

## Socioeconomic deprivation and the development of neuropsychological functions: A study with “street children” in Ecuador

Graham Pluck, Daniel R. Banda-Cruz, M. Victoria Andrade-Guimaraes and Ana F. Trueba

Quito Brain and Behavior Laboratory, Universidad San Francisco de Quito, Quito, Ecuador

### ABSTRACT

Socioeconomic status (SES) is known to have a considerable influence on the development of neuropsychological functions. In particular there is strong evidence for less efficient development of prefrontal-cortex-related functions in children raised in low-SES households. “Street children” are a common feature of low SES in many low- and middle-income countries, and some researchers have suggested that the unique life experiences of street children may drive their neurocognitive development. This study compares a group of 36 former street children in Quito, Ecuador with a control group of 26 never street-connected schoolchildren. All children were assessed with a range of neuropsychological tests. Although the street children group performed significantly below the level of the control group on all measures, they did not demonstrate a generalized lower ability. By controlling the effects of fluid intelligence it was found that there are relatively independent effects on visuospatial ability and executive planning ability. Furthermore, the executive function test scores in general are significantly less affected than the other cognitive functions and may be temporary effects caused by recent substance abuse within the street child sample. The findings generally support results from other countries suggesting that low SES is associated with negative effects on neuropsychological development. However, they also suggest that the local social and economic context, such as in the case of street children, might mitigate the harmful effects of low SES on the development of some executive functions.

### ARTICLE HISTORY

Received 9 February 2016  
Accepted 5 February 2017

### KEYWORDS

Child poverty; Homeless youth; Executive function; Intelligence; Socioeconomic status.

Variation in socioeconomic status (SES) is a feature of all developed societies, though with some geographical variation in degree. The link between SES and the neurocognitive function of adults is reflected in many diverse clinical observations, from the high rate of neuropsychological impairment in homeless adults (Pluck, Lee, David, Spence, & Parks, 2012) to the increased risk of dementia in adults with a low level of education (Evans et al., 1997). Indeed, SES factors can impact the performance and therefore the interpretation of neuropsychological tests in general (e.g., Scazufca, Almeida, Vallada, Tasse, & Menezes, 2009).

**CONTACT** Graham Pluck  [gpluck@usfq.edu.ec](mailto:gpluck@usfq.edu.ec)  College of Social Sciences and Humanities, Universidad San Francisco de Quito, Diego de Robles y Vía Interoceánica, Cumbayá, Ecuador

© 2017 Informa UK Limited, trading as Taylor & Francis Group

In children the effects are even more pronounced, as SES impacts the brain during periods of significant development and plasticity. As a general example, a review that considers the effects of adoption from lower- to higher-SES families (as most adoptions are) concluded that the subsequent increase in IQ score is around 12 points (Nisbett et al., 2012). Although large IQ-score disparities exist, not all neurocognitive functions are affected equally. Frontal lobe cognitive functions appear to be particularly sensitive to variation in SES, probably due to the relatively late physiological maturation of these regions compared to other brain regions (Sowell, Thompson, Holmes, Jernigan, & Toga, 1999). Indeed, it has been shown that children from low-SES families compared to higher-SES children show generally poor prefrontal function. This has been revealed with tests such as verbal fluency and trail making tests, and observations of electrophysiological brain responses equivalent to those seen in patients with damage to the lateral prefrontal cortex (Kishiyama, Boyce, Jimenez, Perry, & Knight, 2009).

The altered prefrontal function of low-SES youth in functional magnetic resonance imaging (fMRI) scans during a rule-learning task has been shown to be linked to sociocultural (complexity of parental language) and biosocial influences (cortisol levels), suggesting multifaceted effects of SES on prefrontal function development (Sheridan, Sarsour, Jutte, D'Esposito, & Boyce, 2012). This finding is supported by neuropsychological research which suggests that various factors linked to low-SES environments are associated with poor performance on putative prefrontal functions. Children in single-parent families have more difficulty with inhibition and cognitive flexibility compared to similarly low-SES children in two-parent families, and low levels of “enrichment activities” (such as the encouragement of hobbies and museum visits) are linked to poor inhibition and working memory (Sarsour et al., 2011).

The effects of lower relative to higher SES on neurocognitive development are not limited to prefrontal functions. Several studies have examined the effects of low SES on various neurocognitive systems and their results suggest that the prefrontal/executive system, the left perisylvian/language system and the parietal/spatial cognition system are most vulnerable to delayed or impaired development (Hackman & Farah, 2009; Noble, McCandliss, & Farah, 2007; Noble, Norman, & Farah, 2005).

However, one problem with measuring the effects of SES on neuropsychological development is the operationalization of SES. Within countries such as the United States (US), where the majority of research has been conducted, there is a reasonable consensus on how to establish SES. Generally SES is defined in terms of household income, education level, and occupation, and possibly includes factors related to race, availability of social support, stress and work environments (Syme, Lefkowitz, & Krimgold, 2002).

Outside of highly-developed, industrialized countries such as the US, SES disparities can be more extreme. At the lower levels of SES, with less governmental resources available, financial social support for the poorest in society may be meager or non-existent, while educational and medical services may be inaccessible or of poor quality. One notable example is that low SES in many low- and middle-income countries is associated with child labor, and this is itself inextricably linked to illiteracy and exclusion from formal education. Perhaps the most visible example of low SES in many countries is that of “street children”, which are usually defined in terms of their extended presence in urban environments unsupervised by adults, and in the context of

extreme poverty (Thomas de Benitez, 2011). They comprise a significant demographic of very low SES in many cities in Latin America, Africa and Asia. No reliable worldwide estimates of the numbers of children living this way exist, but the figure would be counted not in thousands, but in millions. Youth labeled as “street children” are not necessarily homeless—some may be, while others may work for extended periods or be in the urban environment for other reasons but have a home or family to return to.

This necessity to work and survive in dangerous environments without adult assistance has led several writers to suggest that street children in fact fare surprisingly well. This literature, derived mainly from anthropological research, suggests that the life contexts of street-connected children drive their development. For example a study of street children in Nepal found that they had better physical health indicators (height and weight) than control groups from rural areas and urban squatter camps (Panter-Brick, Todd, & Baker, 1996). This may be due to better access to money to buy food. Furthermore, this health advantage may extend to psychological development. It has been argued that street children actually show remarkable levels of resilience and may have better mental health than non-street-connected youth. For example several anthropologists have described street-connected youth as using adaptive survival skills and creative coping strategies, and even exhibiting psycho-physiological adaptation to recurrent stressful events, as suggested by normal blood cortisol levels (for a review, see Panter-Brick, 2002). One anthropologist who used an IQ test with street youth in Colombia hypothesizes that “street life, rather than taking away from cognitive growth, actually added to their problem solving skills” (Aptekar, 1988, p. 231). This suggestion of enhanced problem-solving associated with street-connectedness has recently received support from a neuropsychological study in Bolivia (Dahlman, Bäckström, Bohlin, & Frans, 2013). It was found that homeless street children compared to a control group of children that had homes performed significantly better on the Alternative Uses Test, which is thought to measure divergent thinking but also taps executive processes and fluid intelligence (Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014). Along the same lines, it has also been observed that street child vendors in Brazil develop better mathematical skills than non-working, school-attending children (Saxe, 1988). This is presumably because mathematics is essential for their day-to-day work.

In contrast, the medical literature suggests numerous reasons why the neurocognitive development of street children could be impacted negatively (Woan, Lin, & Auerswald, 2013). Being a street child is associated with high levels of physical trauma (Thomas de Benitez, 2007), psychological trauma and post-traumatic stress disorder (PTSD; Pluck, Banda-Cruz, Andrade-Guimaraes, Ricaurte-Diaz, & Borja-Alvarez, 2015) and substance abuse—particularly glue sniffing, which is common feature of street youth across the world (Woan et al., 2013). These are all associated with neuropsychological impairment. To this the observation could be added that in more-developed countries, youth homelessness has been consistently linked to poor cognitive development (Fry, Langley, & Shelton, 2016), as multiple studies in the US link low SES to poor neurocognitive development (Kishiyama et al., 2009; Noble et al., 2005, 2007).

The research literature therefore portrays opposing effects on the neuropsychological development of street-connected children, with the anthropological literature suggesting positive effects and the more medical literature suggesting generally negative effects. To address this issue, this study compares a group of children with histories of

street-connectedness with a group of children who had no history of street-connectedness. The aim is to examine the cognitive function of street children as a specific subgroup of the low-SES children found in many low- and middle-income countries. Comparisons are made of fluid intelligence, executive functions and visuospatial ability. A measure of general fluid intelligence is included to give an indication of generality of any between-group differences. Thus, we are following a previously used methodology that covaried fluid intelligence scores to indicate whether frontal lobe lesions produce true executive function impairments, or whether they can be explained more parsimoniously by reduced fluid intelligence (Roca et al., 2010). Executive function and visuospatial ability are included as they are known to be sensitive to SES indicators. Considering the suggestion that street and working life may drive or enhance neurocognitive development, it was thought that strong executive function ability may be particularly useful to street children, and thus may benefit from the supposed necessity impetus.

Based on the opposing perspectives presented above, the following hypotheses are tested: 1) being a street child is associated with reduced/enhanced neurocognitive functioning compared to a control group of children who have never been street-connected, and 2) any differences between groups are not a general effect (i.e., general fluid intelligence): some abilities may be selectively reduced/enhanced.

## Method

### Participants

A group of former street children were recruited from a charitable service in Quito, Ecuador. The service, *Su Cambio por el Cambio*, attempts to take working and homeless children from the street and reconnect them with education and their families. The service provides education, health care, and sports practice to around 300 former street children. Only those children who fulfilled the standard definition of “street child” that is frequently used in research were recruited for this study:

Any girl or boy who has not reached adulthood, for whom the street (in the widest sense of the word, including unoccupied dwellings, wasteland, etc.) has become her or his habitual abode and/or sources of livelihood, and who is inadequately protected, supervised or directed by responsible adults. (Treanor, 1994, pp. 88–89, citing Inter-Non Governmental Organisations, Geneva, 1983)

The psychologist at the project selected a convenience sample of 40 children who had on entering the program unequivocally fulfilled the definition. Although around 300 children use the service, the past histories of many are unclear; they are accepted based on being “at risk” due to poverty. The 40 children who participated in this study were selected by the resident psychologist because she knew the details of their histories and felt confident that they had fulfilled the definition stated above. There is no record of how many others would also have fulfilled the criteria, as she stopped searching when the target sample of 40 was identified. It should be therefore recognized that the sample may be biased toward children for whom clear background histories were available. The other inclusion criteria includes speaking Spanish as a daily language, no known perceptual or motor disabilities, and having legal guardians available to be contacted to provide consent. Of the 40 identified, 37 were recruited; the other 3 who had previously been identified as potential participants were not recruited because they

were absent from the program on the days on which the tests were conducted. The age range of the final recruited sample was 10.7 years to 16.2 years, and the majority are male ( $n = 28$ , 75.7%).

A majority of the street children had been street workers ( $n = 21$ , 56.8%), for example shining shoes or selling candies in Quito. Termination of work is a general requirement of entry to the educational program and children are supposed to attend five days per week, thus keeping them away from the urban environment. For this reason the sample is described as consisting of “former street children”. Nevertheless, five participants (13.51%) were current street children at the time of the study due to their continued involvement with street work. One child was identified as a refugee from the conflict in neighboring Colombia, one was an orphan, and a further seven had been abandoned by their parents. Nevertheless, the majority ( $n = 26$ , 70%) were living with at least one parent and the rest with members of their extended families. Self-reported past substance abuse was relatively low; the most commonly reported type of substance abuse was glue sniffing, described by seven participants (19%). However, five participants (14%) reported some form of illicit substance abuse within the past two weeks.

The control group is comprised of a sample of 26 children that were recruited from a state-run school in Quito. The recruitment process was essentially the same as that used with the street children and had the same inclusion and exclusion criteria, with the exception that the control sample were additionally screened to ensure that none of them had a history that would fulfill the definition of “street child” (past or present). The group was selected to match the street children for age and sex. Due to the socioeconomic nature implied by fulfilling or not fulfilling the definition of “street child”, it is not possible to confidently match the street children and control groups on SES. Therefore, the street group represents a particular subgroup of low-SES children who are being compared to a control group of relatively higher SES. For this reason the analyses focus on the differential patterns of performance rather than simple between-group differences.

The demographic details of the two groups are shown in Table 1. The only statistically-significant difference between the groups is ethnicity. There are significantly more children of indigenous or Afro-Ecuadorian descent in the street group ( $\chi^2 = 4.795$ ,  $p = .029$ ). This is consistent with the fact that ethnic minorities in Ecuador are over-represented in the street child population.

### Assessments

The Matrix Reasoning task of the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) was used to assess general fluid ability. This is similar to other matrix-reasoning tasks, and this type of task is generally considered to be the best measure of general fluid intelligence. The WASI is a validated measure for use with children aged 6

**Table 1.** Demographic Features of the Street and Control Groups.

	Street ( $n = 37$ )	Control ( $n = 26$ )
Age (years), $M$ ( $SD$ )	13.54 (1.62)	13.99 (1.54)
Female	9 (24.3%)	11 (42.3%)
Ethnicity		
Indigenous American	2 (5.4%)	0 (0%)
Mestizo	28 (78.7%)	25 (96.2%)
Afro-Ecuadorian	7 (18.9%)	1 (3.9%)

years and up. For the assessment of visuospatial ability, the Block Design task of the WASI was used. The Block Design task, like the Matrix Reasoning task, loads highly on psychometric *g* (Wechsler, 1999). However, factor-analytic studies suggest that while matrix reasoning measures fluid ability, block design is better considered as a measure of visuospatial ability (Keith, Fine, Taub, Reynolds, & Kranzler, 2006).

Assessment of executive function was performed with two tasks selected from the Delis–Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001)—the Tower task and Design Fluency. The D-KEFS has been widely assessed for reliability and validity, and is appropriate for use with children as young as 8 years of age. The D-KEFS Tower task is a version of the classic test of planning also known as the Towers of Hanoi. It involves moving wooden disks held on pegs from a start configuration to a target configuration and is thought to primarily tap the planning and working memory processes of the frontal lobes (Goel & Grafman, 1995). In this research the total achievement score is focused on, which is based on awarding points for the number of moves taken to complete the task within the time limit. The time-per-move ratio, which gives a measure of activation and speed of responding, is also examined. Both of these measures have been shown to be highly sensitive to lateral prefrontal damage (Yochim, Baldo, Kane, & Delis, 2009).

The second assessment from the D-KEFS is the Design Fluency task. This involves the joining of dots on a page to produce meaningless patterns. It is considered a language-free equivalent of the classic verbal fluency tasks that involves naming. The D-KEFS Design Fluency task involves performance under three conditions designed to distinguish three different cognitive processes: initiation (the standard performance of joining dots with four lines), inhibition (joining only white dots after having previously focused on black dots), and switching (alternately joining black and white dots). Adult neuropsychological studies suggest that performance is dependent on the integrity of the frontal cortex (Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001).

Finally, as substance abuse is generally observed to be at raised levels in street child populations (Woan et al., 2013), all children in the street group were interviewed about recent substance abuse and whether or not they had ever used a range of commonly abused substances. It was of particular interest to account for recent substance use (i.e., in the past fortnight), as this can have an acute influence on cognitive test performance.

### *Procedure*

Prior to the data collection, the legal guardians were contacted to provide written informed consent for each child. The children also provided written assent, in accordance with the ethics committee approved protocol. All the children in the street group were individually assessed on the site of the educational program. The children in the control group were individually assessed at their school. In both groups the interviews were conducted in private, quiet rooms. The sequence of cognitive assessments was the same for both groups; first the Block Design and Matrix Reasoning tasks were administered, then the D-KEFS executive function tests. At the end of cognitive testing, each child was verbally debriefed and offered a choice of gifts as compensation (pencil cases and stationery, approximate value US\$5).

The data reported here are part of a larger study that includes the assessment of intellectual function and PTSD in the same sample of street children (Pluck et al., 2015).

### Statistical Analyses

Group mean scores of raw data were calculated for all neuropsychological measures. The normality of the distributions were confirmed with Kolmogorov–Smirnov tests. Where data were significantly non-normally distributed, they were transformed based on Tukey’s ladder of transformations. As age correlates strongly with cognitive performance producing statistical associations between variables due to participant maturation, it was used as a covariate in all analysis of variance (ANOVA) calculations on neuropsychological scores. All calculations are two-tailed with a critical value of .05. Cohen’s *d* was used to estimate effect sizes on the main between-group comparisons (Cohen, 1992). Calculations were performed with SPSS v21 (IBM Corp, 2012).

### Results

Prior to the main analyses, the internal consistency of the different cognitive tests was examined. All of the cognitive assessments employed in this research are subtests from either the WASI or the D-KEFS. In both of these tests, the developers have assessed internal consistency in their own reliability and validity studies, with split-half reliability based on the comparison of odd or even numbered items. Reliability was then estimated using the Spearman–Brown procedure. The same approach was used in this study so that the internal consistency estimates generated could be compared to the results from the normative samples. For the Matrix Reasoning task, the reliability coefficients are high for both the street and control groups, .935 and .899, respectively, compared to .920 for the WASI normative youth sample. Similarly high coefficients were found with the Block Design task, with .842 for the street group and .858 for the control group, which are slightly lower than the coefficient of .900 reported in the WASI manual. For the Towers task, the coefficients of this study are somewhat lower: .662 for the street group and .623 for the control group. Although lower than what would normally be considered “good” internal consistency, these are actually slightly higher than those reported in the D-KEFS manual, which describes coefficients averaging only .607 in the normative sample of the same age range. For the Design Fluency task there is only one trial in each condition, so there is no internal consistency issue.

The mean raw scores on the neuropsychological measures are shown in Table 2. On all measures, the street group scored significantly below the level of the control group. Compared to the control group, the street group scored significantly lower on both the Matrix Reasoning,  $F(1, 60) = 68.313, p < .001$ , and Block Design,  $F(1, 60) = 77.545, p < .001$ , tasks. Similarly on the measures of the Tower task, the street group achieved significantly lower total achievement scores,  $F(1, 60) = 22.163, p < .001$ , and spent longer on the task based on the time-per-move ratio,  $F(1, 60) = 12.874, p = .001$ , compared to the control group.

Regarding the Design Fluency task, the street group produced significantly fewer designs than the control group in each of the conditions: initiation,  $F(1, 60) = 10.299, p = .002$ , inhibition,  $F(1, 60) = 11.870, p = .001$ , and switching,  $F(1, 60) = 11.381,$

**Table 2.** Mean (*SD*) Scores of the Street and Control Groups on the Different Neuropsychological Measures.

	Street	Control	Effect size ( <i>d</i> )
Matrix Reasoning	9.46 (5.41)	23.46 (4.73)	1.63
Block Design	14.08 (9.68)	42.04 (13.39)	1.56
Tower	Total achievement score 12.00 (4.71)	17.08 (3.06)	1.06
	Time-per-move ratio (s) 6.22 (5.98)	3.21 (1.35)	0.62
Design Fluency	Initiation 6.03 (3.38)	8.62 (2.52)	0.79
	Inhibition 7.30 (3.57)	10.19 (2.25)	0.86
	Switching 5.22 (4.24)	8.77 (3.33)	0.84

$p = .001$ . A mixed-model ANOVA was used to examine the possible interactions between the Design Fluency task type and group, with task type as the within-subjects factor and group as the between-subjects factor. There is a significant main effect of group,  $F(1, 60) = 16.941$ ,  $p < .001$ , but no significant main effect of task type,  $F(1, 60) = 1.617$ ,  $p = .203$ , nor a task  $\times$  group interaction,  $F(2, 60) = 0.477$ ,  $p = .622$ . This confirms that the children in the street group drew less designs in general than those in the control group, but the type of design fluency task did not have an effect.

Therefore the results show that the street group performed significantly worse than the control group on various measures of fluid intelligence (Matrix Reasoning), visuospatial ability (Block Design), and executive function (Tower and Design Fluency tasks). Nevertheless, it remains unclear whether there really is reduced executive and visuospatial ability per se, or whether poorer performance on both types of task simply reflects the lower general fluid ability of the street group. To address this issue, all of the above analyses on the Block Design, Tower and Design Fluency tasks were repeated with the fluid intelligence Matrix Reasoning scores included as a covariate. This revealed that the poor performance of the street group on the Block Design task cannot be explained by generally lower fluid intelligence, as the between-group performance difference remains significant,  $F(1, 59) = 17.806$ ,  $p < .001$ . Similarly, with the Tower task, even with Matrix Reasoning scores entered as a covariate, the street group still achieved significantly lower overall achievement scores,  $F(1, 59) = 4.605$ ,  $p < .036$ , and responded more slowly, as shown by higher time-per-move ratios, than the control group,  $F(1, 59) = 4.255$ ,  $p = .044$ . Overall, the results of the covariance with the Matrix Reasoning scores suggest that between-group differences in the Block Design and Tower performance are not due to fluid intelligence differences.

In contrast, it appears that the street group's poorer performance relative to control group on the Design Fluency task can be fully explained by a fluid intelligence difference between the groups. When the Matrix Reasoning scores are covaried, the between-group differences are no longer significant for the design fluency initiation condition,  $F(1, 59) = 0.766$ ,  $p = .385$ , the inhibition condition,  $F(1, 59) = 0.220$ ,  $p = .641$ , or the switching condition,  $F(1, 59) = 2.195$ ,  $p = .144$ .

As shown in Table 2, the significant between-group differences for the various cognitive tasks are all qualitatively "large" effect sizes (i.e.,  $d > 0.80$ ), except for the Tower task time-per-move ratio ( $d = 0.62$ ) and the Design Fluency initiation condition ( $d = 0.79$ ), both of which are qualitatively "medium" effect sizes (i.e.,  $d > 0.50$ ). The largest effect sizes are for Matrix Reasoning ( $d = 1.63$ ) and Block Design ( $d = 1.56$ ). The large differences in the effect sizes appear to show that some cognitive functions were affected more in the child group (compared to the control group) than others. To test

this, all data points for the neuropsychological measures were converted to  $z$  scores and then a repeated measures ANOVA was performed with task type as the within-subjects variable and group as the between-subjects variable. The Tower task time-per-move ratio was not entered, as it is not independent of the Tower task total achievement scores. The Matrix Reasoning scores as a measure of general intelligence were entered but the contrast was not calculated in order to maintain the degrees of freedom. The task  $\times$  group interaction confirmed that some cognitive scores are disproportionately different between groups,  $F(5, 295) = 3.786, p = .002$ . Deviation contrasts revealed that the Block Design task,  $F(1, 59) = 10.350, p = .002$ , is significantly more affected in the street group compared to their overall cognitive performance. None of the contrasts for the Design Fluency or Tower task performance showed significant task  $\times$  group effects.

To examine the possible influence of education on the street group, correlation coefficients were calculated based on the bivariate pairs of the various cognitive measures with the number of months that each child had attended the educational program. Partial correlations were used to control for the effect of age. Most of the cognitive variables show no significant correlation with time spent in the program, all  $ps > .130$ . The one exception is a significant positive correlation with the Design Fluency switching task,  $r = .401, p = .017$ , suggesting a better performance in those with the longest periods of attendance.

As street child populations are frequently associated with substance abuse, it is possible that this was a relevant factor in these associations. The control children were not asked about substance abuse because they were not considered to be at risk. However, data were collected on the street children. In general, reported drug abuse was fairly low, with only five children reporting substance abuse in the past two weeks. To examine whether these could have biased the results, the between-group comparisons and correlations were repeated with the five children who reported recent substance abuse excluded. The results reported above as either significant or not significant were not altered, with two exceptions. The previous significant difference between the groups on the Towers task (when the Matrix Reasoning scores were covaried) is no longer significant,  $F(1, 54) = 3.385, p = .071$ . The other exception is the correlation between the Design Fluency switching task and the time spent in the educational program, which is also no longer significant,  $r = .322, p = .083$ .

Finally, the effect of gender on cognitive performance was examined, and no significant differences were found between the scores of males and females in either group.

## Discussion

The current research used a similar methodology to that used in previous studies that compared a low-SES group of children to a group that has a relatively higher SES (e.g., Farah et al., 2006; Kishiyama et al., 2009; Noble et al., 2005). However, this study examines a particular subgroup of very low SES found in many low- and middle-income countries: street children. In addition, the extent to which the observed neuropsychological score discrepancies can be explained by general fluid intelligence effects is also examined. In this respect, the methodology used is similar to that used in a study that examined frontal lobe injuries in adults and revealed that apparent

impairments on common tests such as the Wisconsin Card Sort test of the Iowa Gambling task can be fully explained by reduced fluid intelligence (Roca et al., 2010).

The current research uses the Matrix Reasoning task of the WASI, which is considered a strong measure of general fluid intelligence (Wechsler, 1999). The concept of fluid intelligence has received a great deal of attention within the field of neuropsychology, as its role in novel and online problem-solving is similar to that of several supposed executive functions. Traditionally it has been considered that intelligence as measured by IQ tests is independent of executive functions as it is not particularly dependent on the prefrontal cortex (e.g., see Shallice & Burgess, 1991). However, when measures of fluid intelligence are used there are clear impairments related to prefrontal lesions (Duncan, Burgess, & Emslie, 1995). Nevertheless, several executive “frontal lobe” functions dissociate from fluid intelligence after frontal lobe lesions (Roca et al., 2010), suggesting that fluid intelligence and executive function tests are not necessarily measuring the same construct.

A question remains though as to whether or not fluid intelligence as measured in the contexts in which the concept was developed (i.e., developed Western countries) is still a valid construct when evaluated in individuals with very different life contexts, such as street children. This is a difficult issue to address without significant further research, but it could be argued that fluid intelligence—as a pervasive cognitive ability impinging on many cognitive processes—may be a basic and invariant feature of human brain functioning. In the current research it was found that the Matrix Reasoning tasks have an internal consistency that is equivalent to the normative sample of the test manufacturer, suggesting that it is measuring the same latent construct which is assumed to be fluid intelligence. There is also some evidence of the predictive validity of the Matrix Reasoning task in that the same test has been shown to correlate reasonably well with academic school performance ( $r = .41$ ) in children living in homeless shelters in the US (LaFavor, 2012).

The present results suggest that street children have reduced levels of general fluid intelligence as well as more specific weaknesses in visuospatial and executive function performance when compared to non-street-connected children. These results are broadly consistent with previous research which has shown similar associations with low-SES children in the US (Kishiyama et al., 2009; Noble et al., 2005, 2007). Furthermore, the differences observed are not explainable as being simply due to lower fluid intelligence in the street group. Although, there are no between-group differences on the Design Fluency tasks when covarying fluid intelligence, the differences for the Tower task and the Block Design task remain. This suggests that although fluid intelligence is affected by SES, certain executive functions and visuospatial ability are affected relatively independently of it. It should be noted however that when the street children who reported recent substance abuse are excluded from the sample, the total achievement score on the Towers task is no longer significantly different between groups (when covarying fluid intelligence). This suggests that although there is an executive planning impairment that appears to be independent of fluid intelligence, its occurrence is at least partly related to substance abuse within the street group. It seems possible therefore that substance abuse within the street group is one of the underlying causes of the between-group differences on neuropsychological function. Nevertheless, substance abuse is clearly only one of several background variables that differ between the groups and

which could have affected neuropsychological development, among other factors such as access to education and medical care, trauma exposure, diet, and so forth.

It is also observed that visuospatial ability was affected to a similar extent as fluid intelligence, and that both are significantly more affected by the SES disparity than the tests considered to measure executive functions. In this respect the present results differ from some of those reported from the US, which have suggested that the development of visuospatial abilities is not affected by low SES (Farah et al., 2006; Noble et al., 2005). However, one study by the same research group found that in a sample of young children, SES accounts for 17% of the variance in visuospatial test scores (Noble et al., 2007), suggesting that visuospatial ability is indeed sensitive to SES.

Summarizing the results, there is evidence to suggest that low SES in childhood, in the form of street-connectedness, is linked to poorer development of fluid intelligence, executive functions and visuospatial ability. The results support the first hypothesis that lower SES in the context of youth street-connectedness is indeed associated with poorer neuropsychological test performance. The second hypothesis, that group differences are not simply a general effect caused by global cognitive impairment, can also be accepted. Clear evidence has been found that executive functions and visuospatial ability are associated with street-connectedness independently of a fluid intelligence difference between the street and control groups. Interestingly, lower fluid intelligence and visuospatial ability are associated with the street group significantly more than executive functions.

These results therefore in part support the suggestion that the challenges of street-connectedness may have some role in building problem-solving skills. In this case, the executive functions measured by the Tower and Design Fluency tasks seem to be relatively preserved compared with performance on other cognitive tasks. Furthermore, when fluid intelligence differences or recent substance abuse are taken into account, there are no significant differences on the executive function measures between the street and control groups. Similarly, Dahlman et al. (2013) have reported that performance on a fluency task, the Alternative Uses Test, was significantly better in a sample of homeless street children than in a control group of similarly poor but never homeless children. In addition, they found no significant differences on a range of other cognitive tests, including of general intelligence. The present findings add to those of Dahlman et al., suggesting that street-connectedness might have a positive influence on the development of executive ability, albeit in the context of generally poorer neuropsychological development.

The street group is not compared with an SES-matched non-street-connected group; instead, it is treated as being representative of a particular low-SES demographic and compared with participants from a group who are of higher SES. Although it would be interesting to compare matched SES groups, the very nature of street-connectedness and its intimate connection to extreme poverty means that it is debatable whether matching SES status while still varying street-connectedness status is really possible. In addition, the SES of the families of the individual participants was not empirically measured, a limitation that could not be practically avoided because there was no opportunity to acquire data on SES from the participants' families or guardians.

Furthermore, all of the children in the street group had a family member or legal guardian who could provide research participation consent, and all were attending a daily program. They may therefore represent a subset of street children who are less vulnerable and perhaps

less traumatized. In addition, children who enter such a program for street children may be higher functioning than those who do not, and may benefit cognitively due to their attendance. Mild support for this is provided by the observed positive correlation between time spent attending the program and higher scores on the Design Fluency switching task. Consequently, the sample of street children used in this study may be somewhat unrepresentative of the wider population of street-connected youth.

Nevertheless, the current findings are interesting because they broadly replicate research from other countries that have shown poorer development of executive functions, visuospatial and verbal ability to be associated with low SES. At the same time, they extend the findings beyond the context of high-income countries, suggesting that the local social and economic context may be an important moderating effect that influences which neurocognitive functions are most impacted by low SES. In particular, they add to the hypothesis that the type of adversity experienced may in some cases mitigate the harmful effects of low SES on the development of executive functions.

## Disclosure Statement

No potential conflict of interest was reported by the authors.

## References

- Aptekar, L. (1988). Street children of Colombia. *The Journal of Early Adolescence*, 8, 225–241. doi:10.1177/0272431688083002
- Baldo, J. V., Shimamura, A. P., Delis, D. C., Kramer, J., & Kaplan, E. (2001). Verbal and design fluency in patients with frontal lobe lesions. *Journal of the International Neuropsychological Society*, 7(5), 586–596. doi:10.1017/S1355617701755063
- Benedek, M., Jauk, E., Sommer, M., Arendasy, M., & Neubauer, A. C. (2014). Intelligence, creativity, and cognitive control: The common and differential involvement of executive functions in intelligence and creativity. *Intelligence*, 46, 73–83. doi:10.1016/j.intell.2014.05.007
- Cohen, J. (1992). A power primer. *Psychological Bulletin*, 112(1), 155–159. doi:10.1037/0033-2909.112.1.155
- Dahlman, S., Bäckström, P., Bohlin, G., & Frans, Ö. (2013). Cognitive abilities of street children: Low-SES Bolivian boys with and without experience of living in the street. *Child Neuropsychology*, 19(5), 540–556. doi:10.1080/09297049.2012.731499
- Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan Executive Function System*. San Antonio, TX: Psychological Corporation.
- Duncan, J., Burgess, P., & Emslie, H. (1995). Fluid intelligence after frontal lobe lesions. *Neuropsychologia*, 33(3), 261–268. doi:10.1016/0028-3932(94)00124-8
- Evans, D. A., Hebert, L. E., Beckett, L. A., Scherr, P. A., Albert, M. S., Chown, M. J., . . . Taylor, J. O. (1997). Education and other measures of socioeconomic status and risk of incident Alzheimer disease in a defined population of older persons. *Archives of Neurology*, 54(11), 1399–1405. doi:10.1001/archneur.1997.00550230066019
- Farah, M. J., Shera, D. M., Savage, J. H., Betancourt, L., Giannetta, J. M., Brodsky, N. L., . . . Hurt, H. (2006). Childhood poverty: Specific associations with neurocognitive development. *Brain Research*, 1110(1), 166–174. doi:10.1016/j.brainres.2006.06.072
- Fry, C. E., Langley, K., & Shelton, K. H. (2016). A systematic review of cognitive functioning among young people who have experienced homelessness, foster care, or poverty. *Child Neuropsychology*, 1–28. doi:10.1080/09297049.2016.1207758
- Goel, V., & Grafman, J. (1995). Are the frontal lobes implicated in “planning” functions? Interpreting data from the Tower of Hanoi. *Neuropsychologia*, 33(5), 623–642. doi:10.1016/0028-3932(95)90866-P

- Hackman, D. A., & Farah, M. J. (2009). Socioeconomic status and the developing brain. *Trends in Cognitive Sciences*, 13(2), 65–73. doi:10.1016/j.tics.2008.11.003
- IBM Corp Released (2012). IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.
- Keith, T. Z., Fine, J. G., Taub, G. E., Reynolds, M. R., & Kranzler, J. H. (2006). Higher order, multisample, confirmatory factor analysis of the Wechsler Intelligence Scale for Children – Fourth Edition: What does it measure? *School Psychology Review*, 35(1), 108–127.
- Kishiyama, M. M., Boyce, W. T., Jimenez, A. M., Perry, L. M., & Knight, R. T. (2009). Socioeconomic disparities affect prefrontal function in children. *Journal of Cognitive Neuroscience*, 21(6), 1106–1115. doi:10.1162/jocn.2009.21101
- LaFavor, T. L. (2012). *The impact of executive function and emotional control and understanding on the behavioral functioning and academic achievement of children living in emergency homeless shelters* (Doctoral dissertation). Minneapolis, MN: University of Minnesota.
- Nisbett, R. E., Aronson, J., Blair, C., Dickens, W., Flynn, J., Halpern, D. F., & Turkheimer, E. (2012). Intelligence: New findings and theoretical developments. *American Psychologist*, 67(2), 130–159. doi:10.1037/a0026699
- Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science*, 10(4), 464–480. doi:10.1111/j.1467-7687.2007.00600.x
- Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science*, 8(1), 74–87. doi:10.1111/j.1467-7687.2005.00394.x
- Panther-Brick, C. (2002). Street children, human-rights and public health: A critique and future directions. *Annual Review of Anthropology*, 31, 147–171. doi:10.1146/annurev.anthro.31.040402.085359
- Panther-Brick, C., Todd, A., & Baker, R. (1996). Growth status of homeless Nepali boys: Do they differ from rural and urban controls? *Social Science & Medicine*, 43(4), 441–451. doi:10.1016/0277-9536(95)00410-6
- Pluck, G., Banda-Cruz, D. R., Andrade-Guimaraes, M. V., Ricaurte-Diaz, S., & Borja-Alvarez, T. (2015). Post-traumatic stress disorder and intellectual function of socioeconomically deprived “street children” in Quito, Ecuador. *International Journal of Mental Health and Addiction*, 13, 215–224. doi:10.1007/s11469-014-9523-0
- Pluck, G., Lee, K. H., David, R., Spence, S. A., & Parks, R. W. (2012). Neuropsychological and cognitive performance of homeless adults. *Canadian Journal of Behavioural Science*, 44, 9–15. doi:10.1037/a0025382
- Roca, M., Parr, A., Thompson, R., Woolgar, A., Torralva, T., Antoun, N., ... Duncan, J. (2010). Executive function and fluid intelligence after frontal lobe lesions. *Brain*, 133(1), 234–247. doi:10.1093/brain/awp269
- Sarsour, K., Sheridan, M., Jutte, D., Nuru-Jeter, A., Hinshaw, S., & Boyce, W. T. (2011). Family socioeconomic status and child executive functions: The roles of language, home environment, and single parenthood. *Journal of the International Neuropsychological Society*, 17(1), 120–132. doi:10.1017/S1355617710001335
- Saxe, G. B. (1988). The mathematics of child street vendors. *Child Development*, 59, 1415–1425. doi:10.2307/1130503
- Sczufca, M., Almeida, O. P., Vallada, H. P., Tasse, W. A., & Menezes, P. R. (2009). Limitations of the Mini-Mental State Examination for screening dementia in a community with low socioeconomic status: Results from the Sao Paulo Ageing & Health Study. *European Archives of Psychiatry and Clinical Neurosciences*, 259(1), 8–15. doi:10.1007/s00406-008-0827-6
- Shallice, T., & Burgess, P. W. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain*, 114(2), 727–741. doi:10.1093/brain/114.2.727
- Sheridan, M. A., Sarsour, K., Jutte, D., D’Esposito, M., & Boyce, W. T. (2012). The impact of social disparity on prefrontal function in childhood. *Plos One*, 7(4), e35744. doi:10.1371/journal.pone.0035744

- Sowell, E. R., Thompson, P. M., Holmes, C. J., Jernigan, T. L., & Toga, A. W. (1999). In vivo evidence for post-adolescent brain maturation in frontal and striatal regions. *Nature Neuroscience*, 2(10), 859–861. doi:[10.1038/13154](https://doi.org/10.1038/13154)
- Syme, S. L., Lefkowitz, B., & Krimgold, B. K. (2002). Incorporating socioeconomic factors into U. S. health policy: Addressing the barriers. *Health Affairs*, 21(2), 113–118. doi:[10.1377/hlthaff.21.2.113](https://doi.org/10.1377/hlthaff.21.2.113)
- Thomas de Benitez, S. (2007). *State of the world's street children: Violence*. London, UK: Consortium for Street Children.
- Thomas de Benitez, S. (2011). *State of the world's street children: Research*. London, UK: Consortium for Street Children.
- Treanor, T. J. (1994). Relief for Mandela's children: Street children and the law in the new South Africa. *Fordham Law Review*, 63(3), 883–925.
- Wechsler, D. (1999). *The Wechsler Abbreviated Scale of Intelligence: Manual*. San Antonio, TX: The Psychological Corporation.
- Woan, J., Lin, J., & Auerswald, C. (2013). The health status of street children and youth in low- and middle-income countries: A systematic review of the literature. *Journal of Adolescent Health*, 53(3), 314–321.e12. doi:[10.1016/j.jadohealth.2013.03.013](https://doi.org/10.1016/j.jadohealth.2013.03.013)
- Yochim, B. P., Baldo, J. V., Kane, K. D., & Delis, D. C. (2009). D-KEFS Tower Test performance in patients with lateral prefrontal cortex lesions: The importance of error monitoring. *Journal of Clinical and Experimental Neuropsychology*, 31(6), 658–663. doi:[10.1080/13803390802448669](https://doi.org/10.1080/13803390802448669)