

# Working for the future: parentally deprived Nigerian Children have enhanced working memory ability

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**Background:** The dominant view based on the deficit model of developmental psychopathology is that early adverse rearing impairs cognition. In contrast, an emerging evolutionary–developmental model argues that individuals exposed to early-life stress may have improved cognitive abilities that are adapted to harsh environments. We set out to test this hypothesis by examining cognitive functions in parentally deprived children in Nigeria. **Methods:** Cognitive performance was compared between 53 deprived children who currently live in institutional homes and foster families and 51 nondeprived control participants. We used a multifaceted neurocognitive test battery for the assessment of inhibition, set-shifting and working memory. **Results:** Results showed that the deprived and nondeprived group did not significantly differ in their performance on set-shifting and inhibition tasks. Conversely, the deprived group performed significantly better than the nondeprived group in the working memory task. **Discussion:** We interpret the enhanced working memory ability of the deprived group as a correlate of its ecological relevance. In Nigeria, underprivileged children may need to rely to a larger extent on working memory abilities to attain success through academic work. This study provides further evidence that exposure to early adversity does not necessarily impair cognitive functions but can even enhance it under some conditions and in some domains. **Keywords:** Deprivation; adverse rearing; cognition; executive functions; inhibition; set-shifting; working memory.

## Introduction

### *Background of the study*

Early parental deprivation has been associated with enduring impairment in cognitive abilities (Merz, Harlé, Noble, & McCall, 2016). Many children who live in institutional homes (e.g. orphanages) or foster family homes have been exposed to (mental) health risks (e.g. poor prenatal and postnatal care, frequent caregiver transitions) at an early time of their life (Merz et al., 2016). These factors may compromise brain development and result in cognitive and behavioural difficulties later on. Both institutionalization and foster care are common in Nigeria, as high poverty rate and high teenage pregnancy rates have led to an increase in the number of children who cannot grow up with their biological parents (Eseadi, Onwuasonya, Ugwuanyi, Ugwu, & Achagh, 2015). Here, we examine, for the first time, whether Nigerian children raised under such adverse condition show cognitive deficits in one or multiple domains of executive functioning.

### *Prevailing models of early adversity on cognitive development*

The traditional view is that early-life adversity, in general, causes cognitive impairment (Ellis, Bianchi, Griskevicius, & Frankenhuis, 2017; Frankenhuis & de Weerth, 2013). This is because children who grew

up in stressful environments have shown reduced performance in standard tests of intelligence, memory, inhibition and other general cognitive abilities (Frankenhuis & de Weerth, 2013). This approach has also established neurobiological pathways through which early-life adversity disrupts cognitive and mental functioning. Principally, the absence of attachment figures, low caregiver's sensitivity or frequent changes in caregiving undermines prefrontal development through dysregulated stress physiology (Merz et al., 2016). This approach suggests that acts of neglect, deprivation or abuse early in life may lead to elevated stress hormone levels that adversely affect the development of the hypothalamic–pituitary–adrenal pathway (HPA; Hostinar, Stelern, Schaefer, Carlson, & Gunnar, 2012). Through abnormal HPA functioning, chronic stress compromises neural structures and functions, including those cognitive functions which are supported by the prefrontal cortex (Arnsten, 2009; McEwen & Morrison, 2013). This evidence has led to intervention studies (e.g. Diamond & Lee, 2011) aimed at preventing, reducing and repairing the damage related to early-life adversity.

On the other hand, the evolutionary–developmental model argues that the assumptions of the deficit model are incomplete. It assumes that childhood adversity or chronic stress may shape cognitive processes to become specifically adapted to stressful environments (Ellis et al., 2017; Frankenhuis & de Weerth, 2013; Mittal, Griskevicius, Simpson, Sung, & Young, 2015; Young, Griskevicius, Simpson, Waters & Mittal, 2018). In other words, harsh or

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unpredictable environments do not necessarily impair cognitive processes, but children's cognition becomes developmentally adapted to solving problems that may be ecologically relevant in such environments. For example, people who grow up in harsh and unpredictable environments may prefer immediate rewards over long-term rewards (Brezina, Tekin, & Topalli, 2009), a preference which evolutionists view as maladaptive in a predictable environment but adaptive in an unpredictable environment (Mittal et al., 2015). In addition, people reared in stressful environments may also benefit from enhanced cognitive abilities when these abilities are probed under stressful conditions (Mittal et al., 2015; Young et al., 2018). Taken together, these recent findings make a compelling case that while early-life adversity may relate to a variety of mental health risks, it can also provide adaptive skills that can enhance some cognitive functions under specific conditions.

### *Executive functions in postinstitutionalized and adopted children*

A cognitive domain that is likely to be particularly sensitive to early-life adversity are the executive functions. Executive functions are higher-level cognitive processes that enable adaptive, goal-directed behaviour by exerting control over lower-level functions (Diamond, 2013). Executive functioning is commonly conceptualized as a multifaceted construct consisting of three key overlapping cognitive processes: inhibition, set-shifting and working memory (Miyake et al., 2000). Efficient executive functioning is believed to depend on the integrity of the frontal cortical areas of the brain (Alvarez & Emory, 2006; Collette, Hogge, Salmon, & Van der Linden, 2006).

Behavioural studies have shown that institutionalized and foster children have reduced performance in these domains of executive functioning. For example, some studies have shown that postinstitutionalized children perform worse than children who grew up with their biological parents in simple inhibition tasks, which assess the ability to override dominant responses (e.g. in a go/no-go task, Eigsti, Weitzman, Schuh, De Marchena, & Casey, 2011, and a Stop Signal task, McDermott, Westerlund, Zeanah, Nelson, & Fox, 2012). Performance deficits have also been found on more complex inhibition tasks, which require the ability to suppress interference (e.g. on a Stroop task, Colvert et al., 2008, flanker tasks, Loman et al., 2012; McDermott et al., 2012, and a knock and tap, Pollak et al., 2010). In set-shifting tasks, there have been mixed findings on the neurodevelopmental effects of early parental deprivation. Some studies that used the Wisconsin Card Sorting Test (Bauer, Hanson, Pierson, Davidson, & Pollak, 2009) and other set-shifting tasks (Hanson et al., 2013; Hostinar et al., 2012) found

reduced performance in institutionalized or adopted children, while Pollak et al. (2010) did not find such an association. With regard to working memory functioning, several studies have found that children reared in orphanage homes have greater difficulty compared to nonadapted children on spatial working memory tasks (Bauer et al., 2009; Bos, Fox, Zeanah, & Nelson, 2009; Hanson et al., 2013; Hostinar et al., 2012; Pollak et al., 2010). Taken together, these studies suggest that early parental deprivation has lasting adverse effects on executive functioning.

### *Current study*

Drawing upon the theoretical frameworks of both deficit and evolutionary models of early childhood adversity, we conducted an exploratory study to examine executive functioning in parentally deprived (i.e. institutionalized and fostered) children in Nigeria. Depending on the age of placement in the institutions or foster homes, these deprived children in Nigeria are at increased risk of having experienced extreme poverty, maternal malnutrition (during pregnancy), severe neighbourhood stress and parental death. Placement in institutions or foster homes is often motivated by these risk factors, yet some deprivation-related stress (e.g. inconsistent caregiving, neglect, chronic uncertainty) still persists after placement. In the current study, we examined whether early placement in institutions or foster homes is related to alterations in executive functioning. To assess potential domain-specific changes, we employed a test battery covering the three basic factors of executive functioning (i.e. inhibition, set-shifting and working memory) established by Miyake et al. (2000). By this means, we aimed to examine whether deprivation-related cognitive changes reported in Western samples generalize to the Nigerian context and to contribute to a nuanced understanding of the cognitive profile of parentally deprived children.

## **Methods**

### *Participants*

A total of 104 participants between the ages 9–18 years were recruited for the study. The group of deprived children consisted of 12 institutionalized children who were being reared in a local orphanage home during the time of the study and 41 children in foster care recruited from five high schools in the Enugu State, Nigeria. The most common cause for a child's placement in Nigerian institutions is birth from teenage girls who give up their child to the institution almost immediately after childbirth. On the contrary, placement in foster care is primarily driven by extreme family poverty and sudden adversity (e.g. death of both parents). Placement in foster care in Nigeria, which can occur at any childhood period, is aimed at protecting the welfare of the developing child (e.g. by providing basic education training) in a foster home up to early adulthood (Eseadi et al., 2015). The average age of placement of foster children in our

sample was 10.39 years ( $SD = 2.74$ ). The control group comprised 51 participants recruited from high schools in the local districts. These were children who were living with and who were being cared for by their biological parent(s). Participants in both groups were orally screened for history of neurological diseases, seizures or psychiatric disorders for self or first-degree relatives. No child was identified nor excluded on the basis of these conditions. To assess whether the groups of deprived and nondeprived children were matched in basic demographic and psychiatric variables, we compared them on age, education, gender distribution, socioeconomic status and paediatric symptoms checklist. The deprived group did not significantly differ from the control group in age,  $t(102) = -.26$ ,  $p = .79$ , or education measured by the number of years completed in school,  $t(101) = -1.01$ ,  $p = .31$ . However, there was significant difference in gender distribution,  $\chi^2(1,104) = 18.63$ ,  $p < .05$ , with more females in the deprived group and more males in the control group. As a proxy for participants' socioeconomic background, we administered a three-item measure of parental socioeconomic status (example item: 'My family usually had enough money when I was growing up'). Responses were dichotomous and coded in binary format (e.g. Yes = 2, No = 1) with higher values indicating higher socioeconomic status. These items were not given to children from the orphanage. Deprived children did not differ significantly from control participants in the sum score across the three items,  $t(90) = -1.42$ ,  $p = .15$ . Participants were also screened with a revised 17-item version of the paediatric symptom checklist (PSC; example item: 'I feel sad, unhappy'; Gardner et al., 1999) to measure psychiatric symptoms ( $\alpha = .84$ ). Responses were obtained and coded in ordinal format (e.g. Never = 0, sometimes = 1, often = 2). Higher values correspond to higher paediatric symptoms checklist and poorer wellbeing. Deprived children did not report significantly higher symptom scores than control participants  $t(102) = -1.79$ ,  $p = .07$ . Descriptive data for all demographic and psychiatric variables are shown in Table 1.

## Procedure

A support letter from the head of the Department, Psychology, University of Nigeria, Nsukka, was forwarded to the principals of the high schools and matron of the orphanage home from where the participants were drawn, who granted the permission to proceed with the study. All children who met eligibility criteria for inclusion in either the deprived or control groups were first identified by the form teachers of the participating schools who provided the consent. The children were informed that

**Table 1** Demographic and clinical information of whole sample, deprived and nondeprived children

Variables	Whole sample Mean ( <i>SD</i> )	Deprived Mean ( <i>SD</i> )	Nondeprived Mean ( <i>SD</i> )
<i>N</i>	104	53	51
Age	13.50 (1.89)	13.45 (2.13)	13.55 (1.62)
Gender:	47/57	13/40	34/17
Male/Female			
Education (years)	8.24 (1.29)	8.12 (1.63)	8.37 (0.82)
SES	3.90 (0.89)	3.76 (0.92)	4.02 (0.86)
PSC	11.30 (5.29)	10.40 (5.18)	12.24 (5.29)
Duration in foster care	–	3.37 (2.76)	–

*N* = number of participants; education = number of years completed in school; SES = sum score of socioeconomic status scale; PSC = sum score of paediatric symptoms checklist; Duration = number of years spent in foster home.

participation was entirely voluntary and only those who signed and returned their consent forms were scheduled for appointment in the computer laboratory of their schools. In the laboratory, participants first provided information regarding the control variables described above before completing a battery of three computerized tasks on a 15.6-inch HD display screen laptop. The study lasted for approximately 30 min for each participant and was approved by the local ethics committee.

## Measures

Data were obtained from three different tasks, designed and run using OpenSesame version 3.1.4 (Mathôt, Schreij, & Theeuwes, 2011). Participants also completed a fourth task (a version of the Stop Signal task, van den Wildenberg et al., 2006), but a problem with the staircase algorithm calibrating the difficulty of the task rendered the associated data uninterpretable (many participants slowed down to anticipate the occurrence of a stop signal). The tasks were administered in the same fixed order to all participants (Colour-Shape Shifting task, Numerical Stroop task, Stop Signal task and Digit Span task).

**Colour-Shape Shifting task.** The Colour-Shape Shifting task is a test of cognitive set-shifting (Friedman et al., 2006, 2008, 2017) that requires participants to respond to either the colour or the shape of a target stimulus (a circle or triangle, presented in either red or green). A cue of 'C' = colour or 'S' = shape preceded the target stimulus by 350 ms to indicate the sorting rule to apply at each trial. Participants responded to the target stimulus by pressing one of two keys ('Z' for red and circle, '/' for green and triangles). The task began with two single-task blocks of 24 trials each where participants had to apply only one rule. Participants then completed two mixed-task blocks of 56 trials each involving repeat and switch trials (see Lange & Dewitte, 2019, for more detailed descriptions). On repeat trials, participants had to apply the same rule as on the previous trial (e.g. colour followed by colour), whereas on switch trials participants had to apply a different rule than on the repeat trial (e.g. colour followed by shape).

We first calculated error rates and mean response times during repeat and switch trials of mixed-task blocks. For the calculation of participants' mean response times, we excluded responses on or following incorrect trials, responses faster than 200 ms and response times more than three standard deviations above a participant's mean response time. Switch cost was computed as the difference in error rates and mean response times between switch and repeat trials. To further aggregate participants' performance, we computed linear integrated speed-accuracy scores (LISAS; Vandierendonck, 2016), combining error rates and mean response times into a single score. The difference between LISAS on switch trials and LISAS on repeat trials (i.e. the LISAS switch cost) was the primary outcome measure for this task. Higher switch cost indicates poorer set-shifting skills.

**Numerical Stroop task.** In designing the Numerical Stroop task, we followed the processes described by Henik and Tzelgov (1982). The task served to assess participants' ability to inhibit irrelevant, interfering information. It contained strings of numbers that appeared in the centre of the screen, and participants were required to indicate (by pressing the corresponding key of the NumPad of the computer keyboard) how many numbers they saw. The kind of digits that appeared (i.e. whether it was string of threes or a string of fours) was declared to be irrelevant. On some trials, the strings that appeared were compatible with the kind of number shown (e.g. the string '3 3 3', requiring the response '3'). On other



trials, the total number and the kind of strings shown were incompatible (e.g. the string '5 5 5', requiring the response '4'). The task consisted of a total of 120 trials made up of 60 compatible trials and 60 incompatible trials. Error rates and mean response times were calculated separately for compatible and incompatible trials. For the calculation of mean response times, we excluded responses on or following incorrect trials, responses faster than 200 ms and response times more than three standard deviations above a participant's mean response time. We further computed differences in error rates and mean response times between incompatible and compatible trials (i.e. the Stroop effect). As we did with the Colour-Shape Shifting task, we combined error rates and response times into a single score using the LISAS approach. The LISAS Stroop effect (i.e. the difference between LISAS on incompatible trials and LISAS on compatible trials) was the primary outcome measure. Higher values indicate poorer interference inhibition.

**Digit Span task.** The Digit Span task is a behavioural measure of working memory capacity, the cognitive ability to temporarily store and manipulate information. The Digit Span task used in this study comprised of a forward and a backward version. In the forward version, participants were informed that they would see strings of digits, one at a time, and that they would be required to type the list of digits in the same order as they saw it (after the presentation of the last digit). For example, if they see '24', they should just type '24'. The digits were presented in progressing order of difficulty beginning with three-digit sequences (e.g. '793') up to ten-digit sequences (e.g. '4729613088'). At each level, participants received two opportunities to correctly repeat the presented sequence of digits. If they provided at least one correct response, they moved to the next level of difficulty. For the backward version, the instructions and processes were the same, except that participants were asked to type the sequence of digits presented in reverse order. For example, if they saw '793', they were required to type '397'. The last level of difficulty that participants correctly attempted was determined separately for the forward and backward version and summed up across both versions to yield our primary outcome measure for the Digit Span task. Higher values indicate higher working memory ability.

### Design and statistics

For each task, participants were only included in the analysis when it could be assured that they understood the task instruction at least to a basic degree. For the Colour-Shape Shifting and Numerical Stroop tasks, they were required to correctly complete significantly more than half of the control trials of these tasks. Inclusion thresholds (at least 31 correct single-task trials and 35 correct repeat trials in the mixed-tasks blocks of the Colour-Shape Shifting task trials, at least 37 correct compatible trials of the Numerical Stroop task) were determined by one-sided binomial tests ( $\alpha = .05$ ) against the probability of 50%. For the Digit Span task, they had to successfully complete at least one three-digit trial in both the forward and the backward version of the task. These inclusion criteria led to the exclusion of three participants in the Stroop task (2 deprived children and 1 control), 55 participants in the set-shifting task (23 in deprived group and 32 controls) and 45 participants in the Digit Span task (22 deprived and 23 control children).

In sum, we assessed participants' performance on three primary outcome measures obtained from the three tasks. Performance on these measures was compared between deprived and control participants by means of two-sided independent t-tests. Following recent recommendations (Delacre, Lakens & Leys, 2017), we did not make our test choice contingent on the results of assumption checks, but

instead used Welch's t-test by default. To control for the number of comparisons, we set the level of significance to  $\alpha = .05/3 = .0167$ . In addition, we ran exploratory correlation analyses to examine the associations between performance measures on the one hand and participants' age, education status, socioeconomic status and paediatric symptom status on the other hand.

To assess the robustness of our findings, we conducted two robustness analyses where we relaxed our inclusion criteria and reran our primary analysis. Children were included in the first robustness analysis if they correctly completed at least half of the single-task trials (i.e. at least 24) and at least half of the repeat trials in the mixed-tasks blocks (i.e. at least 28) of the Colour-Shape Shifting task and when they correctly completed at least 30 compatible trials of the Numerical Stroop task. This led to the inclusion of 33 additional Colour-Shape Shifting task datasets and 1 additional Numerical Stroop task dataset. For the Digit Span task, children were included if they successfully completed a three-digit trial in either the forward or backward version of the task. Twenty-nine additional datasets were included on this account. For the second robustness analyses, we included all participants regardless of performance. Full results of these robustness analyses and group comparisons involving nonaggregated performance data can be found in Tables S1-S3.

## Results

Performance data from the three administered tasks of executive functioning are displayed in Table S1. The results of independent t-tests show that deprived children ( $Mean = 57.69$ ;  $SD = 304.02$ ) did not significantly differ from nondeprived children ( $Mean = 60.10$ ;  $SD = 107.76$ ) in their performance on the Colour-Shape Shifting task;  $t(39.16) = .04$ ,  $p = .969$ ,  $d = 0.01$ , 95% confidence interval (CI)  $[-0.56, 0.59]$ , or on the Numerical Stroop task (deprived:  $Mean = 148.97$ ;  $SD = 122.35$ ; nondeprived:  $Mean = 132.01$ ;  $SD = 81.50$ ),  $t(87.26) = .82$ ,  $p = .414$ ,  $d = 0.16$ , 95% CI  $[-0.23, 0.55]$ . As displayed in Figure 1, the distributions for these variables included some extreme values. When repeating our analysis after exclusion of participants who performed more than 2 SD above or below their group mean, results changed only minimally (Colour-Shape Shifting task:  $d = 0.24$ , 95% CI  $[-0.36, 0.84]$ ; Numerical Stroop task:  $d = 0.34$ , 95% CI  $[-0.12, 0.80]$ ). In contrast, at the adjusted significance level of  $\alpha = .0167$ , the deprived children ( $Mean = 9.26$ ;  $SD = 1.57$ ) performed significantly better than the nondeprived children ( $Mean = 7.39$ ;  $SD = 0.96$ ) on the Digit Span task,  $t(50.28) = 3.63$ ,  $p < .001$ ,  $d = 1.45$ , 95% CI  $[0.87, 2.02]$ . When combining the maximum sequences recalled in the forward and backward version of the task, deprived children were able to memorize almost two additional digits, corresponding to a group difference of about one and a half standard deviations. Results did not change when we relaxed our inclusion criteria for the robustness analyses reported in Tables S2 and S3. The group difference in Digit Span task performance remained significant across all robustness checks and for both the forward and the backward version of the task.

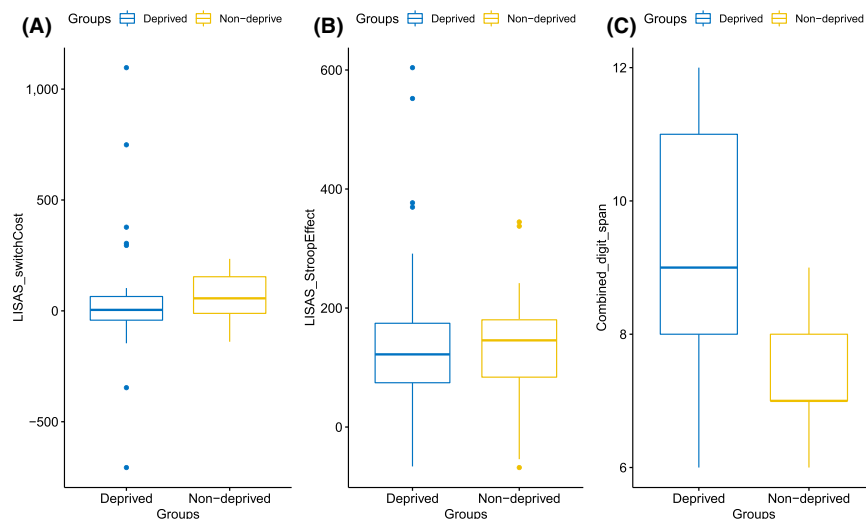
Exploratory correlation analyses (Table 2) revealed positive correlations of medium size between Digit Span task performance and education, indicating that the ability of children in both groups to recall digits increased as the number of years they have spent in school increased. Correlations of all study variables can be found in Tables S4-S7.

## Discussion

The study examined changes in executive functioning related to parental deprivation in institutionalized and foster care children in Nigeria. Participants' performance was assessed on tasks of inhibition, set-shifting and working memory. While being matched to nondeprived control participants in terms of age, education, socioeconomic and clinical status, the deprived group performed significantly and consistently better than the nondeprived group on the working memory task across all analyses. This group difference held when we conservatively controlled for multiple comparisons. We found no difference between the groups in set-shifting and inhibition performance. These results give credence to the developmental evolutionary model that proposes that early adverse rearing may not necessarily impair cognitive functions, but may even relate to cognitive benefits in some domains of executive functioning.

Taken together, our findings are contrary to previous empirical studies that have shown reduced performance in inhibition (Colvert et al., 2008; Eigsti et al., 2011; Hostinar et al., 2012; Loman et al., 2012; McDermott et al., 2012; Mittal et al., 2015; Nederhof & Schmidt, 2012; Pollak et al., 2010), set-shifting (Bauer et al., 2009; Hanson et al., 2013; Hostinar et al., 2012) and working memory (Bauer et al., 2009; Bos et al., 2009; Hanson et al., 2013; Hostinar et al.,

2012; Pollak et al., 2010) in adopted or previously institutionalized children. However, the enhanced working memory ability of the deprived children in our study was consistent with a recent study by Young et al. (2018), which found that under conditions of uncertainty, early childhood adversity was positively related to working memory updating, but not working memory capacity. Although the Digit Span task used in the current study focuses on the capacity component of working memory ability, it does not involve distraction to the same extent as the working memory capacity task used by Young et al. (2018). This design feature makes the Digit Span task in our study similar to the working memory updating task used by Young and colleagues. Similarly, while our finding is at odds with some other previous reports of impaired working memory in deprived children (Bauer et al., 2009; Bos et al., 2009; Hanson et al., 2013; Hostinar et al., 2012; Pollak et al., 2010), it is important to note that these studies relied on spatial working memory tasks, while we administered a Digit Span task for the assessment for working memory capacities. Differences between present and previous results might thus be due differences in the targeted working memory domain. Additionally, in contrast to previous correlational studies examining cognitive effects of childhood adversity in postinstitutionalized individuals, we tested parentally deprived children who were still living under potentially stressful conditions in institutions or foster homes. This design bears some similarity with studies that actively created conditions of uncertainty and unpredictability reminiscent of participants' early childhood experiences (e.g. Young et al., 2018). In accordance with these studies, our results suggest that working memory performance under stressful conditions might improve following early childhood adversity. Future



**Figure 1** Distribution of groups performance across the three primary measures: A = linear integrated speed-accuracy scores (LISAS) switch cost on the Colour-Shape Shifting task; B = LISAS Stroop effect on the Numerical Stroop task; C = combined Digit Span on the Digit Span task. The lower and upper whiskers represent the first and third quartiles of the performance distribution. The horizontal box lines indicate the groups' medium performance. Higher values in LISAS switch cost and LISAS Stroop effect = poorer set-shifting and inhibition skills; higher values in Combined Digit Span = higher working memory ability

**Table 2** Bivariate correlations involving primary neurocognitive measures and key demographic/clinical variables

S/N	Primary measures	Whole sample				Deprived					Nondeprived			
		Age	Education	SES	PSC	Age	Education	SES	PSC	Duration	Age	Education	SES	PSC
1	LISAS	1	2	3	4	1	2	3	4	5	1	2	3	4
1	LISAS	-.10	-.19	-.20	.00	-.14	-.20	-.29	-.09	-.19	.19	-.02	.16	.50*
2	Switch cost													
2	LISAS	-.03	-.14	.09	-.03	-.08	-.13	.14	-.12	-.23	.06	-.17	.06	.14
3	Stroop effect													
3	Combined Digit Span	.13	.29	-.06	-.17	.24	.42*	.08	-.02	.05	.02	.34	-.16	-.22

Whole sample; correlation between Colour-Shape Shifting task and other variables:  $n = 49$  (SES = 41); correlation between Numerical Stroop task and other measures:  $n = 101$  (SES = 90); correlation between Combined Digit Span and other variables:  $n = 59$  (SES = 54); deprived sample; correlation between Colour-Shape Shifting task and other variables:  $n = 30$  (SES and duration 22)\*\*; correlation between Numerical Stroop task and other measures:  $n = 51$  (SES and duration = 40)\*\*; correlation between Combined Digit Span and other variables:  $n = 31$  (SES and duration = 26)\*\*; nondeprived sample; correlation between Colour-Shape Shifting task and other variables:  $n = 19$ ; correlation between Numerical Stroop task and other measures:  $n = 50$ ; correlation between Combined Digit Span and other variables:  $n = 28$ ; Education = measured by the number of years completed in school; SES = parental socioeconomic status; PSC = Paediatric symptoms checklist; duration = number of years spent in foster care.

\*Correlation is significant at 0.05 level (2-tailed).

\*\*Deprived children excluding institutionalized.

experimental studies manipulating the stressfulness or uncertainty of the current context in our Nigerian study population may generate more conclusive evidence in this direction.

The pattern of consistently enhanced working memory ability of deprived children in our study may be taken to indicate that cognitive processes in deprived children are tuned to their ecological conditions. Central to the evolutionary model is the life history hypothesis (Charnov, 1993) that posits that greater resource allocation is made in areas that have greater developmental relevance. Previous studies have reported that maltreated and abused children have greater memory recall and enhanced capacity to detect threat-specific stimuli than nonmaltreated and nonabused children (Eisen, Goodman, Qin, Davis, & Crayton, 2007; Rieder & Cicchetti, 1989). If cognitive processes of deprived children are traded off for the most ecologically important functions (e.g. specialized memory domains), a likely explanation for our finding is that the development of working memory abilities has been prioritized due to deprivation-specific challenges in the early life of deprived children. Working memory capacity has been found to be a powerful predictor of academic success (Alloway & Alloway, 2010), and early academic success may be particularly vital to deprived children in Nigeria. In comparison to Western countries, fewer governmental mechanisms to promote social mobility exist in Nigeria (Page & Okeke, 2019). If underprivileged children are to change their socioeconomic conditions, one channel of success that has been emphasized by teachers and guardians is through academic success which could secure them a rare, competitive scholarship at the tertiary level of education. This specific

culture-context relevance of working memory-dependent academic achievement may account for our observation of improved working memory in deprived children. Unfortunately, we did not collect information on children's academic performance (e.g. maths grades) to see if higher working memory ability relates to greater academic success. Whether working memory-dependent academic success is indeed more relevant for deprived than nondeprived Nigerian children is a question that needs to be addressed in future studies.

### *Strengths and limitations of the study*

This study is particularly relevant because it is the first examination of deprivation-related changes in cognitive functioning in sub-Saharan Africa. The implications of parental deprivation may differ substantially between this study context and Western societies (where most previous studies have been conducted). Attempts to generalize findings from Western societies to other contexts are critically needed to test whether relationships between early-life adversity and cognitive changes are universal or culture-specific in nature. Another merit of this study is that it employed a comprehensive battery of executive functioning tasks that covered the major domains of set-shifting, inhibition and working memory. This enabled understanding of domain-specific changes in the executive abilities of parentally deprived children.

However, the current study is limited by lack of information on the children actual adversity exposures across the two groups. While it is sensible to assume that the deprived children may have a more uncertain future and would have experienced more

cumulative adversity exposure, it is important to acknowledge that within-group distributions in actual deprivation experiences are likely to overlap between the deprived and the nondeprived group. Future studies in this population may thus benefit from additional information on past and current childhood experiences. Also, an even more comprehensive assessment of executive functioning might be advisable for future investigations. This will further add to our understanding of the specific subdomain of executive functioning impaired or shaped by deprivation (e.g. working memory capacity vs. updating, verbal vs. spatial working memory). For the present study, we decided to expose participants to not more than four executive functioning tasks to ensure continued motivation to perform well.

## Conclusions

In conclusion, we found evidence of enhanced performance in a working memory task in parentally deprived children from Nigeria. These findings are compatible with the life history and specialization hypotheses of the evolutionary–developmental model that argues that early-life adversity does not necessarily impair cognitive functioning but may even result in specific cognitive benefits. However, when interpreting such findings, it should be kept in mind that these benefits are likely to be rather subtle in comparison to the plethora of costs that parentally deprived children have to bear (Bauer et al., 2009; Bauer et al., 2009; Hanson et al., 2013; Hostinar et al., 2012; McDermott, et al., 2012).

## Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article:

**Table S1.** Group comparison between deprived and non-deprived children on measures of executive functioning.

**Table S2.** Robustness analysis 1: Group comparison between deprived and non-deprived children on

measures of executive functioning with relaxed inclusion criteria.

**Table S3.** Robustness analysis 2: Group comparison between deprived and non-deprived children on measures of executive functioning without inclusion criteria.

**Table S4.** Bivariate correlation table showing the Pearson correlation coefficient of demographic variables and executive functioning measures across the whole sample and independent groups.

**Table S5.** Bivariate correlation matrix of the whole sample group showing relationship between the demographic, socioeconomic, clinical and executive functioning measures.

**Table S6.** Bivariate correlation matrix showing association between demographic, socioeconomic, clinical and executive functioning measures in the deprived children.

**Table S7.** Bivariate correlation matrix showing association between demographic, socioeconomic, clinical and executive functioning measures in non-deprived children.

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## Ethical approval

All procedures performed in this were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki declaration and its amendments or comparable ethical standards.

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## Key points

- The dominant view is that early-life adversity impairs cognitive functioning in general; however, recent empirical studies have found that growing up in a harsh environment may also enhance particular cognitive functions.
- We examined parentally deprived Nigerian children (institutionalized and foster cared children) on a battery of executive functioning tasks assessing inhibition, set-shifting and working memory.
- Deprived children performed significantly better than nondeprived control children in the working memory task. The groups did not differ in inhibition and set-shifting performance.
- Improved working memory ability in deprived children may be a result of ecological needs that require deprived children in Nigeria to attain career success through hard academic work.



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