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Understanding Racial Differences in Exposure to Violent Areas: Integrating Survey, Smartphone, and Administrative Data Resources

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Abstract

Emerging evidence indicates that exposure to violent areas may influence youth wellbeing. We employ smartphone GPS data on youth activity spaces to examine the extent of, and potential explanations for, racial disparities in these exposures. Multilevel models of data from the *Adolescent Health and Development in Context* study indicate that exposures to violent areas vary significantly across days of the week and between youth who reside in the same neighborhood. African American youth are exposed to areas with substantially higher levels of violence. Residing in a disadvantaged neighborhood is significantly associated with exposure to violent areas and explains a non-trivial proportion of the racial difference in this outcome. However, neighborhood factors are incomplete explanations of the racial disparity. Characteristics of the activity locations at which youth spend time explain the residual racial disparity in exposure to violent areas. These findings highlight the importance of youth activity spaces, above and beyond their neighborhood environments.

Keywords

activity spaces; exposure to violence; neighborhoods; adolescents; social disparities

Research on exposure to violence (EtV) during adolescence has demonstrated nontrivial effects of EtV on a range of developmental outcomes including mental health (Browning et al. 2013; Fowler et al. 2009), physical health (Sternthal et al. 2010), educational outcomes (Sharkey 2010), externalizing behaviors (Kirk and Hardy 2014; Sharkey et al. 2012), and risk behaviors/delinquency (Fagan, Wright, and Pinchevsky 2015; Sampson, Morenoff, and Raudenbush 2005). Much of this research has emphasized individual exposures through the experience of victimization or direct witnessing of violence either in the home or community. Findings demonstrate that both victimization and witnessing are consequential for subsequent developmental outcomes of youth and these effects are observed for experiences occurring in the home and community (Margolin and Gordis 2000). A related stream of research has examined the impact of residence in violent neighborhoods on youth wellbeing, offering evidence that exposure to violent areas is developmentally detrimental

(Carroll-Scott et al. 2013; Massey 2004; Sampson et al. 2005; Sharkey 2010). Although the effects of residence in a high violence neighborhood may operate through direct experiences of witnessing or victimization, high aggregate levels of violence – even if not directly witnessed or experienced – may have independent negative effects on adolescents' wellbeing (Sharkey 2010).

Exposure to violence has been offered as a potential explanation for racial disparities in health and wellbeing among youth. Black youth typically reside in neighborhoods characterized by substantially higher violent crime rates than other race/ethnic groups. Chronic exposure to violent neighborhoods, in turn, is likely to result in disparities in consequential stress processes and behavioral development, with implications for life prospects and long-term risk of chronic conditions (Shonkoff et al. 2012). Accordingly, understanding the factors that account for racial differences in exposure to aggregate levels of violence is a necessary step in the larger effort to reduce health and developmental disparities across race/ethnic groups.

Emerging research on urban space use calls into question the standard approach to conceptualizing and measuring adverse exposures, particularly, the conventional reliance on administratively defined neighborhoods to proxy relevant exposure spaces. Employing neighborhood violent crime rates as the relevant exposure measure for resident youth ignores the likely substantial variability both within and between youth residing in the same neighborhood in the nature of everyday exposures. Adequate explanation of variability in adverse exposures requires information on the geographic location of routine activities for urban youth. To date, with the exception of a small number of studies that have collected data on additional routine activity locations (Basta, Richmond, and Wiebe 2010; Wiebe et al. 2016; Wikström et al. 2012), rich information on everyday geographic exposures among youth has been unavailable.

Employing novel data from the Adolescent Health and Development in Context (AHDC) study on the geographic exposures of a sample of urban youth, we address a number of questions regarding the sources of variability in exposure to aggregate levels of violence. First, we estimate the percentage of variability in exposure to violence in youths' *activity spaces* that rests at the residential neighborhood level (testing the implicit assumption of extant research relying on neighborhood violence rates to estimate the consequences of exposure to violence). Second, we ask whether evidence of racial disparities in residential neighborhood levels of violence extend to the actual routine activity locations of urban youth. Third, we examine a number of hypotheses for observed racial disparities in exposure to activity space violence, asking whether disparities are due to differences in family and residential neighborhood disadvantages or due to constraints beyond these factors that shape the disadvantage levels of routine activity locations black youth typically experience.

Exposure to Violent Areas and Urban Youth Outcomes

Exposure to community violence has been linked with a wide range of developmental outcomes among youth. Here we define community EtV to include both direct violent victimization and witnessing of violence as well as indirect exposure through “hearing

about” violence levels or trends within an area to which the youth is regularly exposed. Research has offered mounting evidence of associations between community EtV and behavioral, mental health, and physical health outcomes, suggesting that EtV has wide-ranging negative impacts on children (Bingenheimer, Brennan, and Earls 2005; Foster and Brooks-Gunn 2009; Kupersmidt, Shahinfar, and Voegler-Lee 2002; Margolin and Gordis 2004; Osofsky and Osofsky 2004; Osofsky 1999). These associations also appear to be durable. Ford and Browning (2014), for instance, found that males who witnessed violence with a weapon (a shooting or stabbing) and females who were victims of violence (shot, cut, stabbed, or had a knife or gun drawn on them) during adolescence were more likely to have hypertension in young adulthood.

A number of mechanisms have been advanced to explain the link between EtV and compromised health and development. We consider both stress and social learning processes as critical conduits of the adverse impact of EtV. Stress process explanations for the impact of EtV focus on the role of exposure to severe violence in affecting health-consequential physiological stress and socio-emotional pathways with implications for development. Research on the acute effects of exposure to homicide, for instance, demonstrates that, among African American youth, residing in a census block group in which a recent homicide has occurred substantially decreases performance on cognitive evaluations (Sharkey 2010). Sharkey and colleagues point to the role of emotional responses such as fear and helplessness in response to residentially proximate homicide events in inducing PTSD-related symptomatology such as compromised sleep, concentration problems, and increased anxiety.

Acute stress effects of EtV may also be embedded in ongoing chronic stress responses due to routine exposure to high levels of violence. Life course and stress theories (e.g. allostatic load) (Elder 1998; Halfon et al. 2013; McEwen and Stellar 1993; Pearlin et al. 2005; Shonkoff et al. 2012; Theall et al. 2013) posit that chronic psychological stress associated with adverse exposures cumulatively affects health through damage to organs and tissues as a consequence of recurrent and prolonged activation of the stress response systems. These negative effects may be more salient if exposure occurs during sensitive developmental periods or life transitions, such as adolescence (Elder, Johnson, and Crosnoe 2003; Halfon et al. 2013). Recent research supports this hypothesis as youth living in neighborhoods characterized by violence, poverty or “stressors” (e.g. composites of poverty, disorder and/or violence) were found to have irregular salivary diurnal patterns or acute stress reactivity (Brenner et al. 2013; Chen and Paterson 2006; Hackman et al. 2012; Rudolph et al. 2014), and in one study, elevated levels of hair cortisol (Vliegenthart et al. 2016) Although the detrimental effect of exposure to high violence neighborhoods is likely to work, in part, through direct victimization and witnessing experiences, the impact of routine exposure to the threats posed by high violence areas may independently affect wellbeing.

Additional pathways through which exposure to violence may operate include the role of social learning and informal social control processes in influencing behavioral proclivities among youth. In a well-known ethnographic study of an urban, African American neighborhood, Anderson points to the role of violence as a defensive posture. Residing in neighborhoods observed or expected to be characterized by high levels of violence is

hypothesized to propagate such violence by leading youth to maintain violent demeanors or to act violently to reduce the subsequent threat of victimization (Anderson 1999). In this view, violence becomes a self-reinforcing adaptation to routine exposure to threatening environments. High levels of neighborhood violence may also cue the breakdown of social order, leading to reduced guardianship of public space (Felson and Cohen 1980) and expectations among youth that pro-social norms will not be as effectively enforced (Skogan 1990). Existing evidence indicates that residing in high violence neighborhoods is linked with increased risk of individual level violence (Sampson et al. 2005) and aggression (McMahon et al. 2013; Vanfossen et al. 2010), pointing to the potential relevance of learning and informal social control processes in the link between neighborhood violence and behavioral outcomes (although few studies have attempted to uncover the mechanisms responsible for neighborhood violence effects). In short, evidence suggests that exposure to high aggregate levels of violence is harmful across a number of domains for urban youth and may account for a nontrivial proportion of racial disparities in these outcomes.

Neighborhoods and Activity Spaces as Exposure Spaces for Youth

Research on “neighborhood effects” expanded dramatically in the aftermath of seminal publications, notably William Julius Wilson’s *The Truly Disadvantaged* (1987). By highlighting the spatial concentration of joblessness, teenage pregnancy and childbirth, delinquency and crime, and other phenomena, Wilson helped spur a sustained interest in understanding community-level factors that shape the life prospects of the urban poor. The subsequent decade of the 1990s saw the emergence of multilevel research designs that disentangled individual and contextual contributions to a range of outcomes. On balance, this research effort led to acknowledgment of “neighborhood effects” on developmental trajectories and the importance of context in youths’ lives (Sampson, Morenoff, and Gannon-Rowley 2002).

Although a fruitful approach to understanding and measuring contextual effects, the multilevel design embedding individuals in their residential neighborhood and linking features of the latter with youth outcomes is potentially problematic. Most notably, the approach assumes that the residential census unit employed (typically tract or block group) captures the relevant exposure space. Yet, the observation that individual mobility extends beyond the boundaries of residential neighborhoods is almost as old as urban sociology itself (Browning and Soller 2014; McKenzie 1921). The practice of embedding youth in residential census units nevertheless became the default design for neighborhood effects studies due, in large part, to limitations in available data on exposures. A limited number of studies (Cook et al. 2002; Massey and Brodmann 2014) incorporated information on both neighborhood and school contexts (Bowen and Bowen 1999; Kirk 2009; Owens 2010; Teitler and Weiss 2000). These “multi-contextual” approaches, however, remained rare through the ‘90s and 2000s.

More recently, an emerging body of research has employed an “activity space” approach to assessing the contexts of exposures. Activity spaces capture all the locations to which individuals are regularly exposed (Browning and Soller 2014; Jones and Pebley 2014; Kwan 2009, 2013; Sharp, Denney, and Kimbro 2015; Wikström et al. 2012). In this view, theories

of contextual impact that rely on an exposure mechanism should empirically determine the span of adolescent exposures in order to validly estimate the impact of context. Wikstrom (2012), for instance, employs a space-time budget approach adapted from geographic methods (Hägerstrand 1970) in order to capture locations, activities, behaviors, and social network partner presence as they vary over a four-day period. The ability to situate acts of delinquency and crime in space and time allows for more precise assessment of context effects than conventional approaches relying on residential neighborhood units of unknown relevance with respect to exposures.

The location and characteristics of residential neighborhoods are likely to be important determinants of activity space features. In some instances, residential neighborhoods may, in fact, overlap significantly with activity space locations. However, we argue that the daily travel trajectories of urban youth are likely to extend beyond the residential boundary resulting in both substantial within-individual variability in everyday exposures as well as variability between individual youth who reside in the same neighborhood. Observed heterogeneity in everyday exposures to areas characterized by high levels of violence would indicate that the conventional neighborhood effects design is likely to mischaracterize exposures to an unknown degree, attenuating their estimated impact on wellbeing. Moreover, emphasis on residential neighborhood violence rates as the relevant exposure shifts research questions on the origins of differential exposure to residential mobility patterns (i.e. determinants of neighborhood in which to reside) rather than everyday routine activity patterns (i.e. determinants of areas in which time is spent). Our approach focuses on estimating and explaining variability in exposure to violent areas in the course of everyday routines, emphasizing the magnitude and determinants of racial disparities in this outcome.

Explaining Variability in Activity Space Violence

Extant research on the origins of health and wellbeing among urban youth, including racial disparities in these outcomes, has largely focused on family resources, family processes, and neighborhood-level determinants. Here, we apply these approaches to understanding the allocation of time across non-home routine activity locations characterized by varying levels of violent crime. First, the *family investment model* highlights the role of family socioeconomic status in providing opportunities for investment in children that promote health and development. Limitations on the availability of economic resources constrain families to focus on more immediate material needs (Mayer 1997) to the potential detriment of developmentally beneficial exposures. Parental investments include provision of an adequate standard of living, promoting educational and extracurricular opportunities, and engaging with youth on developmentally significant tasks such as academic advancement (Conger and Donnellan 2007; Simons et al. 2016). A key component of family investment models is parents' choice of neighborhood, as the residential context is seen as a critical source of both risk and resources for youth. Presumably, the quality of the neighborhood context is relevant to the extent that it captures actual exposures that contribute to youth outcomes. Accordingly, an extension of the family investment model would take into account characteristics of youths' non-home activity locations to more directly capture parental investments as they relate to youths' actual exposures (moving beyond the assumption that residential neighborhoods characteristics serve as a proxy for these

exposures). Racial disparities in youth exposure to violent activity space locations would then be hypothesized to follow from differences in family socioeconomic resources and constraints – e.g., income, education, household and family structure (capturing the availability of parental time for investment in youth), and recent financial problems.

Second, like the family investment model, the *family stress model* views socioeconomic factors as critical determinants of the wellbeing of children. However, stress processes and compromised parenting flowing from economic distress are seen to play a critical role in mediating the impact of SES (Conger et al. 1994). In this view, financial problems adversely impact caregiver stress and relational conflict among parents. In turn, parent-child interactional dynamics may be negatively affected, resulting in reduced warmth and support and disruptions in monitoring and supervision of youth activities and behavior. The more frequent occurrence of economic stress among African American families, in this model, would be reflected in compromised family social support and informal social control capacity, with implications for youth's exposure to higher risk activities and locations.

Third, an alternative approach to understanding racial disparities in high risk exposures shifts attention away from family level resources and processes toward the *neighborhood* context in which African American families typically reside by comparison with other race/ethnic groups (Patillo-McCoy 1999). African American youth are more likely to reside in racially segregated or heterogeneous neighborhoods with lower socioeconomic status and higher levels of population turnover, all of which have been linked with higher rates of violent crime (Kubrin and Weitzer 2003; Sampson et al. 2005; Sampson, Raudenbush, and Earls 1997). Thus non-home exposures may be constrained by the availability of spatially proximate lower violent crime areas in which to engage in everyday routine activities. Neighborhood effects approaches to explaining racial disparities in exposure to violence have relied heavily on this approach (Buka et al. 2001; Selner-O'Hagan et al. 1998) under the assumption that family level factors alone are unlikely to completely explain risk of exposure to violence given disadvantage levels in the residential environment that constrain access to less violent activity locations.

Finally, the *activity space* approach acknowledges the likely substantial variation in the location and characteristics of routine activity settings. Neighborhood approaches risk a form of determinism by linking residential context characteristics with features of activity locations absent recognition of the complexity of everyday activity spaces and the choices and constraints urban actors face in navigating their environments. Although neighborhoods are likely to be important determinants of activity location characteristics, urban families may encounter opportunities for beneficial exposures (e.g., informal, non-purposive interactions that shape access to higher quality institutional and activity options (Small 2009)) or constraints on the capacity to avoid higher risk locations. In the latter case, even African American families with relatively high levels of advantage residing in higher SES neighborhoods may maintain ties to higher risk areas through relatives, friends, or institutional involvements. For older, more mobile youth, residence in a more advantaged community may still be accompanied by time spent in higher risk areas, if peers are concentrated in such spaces (and less prevalent within the home neighborhood (Clampet-Lundquist and Massey 2008)). The social benefits accrued through these activities may be

willingly sought; nevertheless, African American families face such trade-offs at a far higher rate than other groups, potentially resulting in racial disparities in the exposure to violent areas above and beyond family and neighborhood level determinants.

In summary, we employ smartphone-based GPS data on the travel paths of a sample of youth to estimate variability in the everyday level of exposure to violent crime in a relatively large urban area. We decompose this variation within individual (across days of a week), between individuals within residential neighborhoods, and across neighborhoods. We then consider family, neighborhood, and activity space determinants of time-weighted exposure to violent areas employing three-level, random effects linear models of this outcome. These analyses offer the first large-scale investigation of exposure to violent crime in the activity spaces of urban youth.

Baseline Data and Measures – the *Adolescent Health and Development in Context* study

The AHDC is a longitudinal, representative data collection effort focusing on the multiple contexts of youth development. The study area is a contiguous space within Interstate 270 (the outer belt of the City incorporating a majority of Columbus and a number of suburban municipalities). The study also includes an oversample of predominantly African American, low-income census tracts.¹ For the purposes of the current analysis, we use data on youth who reside within both the study area and the City of Columbus to align with available data on violent crime (limited to Columbus). The resulting sample includes a substantial number of African American youth, allowing for effective estimation of racial disparities in violent exposures.

The study design involves multi-modal data collection over the course of a week. First, an *Entrance Survey* with a focal youth and his/her caregiver is conducted. Caregiver interviews cover a range of topics including demographic and socioeconomic background, household composition, family structure and marital status, employment and income, health, social support, and alcohol/substance use. Caregivers also report youth characteristics, including behavior, mental/physical health, schooling, family conflict, and legal troubles.

Following the Entrance Survey, a seven day smartphone-based Global Positioning System (GPS) tracking and Ecological Momentary Assessment (EMA) data collection period occurs (GPS week). The EMA involves five daily mini-surveys including questions on location, activity, and assessments of the immediate spatial context. The continuous GPS tracking feature of the AHDC design allows for collection of real-time data on the locations at which youth spend time. The phone app prioritizes spatial data from more accurate GPS satellites, and saves location data every 30 seconds when connected. If no GPS satellite position has been saved in the last 10 minutes, location coordinates based on cell tower network position are collected every 60 seconds. We collect battery level of the phone to assess missing GPS time periods due to low battery. The GPS data are uploaded to secure servers every hour.

¹Incorporation of controls for oversample areas result in minimal change to the results presented in Table 2.

Finally, an *Exit Survey Space/Time Budget* is administered to the youth, during which the interviewer walks the youth through five of the seven days covered by the GPS week – the two most recent weekdays and Friday, Saturday, and Sunday. A specialized software application has been designed to employ both GPS inferences on activity locations and EMA data to help the youth recall his or her travel path for the week, facilitating additional collection of information on locations and activities for periods not captured by the EMA (providing continuous data for five days). This process cleans up noise in the GPS coordinates that is present even during stationary periods and provides stable location coordinates for analysis. The raw GPS data are processed through a convex hull detection algorithm to determine stationary periods, which iteratively creates a minimum bounding polygon for a given set of coordinates. When new coordinates increase the size of the convex hull by 100 percent², the algorithm infers that the respondent has left the previous activity location and has begun a travel period. The convex hull can be visualized as the shape formed by a rubberband that has been stretched around the set of points. Convex hull methods have been used recently in several community detection and activity space projects (Chan et al. 2014; Yin et al. 2013). Estimates of GPS data coverage are between 80 to 90 percent of in-scope (i.e. non-school) time, indicating that youth charge and carry the phones relatively consistently and rarely de-activate the phone's GPS.

Data Integration

For the current study, we merge survey-based demographic and background characteristics and GPS-based routine activity location data on the sample of AHDC youth who reside within the City of Columbus boundaries (N=878) with geocoded crime data from the Columbus Division of Police and American Community Survey data to produce estimates of exposure to specific locations characterized by higher levels of violence. These data offer precise estimates of the amount of time youth spend at locations characterized by varying levels of violence.

Measures

Activity space locations from the cleaned GPS data (via the Exit Survey Space-Time budget) with valid latitude and longitude are geocoded to 2010 block groups. We generate time-weighted average exposures to violent crime and other Census-based covariates for each day, using the number of minutes spent at each location during waking hours as the weighting factor. Adjusting the daily average exposure by time allows for locations with longer associated durations to contribute more to the daily average than locations at which less time was spent. Waking time is reported daily on EMA mini-surveys and mean imputed for weekend and weekday separately where self-reports are missing. Note that youth spend some days entirely at home, in which case the youth are not exposed to a non-home violent crime rate and the day is not included in the analyses (as noted in the missing data section below). If the youth does spend time outside the home on a given day, the day is included in the analyses.

²This figure was determined empirically to capture the initiation of travel periods most accurately.

The dependent variable is the time-weighted average of *violent crime*, measured using the violent crime rate (combining aggravated assault, homicide, and robbery) per 1,000 residents in the block group.³ We geocoded crime reports from 2005 through 2012⁴ provided by the Columbus Division of Police to 2010 census block group boundaries. Total population used to construct the rate accounts only for the portion of the block group that is within the city of Columbus if the block group is split across municipalities. An activity location is assigned a violent crime rate if it falls within a block group that is partially or wholly inside Columbus. Therefore, the dependent variable does not account for the total amount of time spent outside the home as it excludes time spent outside Columbus. We control for the number of minutes of non-home time with valid spatial coordinates to account for differences in observed time across days. Although our focus in this analysis is on exposure to aggregate activity space violent crime, bivariate analyses indicate that adolescents with higher average exposure to violent areas report significantly more lifetime exposure to both direct victimization and indirect witnessing of severe violence.

Day-level time-weighted exposure to the following block group characteristics are constructed using 2009–2013 data from the American Community Survey. *Economic disadvantage* is a standardized scale of the following four items: (1) the poverty rate, (2) unemployment rate, (3) the percentage of households that are female-headed, and (4) the percentage of households that receive cash assistance. *Residential instability* is a standardized scale consisting of the percent of residents ages one and older who have moved in the past one year and the percent of occupied housing units that are renter-occupied. *Racial diversity* is the sum of the squared proportions of white, Latino, Black, Asian, and other race/ethnicity populations in the tract subtracted from 1 ($1 - [\text{Pr}(\text{white})^2 + \text{Pr}(\text{black})^2 + \text{Pr}(\text{Asian})^2 + \text{Pr}(\text{Hispanic})^2 + \text{Pr}(\text{Other Race})^2]$). Higher values indicate more race-ethnically diverse activity spaces, as the diversity index captures the likelihood that any two randomly selected individuals are of different race/ethnic groups. We also include a measure of *proportion African American*. At the day level we also control for whether the day is a *weekday* compared to a weekend day.

We include a number of youth and family characteristics that may account for differences in activity space violent crime. We include youth *age* in years and whether the youth is *male* vs. female. Race/ethnicity of the youth is represented as four dummy variables indicating *non-Hispanic black*, *Hispanic*, *Asian*, or *multiracial* with *non-Hispanic white* as the omitted reference category. We include whether the caregiver is *foreign born* and whether he/she is *married*, *cohabiting*, *single*, or *other* (married is the reference category). Household level resources are measured by *caregiver education* (10 categories of highest completed ranging from elementary school to a professional degree), *household size*, and *household income* (14 categories ranging from under \$10,000 in the previous year to more than \$250,000). *Family hardship* is the average level of agreement with three caregiver reports of difficulty paying

³Although rape is typically reported in violent crime rates, the geocoded data available from Columbus Police do not identify rape separately from other types of sexual assault and sexual offences.

⁴We employ eight years of data under the assumption that high crime rate areas establish reputations over a number of years. Consistently high crime areas are likely to engender the social processes (e.g., fear of crime and associated stress; expectations regarding informal social control) relevant for linking exposures to these areas with compromised health and development among youth. Averaging over a number of years also stabilizes violent crime rates at the (relatively small) block group level.

rent or mortgage, paying utility bills, and putting off buying something they needed like food or medical care because they didn't have enough money during the previous 12 months. To assess family supervision and monitoring capacity, youths report on *family control*, a subscale of the Family Environment Scale (Moos and Moos 1994). The number of mostly true responses (vs. mostly false) are counted, so that higher values indicate more family social control. The scale includes 9 items such as "there are very few rules to follow in our family (reverse coded)", "there are set ways of doing things at home", "rules are pretty inflexible in our household", and "you can't get away with much in our family". We also include *family support*, which is a 5-item adolescent report indicating the average level of agreement on a 3 point scale (Cronbach's $\alpha=.81$) with the statements such as: "my family lets me know they think I'm a worthwhile (valuable) person," "people in my family have confidence in me," and "I know my family will always stand by me" (Turner, Frankel, and Levin 1983). We also include a control for *season* at the youth/family level.

At the neighborhood level we control for a range of characteristics of the home residence block group using 2009–2013 American Community Survey data. We include four measures, constructed at the block group level in the same manner as the activity space block group characteristics: neighborhood *economic disadvantage*, *residential stability*, *racial diversity*, and *proportion African-American*.⁵

Missing Data

We start with 4,012 days that have 1,440 minutes (a full day) or less of spatial data coverage from 878 youth that live in the city of Columbus.⁶ We remove 138 locations (0.5 percent) with missing or problematic spatial coordinates which affects 17 days (primarily days with no phone-based GPS due to disabled location services or the phone not being charged). We then remove 727⁷ days where all recorded time was spent at home, during which the youth has no non-home violent crime exposure. Finally, we limit the analysis to only locations visited within the city of Columbus during waking hours for which we have geocoded violent crime rates available, dropping 182 days and 21 youth with no time spent at non-home Columbus locations. For days in the analysis, 90 percent of the total waking non-home time is spent in locations in Columbus. Listwise deletion of cases missing on independent variables results in a sample size of 2643 days nested with 729 youth⁸ and 351 block groups. We employ multiple imputation using Stata's *mi impute chained* equations commands to

⁵Although diversity and proportion African American are structurally dependent at extreme values, incorporating both does not result in multicollinearity in the analyses presented below. Parameter estimates for the two variables change minimally when included separately or simultaneously.

⁶We lose 198 days due to total time summing to greater than 1,440 minutes or lost timing data. These cases are due primarily to interviewer error in cleaning exit graphic timing data.

⁷Roughly a fifth of eligible days were spent entirely at home. This is due, in part, to the fact that exit graphic days included three weekend days vs. only two weekdays. Dropping these days results in a potential selection problem if some families or youths systematically avoid exposure to non-home locations, perhaps due to high levels of violence in the non-home environment. In order to address this possibility, we estimated a logistic regression model of the likelihood of having one or more days entirely at home among youth, including a host of covariates. The predicted probability from this selection model was then included in models otherwise replicating those presented in Table 2. The estimates for the racial disparity in exposure to violent locations changed minimally across models.

⁸As is typical in social surveys, missing data on household income is primarily responsible for the loss of cases due to listwise deletion.

address missing data in youth/family-level independent variables for a final sample of 3086 days nested within 857 youth and 373 block groups.⁹

Analytic Strategy

We employ three-level linear models nesting average log violent crime exposures at the day level (level 1) within individual youth (level 2) within home block groups (level 3). We define our outcome, Y_{ijk} , to be the average, time-weighted, violent crime rate of the non-home areas to which youth j , residing in block group k , was exposed on day i . Our analytic approach allows us to decompose the variation in exposure to violent areas across days, individuals and neighborhoods in unconditional models (without covariates included) and adjusts coefficient standard errors for clustering of cases within individual and block groups in conditional models. We begin by decomposing variance in the outcome across levels and constructing intraclass correlations for each level of the nested data structure (model 1, using the following model:

$$\begin{aligned} Y_{ijk} &= \pi_{0jk} + e_{ijk} & e_{ij} &\sim N(0, \sigma^2) \\ \pi_{0jk} &= \beta_{00k} + r_{0jk} & r_{0jk} &\sim N(0, \tau_\pi) \\ \beta_{00k} &= \gamma_{000} + u_{00k} & u_{00k} &\sim N(0, \tau_\beta) \end{aligned}$$

In this unconditional model, Y_{ijk} is modeled as a function of π_{0jk} – a youth-specific mean violent crime exposure level over the course of the GPS week – and e_{ijk} – a day-specific deviation from the youth mean exposure (assumed to be independently, normally distributed with variance σ^2). Comparable models are fit to youth and block group mean log violent crime exposures at levels 2 and 3, respectively. Intraclass correlations (ICCs) capture the proportion of the variability at each level of the model in this unconditional specification (e.g., the proportion of the variability at the day level is simply $\sigma^2/(\sigma^2 + \tau_\pi + \tau_\beta)$).

In order to test hypotheses regarding any observed racial differences in exposure to violent areas, we fit a series of conditional models, incorporating key covariates at each level. Each of these models is a special case of the following in which all distributional assumptions are identical to the unconditional model introduced above:

$$\begin{aligned} Y_{ijk} &= \pi_{0jk} + \sum_p \pi_{p00} (\text{Activity Space Disadvantage})_{pijk} + e_{ijk} \\ \pi_{0jk} &= \beta_{00k} + \sum_{q1} \beta_{q100} (\text{Race Ethnicity})_{q1jk} + \sum_{q2} \beta_{q200} (\text{Family Disadvantage})_{q2jk} + \sum_{q3} \beta_{q300} (\text{Family Stress})_{q3jk} + r_{0jk} \\ \beta_{00k} &= \gamma_{000} + \sum_s \gamma_{s00} (\text{Tract Disadvantage})_{sk} + u_{00k} \end{aligned}$$

We begin by entering covariates at level two, including a measure of race/ethnicity, focusing specifically on estimating the African-American – white disparity in exposure to violent areas (model 2). We then turn to family resources and investment capacity (household income, caregiver education, caregiver marital status, and economic distress – model 3) and family stress outcomes (youth-reported family control and family social support – model 4) in order to determine whether these factors account for the racial disparity in exposure to

⁹Clustering of youth within block groups is limited. Employing census tracts as the neighborhood unit of analysis results in minimal change to the ICCs.

violent areas. We then include measures of tract-level disadvantage (model 5) at level 3 to examine whether residential characteristics are significantly associated with exposure to violent areas and further explain the racial disparity. Finally, we incorporate activity space disadvantage measures (at level 1) to assess the independent role of these covariates in influencing exposure to violent areas and explaining any residual racial difference.

Results

Table 1 presents descriptive statistics for the day, youth, and neighborhood variables included in the analyses. Of the AHDC youths who reside in the city of Columbus, 35% are non-Hispanic white, and 48% are non-Hispanic black.

We begin by fitting the unconditional model (model 1 of table 2) to decompose variance in exposure to violent areas across levels of analysis. Under the assumption that neighborhood (in this case, block group) level violence rates are the relevant exposure to capture the contextual impact of aggregate violence, the ICC would result in 100% of the variability at the neighborhood level (i.e., youth who reside in the same neighborhood will have the same level of exposure to violence on an everyday basis). In contrast to this expectation, we find that the block group accounts for 35% of the variance in exposure to violent areas, with 28% at the youth (within neighborhood) level and 37% at the day (within individual) level. Consequently, youth experience substantial variability by day in average levels of activity space violence and, among youth who live in the same neighborhood, exposure to violent areas varies non-trivially. These results indicate not only that youth venture beyond the borders of their neighborhood environment in their everyday activities, but that non-neighborhood environments are heterogeneous with respect to violence rates.

Models 2–6 test key hypotheses regarding racial disparities in exposure to violent areas and their explanation. Model 2 incorporates race/ethnicity dummy variables and controls for weekend, season, day-level amount of time spent outside the home, gender, and age. Race/ethnic dummy variables indicate that African American race is powerfully positively associated with activity space violence ($p < .001$) as is being multiracial. Specifically, being African American is associated with a 66% increase in the average violence level of areas to which youth are exposed outside of home (time-weighted). Latino ethnicity is marginally positively associated with activity space violence ($p < .10$).

Model 3 adds measures of family resources in order to examine their unique association with activity space violence and the extent to which these factors explain the observed substantial disparity by race. Among family resource variables, we find that household size is positively associated with activity space violence ($p < .05$) while household income is negatively associated with the outcome ($p < .01$). The addition of family resource variables reduces the coefficient for African American race by 12% and the coefficient for multiracial identification by 14%.

Model 4 considers the association between measures of family control and social support as potential social process outcomes of economic stress that may influence activity space

disadvantage. Neither measure was a significant predictor of activity space violence, nor were coefficients for race/ethnicity altered in this model specification.

Models 5 and 6 include measures of neighborhood and activity space disadvantage, respectively. Consistent with prior research, youth who reside in more segregated neighborhoods with larger proportions of African American residents are exposed to more violent areas. Similarly, higher levels of economic disadvantage and race/ethnic diversity in the residential block group are also positively associated with time spent in violent areas. Only residential instability did not achieve significance in this model specification. Of note are declines in the magnitude of individual level race coefficients. Coefficients for African American, Latino, and multiracial identification all decline by roughly 50% in model 5 by comparison with baseline estimates in model 2, but the coefficients for African American and multiracial remain statistically significant. In the former case, the effect remains highly statistically significant ($p < .001$) and of non-trivial magnitude: being African American is associated with a 33% increase in the average violence level of non-home exposures.

Finally, model 6 adds day-level measures of activity space disadvantage (time-weighted). Unsurprisingly, we find that characteristics of the activity spaces youth encounter are associated with the violence rates of those areas. All four measures of activity space disadvantage are powerfully positively associated with the outcome ($p < .001$). Moreover, inclusion of these measures results in an 83% reduction in the magnitude of the baseline coefficient for African American race in model 2; the coefficient is no longer statistically significant in model 6. With the exception of home block group economic disadvantage (which remains a significant predictor of activity space disadvantage), coefficients for residential neighborhood disadvantage are also no longer significant in model 6. Of note is the effect of multiracial identity, which remains a significant predictor of activity space violence ($p < .05$) after taking into account neighborhood and activity space characteristics.

Figure 1 presents the expected values of violent crime rate by race/ethnicity for Models 2 through 6, holding all other covariates at their means. The expected logged crime rates are exponentiated in order to present rates in their original metric. As noted in the discussion above, the gap between African American and white youth narrows substantially with the addition of residential disadvantage in Model 5 and activity space disadvantage in Model 6.

Conclusion

Exposure to violence is a well-established risk associated with residing in a large urban area in the contemporary US. Exposure to violence has documented negative developmental consequences for urban youth, including compromised mental and physical health and behavioral development. Evidence suggests that exposure to violent neighborhoods may be detrimental independent of the experience of direct victimization or witnessing (Sharkey 2010), pointing to the importance of understanding racial disparities in this experience.

Our analyses offer the first examination of violence levels in the actual GPS-measured activity spaces of urban youth. We employed detailed information on the travel paths of a sample of youth over the course of a week incorporating additional respondent input at the

end of the week to enhance accuracy of the location data. Decomposing variability in violent crime rate exposures across days, individuals, and residential neighborhoods, we found that a majority of the variability in exposure to violent areas is at the day and youth level, rather than the residential neighborhood. This finding points to the substantial heterogeneity in violence exposures that urban youth experience. Employing residential neighborhood violence rates alone significantly misrepresents this heterogeneity.

We next examined hypotheses regarding the sources of variability in exposures to violent areas, considering family, neighborhood, and activity space determinants. Although family resources, specifically income and household size, were associated with exposure to violent areas, they accounted for a relatively modest proportion of the observed racial disparity. Family process measures were not associated with the outcome. In contrast, neighborhood disadvantage measures accounted for roughly 39% of the baseline African American-white disparity in exposure to violence areas. Measures of segregation, race/ethnic heterogeneity, and socioeconomic disadvantage in the home block group were powerful predictors of activity space disadvantage, supporting the hypothesis that residential neighborhoods shape activity space exposures to substantial extent.

Nevertheless, neighborhood measures only partially accounted for the racial disparity in exposure to violent areas. Indeed, the incorporation of neighborhood disadvantage and family-level predictors explained only half the baseline racial disparity. Even after including these measures, the race effect was statistically significant and non-trivial. Including measures of activity space disadvantage explained an additional 33% of the baseline racial disparity and rendered the African-American-white coefficient insignificant. Considered in the absence of neighborhood covariates, incorporation of activity space disadvantage measures explains roughly 70% of the racial disparity (with an insignificant residual racial disparity).

Although we would expect that characteristics of activity space locations would be associated with the violent crime rates of those areas (just as a long history of neighborhood research on violence has demonstrated), the proportion of the racial disparity that is accounted for by considering activity space locations vs. residential neighborhoods alone speaks to the necessity of looking beyond neighborhood environment to understand the everyday exposures of urban youth. The substantial heterogeneity in exposures observed over time and within residential neighborhood further supports this assertion.

Beyond the analysis of exposure to violent areas, these findings raise a number of questions regarding the continued reliance on conventional “neighborhood effects” approaches to assessing contextual effects on youth development. The literature examining neighborhood influence on child and adolescent outcome is now vast and expanding daily. Yet, the practice of investigating neighborhood effects by embedding youth in their residential unit (and relating characteristics of this unit to an outcome) is likely to significantly misrepresent actual developmentally relevant exposures. The ongoing controversy regarding the magnitude and import of neighborhood effects is based on extant research that largely employs a potentially crude characterization of non-home exposure. The currently dominant

research design, then, may be resulting in attenuated estimates of contextual influence due to inadequate measurement of exposures.

Second, a focus on activity spaces points to the need to understand how such spaces are shaped in the context of everyday routines. Clearly, the problem of selection (notoriously afflicting neighborhood research) remains a significant concern in this approach. Choices regarding routine activities and their locations are shaped by a complex nexus of individual, social network, and spatial factors that introduce new challenges in understanding the causal effect of context. At the same time, activity space approaches allow for more accurate measurement of “treatment” effects (e.g., the “dose” of a given exposure). Moreover, the effects of exogenous changes in activity space environments (e.g., institutional changes) may be leveraged to assess contextual influences more precisely when specific information on geographic exposures is available.

It is important to acknowledge a number of limitations to our analyses. Our estimates of exposure to violent areas are based on non-home time at the day level. Selection processes not accounted for in our models of the propensity to have one or many days spent entirely at home may be affecting the likelihood of experiencing non-home time (including factors related to safety in the environment). Our analyses were also limited to both youth and routine activity locations within the City of Columbus. Although these locations account for the vast majority of non-home time (90 percent), incorporating exposures beyond the City of Columbus would be necessary to estimate the true variability in exposure to violent areas. Including these non-city, mostly suburban exposures would likely also reveal more pronounced racial disparities.

An important next step in modeling exposure to violent areas would be to examine the amount of time youth spend in *highly* violent areas. The most violent areas of cities may be uniquely detrimental in their impact on youth and considering exposure to the most dangerous neighborhoods may reveal even more pronounced racial disparities.

Although activity space data introduce a range of new challenges, they also present new and exciting opportunities to researchers interested in the nature of environmental influence on youth development. Research on contextual effects will benefit tremendously from the ongoing introduction and refinement of new smartphone-based technologies for data collection and far more precise and extensive administrative and commercial data on the spatial environments to which urban youth are exposed.

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Figure 1.
Predicted Daily Activity Space Violent Crime Rates by Race/Ethnicity^a
^aPredicted log violent crime rates are exponentiated.

Table 1

Descriptive Statistics of Day, Youth, and Neighborhood Level Variables in the Analysis, from the Adolescent Health and Development in Context Study

	Mean	Standard Deviation
<i>Youth Characteristics (N=857)</i>		
Winter	0.21	
Spring	0.20	
Summer	0.27	
Autumn	0.31	
Age	14.19	1.85
Male	0.47	
Non-Hispanic White	0.35	
Non-Hispanic Black	0.48	
Hispanic	0.06	
Asian	0.01	
Multiracial	0.10	
Caregiver foreign born	0.05	
Household size	4.68	1.71
Caregiver education	5.63	1.57
Household income	4.94	3.37
Caregiver married	0.46	
Caregiver cohabiting	0.12	
Caregiver single	0.25	
Caregiver other marital status	0.17	
Family hardship	2.22	1.04
Family control	5.34	2.06
Family support	2.62	0.42
<i>Neighborhood (N=373)</i>		
Proportion Black	0.37	0.31
Racial diversity	0.39	0.18
Economic disadvantage	0.43	0.92
Residential Instability	0.54	0.91
<i>Daily Weighted Activity Location Exposures (N=3,086)</i>		
Logged Violent Crime Rate	1.70	1.20
Proportion Black	0.34	0.28
Racial diversity	0.39	0.15
Economic disadvantage	0.28	0.77
Residential Instability	0.59	0.81
Weekend day	0.36	
Minutes of waking non-home time	563.05	311.04

Table 2
Multilevel Linear Models of Daily Time-Weighted Exposure to Violent Crime with Day, Youth, and Neighborhood Predictors

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
<i>Youth characteristics</i>						
Season	-0.008	-0.008	-0.008	-0.007	-0.010	-0.003
Minutes of waking non-home time	0.000	0.000	0.000	0.000	0.000	0.000
Age	0.025	0.035 *	0.030	0.030	0.028	0.022
Male	-0.071	-0.061	-0.051	-0.050	0.003	
Non-Hispanic Black	0.664 ***	0.584 ***	0.598 ***	0.330 ***	0.110	
Latino	0.234	0.237	0.253	0.110	0.091	
Asian	-0.093	-0.079	-0.082	-0.191	-0.262	
Multiracial	0.433 ***	0.373 ***	0.377 ***	0.240 *	0.205 **	
Caregiver foreign born	0.000	-0.053	-0.054	0.034	-0.028	
Household size		0.039 *	0.038 *	0.020	0.005	
Caregiver education		-0.031	-0.031	0.003	0.012	
Household income		-0.044 ***	-0.042 ***	-0.024 *	-0.017	
Caregiver Cohabiting		0.122	0.117	0.042	0.026	
Caregiver Single		0.081	0.076	0.023	-0.031	
Caregiver Other marital status		0.135	0.130	0.091	0.016	
Family hardship		-0.010	-0.012	-0.009	-0.005	
Family control			-0.008	-0.009	-0.005	
Family support			-0.111	-0.109	-0.043	
<i>Neighborhood Level</i>						
Proportion Black				0.605 ***	0.043	
Racial diversity				0.465 *	0.088	
Economic disadvantage				0.274 ***	0.162 ***	
Residential Instability				0.060	0.020	
<i>Daily Activity Location Exposure</i>						
Proportion Black					0.985 ***	
Racial diversity					1.126 ***	

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Economic disadvantage						0.305***
Residential Instability						0.329***
Weekend day		-0.011	-0.011	-0.011	-0.013	-0.046
Constant	1.703***	1.092***	1.210***	1.567***	1.006**	0.345
Variance Components						
Day	0.767	0.766	0.766	0.766	0.766	0.655
Youth	0.569	0.565	0.577	0.577	0.562	0.414
Home Block Group	0.725	0.606	0.519	0.516	0.396	0.322

p<.001;**
p<.01;*
p<.05;