

## Working Memory Differences Between Children Living in Rural and Urban Poverty

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This study was designed to investigate if the working memory profiles of children living in rural poverty are distinct from the working memory profiles of children living in urban poverty. Verbal and visuospatial working memory tasks were administered to sixth-grade students living in low-income rural, low-income urban, high-income rural, and high-income urban developmental contexts. Both low-income rural and low-income urban children showed working memory deficits compared with their high-income counterparts, but their deficits were distinct. Low-income urban children exhibited symmetrical verbal and visuospatial working memory deficits compared with their high-income urban counterparts. Meanwhile, low-income rural children exhibited asymmetrical deficits when compared with their high-income rural counterparts, with more extreme visuospatial working memory deficits than verbal working memory deficits. These results suggest that different types of poverty are associated with different working memory abilities.

We depend on our working memory to actively hold and manipulate information in our mind. Given how frequently we need to utilize this cognitive ability on a daily basis, it is troubling that recent research has found that children of a low socioeconomic status (SES) exhibit working memory deficits compared with their high-SES peers. Specifically, the visuospatial working memory scores of low-SES preschoolers and kindergarteners are significantly lower than those of their high-SES counterparts (Fernald, Weber, Galasso, & Ratisfandrihamanana, 2011; Noble, Norman, & Farah, 2005). Similarly, the verbal working memory scores of low-SES first-grade urban students are lower than those of high-SES first-grade urban students (Noble, McCandliss, & Farah, 2007). Composite working memory scores have also been shown to differ between low- and high-SES children, even after controlling for gender, age, and ethnicity (Farah et al., 2006). Taken together, these results clearly suggest that school-aged low-SES children exhibit both verbal and visuospatial working memory deficits. However, no study has directly *compared* their verbal working memory deficits to their visuospatial working memory deficits; thus, the relationship between poverty and verbal working memory relative to that of poverty and visuospatial working memory is not known.

Importantly, there is evidence that some of the cognitive resources utilized by verbal and visuospatial working memory are distinct, suggesting that studies should measure and analyze

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the two components separately. According to Baddeley and Hitch's (1974) model of working memory, when one is engaged in a verbal working memory task, the phonological loop and central executive work together to temporarily store and process the information, but when one is engaged in a visuospatial task, the visuospatial sketchpad and central executive work together to temporarily store the information. Numerous empirical studies support this tripartite model composed of a shared central executive but separate temporary, short-term storage components (e.g., Jarvis & Gathercole, 2003; Lobley, Gathercole, & Baddeley, 2005; Shah & Miyake, 1996). Hence, it is important to consider that children living in poverty could exhibit different verbal versus visuospatial working memory deficits.

The body of literature examining working memory and poverty has also failed to compare verbal and visuospatial working memory when investigating the specific mechanisms by which poverty affects working memory. More specifically, recent work has determined that chronic stress explains SES differences in visuospatial working memory such that the relationship between SES and visuospatial working memory is fully mediated by allostatic load, an index of the cumulative physiological wear and tear caused by trying to adapt to chronic, stressful life events (Evans & Schamberg, 2009; McEwen & Stellar, 1993). The longer a child lives in poverty, the higher the amount of stress experienced, and in turn, the greater the reduction in visuospatial working memory capacity (Evans & Schamberg, 2009). This strongly suggests that the chronic stress of poverty negatively affects visuospatial working memory. However, it is not known whether the same effects extend to verbal working memory.

Further, it is not known whether the distinct stresses of living in urban versus rural poverty differentially affect verbal and/or visuospatial working memory. Yet, poverty clearly exists in both rural and urban areas and there are differences in the stresses experienced in the two contexts. The urban poor often cluster in neighborhoods with substandard and crowded housing, excessive noise levels, and numerous but inadequate services such as health care, education, libraries, and police enforcement (Bobo, 2009). Meanwhile, individuals living in rural areas face great isolation from people, technology, institutions, and services of any kind (Duncan, Brooks-Gunn, Yeung, & Smith, 1998), often preventing the rural poor from utilizing social support networks (Amato, 1993; Hofferth & Iceland, 1998). Indeed, rural families receive, give, and expect significantly less help from friends than do urban families, which is relevant because social support is thought to buffer individuals from stress (Amato, 1993; Sandler, 1980). However, rates of crime, psychological disorders, divorce, and other social pathologies are higher in urban than in rural areas (Glass & Singer, 1972; Power, 1996). Also, impoverished urban children are more likely than impoverished rural children to be a racial minority in the United States (U.S. Census Bureau, 2010). In turn, it is more likely that these poor urban children experience stress related to racial discrimination than do their rural counterparts (Jensen, 2006). Overall, it seems likely that the distinct developmental contexts of rural and urban poverty could have distinct influences on cognitive development, particularly in terms of working memory, as there is evidence that working memory is negatively impacted by chronic stress (Evans & Schamberg, 2009).

As such, the goal of the current study is to investigate differences in the verbal and visuospatial working memory abilities of children living in rural and urban poverty. For comparison purposes, the working memory abilities of rural and urban children living in high-income areas were also measured. From a theoretical standpoint, this study adopts an ecological framework of development. An ecological framework considers development as an ongoing process between

children and their immediate settings (Bronfenbrenner, 1979, 1993; Furstenberg, Cook, Eccles, Elder, & Sameroff, 1999). In this study, the immediate settings of rural and urban poverty are distinct from one another. Therefore, it is hypothesized that the development of children living in these settings may also be distinct. This study is also based on Baddeley and Hitch's (1974) tripartite model of working memory in that it measures both verbal and visuospatial working memory but measures them separately, thus supporting the distinction that verbal and visuospatial working memory are related, but separate, cognitive processes (Baddeley, 1986, 2000; Baddeley & Hitch, 1974).

Based on previous research, it was expected that both low-income rural and urban children would show verbal and visuospatial working memory deficits compared with their high-income counterparts (i.e., Farah et al., 2006; Fernald et al., 2011; Noble et al., 2005, 2007). Due to a lack of prior comparative research, the hypotheses regarding the potential differences between the low-income rural and urban participants' visuospatial and verbal working memory scores remained open. This study extends the literature by: 1) addressing comparative deficits in visuospatial *and* verbal memory among children living in poverty, and 2) directly comparing the working memory weaknesses of children living in urban *and* rural poverty. In addition, the current study addresses a general void in the research about the cognitive development of children living in rural areas.

## METHOD

### Participants

One-hundred and eighty-six 6th-grade students participated in the study ( $M_{\text{age}} = 11;3$ ; range = 10;4–12;2). Participants were recruited from three low-income rural schools ( $n = 46$ ; girls = 19, boys = 27), one low-income urban school ( $n = 48$ ; girls = 26, boys = 22), one high-income rural school ( $n = 42$ ; girls = 20, boys = 22), and one high-income urban school ( $n = 50$ ; girls = 24, boys = 26). The following criteria were used to characterize the developmental context of each participant as low-income rural, low-income urban, high-income rural, or high-income urban. Participants were considered *low-income* if they met all three of the following criteria: 1) They attended a school that serves a community with a median family income below the national median family income of \$50,033 (U.S. Census Bureau, 2010); 2) they attended a school in which at least 75% of students qualify for free or reduced-price lunch and therefore meet the definition of "high poverty" set by the National Center for Education Statistics (2009); and 3) they themselves qualified for free (not reduced-price) lunch. (Using the Family Size and Income Guidelines published by the U.S. Department of Agriculture [2011], students living in a household of four with an income of less than \$29,005 would be certified as eligible for a free lunch, whereas students from households with an income of less than \$41,348 would be certified as eligible for a reduced-price lunch.) Participants were considered *high-income* if they met all three of the following criteria: 1) They attended a school that serves a community with a median family income above the national family income of \$50,033 (U.S. Census Bureau, 2010); 2) they attended a school in which less than 25% of the student body qualified for free or reduced-price lunch, and 3) they themselves did not qualify for free or reduced-price lunch.

Participants were characterized as urban or rural based on criteria outlined by McCracken and Barcinas's (1991) work that distinguished the unique aspects of urban and rural school contexts. More specifically, participants were characterized as *urban* if the school they attended: 1) served an "urbanized area," as defined by the U.S. Census Bureau (2010; a densely settled territory consisting of core census block groups or blocks that have a population density of at least 1,000 people per square mile and surrounding census blocks that have an overall density of at least 500 people per square mile); 2) was located in a county with a population of more than 200,000; and 3) had an average enrollment per grade level at the secondary level of more than 300 students. Participants were characterized as *rural* if the school they attended: 1) was located outside of an urbanized area, as defined by the U.S. Census Bureau (2010); 2) was located in a county with a population of less than 40,000; and 3) had an average enrollment per grade level at the secondary level of fewer than 125 students.

Six participants qualified for a reduced-price, but not free, lunch and were therefore excluded from analyses. Of these six participants, four attended a low-income urban school and two attended a low-income rural school. It is worth noting that the income criteria used in the current study were stringent compared with those used in the vast majority of income studies by 1) setting both school and individual income criteria, and 2) limiting the low-income participant pool to only those who receive free lunch, as opposed to free and reduced-price lunch. In addition, study participants are purposefully referred to as high- or low-*income* and not as high- or low-*SES*, as the data collected were related to income but not maternal education or employment.

The low-income schools that participated were specifically recruited because they served communities with similar overall median family income levels (see Table 1). This was done to help ensure that any potential working memory differences between the low-income rural and urban samples would not be a reflection of one sample coming from a community that was more deeply impoverished than the other. The high-income schools also served communities with similar overall median family income levels.

## Procedure

Each participant completed four computerized working memory tasks during an individual session lasting approximately 30 min that took place during the school day in a small, quiet room.

TABLE 1  
Median Family Incomes of Participating School Communities

	<i>Low-Income</i>		<i>High-Income</i>	
	<i>Rural</i>	<i>Urban</i>	<i>Rural</i>	<i>Urban</i>
School 1	\$33,148*	\$31,733*	\$83,374	\$83,470
School 2	\$36,630			
School 3	\$29,092*			
	<i>M</i> = \$32,957	<i>M</i> = \$31,733	<i>M</i> = \$83,374	<i>M</i> = \$83,470

\*This school serves more than one town. Therefore, the median listed in the table is the mean of the median incomes of each town served by that school.

The order of the four computerized tasks was randomized across participants. All four tasks were administered on a PC laptop provided by the researchers, ensuring identical stimulus presentation across items and participants.

## Measures

The four working memory tasks were part of the Automated Working Memory Assessment (AWMA), which has been standardized for this age range (Alloway, 2007). The AWMA has been shown to be highly reliable and valid. Test–retest reliability correlation coefficients range from .76 to .88 (Alloway, 2007). Within-construct coefficients are higher than between-construct coefficients, suggesting good internal validity (Alloway, 2007). Seventy-five percent of children with poor AWMA working memory scores obtained standard scores of 85 or less on the Wechsler Intelligence Scale for Children, indicating validity of the AWMA measures (Alloway, 2007).

Two tasks assessed verbal working memory and two assessed visuospatial working memory. The tasks began with a set of practice trials immediately followed by test trials. The test trials were presented as a series of blocks. Each block consisted of six trials and followed “move-on” and “discontinue” rules. If a child correctly responded to the first four trials within a block, the program automatically proceeded to the next block and a score of 6 was given for the block just completed. If a child responded correctly to four of five trials within a block, the program automatically began the next block and a score of 5 was given for the block just completed. If a child made three or more errors within a block, the program automatically ended. The trials in the first block of each task had a list length of two stimuli. The list length of the trials in each consecutive block increased by one additional stimulus.

*Verbal working memory.* A listening recall task and backward digit-recall task were administered to measure verbal working memory. The listening recall task, often referred to as a listening span task in the literature, was a version of a complex span task. In each trial, the child heard a voice on the computer speak a series of individual sentences. After they heard each sentence, they judged if the sentence was true or false. To record their judgment, they were asked to point to a “T” or “F” on the computer screen and say “true” or “false” aloud. At the end of a trial, the child attempted to recall the final word of each sentence in that trial in the correct order. There were two raw scores for this task. The raw precision score was the number of trials in which the participant made all correct true/false judgments. The raw working memory score was the number of trials in which the participant correctly recalled the final word of each sentence in the correct order.

In each trial of the backward digit-recall task, the child heard a voice on the computer speak a sequence of digits. Then the child was asked to recall aloud the sequence in backward order. The raw working memory score for this task was the total number of trials that a child correctly repeated back all of the numbers in a trial in the reverse order as presented.

The raw working memory scores for the two verbal working memory tasks were converted into standardized percentile scores by the AWMA program (Alloway, 2007). Finally, an overall verbal working memory percentile score was computed for each participant by computing the mean of their listening recall standardized percentile score and their backward digit-recall standardized percentile score. An overall verbal working memory precision proportion score was

also computed by dividing the listening recall raw precision score by the total number of listening recall trials completed.

*Visuospatial working memory.* Both the odd-one-out and Mr. X tasks were administered to measure visuospatial working memory. The odd-one-out task was a variety of a complex span task. In each trial, the child viewed a series of rows of shapes, each row composed of three shapes. The rows were presented one at a time on the computer screen and one shape was an “odd-one-out” shape, meaning it was different than the other two shapes. The participant pointed to the location of each odd-one-out shape as each row was presented (i.e., left, center, right). At the end of each trial, the child recalled, in order, the location they believed each odd-one-out shape had appeared by tapping the appropriate location on the computer screen. The raw precision score was the total number of trials that the child identified all the correct odd-one-out shapes as they were presented. The raw working memory score was the total number of trials in which the child correctly recalled, in sequence, the location of all the odd-one out shapes presented.

In each trial of the Mr. X task, the child viewed a series of pictures on the computer screen. Each picture showed two Mr. X figures, each holding a ball. The child identified whether the Mr. X with the blue hat was holding the ball in the same hand or in a different hand as the Mr. X in the yellow hat. The Mr. X with the blue hat was also rotated. At the end of each trial, the child had to recall the location of each ball that Mr. X with the blue hat had held, by pointing to a location on a picture on the computer screen of a circle with eight compass points. The raw precision score was the total number of trials in which the child correctly identified whether Mr. X with the blue hat was holding the ball in the same hand or in a different hand as Mr. X with the yellow hat. The raw working memory score was the number of trials in which the child correctly recalled the position of each ball in the same sequence as presented.

The raw working memory scores for the two visuospatial working memory tasks were converted into standardized percentile scores by the AWMA program (Alloway, 2007). An overall visuospatial working memory percentile score was computed for each participant by computing the mean of their odd-one-out standardized percentile score and their Mr. X standardized percentile score. An overall visuospatial working memory precision proportion score was also computed by summing the raw precision scores of the two visuospatial working memory tasks and dividing the sum by the total number of trials completed across the two tasks.

A composite working memory percentile score was also computed for each participant by averaging their overall verbal working memory percentile score and their overall visuospatial working memory percentile score.

## RESULTS

### Participant Characteristics

Chi-square tests of independence were performed to examine the distribution of gender and ethnicity across the four developmental contexts (low-income rural, low-income urban, high-income rural, high-income urban). Although there were no significant differences in gender distribution, there was a significant difference in the distribution of ethnicity as a function of developmental context,  $X^2(3, n = 186) = 28.50, p < .001$ . The majority (96%) of the students

from the low- and high-income rural schools identified as Caucasian. The majority (62%) of the students from the low-income urban school and approximately one third (36%) of the students from the high-income urban school identified as a racial minority, either American Indian, Alaskan Native, Asian, Black/African American, or Pacific Islander.

### Correlations

Verbal working memory and visuospatial working memory were positively associated with one another within the high-income urban, high-income rural, low-income urban, and low-income rural samples. See Table 2 for a zero-order correlation matrix.

### Precision Scores

To determine if there were group differences in precision scores, a 2 (precision scores: verbal, visuospatial)  $\times$  4 (developmental context) mixed-design analysis of variance (ANOVA) was run with precision scores as a within-subjects variable and developmental context as a between-subjects variable. No significant main effects or interactions were found. The mean precision proportion score across the entire sample was .97 ( $SD = 0.02$ ), suggesting that participants accurately perceived the verbal and visuospatial stimuli presented in the tasks.

### Working Memory Differences by Developmental Context

To replicate previous literature showing a difference in composite working memory percentile scores between high- and low-income participants, a  $t$  test was run. As expected, low-income children had lower composite working memory percentile scores than did high-income students ( $M = 37.47$ ,  $SE = 0.76$  for low-income students, and  $M = 60.70$ ,  $SE = 0.75$  for high-income students),  $t(184) = 15.38$ ,  $p < .001$ .

To determine if verbal and visuospatial working memory skills varied as a function of developmental context, a 2 (working memory: verbal, visuospatial)  $\times$  4 (developmental context) mixed-design ANOVA was run with working memory percentile score as a within-subjects variable and developmental context as a between-subjects variable. All effects met the equality of error

TABLE 2  
Zero-Order Correlations of Verbal and Visuospatial Working Memory by  
Developmental Context

<i>Developmental context</i>	<i>r of Verbal and visuospatial working memory scores</i>
High-income urban	.45**
High-income rural	.59**
Low-income urban	.70**
Low-income rural	.68**
Entire sample	.74**

\*\* $p < .01$ .

variances as tested by Levene's procedure and equality of covariance matrices as tested by Box's  $M$  test. Main effects of working memory,  $F(1, 182) = 25.24, p < .001, \eta_p^2 = .12$ , and development and developmental context,  $F(1, 182) = 79.05, p < .001, \eta_p^2 = .57$ , can be best understood in the context of the significant interaction between these two variables,  $F(1, 182) = 29.37, p < .001, \eta_p^2 = .33$ ; (see Figure 1).

Post-hoc tests using Bonferroni adjusted alpha levels of .008 (.05/6) were run to compare the verbal and visuospatial working memory percentile scores of the developmental context groups. There were no differences between the verbal or visuospatial working memory percentile scores of high-income rural and urban students,  $p = .849$  and  $p = .989$ , respectively. As expected, low-income rural students had significantly lower verbal and visuospatial working memory percentile scores than did high-income rural students and high-income urban students ( $p < .001$  in all four cases). Similarly, low-income urban students had significantly lower verbal and visuospatial working memory percentile scores compared with high-income urban students and high-income rural students ( $p < .001$  in all four cases). Interestingly, low-income rural students had significantly higher verbal working memory percentile scores compared with low-income urban students ( $p = .003$ ), but they had significantly lower visuospatial working memory percentile scores ( $p = .002$ ). Within-group comparisons of verbal and visuospatial working memory also revealed interesting patterns. Bonferroni post-hoc tests using adjusted alpha levels of .0125 (.05/4) revealed no significant difference between the verbal and visuospatial working memory percentile scores of low-income urban students ( $p = .430$ ), but there was a difference for the low-income rural students. Specifically, low-income rural students obtained lower visuospatial working memory percentile scores than verbal working memory percentile scores ( $p < .001$ ).

To further explore the unique patterns of working memory percentile scores among participants, regression analyses examined the extent to which the variance in 1) verbal working memory and 2) visuospatial working memory percentile scores could be statistically accounted for by developmental context. In both models, the four developmental contexts were coded into three dummy/indicator variables; the high-income urban developmental context was used as the reference group. Analyses showed that developmental context accounted for 50% of the variance

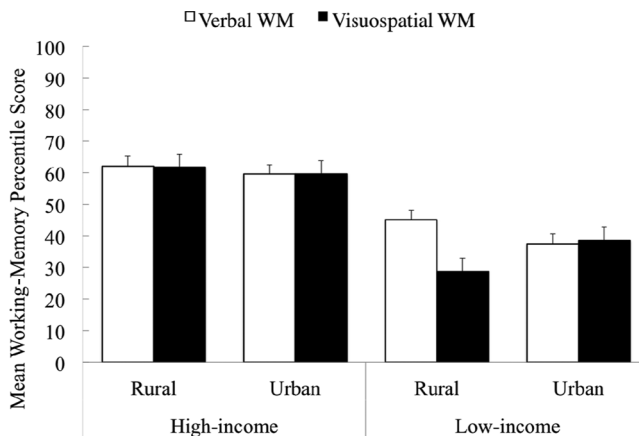


FIGURE 1 Mean verbal and visuospatial working memory percentile scores as a function of developmental context.



TABLE 3  
Regression Statistics: Developmental Context Predicts Verbal and Visuospatial Working Memory

<i>Variable</i>					
<i>Dependent</i>	<i>Indicator</i>	<i>Change in R<sup>2</sup></i>	<i>B (SE)</i>	<i>β</i>	<i>R<sup>2</sup></i>
Verbal WM		.50***			.50
	Group 1		-14.57 (2.13)	-.43***	
	Group 2		-22.28 (2.10)	-.67***	
	Group 3		2.39 (2.18)	.07	
Visuospatial WM		.55***			.55
	Group 1		-30.92 (1.78)	-.71***	
	Group 2		-21.06 (2.55)	-.49***	
	Group 3		2.10 (2.64)	.05	

\*\*\**p* < .001.

of verbal working memory percentile scores,  $F(3, 182) = 59.74, p < .001$ , and 55% of the variance in visuospatial working memory percentile scores,  $F(3, 182) = 75.00, p < .001$ . See Table 3 for the regression statistics.

## DISCUSSION

Four sets of results document the verbal and visuospatial working memory abilities of children living in low-income rural, low-income urban, high-income rural, and high-income urban developmental contexts. The first set of results showed that low-income children had poorer working memory compared with high-income children, which is consistent with previous reports (Evans & Schamberg, 2009; Farah et al., 2006; Fernald et al., 2011; Noble et al., 2005, 2007).

But importantly, the second set of results uncovered that the working memory profiles of the low-income rural children were distinct from the profiles of the low-income urban children. Low-income urban children had visuospatial and verbal working memory scores that were similar, with both averaging just below the 40th percentile. Growing up in a low-income urban context seems to be associated with similar verbal and visuospatial working memory weaknesses. To the contrary, growing up in a low-income rural context seems to be associated with different verbal and visuospatial working memory weaknesses. Specifically, low-income rural children had worse visuospatial working memory than verbal working memory; their average visuospatial working memory scores (29th percentile) were significantly lower than were their average verbal working memory scores (45th percentile).

This set of results leads to two separate conclusions. First, the finding that children in urban poverty showed symmetric working memory weaknesses, but children in rural poverty showed asymmetric weaknesses, suggests that these two types of poverty are associated with different patterns of working memory function. Regression analyses corroborate this suggestion, as developmental context accounted for a significant amount of the variance in both visuospatial and verbal working memory tasks. Second, the finding that children in rural poverty exhibited asymmetric verbal and visuospatial working memory abilities lends credence to Baddeley and Hitch's

tripartite model of working memory (Baddeley, 1986, 2000; Baddeley & Hitch, 1974). Even though verbal and visuospatial working memory did not differentiate in the low-income urban sample, the fact that they can differentiate, as evidenced in the low-income rural sample, supports the theory that they are related but distinct cognitive processes.

A third set of results was based on a direct comparison of the verbal and visuospatial working memory percentile scores of children living in rural poverty to those of children living in urban poverty. Low-income rural children exhibited higher verbal working memory percentile scores than did low-income urban children but exhibited lower visuospatial working memory percentile scores. Why would children in low-income rural contexts exhibit stronger verbal working memory but weaker visuospatial working memory compared with their low-income urban counterparts? There is little work that links specific environmental stressors to specific working memory components, but the few findings that do exist are aligned with the results of the current study. For example, there is less noise pollution in rural contexts than in urban contexts (Bobo, 2009), and chronic noise pollution has a negative effect on verbal working memory and tasks that draw heavily on verbal working memory resources, such as reading and speech (Evans, 2006; Evans & Lepore, 1993; Evans & Maxwell, 1997; Smith & Jones, 1992). In fact, research suggests that the specific exposure to chronic aircraft noise has a negative impact on children's backward digit span, one of the very verbal working memory tasks measured in this study (Hygge, Evans, & Bullinger, 2002). Not surprisingly, the low-income urban school that participated in the current study was in closer proximity to chronic aircraft noise than were the low-income rural schools; there were three airports located within a 10-mile radius of the low-income urban school, whereas the low-income rural schools were all located more than 50 miles from an airport. As such, it seems likely that the low-income rural participants were exposed to less chronic noise pollution, perhaps partially explaining their higher verbal working memory scores.

No work to date explores how specific aspects of the environment impact visuospatial working memory. Therefore, the explanation as to why children growing up in rural poverty exhibited particularly weak visuospatial working memory (compared with the visuospatial working memory abilities of their low-income urban peers and their own verbal working memory abilities) will need to be investigated in future research. It is, however, widely accepted that the brain exhibits plasticity and that the environment plays a key role in plasticity (Drubach, 2000). According to U.S. Census data, the environments of rural and urban areas are different in many ways, one of which is that rural environments have less everyday visual stimulation such as traffic, crowds, commercial, residential, and industrial buildings and signs, and opportunities to navigate public transportation systems (U.S. Census Bureau, 2010). Likewise, a smaller percentage of homes in rural poverty have computers and Internet access, which may provide another type of visual stimulation (U.S. Department of Commerce, 2013). Considering these differences, it seems possible that children in rural poverty do not use their visuospatial working memory as frequently as do children in urban poverty, which could hinder its development.

The fourth and final set of results suggests that living in a rural versus urban area is associated with working memory function for low-income children, but not high-income children. As previously discussed, the low-income rural and urban samples exhibited distinct working memory profiles from one another. In other words, it seems living in a rural versus urban area is associated with working memory in low-income contexts. Yet, the high-income rural and urban samples had almost identical working memory profiles to one another; both exhibited similar and

symmetrical verbal and visuospatial working memory abilities hovering around the 60th percentile. In other words, it does not seem as if living in a rural versus urban area is associated with working memory in high-income contexts. These findings are not surprising when considering recent heritability research, which suggests that environmental factors (e.g., living in rural or urban areas) account for different amounts of variance in cognitive ability for low- and high-income children. Specifically, heritability research shows that for low-income children, shared environmental factors account for the majority of variance in cognitive ability while genes account for little variance in cognitive ability (Harden, Turkheimer, & Loehlin, 2006; Turkheimer, Haley, Waldron, D'Onofrio, & Gottesman, 2003). Conversely, in high-income children, genes account for the majority of variance in cognitive ability while shared environmental factors account for little variance (Harden et al., 2006; Turkheimer et al., 2003). In accordance with these findings, the current study suggests that for low-income children, the shared environmental factor of living in either a rural or urban area was associated with working memory ability. But for high-income children, the shared environmental factor of living in a rural or urban area was not associated with working memory ability.

It is important to highlight that the participants in the current study were not randomly assigned to distinct developmental contexts. Therefore, although it may seem reasonable to interpret the findings as evidence that rural and urban poverty *influence* verbal and visuospatial working memory in different ways, one needs to be careful about making such a causal inference. It is possible that low-income parents (and in turn, children) with particularly weak verbal working memory abilities tend to seek out low-income urban areas, or on the contrary, low-income parents and children with relatively weak visuospatial working memory self-select into low-income rural areas. This alternative explanation seems unlikely considering that the opportunity for mobility of any type among low-income residents tends to be quite limited (Foulkes & Schafft, 2010). Yet, it is important to remain cautious about making causal interpretations based on quasi-experimental designs like the one used in the current study.

It is also important to note that the racial makeup of the low-income rural and urban samples was quite different, with the majority of the low-income rural sample identifying as Caucasian and the majority of the low-income urban sample identifying as a racial minority. As such, it is possible that the working memory differences between the two groups are in part a result of cultural differences associated with different racial identities. Moreover, it is possible that as racial minorities, the low-income urban sample was more likely than the low-income rural sample to experience race-based stereotype threat, which has been shown to reduce working memory capacity (Schmader & Johns, 2003).

The working memory differences between the low-income rural and urban children could also be, in part, a reflection of language ability differences that exist between the two samples. Although no extant research specifically compares the language ability of low-income rural and urban children, language ability is known to be related to working memory ability (Just & Carpenter, 1992; Moser, Fridriksson, & Healy, 2007) as well as race (Pungello, Iruka, Dotterer, Mills-Koonce, & Reznick, 2009), both of which are variables that systematically varied between the low-income rural and urban samples. Further, the working memory differences between the low-income rural and urban children could be attributed to a difference in the proportion of non-native English speakers between the two samples. Specifically, it is likely that the low-income urban sample had a larger proportion of non-native English speakers than did the low-income rural sample, as the general low-income urban population has a larger proportion

of non-native English speakers than the low-income rural population (National Center for Education Statistics, 2012). This is relevant because non-native English speakers might have found the verbal working memory tasks particularly difficult due to the fact that these tasks 1) were presented in English, and 2) are inherently language-based. In turn, non-native English speakers might have obtained lower verbal working memory scores than they would have if the tasks had been administered in their native language. As a result, the mean verbal working memory score of the low-income urban sample may underestimate the actual verbal working memory abilities of the group. Future research should explore the role that native and non-native language ability plays in working memory ability.

The current finding that children living in rural and urban poverty exhibit distinct working memory profiles has applied and research implications. First, working memory plays an integral role in most higher-level cognitive activities, including but not limited to decision-making, strategy use, processing speed, and broad attention, all of which are frequently used in everyday life (Dehn, 2008; McGrew & Woodcock, 2001; McNamara & Scott, 2001). In addition, there is a strong association between working memory and academic achievement (Gathercole, Brown, & Pickering, 2003). It is important to understand that this association is not a function of working memory acting as a proxy for IQ. Admittedly, IQ and working memory are correlated (Colom, Rebollo, Palacios, Juan-Espinosa, & Kyllonen, 2004; Jensen, 1998; Stauffer, Ree, & Carretta, 1996). However, a growing body of work shows that working memory contributes *uniquely* to academic achievement (Cain, Oakhill, & Bryant, 2004; Gathercole, Alloway, Willis, & Adams, 2006). In fact, a longitudinal study confirmed that a child's working memory in kindergarten is a better predictor of later academic success than IQ (Alloway & Alloway, 2010). Clearly, it is important to be mindful of children's working memory abilities when considering ways to foster their academic achievement.

Further, and of particular relevance to the findings of the current study, different types of academic achievement tend to utilize verbal and visuospatial working memory to different degrees. For example, a meta-analysis shows reading relies heavily on verbal working memory even when verbal IQ, reasoning, processing speed, and other cognitive abilities are factored out (Daneman & Merikle, 1996; Swanson & Jerman, 2007). However, mathematics seems to be more strongly related to visuospatial working memory than to verbal working memory (McKenzie, Bull, & Gray, 2003). Specifically, Wilson and Swanson (2001) concluded that verbal working memory can predict mathematics calculation ability, but that visuospatial working memory is a better predictor.

As such, it is possible that the specific verbal and visuospatial working memory abilities of children living in rural and urban poverty are associated with the way they process and learn tasks related to reading and mathematics. Moving forward, we need to think about ways that low-income rural and urban children can overcome their specific working memory difficulties so they can optimize their learning on these academic tasks. There are two possible ways that this could be achieved. First, we could focus on determining ways to improve verbal and/or visuospatial working memory. A handful of researchers have taken this approach, but the training programs created have been found to be ineffective at producing long-term or generalizable gains (see Melby-Lervag & Hulme, 2013). Alternative methods to optimize learning could include: 1) decreasing the verbal or visuospatial working memory demands placed on children in a classroom during a specific learning activity, or 2) thinking of ways to capitalize on their relative verbal or visuospatial working memory strengths. Now that the verbal and visuospatial

working memory profiles of children living in rural and urban poverty have been accurately established, we are in a better position to design and test targeted interventions based on local needs. In addition, the current findings serve as a general reminder to researchers to not generalize urban findings to both urban and rural populations.

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