspect of housing and neighborhood selection.

These limitations not withstanding, this study demonstrates that housing quality and market distress are important factors in understanding the ecological context for early educational success. By looking at a continuous record of neighborhood and housing exposure, month-by-month during the pre-school years, this study addresses a need that has been identified in the literature for contextual studies that adopt a longitudinal and developmental framework (Sampson, Sharkey, & Raudenbush, 2008; Wodtke et al., 2011). Young children are probably unique in the vital role that housing can play because they spend much of their time in the home setting and are quite vulnerable to housing problems that raise parental distraction and distress. Toxic exposures that young children experience in the home, such as those resulting in lead poisoning, set the stage for future development. Numerous studies have suggested the deleterious effects of neighborhood socio-economic disadvantage on early development, but this research shows that the state of repair of families' housing units within neighborhoods are influences that further contribute to kindergarten readiness. It is important that future research pay closer attention to the role that housing quality and market conditions play in early childhood development and investigate ways to prevent young children's prolonged exposure to deteriorated and unstable housing units.

The findings of this study are pertinent to stimulating policy discussions that fully connect housing and neighborhood conditions to the well-being of young children in urban areas. In particular, current policies that address housing market stabilization and housing quality do not take into account children's housing experiences in their investment strategies or allocation of resources. Similarly, policies directed at early childhood education and risk reduction do not incorporate neighborhood and housing conditions into their planning and implementation.

Greater attention to the role of housing in educational success could lead to policies and programs to promote school readiness that involve school districts, municipal building and environmental health departments, early childhood programs, housing providers, and community development agencies. Residential instability, child maltreatment and elevated lead levels, which are exacerbated by housing problems, could be a target for early detection and prevention. Early care and education providers could potentially be a source of information to parents on the importance of housing quality and stability for their young children. Health care providers could also play a role in screening for housing problems and in referring at risk families for assistance. Child welfare agencies also need to carefully evaluate the housing problems facing families that come to their attention and expand their partnerships with housing agencies to prevent housing instability and exposure of young children to deleterious conditions.

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