Verbal learning in schizopsychotic outpatients and healthy volunteers as a function of cognitive performance levels

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Abstract

OBJECTIVE: The aim was to analyze and compare neurocognitive test profiles related to different levels of verbal learning performance among schizopsychotic patients and healthy volunteers.

METHOD: A single-center patient cohort of 196 participants was compared with an equal-sized volunteer group to form three cognitive subgroups based on the shared verbal learning performance.

RESULTS: 43.9% of the patients had normal learning ability. Despite this, all patients underperformed the volunteers on all subtests with the exception of working memory, and, for those with high learning ability, even verbal facility. All patients also presented equally poor visuomotor processing speed/efficacy.

CONCLUSION: A global neurocognitive retardation of speed-related processing in schizophrenia is suggested.

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1. Introduction

Neurocognitive impairments have been shown repeatedly to be a prominent feature of schizophrenia. Nevertheless, the issue of whether this is due to generalized neurocognitive impairment or differential deficits in specific neurocognitive processes remains unresolved.

Neurocognitive functioning, a core feature of notions concerning general and specific neurocognitive deficits in the schizophrenic patient, hinges on learning ability. Almost every aspect of behavior and cognition requires learning. Learning goes hand in hand together with memory. Learning may be defined as the acquisition of new information, while memory is the capacity for storing and retrieving this material (Wickens, 2005). A genetic study of cognitive trait components in schizophrenia has shown verbal learning to be linked to the same locus as delayed memory, with semantic clustering linked to the same region (Paunio et al., 2004).

Already at the very first presentation of psychotic symptoms, schizophrenic patients have been found to show significant impairment on tasks of executive function, verbal learning, delayed recall from non-verbal memory, and...
psychomotor speed (Riley et al., 2000). These functions showed significant impairment against a background of generalized, but non-significant, underperformance on all neuropsychological variables. A study of unmedicated schizophrenic patients (Saykin et al., 1991) found them to show generalized impairment relative to controls and a selective deficit in memory and learning compared with other functions. A meta-analysis conducted on 70 studies of memory in schizophrenia showed that the memory impairment is stable, wide ranging, and not substantially affected by potential moderating factors such as severity of psychopathology and duration of illness (Aleman, Hijman, de Haan, & Kahn, 1999).

Even unaffected relatives outside the peak age of risk for schizophrenia, with neither spectrum nor other psychiatric disorders, have deficits in verbal learning and motor speed (Hoff et al., 2005). A meta-analysis of 37 studies comprising 1639 relatives of schizophrenic patients and 1380 control subjects showed the largest difference between relatives and controls to be on verbal recall and executive functioning (Sitskoorn, Aleman, Ebisch, Appels, & Kahn, 2004).

Despite the finding that schizophrenic patients as a group perform worse than healthy controls, there is a considerable variation between the patients’ performance, suggesting the presence of at least two neurocognitive subgroups: impaired versus unimpaired. Such subdivisions have been based on demographic and/or clinical variables (Brazo et al., 2002; Heaton et al., 2001), preserved and compromised intellect (Weickert et al., 2000), a screening test of attention and auditory perception (Bruder, Wexler, Sage, Gil, & Gorman, 2004), cluster analysis (Abi-Saab, Fiszdon, Bryson, & Bell, 2005; Heinrichs & Awad, 1993; Hill, Ragland, Gur, & Gur, 2002), prototypes from the clinical literature (Kremen, Seidman, Faraone, Toomey, & Tsuang, 2004), and fixed standard deviations from a verbal memory test (McDermid Vaz & Heinrichs, 2002).

A cross-sectional approach would be expected in comparisons of two to even five neurocognitive subgroups of schizophrenic patients to healthy volunteers, yet for some reason, the volunteers are usually treated as a single homogeneous “control group”. For example, Horan and Goldstein (2003) based their Z-score conversion upon the raw scores of the total study sample, including both schizophrenic and non-psychotic patient control participants, but still divided the schizophrenic patients into four clusters while the non-psychotic patients formed a single “cluster”. This kind of approach neglects the issue of “real-life” differences between schizophrenic patients and a control group, as there is a considerable variation even within the performance of controls and healthy volunteers.

The present study assesses neurocognitive performance in schizophrenic patients relative to that of healthy volunteers. Thus, a single-center patient cohort was compared with an equal-sized healthy volunteer group to form cognitive subgroups based on the shared verbal learning performance. The subgroups were then analyzed in order to find the best predictors of verbal learning performance. The results were studied also for differences in general neurocognitive performance patterns between schizophrenic patients and healthy volunteers.

2. Method

2.1. Participants

196 schizopsychotic outpatients (116 males, 80 females) between the ages of 19 and 74 years (mean = 46.31, S.D. = 11.76) and 196 healthy volunteers (78 males, 118 females) from 20 to 80 years (mean = 47.81, S.D. = 18.09) participated in this study.

The patients originated from an ongoing epidemiological study of a population of about 670 patients at outpatients settings in Western Sweden with the diagnoses schizophrenia, schizoaffective disorder or delusional disorder according to DSM-IV and ICD-10. Out of the total number, 516 patients were considered to be in a stable phase of the disorder as assessed from the patients’ medical records and observations of the psychiatric personnel, personnel from the community psychiatry and relatives. These patients were not presenting co-morbidity of other symptoms, such as dementia, that could influence the result. In total, 284 patients volunteered for the investigation and were presented with an extensive clinical test and interview battery, including study of their medical records. After 20 patients had been excluded due to having other diagnoses than those allowed, 264 patients remained. Of these, 233 had completed at least one of the neurocognitive tests administered. Missing value analysis resulted in a final group of 196 patients with complete results from all neurocognitive testing.

Of the 196 patients included in the present study, 25 individuals (12.8%) were diagnosed with delusional syndrome, 6 (3.1%) with disorganised schizophrenia, 1 (0.5%) with catatonic schizophrenia, 66 (33.7%) with paranoid schizophrenia, 10 (5.1%) with residual schizophrenia, 44 (22.4%) with schizoaffective disorder and finally 44 individuals (22.4%) with undifferentiated schizophrenia, according to their medical records. All but nine patients were on antipsychotic
medication, with one of the nine ordained medications the patient did not take. Five patients were about to be released from a psychiatric ward at the time of the testing; the others were living in the community.

The 196 healthy volunteers originated from a standardization study conducted by undergraduate students at Karlstad University, Sweden. Ten persons were excluded from the original group of 302 subjects: six persons who reported suffering from mental illness, and four persons who had a close relative with psychosis. After missing value analysis, 26 persons were removed from the group. Before reducing the group size to match the patient group, all individuals with low scores (39 words or lower) on the main parameter Rey Auditory Verbal Learning Test (RAVLT) were saved, as there were only 27 of these in the whole volunteer group. Thereafter, a supplementary random selection was made in order to obtain a total group size of 196 healthy volunteers.

2.1.1. Difference among samples

Independent t-test showed that the schizopsychotic (mean = 46.31, S.D. = 11.76) and healthy volunteer (mean = 47.81, S.D. = 18.09) groups were well matched for age (t = −0.97, df = 334.89, p = 0.331, equal variances not assumed), but Mann–Whitney test indicated differences with regard to sex assignment (Z = −3.83, p < 0.0001, two-tailed). There were more males than females in the schizopsychotic group (males: 59.2%, females: 40.8%) whereas the ratio was reversed in the group of healthy volunteers (males: 39.8%, females: 60.2%).

There was a significant difference between the two groups in their level of education (Z = −8.63, p < 0.0001, two-tailed) and civil status (Z = −8.30, p < 0.0001, two-tailed). Most of the healthy volunteers had a college-level education (elementary school: 18.9%, high school: 25.0%, college/university: 56.1%) and were married (single: 17.9%, divorced/widowed: 17.4%, married/common law: 64.6%), whereas most of the schizopsychotic patients had only completed elementary school (elementary school: 46.9%, high school: 40.3%, college/university: 12.8%) and had never been married (single: 54.1%, divorced/widowed: 20.4%, married/common law: 25.5%).

The healthy volunteers had more children (mean = 1.33, S.D. = 1.33) than the schizopsychotic patients (mean = 0.78, S.D. = 1.16). This difference was significant (t = −4.38, df = 382.46, p < 0.0001, equal variances not assumed), as was the difference in the number of children currently living with the subjects (t = −2.26, df = 369.48, p = 0.025, equal variances not assumed). The healthy volunteers had more children at home (mean = 0.35, S.D. = 0.75) than the schizopsychotic patients (mean = 0.20, S.D. = 0.59).

2.2. Data analysis

Mann–Whitney U-test and t-test were conducted for a comparison of background variables for the two study groups. In order to analyze the effect of age and education on verbal learning performance, one-way analysis of variance (ANOVA) and chi-square were used. Multivariate analysis of variance (MANOVA) was used to compare the effect of verbal learning performance level, study group and sex on the combined cognitive test variable. Pairwise testing between groups was carried out using the Tukey-HSD test. In order to identify the best combination of cognitive variables to predict the level of verbal learning performance, discriminant function analysis was conducted separately for each study group and each level of verbal learning performance. The Mahalanobis distance method was used in the analyses (Hair, Anderson, Tatham, & Black, 1998, p. 262), which were then cross-validated with Press’s Q-test. The critical $\chi^2$ value was set at significance level of 0.01 (6.64 for one degree of freedom and 9.21 for two degrees of freedom), unless where otherwise stated.

2.2.1. Statistical significance

For univariate tests, an alpha level of 0.05 was used. When multiple tests were conducted, a Bonferroni adjustment of the alpha level was made (0.008). For multivariate tests, a more strict alpha level of 0.01 was used to compensate for some violation of the basic multivariate assumptions.

All statistical analysis was performed on the Statistical Package for the Social Sciences (SPSS) version 11.5.1 for Windows.

2.3. Design

The aim of this demographic cross-sectional study was to analyze and compare neurocognitive test profiles related to different levels of verbal learning performance among schizopsychotic patients and healthy volunteers, in order to identify the major predictors of category assignment.
To produce the variable “verbal learning performance level”, the schizopsychotic and healthy volunteer groups were combined into one single group of 392 persons. The total number of words correctly recalled, summed across Rey Auditory Verbal Learning Test (RAVLT) trials I through V, was used as a learning summary score. This summary score is widely used (Schmidt, 1996), has good test-retest reliability (Geffen, Butterworth, & Geffen, 1994), has been shown to discriminate mixed groups of neurological patients from normal subjects (Powell, Cripe, & Dodrill, 1991), and memory impairment from memory intact patients (Rosenberg, Ryan, & Prifitera, 1984; Ryan & Geisser, 1986).

The RAVLT summary scores for the combined group were converted into standardized scores by the statistics program. Among the schizopsychotic patients, Z-scores ranged from −2.70 at the lowest to 1.65 at the highest. For the healthy volunteers, the lowest value was −1.38 and the highest value 2.11. The combined group scores were then divided into three subgroups with −/+ 0.5 standard deviations as fixed markers. These markers were chosen according to Harvey and Sharma (2002, p. 17), who have defined 0.5–1 standard deviations below mean as representing a mild level of cognitive deficit. This resulted in the following group sizes: low verbal learning performance level (under −0.5 standard deviations from the combined group mean), 130 subjects (33.2%); average verbal learning performance level (between −0.49 and +0.49 standard deviations from the combined group mean), 129 subjects (32.9%); high learning verbal performance level (over +0.5 standard deviations from the combined group mean), 133 subjects (33.9%).

Within the patient group, 110 subjects (56.1%) were classified as low-level verbal learning performers, 60 subjects (30.6%) as average-level verbal learning performers, and 26 subjects (13.3%) as high-level verbal learning performers. Within the volunteer group, 20 subjects (10.2%) were classified as low-level verbal learning performers, 69 subjects (35.2%) as average-level verbal learning performers, and 107 subjects (54.6%) as high-level verbal learning performers.

Fig. 1 presents the relationship between the two study groups, the schizopsychotic patients and healthy volunteers, as a function of low, average, and high verbal learning performance.

2.4. Neuropsychological measures

2.4.1. Rey auditory verbal learning test (RAVLT)

The RAVLT is a commonly used clinical measure of verbal learning and memory (Rey, 1964; Schmidt, 1996) that measures immediate memory span, provides a learning curve, reveals the presence or absence of learning strategies,
elicits retroactive and proactive interference tendencies and tendencies to confusion or confabulation on memory tasks, measures both short-term and longer-term retention following interpolated activity, and allows for a comparison between retrieval efficiency and learning (Lezak, 1995, p. 438). In the present study, the Cronbach alpha coefficient for RAVLT was 0.96.

RAVLT consists of a 15-item word list that is presented five times, always in the same order, with an assessment of recall immediately after each presentation. Thereafter an interference list is presented, followed by a request to recall the original list without further presentation of the original list words. Finally, a delayed recall test is presented after 20 min.

In this study, the RAVLT total score (the number of words correctly recalled, summed across the five immediate recall trials) was solely used to form the variable verbal-learning performance level.

2.4.2. Continuous performance test—identical pairs version (CPT-IP)

The CPT-IP is a computerized vigilance test (Cornblatt, Risch, Faris, Friedman, & Erlenmeyer-Kimling, 1988; Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956) that assesses the subjects’ ability to respond to a target stimulus, namely the second of a pair of identical stimuli (a four-digit number). Stimuli is flashed on the computer screen at a constant rate of 1 s\(^{-1}\), with a stimulus “on” time of 50 ms. Responses are made as fast as possible by a fingerlift from a mouse button.

The test is constructed in three equal-sized sequences, each with 150 trials. The total d’ score (a measure of perceptual sensitivity or attentional capacity, i.e. the participants ability to discriminate targets from non-targets) for the 450 trial condition was used in this study as a measure of vigilance.

2.4.3. Trail Making Test Part A and Part B (TMT-A and TMT-B)

The Trail Making Test, originally part of the Army Individual Test Battery, is one of the most widely used and most sensitive brief examinations for brain impairment (Reitan, 1958). Subjects are required to join consecutive numbers (Part A) and to alternate between two sets, connecting numbers and letters (Part B), all under the pressure of doing the task as rapidly as possible. The tests are scored as introduced by Reitan (Lezak, 1995, p. 381).

In this study, the time to completion (in seconds) for the Part A condition was used as a measure of visuomotor processing speed/efficacy, and the time to completion (in seconds) for the Part B condition as a measure of cognitive flexibility. Note: the scales are inverted, as low scores stand for better performance.

2.4.4. Letter-number sequencing (LNS)

The LNS, now a supplementary subtest in the WAIS-III (Wechsler, 1997), is often used for assessment of auditory working memory performance (Gold, Carpenter, Randolph, Goldberg, & Weinberger, 1997). It requires the subjects to sort out letters from numbers within a row of alternating letters and numbers that are read to them, and to separately recall the letters and numbers in successive order. The subject can either pass or fail on each trial.

The number of trials (out of 21) on which the subject was successful in producing the information correctly was used in this study as a measure of working memory.

2.4.5. Vocabulary subtest from Wechsler adult intelligence scale-revised (WAIS-R)

This test has been identified as the single best measure of both verbal and general mental abilities (Wechsler, 1981). The subject is asked the meaning of 40 words, arranged in order of difficulty, and their explanation is given 0, 1 or 2 points. The sum score was used in this study as a measure of verbal facility.

2.4.6. Wisconsin card sorting test (WCST)

The WCST has increasingly been employed as a clinical neuropsychological instrument and can be considered a measure of executive function (Heaton, Chelune, Talley, Kay, & Curtiss, 1993).

The WCST consists of four stimulus cards and 128 response cards that depict figures, colors, and numbers. The subject is instructed to match each consecutive card from the deck with one of the stimulus cards by pressing a computer key. A message on the computer screen tells the subject whether each response is right or wrong. Once the subject has made a specified number of consecutive correct matches to the initial sorting principle, the sorting principle is changed without warning. The WCST proceeds in this manner through a number of shifts in sorting principle among the three possible sorting categories. The computer program calculates the test scores.
In this study, the total number of completed categories (out of six) was used as a measure of executive functioning.

2.5. Procedure

2.5.1. Schizopsychotic outpatients

The present study was carried out at the Department of Psychiatry, NU Health Care in Western Sweden, during the period November 2000 to June 2004. Inclusion criteria were: any of the diagnoses schizophrenia, schizoaffective disorder or delusional disorder, according to DSM-IV and ICD-10; remaining within a stable phase of the illness representing the best of symptom control and performance level; and being registered at any one of the outpatient settings. The exclusion criterion was that the patients should not be afflicted by any other psychiatric disorder that might affect the test results, as for instance dementia. Patients were recruited through their case manager at the outpatient settings at which they received treatment. All participation was on a free volunteer basis and could be terminated whenever the patient so wished and without having to provide any rationale. Patients accepting to participate in the investigation underwent tests and interviews that were not normally a part of their treatment interviews. Patients meeting with the inclusion criteria were examined over 2 days and certain patients with serious cognitive disturbance may have required examination over an extra day. Medical records were examined to complement the already-existing information. Finally, the patients’ closest relative was asked to complete a questionnaire concerning how the disorder affected the rest of the family. All the assessments were carried out by a total of four researchers in the research team. The same licensed psychologist (corresponding author) carried out all neurocognitive testing.

Written informed consent was obtained for each subject and the project received hospital and university ethical approval.

2.5.2. Healthy volunteers

The healthy volunteer control group was examined at the Department of Psychology, Karlstad University, Sweden, during the spring semesters of 2004 and 2005. A homogenous population with regard to sex, age and education was sought after. Participants with psychotic disorder within any close relative were excluded from the final control group. Recruitment of healthy volunteers was carried out through direct contact with employees of various organizations, university students, pensioners, and through advertisement in the local newspapers. All subjects were informed that their participation was anonymous and on a volunteer basis and that all the material collected would be treated with complete confidentiality. Each participant was tested singly over an interval of about 1 h. On completion of the task, each participant was awarded a raffle ticket (worth 50 Swedish crowns, about 5 Euro). All experimental testing was performed by altogether eight undergraduate psychology students, all of whom had completed a basic course in application of the neuropsychological test battery. A standardized procedure was observed carefully by each of the experimenters.

3. Results

3.1. Demographic data

3.1.1. Effect of age on verbal learning performance

One-way univariate analysis of variance (ANOVA) indicated a significant effect of age on verbal learning performance both in the schizopsychotic group ($F_{(2,193)} = 5.00, p = 0.008$) and the healthy volunteer group ($F_{(2,193)} = 17.45, p > 0.0001$). Post hoc testing (Tukey–HSD, 5% level) indicated that in the patient group, the low-level verbal learning performers were older (mean = 48.61, S.D. = 11.26) than the average-level verbal learning performers (mean = 43.40, S.D. = 12.23), who did not differ from the high-level verbal learning performers (mean = 43.27, S.D. = 11.00). Among the healthy volunteers, the age differences were more marked. Post hoc testing (Tukey–HSD, 5% level) indicated that the low-level verbal learning performers were the oldest (mean = 62.25, S.D. = 17.01) and the high-level verbal learning performers the youngest (mean = 41.83, S.D. = 16.50), whereas the average-level verbal learning performers (mean = 52.88, S.D. = 17.01) had an in between position.
3.1.2. Effect of education on verbal learning performance

There was a significant effect of education on verbal learning performance in both the healthy volunteer ($\chi^2 = 31.91$, Fisher’s exact $p > 0.0001$) and patient group ($\chi^2 = 19.69$, Fisher’s exact $p > 0.0001$), but the effect differed within the two groups.

In the healthy volunteer group, elementary education was mostly associated with an average-level of verbal learning performance (low: 13.5%, average: 64.9%, high: 21.6%), whereas education at or above high school level was mostly associated with high verbal learning performance (high school = low: 18.4%, average: 36.7%, high: 44.9%; college/university = low: 5.5%, average: 24.5%, high: 70.0%).

In the schizophrenic group, education under college level was mostly associated with a low level of verbal learning performance (elementary education = low: 69.6%, average: 22.8%, high: 7.6%; high school = low: 46.8%, average: 40.5%, high: 12.7%), whereas those with higher education mostly had either a low or high-level of verbal learning performance (low: 36.0%, average: 28.0%, high: 36.0%).

3.2. Group-related differences in neurocognitive performance

Multivariate analysis of variance (MANOVA) was performed to investigate group-related differences in cognitive test results. The three independent variables were study group (schizophrenic patient/healthy volunteer), sex (male/female) and verbal learning performance level (low/average/high). Six dependent variables were used: vigilance, visuomotor processing speed/efficacy, cognitive flexibility, working memory, verbal facility and executive function.

No interaction effect was detected (verbal learning performance level by group: $F_{(12,752)} = 1.98$, $p = 0.023$; verbal learning performance level by sex: $F_{(12,752)} = 2.00$, $p = 0.022$; group by sex: $F_{(6,375)} = 1.50$, $p = 0.176$; verbal learning performance level by group by sex: $F_{(12,752)} = 0.69$, $p = 0.764$).

There was a statistically significant difference between schizophrenic patients and healthy volunteers on the combined dependent variables ($F_{(6,375)} = 24.35$, $p < 0.0001$, Wilks’ lambda = 0.72, partial $\eta^2 = 0.28$, power > 0.99), as well as between males and females ($F_{(6,375)} = 5.96$, $p < 0.0001$, Wilks’ lambda = 0.91, partial $\eta^2 = 0.09$, power = 0.99). There was also a significant difference between the three levels of verbal learning performance on the combined dependent variables ($F_{(12,752)} = 8.69$, $p < 0.0001$, Wilks’ lambda = 0.76, partial $\eta^2 = 0.13$, power > 0.99).

3.2.1. Effect of study group on neurocognitive performance

Taking into consideration the two study groups, the results pertaining to the dependent variables, using a Bonferroni adjusted alpha level, were as follows:

3.2.1.1. Vigilance. Univariate $F$-test indicated a significant effect of study group upon vigilance ($F_{(1,380)} = 56.96$, $p < 0.0001$, partial $\eta^2 = 0.13$, power > 0.99), whereby an inspection of the mean scores indicated that the healthy volunteers had better attentional capacity (mean = 1.25, S.D. = 0.71) than the schizophrenic group (mean = 0.48, S.D. = 0.58).

3.2.1.2. Visuomotor processing speed/efficacy. Univariate $F$-test indicated a significant effect of study group upon visuomotor processing speed/efficacy ($F_{(1,380)} = 52.18$, $p < 0.0001$, partial $\eta^2 = 0.12$, power > 0.99), whereby an inspection of the mean scores indicated that healthy volunteers had higher processing speed/efficacy (mean = 28.90, S.D. = 10.92) than the patients (mean = 55.14, S.D. = 32.12).

3.2.1.3. Cognitive flexibility. Univariate $F$-test indicated a significant effect of study group upon cognitive flexibility ($F_{(1,380)} = 58.66$, $p < 0.0001$, partial $\eta^2 = 0.13$, power > 0.99), whereby an inspection of the mean scores indicated that the healthy volunteers had better ability to shift set (mean = 64.15, S.D. = 28.37) than the schizophrenic patients (mean = 150.77, S.D. = 86.32).

3.2.1.4. Working memory. No significant effect of study group upon working memory was obtained ($F_{(1,380)} = 4.70$; $p = 0.031$).

3.2.1.5. Verbal facility. Univariate $F$-test indicated a significant effect of study group upon verbal facility ($F_{(1,380)} = 24.94$, $p < 0.0001$, partial $\eta^2 = 0.06$, power = 0.99), whereby an inspection of the mean scores indicated
that the healthy volunteers had a better understanding of words (mean = 47.06, S.D. = 10.65) than the schizopsychotic group (mean = 38.32, S.D. = 11.30).

3.2.1.6. Executive functioning. Univariate F-test indicated a significant effect of study group upon executive functioning \((F_{(1,380)} = 49.93, p < 0.0001, \text{partial } \eta^2 = 0.12, \text{power} > 0.99)\), whereby an inspection of the mean scores indicated that the healthy volunteer group possessed a higher level of executive functioning (mean = 4.91, S.D. = 1.78) than the schizopsychotic patients (mean = 2.65, S.D. = 2.08).

3.2.2. Effect of sex on neurocognitive performance

When the results for the dependent variables were considered for males and females, the only differences to reach statistical significance, using a Bonferroni adjusted alpha level, were sustained attention \((F_{(1,380)} = 20.58, p < 0.0001, \text{partial } \eta^2 = 0.05, \text{power} = 0.97)\) and executive functioning \((F_{(1,380)} = 10.25, p < 0.001, \text{partial } \eta^2 = 0.02, \text{power} = 0.73)\). An inspection of the mean scores indicated that males (mean = 0.91, S.D. = 0.77) had better sustained attention than females (mean = 0.82, S.D. = 0.74), whereas females (mean = 3.84, S.D. = 2.30) had slightly better executive functioning than males (mean = 3.72, S.D. = 2.18).

3.2.3. Effect of verbal learning performance level on neurocognitive performance

Taking into consideration the three levels of verbal learning performance, the results pertaining to the dependent variables, using a Bonferroni adjusted alpha level, were as follows:

3.2.3.1. Vigilance. Univariate F-test indicated a significant effect of verbal learning performance level upon vigilance \((F_{(2,380)} = 20.15, p < 0.0001, \text{eta}^2 = 0.10, \text{power} > 0.99)\), whereby post hoc testing (Tukey–HSD, 1% level) indicated that the high-level verbal learning performers had the highest target discrimination ability (mean = 1.31, S.D. = 0.70) and the low-level verbal learning performers (mean = 0.39, S.D. = 0.61) the lowest, whilst the medium-level verbal learning performers (mean = 0.88, S.D. = 0.63) had an intermediate target discrimination ability.

3.2.3.2. Visuomotor processing speed/efficacy. No significant effect of verbal learning performance level upon visuomotor processing speed/efficacy was obtained \((F_{(2,380)} = 4.54; p = 0.011)\).

3.2.3.3. Cognitive flexibility. Univariate F-test indicated a significant effect of verbal learning performance level upon cognitive flexibility \((F_{(2,380)} = 26.61, p < 0.0001, \text{eta}^2 = 0.13, \text{power} > 0.99)\), whereby post hoc testing (Tukey–HSD, 1% level) indicated that the high-level verbal learning performers were the most flexible in shifting the course of an ongoing activity, the low-level verbal learning performers (mean = 165.96, S.D. = 86.86) the least flexible, and the medium-level verbal learning performers (mean = 95.45, S.D. = 64.30) showed an intermediate level of cognitive flexibility.

3.2.3.4. Working memory. Univariate F-test indicated a significant effect of verbal learning performance level upon working memory \((F_{(2,380)} = 36.01, p < 0.0001, \text{eta}^2 = 0.16, \text{power} > 0.99)\), whereby post hoc testing (Tukey–HSD, 1% level) indicated that the high-level verbal learning performers showed the most proficient working memory (mean = 11.57, S.D. = 2.32), the low-level verbal learning performers (mean = 7.65, S.D. = 2.72) the least proficient, whereas the medium-level verbal learning performers (mean = 9.91, S.D. = 2.44) showed an intermediate level of proficiency.

3.2.3.5. Verbal facility. Univariate F-test indicated a significant effect of verbal learning performance level upon verbal facility \((F_{(2,380)} = 8.03, p < 0.0001, \text{eta}^2 = 0.41, \text{power} = 0.86)\), whereby post hoc testing (Tukey–HSD, 1% level) indicated that both the high \((\text{mean} = 46.88, \text{S.D.} = 10.70)\) and the average \((\text{mean} = 44.53, \text{S.D.} = 9.66)\) level verbal learning performers had significantly better vocabulary skills than the low-level verbal learning performers \((\text{mean} = 36.58, \text{S.D.} = 12.40)\).

3.2.3.6. Executive functioning. Univariate F-test indicated a significant effect of verbal learning performance level upon executive functioning \((F_{(2,380)} = 15.98, p < 0.0001, \text{eta}^2 = 0.08, \text{power} > 0.99)\), whereby post hoc testing (Tukey–HSD, 1% level) indicated that the high-level verbal learning performers completed more categories
Fig. 2. Group centroids for the three performance levels on the first discriminant function, per study group, depicting the marked difference between patients and volunteers.

(mean = 5.00, S.D. = 1.70) than the other two groups. The low-level verbal learning performers (mean = 2.28, S.D. = 2.01) completed the least number of categories, whereas the medium-level verbal learning performers (mean = 4.04, S.D. = 2.08) showed an intermediate level of performance.

3.3. Prediction of level of verbal learning performance for the two study groups

A series of separate stepwise discriminant analysis was conducted to determine which of the neurocognitive variables were the best predictors of the different levels of verbal learning performance within the two subgroups (schizopsychotic patients/healthy volunteers). The grouping variable was verbal learning performance level, and the predictor variables were vigilance, visuomotor processing speed/efficacy, cognitive flexibility, working memory, verbal facility and executive function. The Mahalanobis distance method was used in the analyses.

Group centroids (mean discriminant scores for the three levels of verbal learning performance for the first discriminant function, per study group) are presented graphically in Fig. 2.

3.3.1. Predictors of verbal learning performance level for schizopsychotic patients

A total of 196 cases were analysed. Bonferroni adjusted univariate F-tests revealed that the levels of verbal learning performance differed significantly on all but one (visuomotor processing speed/efficacy) of the six predictor variables. Two discriminant functions were calculated. The value of the first function was significantly different for the levels of verbal learning performance ($\chi^2 = 80.43$, df = 6, $p < 0.0001$, Wilks’ lambda = 0.66). The value of the second function was nonsignificant ($\chi^2 = 0.80$, $p = 0.669$). The correlations between predictor variables and the discriminant function suggested that working memory (0.83) was the best predictor of the level of verbal learning performance. There was also a moderate correlation between the discriminant function and vigilance (0.59) along with vocabulary (0.58).

Overall the discriminant function successfully predicted outcome for 62.8% of the cases, with accurate predictions being made for 71.8% of the low-level verbal learning performers, 41.7% of the average-level verbal learning performers, and 73.1% of the high-level verbal learning performers.

The discriminant analysis was then cross-validated by dividing the same schizopsychotic patient group into an analysis sample of 120 (61%) subjects and a hold-out sample of 76 (39%) subjects in a random fashion. Overall the cross-validation of the discriminant function successfully predicted outcome for 59.2% of the cases, with accurate predictions being made for 78.9% of the low-level verbal learning performers, 37.0% of the average-level verbal learning performers, and 45.5% of the high-level verbal learning performers.
The discriminant power of the classification matrix was compared with a chance model with Press’s $Q$-test. The result (22.90) exceeded the critical value (9.21), implying that the classification matrix was statistically significant.

### 3.3.2. Predictors of verbal learning performance level for healthy volunteers

A total of 196 cases were analysed. Bonferroni adjusted univariate $F$-tests revealed that the levels of verbal learning performance differed significantly on all but one (verbal facility) of the six predictor variables. Two discriminant functions were calculated. The value of the first discriminant function was significantly different for the levels of verbal learning performance ($\chi^2 = 78.90, \text{df} = 4, p < 0.0001$, Wilks’ $\lambda = 0.66$). The value of the second discriminant function was also significant ($\chi^2 = 9.02, \text{df} = 1, p = 0.003$, Wilks’ $\lambda = 0.95$). The correlations between predictor variables and the discriminant function suggested that cognitive flexibility (0.95) was the best predictor of the level of verbal learning performance on the first and working memory (0.80) on the second discriminant function.

Overall the discriminant functions successfully predicted outcome for 58.2% of the cases, with accurate predictions being made for 50.0% of the low-level verbal learning performers, 50.7% of the average-level verbal learning performers, and 64.5% of the high-level verbal learning performers.

The discriminant analysis was then cross-validated by dividing the same healthy volunteer group into a analysis sample of 120 (61%) subjects and hold-out sample of 76 (39%) subjects in a random fashion. Overall the discriminant function successfully predicted outcome for 55.3% of cases, with accurate predictions being made for 44.4% of the low-level verbal learning performers, 40.7% of the average-level verbal learning performers, and 67.5% of the high-level verbal learning performers.

The discriminant power of the classification matrix was compared with a chance model with Press’s $Q$-test. The result (16.45) exceeded the critical value (9.21), implying that the classification matrix was statistically significant.

### 3.4. Prediction of study group within the three levels of verbal learning performance

A series of separate stepwise discriminant analysis was conducted to determine which of the neurocognitive variables would be the best predictors of study group (schizopsychotic patients/healthy volunteers) within the three levels of verbal learning performance. Grouping variable was study group and the predictor variables were vigilance, visuo-motor processing speed/efficacy, cognitive flexibility, working memory, verbal facility and executive function. The Mahalanobis distance method was used in the analyses. Group centroids (mean discriminant scores for the two study groups for the discriminant function, per verbal learning performance level) are presented graphically in Fig. 3.

#### 3.4.1. Predictors of study group for the high-level verbal performers

A total of 133 cases were analysed. Univariate $F$-test revealed that the study groups differed significantly on all but two (working memory and verbal facility) out of the six predictor variables. One discriminant function was calculated.

![Fig. 3. Group centroids for the study groups on the discriminant function per performance level, depicting the marked differences between patients and volunteers.](image-url)
The value of the discriminant function was significantly different for the two groups ($\chi^2 = 37.97$, $df = 2$, $p > 0.001$, Wilks’ lambda = 0.75). The correlations between predictor variables and the discriminant function suggested that cognitive flexibility (0.91) was the best predictor of study group. There was also a moderate correlation between the discriminant function and executive functioning (−0.64).

Overall the discriminant function successfully predicted outcome for 81.2% of the cases, with accurate predictions being made for 61.5% of the patient group and 86.0% of the healthy volunteer group.

The discriminant analysis was then cross-validated by dividing the same high-level verbal performers into an analysis sample of 81 (61%) subjects and hold-out sample of 52 (39%) subjects in a random fashion. Overall the discriminant function successfully predicted outcome for 75.0% of cases, with accurate predictions being made for 66.7% of the schizopsychotic-group and 76.7% of the healthy volunteer group.

The discriminant power of the classification matrix was compared with a chance model with Press’s $Q$-test. The result (6.50) did not exceed the critical value (6.64) at the set alpha level of 0.01. Nevertheless, the result was significant at an alpha level of 0.05 (3.84).

3.4.2. Predictors of study group for the average-level verbal performers

A total of 129 cases were analysed. Univariate $F$-test revealed that the study groups differed significantly on all but one (working memory) of the six predictor variables. One discriminant function was calculated. The value of the discriminant function was significantly different for the two groups ($\chi^2 = 53.01$, $df = 4$, $p > 0.0001$, Wilks’ lambda = 0.65). The correlations between predictor variables and the discriminant function suggested that cognitive flexibility (0.81) was the best predictors of study group. There was also a moderate correlation between the discriminant function and vigilance (−0.53), and a low correlation between the discriminant function and verbal facility (−0.46).

Overall the discriminant function successfully predicted outcome for 79.8% of cases, with accurate predictions being made for 68.3% of the schizopsychotic-group and 89.9% of the healthy volunteer group.

The discriminant analysis was then cross-validated by dividing the same average-level verbal performers into an analysis sample of 79 (61%) subjects and hold-out sample of 50 (39%) subjects in a random fashion. Overall the discriminant function successfully predicted outcome for 72.0% of cases, with accurate predictions being made for 52.0% of the schizopsychotic-group and 92.0% of the healthy volunteer group.

The discriminant power of the classification matrix was compared with a chance model with Press’s $Q$-test. The result (4.84) did not exceed the critical value (6.64) at the set alpha level of 0.01. Nevertheless, the result was significant at an alpha level of 0.05 (3.84).

3.4.3. Predictors of study group for the low-level verbal performers

A total of 130 cases were analysed. Univariate $F$-test revealed that the study groups differed significantly on only one (working memory) of the six predictor variables. One discriminant function was calculated. The value of the discriminant function was significantly different for the two groups ($\chi^2 = 33.37$, $df = 3$, $p < 0.0001$, Wilks’ lambda = 0.77). The correlations between predictor variables and the discriminant function suggested that vigilance (0.70) and executive function (0.70) were the best predictors of study group. There was also a moderate correlation between the discriminant function and verbal facility (0.68).

Overall the discriminant function successfully predicted outcome for 77.7% of cases, with accurate predictions being made for 79.1% of the schizopsychotic-group and 70.0% of the healthy volunteer group.

The discriminant analysis was then cross-validated by dividing the same low-level verbal performers into a analysis sample of 79 (61%) subjects and hold-out sample of 51 (39%) subjects in a random fashion. Overall the discriminant function successfully predicted outcome for 78.4% of cases, with accurate predictions being made for 85.4% of the schizopsychotic-group and 50.0% of the healthy volunteer group.

The discriminant power of the classification matrix was compared with a chance model with Press’s $Q$-test. The result (8.25) exceeded the critical value (6.64), implying that the classification matrix was statistically significant.

The means and standard deviations for neurocognitive test results with regard to study group for the three levels of verbal learning performance are summarized in Table 1.
Table 1
Means (and standard deviations) for neurocognitive test results with regard to study group (schizopsychotic/healthy volunteer) for the three levels of verbal learning performance (low/average/high)

<table>
<thead>
<tr>
<th>Level</th>
<th>Group</th>
<th>CPT-IP</th>
<th>TMT-A</th>
<th>TMT-B</th>
<th>LNS</th>
<th>Vocabulary</th>
<th>WCST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Schizopsychotic patients</td>
<td>0.297 (0.48)</td>
<td>60.28* (26.94)</td>
<td>176.66* (87.57)</td>
<td>7.51 (2.57)</td>
<td>34.75* (11.53)</td>
<td>1.97* (1.86)</td>
</tr>
<tr>
<td></td>
<td>Healthy volunteers</td>
<td>0.90 (0.95)</td>
<td>35.05 (10.74)</td>
<td>107.15 (54.17)</td>
<td>8.45 (3.40)</td>
<td>46.65 (12.45)</td>
<td>3.95 (2.01)</td>
</tr>
<tr>
<td>Average</td>
<td>Schizopsychotic patients</td>
<td>0.64* (0.57)</td>
<td>49.62* (26.97)</td>
<td>130.35* (79.07)</td>
<td>9.88 (2.08)</td>
<td>41.27* (9.61)</td>
<td>3.40* (2.06)</td>
</tr>
<tr>
<td></td>
<td>Healthy volunteers</td>
<td>1.09 (0.62)</td>
<td>29.28 (7.92)</td>
<td>65.10 (18.68)</td>
<td>9.93 (2.74)</td>
<td>47.36 (8.83)</td>
<td>4.59 (1.95)</td>
</tr>
<tr>
<td>High</td>
<td>Schizopsychotic patients</td>
<td>0.90* (0.69)</td>
<td>46.12* (53.78)</td>
<td>88.35* (43.84)</td>
<td>10.96 (1.76)</td>
<td>46.62 (7.09)</td>
<td>3.81* (2.00)</td>
</tr>
<tr>
<td></td>
<td>Healthy volunteers</td>
<td>1.41 (0.67)</td>
<td>27.51 (12.22)</td>
<td>55.50 (17.48)</td>
<td>11.72 (2.42)</td>
<td>46.94 (11.43)</td>
<td>5.29 (1.49)</td>
</tr>
</tbody>
</table>

CPT-IP = vigilance; TMT-A = visuomotor processing speed/efficacy; TMT-B = cognitive flexibility; LNS = working memory; vocabulary = verbal facility; WCST = executive function.
* Significant effect of study group (Bonferroni adjusted \( p < 0.008 \)) is indicated in the patient row.

4. Discussion

One major finding of the present study was that 43.9% of the schizopsychotic patients had normal (average or high) levels of verbal learning performance. The proportion of unimpaired patients closely resembles that obtained by the American researchers Abi-Saab et al. (2005). Using cluster analysis to form three groups of schizophrenic patients that were tested with Hopkins Verbal Learning Test, Revised edition (HVLT-R), 42% were found to have relatively unimpaired memory. An Australian study (Badcock, Dragovic, Waters, & Jablensky, 2005) formed three subgroups of patients by estimating current intellectual functioning. 41.3% of the patients were categorised as having preserved IQ. This preserved IQ-group had significantly better neurocognitive performance than the deteriorated and compromised IQ groups on, among other tests, RAVLT.

This situation may suggest that in general, approximately four out of ten schizophrenic patients have relatively preserved learning and memory functions. This proportion is about twice as many as reported by earlier research, as cited in Badcock et al. (2005). Nevertheless, does this necessarily imply that these 40% function overall as well as normal controls?

Despite equivalent levels of verbal learning in comparison with healthy volunteers, the schizopsychotic patients in the present study performed worse on all subtests with the exception of working memory. Thus, the patient group showed impaired vigilance, visuomotor processing speed/efficacy, cognitive flexibility and executive function relative to the control group (healthy volunteers). The connection between verbal learning and working memory may be expected, as research has indicated working memory capacity to be an important moderating variable of learning (Psychological Corporation: WAIS-III WMS-III technical manual, 2002, p. 7). This applies to both the patient and volunteer groups, as working memory was a significant predictor of verbal learning performance level in both, even though cognitive flexibility was the strongest predictor for the volunteers. Higher scores on the working memory test were associated with higher verbal learning performance levels for both study groups.

Another interesting finding was that the schizopsychotic high-level verbal learning performers presented a level of vocabulary that was comparable with that of the healthy volunteers, which suggests that superior verbal learning might be facilitated by a good word comprehension. This level of verbal learning performance/level of vocabulary relationship seems applicable only to the patient group since no differences in the verbal facility of the volunteers, despite their level of verbal learning performance, existed. Vocabulary scores are thought to reflect the subjects’ socio-economic and cultural origins rather than their academic achievement (Lezak, 1995, p. 540). However, in this respect an initial inspection of the schizopsychotic patients showing high-level verbal learning performance revealed no obvious demographic pattern that could account for this verbal learning/vocabulary connection.

Thirdly, all the schizopsychotic patients presented equally poor visuomotor processing speed/efficacy, despite their level of verbal learning ability, as no significant differences were found within the patient group. This finding indicates retarded visuomotor processing speed, which has been suggested to be a generalised characteristic of the schizophrenic process (Badcock, Williams, Anderson, & Jablensky, 2004). Thus, even patients with intact learning ability, working memory and vocabulary appear to share this global neurocognitive retardation in speed-related processing, although it may not always be perceived as a prominent feature but as more of a background influence.
5. Conclusion

It is concluded that there is a global neurocognitive retardation in speed-related processing in schizophrenia. Further research ought to address whether this is paired with differential deficits in specific neurocognitive processes.

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References


