# Spatial, verbal and numerical memory of HIV infected children in South Africa

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**Abstract**

We examined the performance on a spatial, verbal and numerical memory task of HIV infected children, ages 3 through 15, in South Africa, and the correlation between these memory tasks. 60 HIV positive children *(Mean age 8.9*) participated in this study. The main task used, was a location learning task that measures visuo-spatial learning and recall. For this task, no standard scores for children were available. Further, the verbal and numerical memory tasks of the McCarthy Scales (MSCA) (McCarthy, 1972) were used, including the means and standard deviations of the McCarthy norm group. The results showed, that the children performed significant lower on the verbal and numerical memory tasks compared to the norm group of the McCarthy Scales. Furthermore the children performed significantly lower on the verbal task compare to the numerical tasks. Finally, the scores on the memory tasks correlated highly significantly. This correlation can not be explained by age. Apparently there must be another factor which creates a strong correlation between performance on the memory tasks, despite the fact that the neural basis for these memory areas is totally different. Possibly this might argue for a HIV associated decline in memory performance, or an influence of the HIV infection causing cognitive stagnation.

## Introduction

South Africa is home to the world's largest population of people living with the human immunodeficiency virus (HIV) (5.7 million) (UNAIDS, 2008). HIV is a virus that attacks the immune system and creates physical symptoms such as tiredness, sweating, fever, dyspnoea and an overall malaise feeling. In South Africa research is conducted in the field of health and social sciences (Vermeer & Tempelman, 2008) of which HIV related studies are supported by various sites of the Southern African Catholic Bishop's Conference (SACBC) AIDS office. The SACBC has a network of more than 100 service programmes for people living with HIV/AIDS in South Africa (hospitals, clinics, hospices, home based care and orphan care). Because HIV is, beside social and societal problems, associated with a stagnation of cognitive development, neuropsychological research in HIV patients is a developing field of research. As an example of studies that are assessed in the neuropsychological research area, Drost et al. (in Vermeer & Tempelman, 2008, p. 501-510) investigated semantic priming in children, aged 7-13 years old, with symptomatic HIV, living in one of the seven sites of the SACBC, who participated in the study, spread over the eastern part of South Africa. The current research will focus on the spatial abilities in HIV infected children and will also be conducted in one of the sites of the SACBC.

As discussed above, HIV is associated with a degradation in cognitive functions. Although advances in the treatment of HIV have resulted in significantly improved survival rates over the past 10 years, HIV-associated neuro-cognitive disorders (HAND) remain highly prevalent and continue to represent a serious public health problem (Woods et al., 2009). The HAND are the outcome of the HIV impacting on the central nervous system.

Based on postmortem neuropathological examination of HIV patients (Everall et al., 1991; Navia et al.,1986) it was shown that HIV infects the central nervous system (CNS) in a diffuse way: the virus infiltrates the CNS by crossing the blood brain barrier affecting different regions (see Hult et al., 2008 for a review), cortical as well as subcortical regions. Some of these infected areas result in the development of HAND. Brain structures that are specifically associated with HAND are the frontal lobe and the basal ganglia and related neural connections (Ketzler et al., 1990; Wiley et al., 1991).

Since the frontal lobe is known to play a central role in working memory (WM) related processes (i.e. temporary maintenance and manipulation of information online) (Baddeley, 1986; Baddeley, 1992; Funahashi et al., 1993; Goldman-Rakic, 1992), it is not surprising that several investigators have found HIV infected individuals to show performance deficits on verbal and spatial working memory tasks (Bartok et al., 1997; Hinkin et al., 2002; Martin et al., 1995; Sahakian et al., 1995). For instance, Hinkin et al. (2002) examined working memory performance in a cohort of 50 HIV infected adults and 23 uninfected controls. They used an n-back paradigm in which alphabetic stimuli were quasi-randomly presented to a quadrant of a computer monitor. In the verbal working memory condition, participants determined whether each letter matched the letter that had appeared two trials earlier, regardless of spatial location. In the spatial working memory condition, participants determined whether each letter matched the spatial location of the letter that had appeared two trials earlier, regardless of letter identity. The results revealed that the HIV-infected participants performed significantly lower than the controls on both the verbal and spatial working memory task.

In contrast, other researchers failed to find HIV associated working memory impairments (Grassi et al., 1999; Law et al., 1994; Mason et al., 2000). For example, Grassi et al. (1999) examined the spatial working memory abilities of 34 HIV infected adults and 34 age- and sex- matched healthy controls. A computer-administered test assessing spatial working memory was used. The task showed a cross in the centre of a computer screen and then, three randomly arrayed dots on the circumference of an imaginary circle centred on the cross appeared. The subject's task was to press a key with the dominant hand if the probe encircles the location of a target dot or with the non dominant hand if it does not. The findings did not show any spatial working memory impairment for the HIV infected adults.

The above described studies show discrepant findings. The Hinkin et al. study (2002) found a HIV-associated decline in performance on verbal and spatial working memory tasks while others did not. Different explanations for this discrepancy can be provided (Hinkin et al., 2002). First of all, differences exist with respect to the cognitive demands needed to perform the working memory tasks: the task of Grassi et al. (1999) appeared to lack the manipulation component central to working memory (Hinkin et al., 2002). For this reason, differences in working memory performance could be attributed to task difficulty (cognitive load), rather than being infected with HIV or not. Secondly, disease severity of the participants included in the different studies may also underlie the discrepant findings. That is, Grassi et al. (1999), Law et al. (1994) and Mason et al. (2000) included only asymptomatic patients (infected with HIV, but yet no symptoms), while Hinkin et al. (2002) included symptomatic patients (infected with HIV and have symptoms) of whom seventy-four percent met CDC diagnostic criteria for AIDS[2]. An association between neurocognitive impairments and disease severity has also been shown by Heaton et al. (1995). They found clinically obvious signs and symptoms of at least mild neurologic disease in approximately 30% of persons with asymptomatic HIV infection and about 50% of individuals with the acquired immunodeficiency syndrome (AIDS). Overall the fact that both normal working memory performance and HIV-associated decline in performance on working memory tasks have

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[2] The CDC is a disease staging system that assesses the severity of HIV disease by CD4 cell counts and by the presence of specific HIV-related conditions (CDC, 1991).

been found, could be due to either the type of task (whether or not the task really measures working memory) and/or the different stages of HIV (asymptomatic or symptomatic).

The above described studies have mainly focused on working memory deficits in HIV infected adults. However, HIV infection is also associated with a delay in cognitive development: HIV infected children are reported to have problems with attention, executive functions, learning and memory (Kaemingk & Kaszniak, 1989; Grant, 1990; Grant & Heaton, 1990; Smith et al., 2006). Besides these few studies that have examined cognitive domains separately, many studies have investigated 'the mental development' in general in children. For example Blanchette et al. (2001) examined mental and motor development in 25 infants with vertically[3] transmitted HIV infection compared with 25 children born to HIV-positive mothers but not infected with the virus. They used the Bayley Mental Development Index (MDI) and Psychomotor Development Index (PDI), both parts of the Bayley Scales of Infant Development (BSID) battery (Bayley, 1994). After controlling for developmental risk factors, the HIV-infected group showed significantly lower scores on a mental scale than the uninfected infants. In a similar way, Smith et al. (2006) investigated the effects of HIV infection on the cognitive development of 117 children who were infected vertically and 422 children who were exposed to, but not infected with, HIV. Children in de study who were HIV negative were assigned to the non-infected group, children who had HIV but did not experience a class C event (AIDS indicator) over the course of the study were assigned to the HIV/no C group, and children who were HIV positive and experienced a class C event before the end of the study period were classified in the HIV/C group. Class C refers to the categorization by the CDC of signs and symptoms of HIV infection (CDC, 1991). They measured cognitive development by using the McCarthy Scales of Children's Abilities (MSCA) (McCarthy, 1972). The MSCA was administered over 7 years, to all children every 6 months, beginning when the child attained the age of 3 years. Results showed that children in the HIV /C group scored significantly lower in all domains of cognitive development (i.e. verbal, perceptual-performance, quantitative skills, and memory), across all time points, compared with the children in the HIV/no C group and the children who were HIV exposed but not infected. Children with HIV infection but no class C event performed as well as non-infected children in measures of general cognitive ability. These results are consistent with the claim of Hinkin et al. (2002) that differences in disease severity of the participants might underlie performances on a spatial working memory task.

The present study will assess whether the results on the spatial memory task, found by Hinkin et al. (2002) in adults, also apply to children living under deprived circumstances in South Africa. And whether the results on the verbal memory and numerical memory tasks,

[3] Children infected by their HIV positive mother at birth.

the memory part of the McCarthy Scales, found by Smiths et al. (2006), also apply to these children. In both adults as well as children it has been shown that the amount of viral load and thus the diversity of disease affects working memory performance (Hinkin et al., 2002; Smith et al., 2006). Therefore, in this study the various stages of the disease in children in the ages between 3 to 15 years were investigated. It is studied how these children performed in regarding verbal and numerical memory compared to the norm group as established in the McCarthy Scales (MSCA) (McCarthy, 1972) and how the verbal, numerical and spatial memory tasks correlate with each other.

The main task used, is first a location learning task that measures visuo-spatial learning and recall. Because of the learning trials and the recall, the location learning task appeals to working memory and has sufficient task difficulties. For this task, no standard scores for children are available. Further, the verbal and numerical memory tasks of the McCarthy Scales (MSCA) (McCarthy, 1972) are used. These are more simple memory tasks. For these tests are means and standard deviations of the McCarthy Scales available. These data are based on samples of 100 children aged from 2.5 to 8.5 years.

Based on the study of Hinkin et al. (2002) and Smith et al. (2006) we expect the children to perform lower on the verbal and numerical memory tasks compared to the norm group of the McCarthy Scales (MSCA) (McCarthy, 1972).

As previous research in South Africa showed that the English language was insufficiently attained (Wierda et al., 2008) we anticipate a discrepancy between performance on the spatial and numerical tasks on the one hand, and the performance on the verbal task on the other.

Further, this study examined the relationship between the spatial, verbal and numerical tasks. In an earlier study this correlation was also examined (Seigneuric et al., 2000). They focused on the relationship between working memory and reading comprehension. Five working memory tasks were executed, two verbal, two numerical and one spatial. The correlations between all working memory measures were significant. Based on this study it is expected that in the current study tasks will also be significantly correlated.

We also expect to find an age effect, i.c. that the younger children will perform lower than the older children.

As said before, in both adults as well as children it has been shown that the amount of viral load and thus the severity of disease affects working memory performance (Hinkin et al., 2002; Smith et al., 2006). Therefore we expect a relationship between the medical parameters (e.g., viral load and CD4 percentage) and the performance on the spatial, verbal and numerical memory tasks.

**Method**

*Participants*

60 HIV-infected children aged 3 to 15 years participated in this study. Ten of these children live in one of the SACBC sites in South Africa, namely St. Francis Care Centre in Boksburg. Five other children live in Winterveldt, another SACBC site in South Africa. These 15 children are abandoned or orphaned children. The other 45 children are children who visit the clinic with a parent or carer, once every three months, for a doctor’s visit and to obtain their medication. All children are on antiretroviral (ARV) medication at the time of the study.

Participant characteristics can be found in Table 1. Each participant was classified according to the WHO staging, before they started with medication. Stage 1 means that the child is infected by HIV, but have no symptoms yet. In stage 2 to 4, the symptoms increase in severity. A child who was classified with stage 4, has AIDS.

**Table 1:** *Subject characteristics*

| Characteristics | All children (N = 60) |
|---|---|
| Age *(months)* | 107.43 (36.98) |
| Sex *(male/ female)* | 33/27 |
| Live *(inside/ outside patients)* | 15/45 |
| CD4% | 18.31 (9.14) |
| Viral load *(copies/ ml)* | 119449.55 (1.91745E5) |
| WHO stage (*N*/ %) | |
| WHO stage 1 | 5 (8.3 %) |
| WHO stage 2 | 14 (23.3 %) |
| WHO stage 3 | 32 (53.3 %) |
| WHO stage 4 | 7 (11.7 %) |

*Note: Means and standard deviations are given unless otherwise noted.*

*Counterfeit Location Learning Task (CLLT)*

The standard stimulus set A of the LLT, developed by Bucks et al. (2000) was counterfeit because there was no original version available. For the counterfeit version, we used the same pictures as the original version after we had checked whether the children in South Africa recognized the pictures. The test started with a practice trial. This was a 2 x 2 grid (15.2x 13.5 centimeters) with 2 pictures (hat and pen). After the practice trial, we started with the test. We used the following pictures: book, boot, cup of tea, envelope, glasses, knife, matches, scissors, umbrella and wallet. The sizes of de pictures were 7.5 x 6.5 centimeters. The counterfeit LLT (CLLT) involves, like the original version, learning the spatial arrangement of a set of pictures of objects on a 5 x 5 grid (42 x 40 centimeters). The pictures were randomly allocated to positions on the grid, with the restriction that no pictures were placed in the corners of the grid. The grid is deliberately constructed so that it did not lend itself to separation into quadrants for easier learning of the locations.

The test was executed by presenting the grid for 30 seconds and then assessing the subject's memory for locations by asking them to place cards bearing a copy of each object onto locations on a blank grid. This was repeated for five trials, or until the subject had completed two correct trials in a row. A delayed trial was added after 15 minutes.

*Verbal and Numerical Memory Task*

Furthermore, a verbal and numerical memory task was used. These tasks were taken from the McCarthy developmental scale (MSCA) (McCarthy, 1972). In the verbal memory task, the child had to repeat phrases and sentences. This task contained 6 trials. In the numerical task the child had to repeat series of numbers in the order given by the experimenter. This task also included 6 trials, but the child was given two attempts if necessary.

*Procedure*

When the child was seated in the testing room, the child was given the following instruction: 'I am interested in how well you can remember where some pictures are on a grid. Here is an example'. The tester placed the practice grid in front of the child and said: 'Please look at this grid. It has four squares on it and two pictures. Note were the pictures are'. The child then studied the grid for six seconds. After it was covered with a blank grid. The subject was given the pictures one after the other and told: 'Please place the pictures in the correct squares'.

After the practice trial, in which the experimenter ascertained that the child had correctly placed the pictures, trials 1 – 5 were performed. The experimenter showed the 5 x 5 grid with the 10 pictures and said that the child has to look at the grid for 30 seconds and to learn the locations of the pictures. After these 30 seconds, the experimenter covered the grid (with a blank grid) and gave the pictures to the child in random order. Then the child had to put the pictures in the correct squares. The child was told that not to worry if he or she did not get it all right first time because he/she will get five tries and there are no time restrictions. The instructions were repeated at trial 2 to 5. In trial 5, the tester said: 'we will come back to this later. Try not to forget the locations of the pictures.'

After an interval of 15 minutes, spend with the (non visual) verbal and numerical memory tasks, the child was instructed to relocate the objects again, without showing the presentation stimulus again.

During the interval, the tester began with the verbal memory task. The child was given the following instruction: 'Now I say a few words and I want to see how much you can repeat it. Wait with answering, until I have said all words. Listen.' The tester then reads the words at a speed of roughly one word per second.

Thereafter the tester introduced the numerical memory task. The child was given the following instruction: ‘Now let’s see how good you can repeat numbers. Listen. Tell me: 2 – 6.’ If the child had answered, the tester went through the series with the score sheet.

*Data analysis*

Various performance measures of the spatial memory task were computed for all participants individually (Bucks et al., 2000). First, for each of the five learning trials as well as for the delayed trial, the Displacement Score was measured, that is, the sum of the errors made for each object placement on that trial. A placement error was calculated by counting the number of cells the object had to be moved both horizontally and vertically in order to be in the correct location. The Total Displacement Score is the sum of the Displacement Scores on the first five learning trials. Secondly, the Learning Index, the average measure for the relative difference in performance between trials, was calculated. Finally, the Delayed Recall Score was computed by determining the difference between trial 5 and the delayed trial as an index of decay (i.e., Displacement Score on trial 5 minus Displacement Score on the delayed trial).

For the verbal memory task the total number of correctly repeated items was computed per person. This was also done for the numerical task.

To investigate whether the children showed significant lower performances on the memory tasks than the norm group for the verbal task and numerical, means and standard deviations were used of the norm group of the McCarthy Scales (MSCA) (McCarthy, 1972). Unfortunately, for the spatial memory task no normative data was available. For the verbal and numerical task using the standard data, z scores were calculated. Then with a one-sample t-test it is investigated whether the scores of the children significant differ from the norm group. Thereafter, a paired-samples t-test is conducted to compare the performance on both the verbal and numerical memory tasks.

The relationship between the spatial, verbal and numerical memory tasks, have been calculated using the Pearson Correlation Coefficient. Thereafter, a partial correlation was conducted to correct for age.

For the question whether age effects mapping, figures have shown age versus performances on the memory tasks. To investigate whether age has a predictive value on performance, a regression analysis was executed.

Finally, to establish the relationship between the medical parameters (e.g., viral load and CD4 percentages) and the performance on the three memory tasks, Pearson Correlation Coefficient was used.

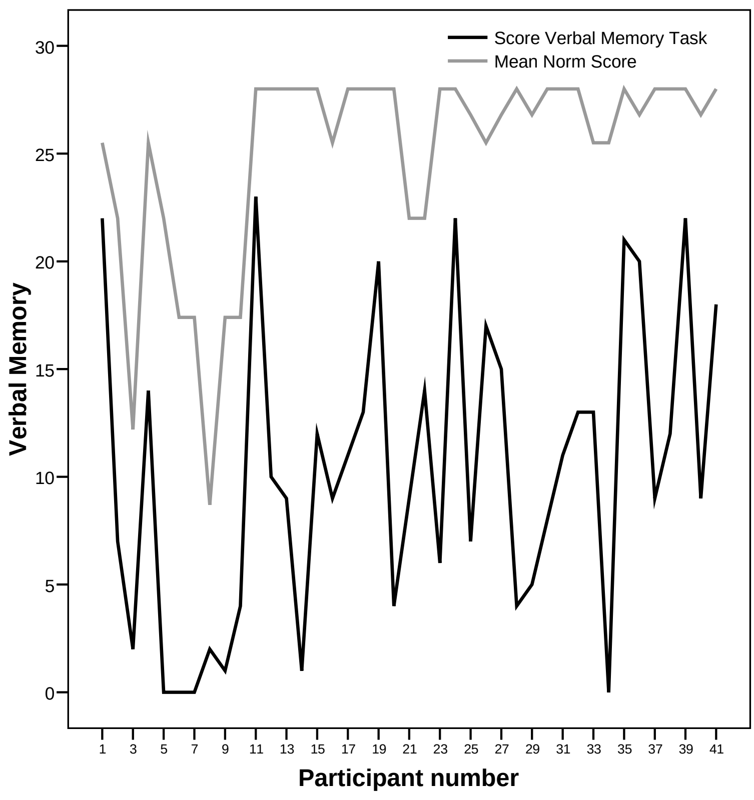
## Results

The mean age of all 60 participants was 8.95 (± 3.08) years, ranging from 3 to 15 years old. 33 males and 27 females participated in this study. Regarding the three memory tasks, means, standard deviations and z-scores are shown in table 2. For spatial memory the Total Displacement Score is given.

**Table 2:** *Means, standard deviations and z-scores for the verbal, numerical and spatial memory tasks*

| | N | M | SD |
|---|---|---|---|
| Verbal | 60 | 12.47 | 7.61 |
| Numerical | 60 | 5.90 | 2.41 |
| Spatial | 60 | 46.17 | 42.71 |
| Z Score Verbal | 41 | -5.01 | 3.20 |
| Z Score Numerical | 41 | -1.04 | 1.04 |

A one-sample t-test was conducted to investigate if the performance of the children on the verbal and numerical memory task, differ from the norm group. As expected, results indicated that the children performed overall significantly lower than the norm group, for both the verbal [$t$ (40) = -10,03, $p < .05$ ] and the numerical task [$t$ (40) = -6,39, $p < .05$]. Figure 1 shows the score on the verbal and numerical memory task per participant and the mean norm score.



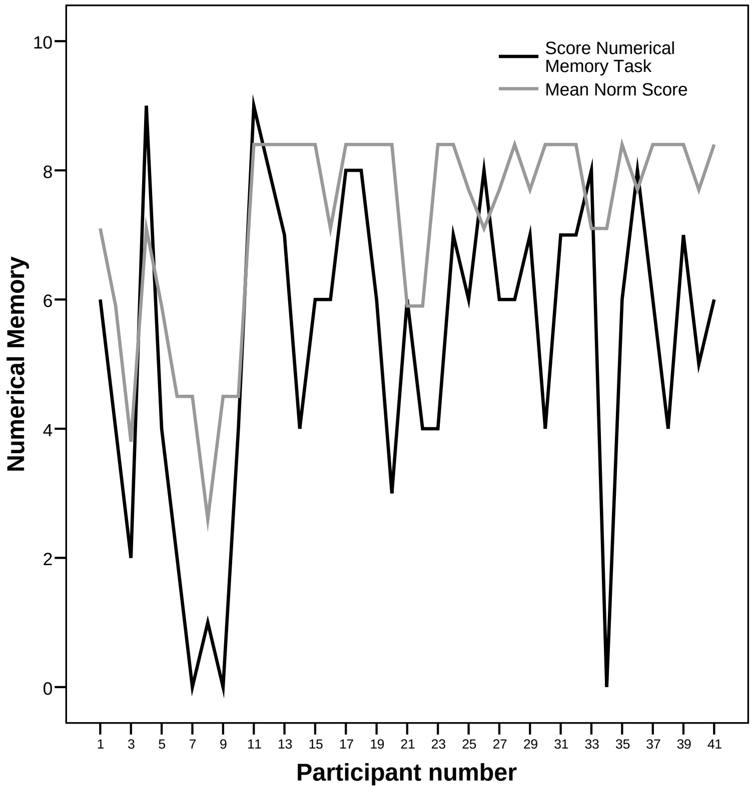



*Figure 1: Score on the verbal and numerical memory task per participant and the mean norm score.*

Furthermore, a paired-samples t-test was used to compare the performance on both the verbal and numerical memory tasks. Results show that the children performed significantly lower on the verbal memory task [$t$ (40) = -8,54, $p$ < .05].

As mentioned earlier, there are no normative data available for the spatial memory task. However it can be shown, that scores on the verbal, numerical and spatial memory tasks correlate highly significant (see table 3). For spatial memory the Total Displacement Score is given.

**Table 3:** *Pearson Correlation Coefficient for the verbal, numerical and spatial memory tasks*

| | | Verbal | Numerical | Spatial |
|---|---|---|---|---|
| Verbal | Pearson Correlation | 1 | .739(**) | -.587(**) |
| | Sig. (2-tailed) | | .000 | .000 |
| | N | 60 | 60 | 60 |
| Numerical | Pearson Correlation | .739(**) | 1 | -.689(**) |
| | Sig. (2-tailed) | .000 | | .000 |
| | N | 60 | 60 | 60 |
| Spatial | Pearson Correlation | -.587(**) | -.689(**) | 1 |
| | Sig. (2-tailed) | .000 | .000 | |
| | N | 60 | 60 | 60 |

** Correlation is significant at the 0.01 level (2-tailed)

A partial correlation was also conducted to correct for age. Even if age is kept constant, the scores on the memory tasks still correlate significantly (see table 4). For spatial memory the Total Displacement Score is given.

**Table 4:** *Partial correlation for the verbal, numerical and spatial memory tasks with age as a control variable*

| Control Variable | | | Verbal | Numerical | Spatial |
|---|---|---|---|---|---|
| Age | Verbal | Correlation | 1 | .618(**) | -.34(**) |
| | | Sig. (2-tailed) | | .000 | .008 |
| | | df | 0 | 57 | 57 |
| | Numerical | Correlation | .618(**) | 1 | -.532(**) |
| | | Sig. (2-tailed) | .000 | | .000 |
| | | df | 57 | 0 | 57 |
| | Spatial | Correlation | -.34(**) | -.532(**) | 1 |
| | | Sig. (2-tailed) | .008 | .000 | |
| | | df | 57 | 57 | 0 |

** Correlation is significant at the 0.01 level (2-tailed)

In both the verbal, numerical and spatial memory task an age effect is found. Results of a regression analysis show that age has a significant predictive value for performance, for all three memory tasks (see table 5). Figure 2 shows the relationship between age and performance per task.

**Table 5:** *Regression analysis for age versus the verbal, numerical and spatial memory tasks*

| | | *B* | *SE B* | *ß* |
|---|---|---|---|---|
| Verbal | | | | |
| | Constant | -0.62 | 2.48 | |
| | Age | 0.12 | 0.02 | .59* |
| Numerical | | | | |
| | Constant | 2.12 | 0.82 | |
| | Age | 0.04 | 0.01 | .54* |
| Spatial | | | | |
| | Constant | 124.79 | 13.34 | |
| | Age | -0.73 | 0.12 | -.63* |

Note $R^2$ = .35 for Verbal; $R^2$ = .29 for Numerical; $R^2$ = .40 for Spatial. * $p < .01$

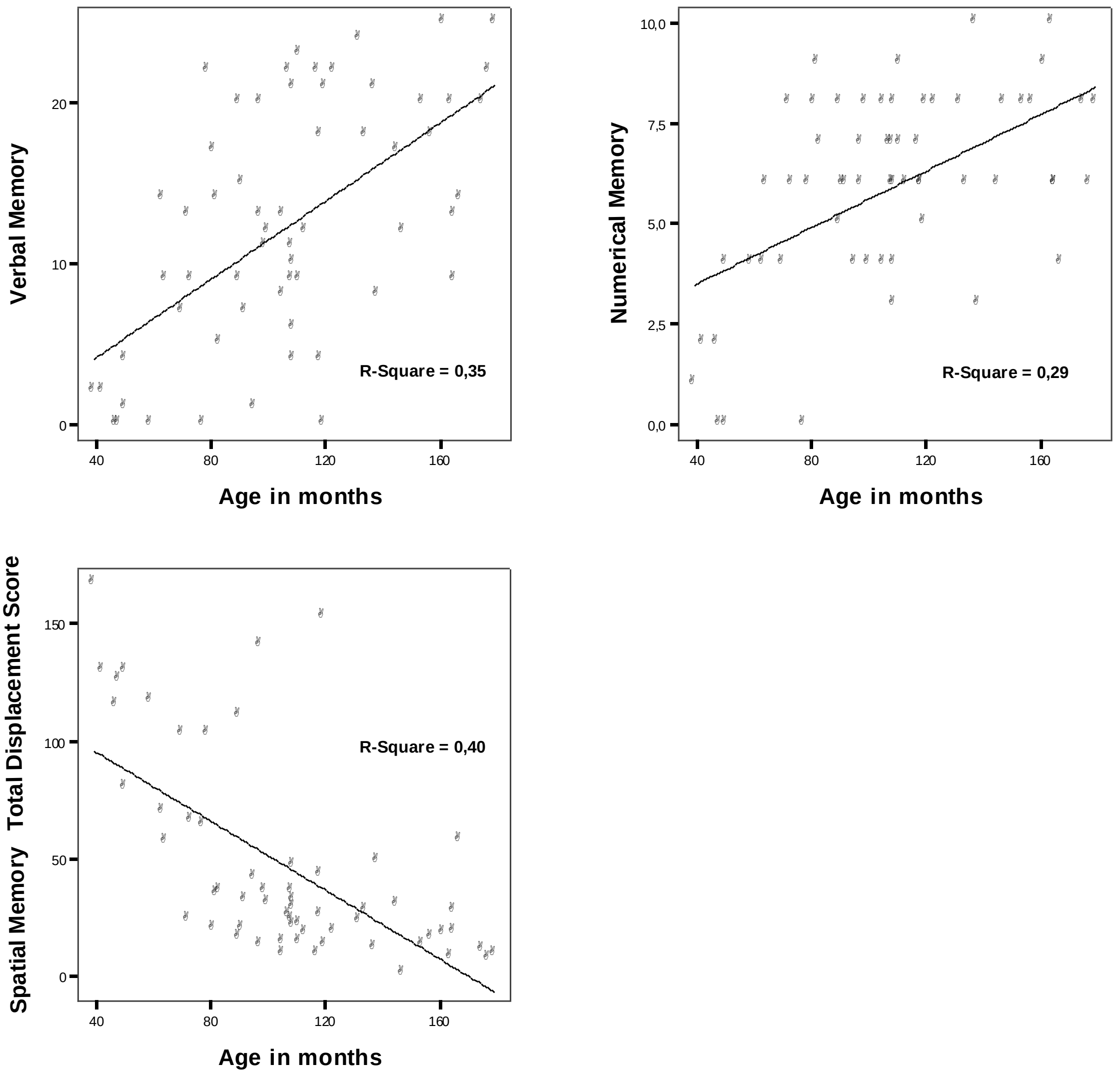



*Figure 2: Age in months versus performance and correlations respectively for the verbal, numerical and spatial memory task.*

The relationship between the medical parameters (e.g., viral load and CD4 percentages) and the performance on the three memory tasks was investigated, using Pearson Correlation Coefficient. Neither viral load, nor CD4 percentage was significantly related to verbal memory ($r$ = -.060, $p$ = .65), nor to numerical memory ($r$ = -.199, $p$ = .13), nor to spatial memory ($r$ = .124, $p$ = .35).

**Discussion**

In this study memory function at the various stages of the HIV infection in children in the ages between 3 to 15 years was investigated. It was studied how these children regarding verbal and numerical memory performed compared to the norm group as established in the McCarthy Scales (MSCA) (McCarthy, 1972) and how the verbal, numerical and spatial memory tasks correlated with each other. As in the studies of Hinkin et al. (2002) and Smith et al. (2006) which showed that HIV-infected patients performed significantly lower on memory tasks compared to healthy controls, children infected by HIV in this study also performed significant lower on the verbal and numerical memory tasks compared to the norm group of the McCarthy Scales (MSCA) (McCarthy, 1972). As expected, the children performed significantly lower on the verbal task compare to the performance on the numerical tasks. No norm group was available for the spatial task. Therefore, the data of this study could not be related to a norm reference. However as in the study of Seigneuric et al. (2000), scores on the verbal, numerical and spatial memory tasks correlated highly significantly. This correlation can not be explained by age. Furthermore, as expected, an age effect was found. The performance of younger children was lower than that the older children on the memory tasks. Finally we did not find a relationship between the medical parameters (e.g., viral load and CD4 percentage) and the performance on the spatial, verbal and numerical memory tasks.

In the study of Hinkin et al. (2002) and Smith et al. (2006) healthy, HIV negative, control groups were used and both examined the influence of the severity of the disease. In this study, no healthy, HIV negative control group is used, because the social difference between the HIV positive and the HIV negative group in South Africa was too big. The children living in an orphanage home, grow up in a poor social environment. Most of these children are HIV positive. They receive little support, little individual attention and some are traumatized. In contrast, HIV negative children grow up in better social environments. They are going to better schools and are encouraged more. Further, to some extent caused by stigmatization, many children did not or didn’t want to know their HIV status. This implied that many HIV positive children in the HIV negative group would be included (Drost et al., 2008). So therefore we have the performance of the children on the verbal and numerical memory tasks, compared to a standardized norm group (MSCA) (McCarthy, 1972). The question is whether we can conclude that the significantly lower performance of the children compared to the norm group was due to the HIV infection. Since no relationship was found between the medical parameters (e.g., viral load and CD4 percentage) and the performance on the memory tasks this cannot be concluded with any certainty. Indeed, an explanation for the fact that the children performed significantly lower than the norm group, could be that the children grow up in a deprived social environment, which also could affect the performance (Drost et al., 2008).

This is also evident from the fact that the children performed significantly lower on the verbal task compared with the performance on the numerical task. The children did not manage the English language well, as was shown by the study of Wierda et al. (2008). The fact that these children spoke little English, was due to a general language problem in South Africa. Especially the children from the townships and the children who grow up under deprived environmental circumstances, only learned the native language, such as Sutu, Xhosa and Zulu. Seigneuric et al. (2000) showed working memory emerged as an important predictor of reading comprehension compared to reading-related basic skills, vocabulary and decoding skills, while the verbal tasks showed to be better predictors than the numerical tasks. Since the children in this study performed lower on the verbal task compared with the numerical, we can expect reading comprehension problems.

As mentioned before, no norm group was available for the spatial memory task. However as in the study of Seigneuric et al. (2000), scores on the verbal, numerical and spatial memory tasks correlated highly significantly. Interesting in this context is the study of Smith et al. (1996) who showed that the neural basis of verbal working memory is distinct from that of spatial working memory. They argued that the most striking difference between spatial and verbal working memory is that spatial memory involves predominantly right-hemisphere regions, whereas verbal memory involves mainly left-hemisphere regions. In this study, the performance on the memory tasks correlated highly with each other, despite the fact that they apparently have a different neural basis. Moreover, this relationship between performance on memory tasks can not be explained by age, although age has a predictive value for the performance on the memory tasks. Apparently there is another factor that creates a strong correlation between performance on the memory tasks, despite the fact that the neural basis for these memory areas is totally different. Possibly this might argue for a HIV associated decline in memory performance, or an influence of the HIV infection causing cognitive stagnation. It is consistent with studies of several investigators who found that HIV infected individuals show performance deficits on verbal and spatial working memory tasks (Bartok et al., 1997; Hinkin et al., 2002; Martin et al., 1995; Sahakian et al., 1995).

However, as mentioned earlier, no relationship was found between the medical parameters (e.g., viral load and CD4 percentage) and the performance on the memory tasks.

Wierda et al. (2008) also did not find a relationship between the psychosocial problems and CD4 percentages of the diseased children. They reasoned that CD4 percentage is not a stable variable, it can change easily due to various illness and can show ups and downs. This would indicate that in the current study, the HIV infection may have had an impact, while no relationship between these medical parameters and the performance on the memory tasks could be established. An important restriction was that the registration of the blood results did not happen always accurately. Sometimes files were lost and sometimes children were not examined by a doctor for a long time, or no initial blood results were present.

In summary, this study investigated the various stages of the HIV infection in children in the ages between 3 to 15 years. Regarding verbal and numerical memory the children performed significantly lower compared to the norm group as established in the McCarthy Scales (MSCA) (McCarthy, 1972), whereby the performance was lower on the verbal task compared to the numerical. Furthermore, the verbal, numerical and spatial memory tasks correlated highly significantly with each other and this relationship can not be explained by age. Our findings suggest a HIV associated decline in working memory performance. However further research should be done by relating a more stable medical parameter to working memory performance in HIV infected children, so can say with certainty that the HIV infection provides a stagnation in development.

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