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# Developing neurocognitive standard clinical care: A study of young adult inpatients

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ABSTRACT

Neuropsychological assessments have provided the field of psychiatry with important information about patients. As an assessment tool, a neuropsychological battery can be useful in a clinical setting; however, implementation as standard clinical care in an inpatient unit has not been extensively evaluated. A computerized cognitive battery was administered to 103 current young adult inpatients (19.2 ± 3.1 years; 72% female) with affective disorder. Neurocognitive tasks included Verbal Recognition Memory (VRM), Attention Switching (AST), Paired Association Learning (PAL), and Rapid Visual Processing (RVP). Patients also completed a computerized self-report questionnaire evaluating subjective impressions of their cognition. Hierarchical cluster analysis determined three neurocognitive subgroups: cluster 1 ($n = 17$) showed a more impaired neurocognitive profile on three of the four variables compared to their peers in cluster 2 ($n = 59$), and cluster 3 ($n = 27$), who had the most impaired attentional shifting. Two of the four neurocognitive variables were significantly different between all three cluster groups (verbal learning and sustained attention). Overall group results showed an association between poorer sustained attention and increased suicidal ideation. These findings strengthen the idea that neurocognitive profiles may play an important role in better understanding the severity of illness in young inpatients with major psychiatric disorders.

## 1. Introduction

Psychiatric illness (including affective disorders such as depression and bipolar) typically emerges during adolescence and young adulthood and has been shown to impact long-term social and functional outcomes over a lifetime for at-risk people. Along with negative mood symptoms and mood instability, cognitive (and thus functional) impairment is a major concern for patients and their clinicians alike.

Historically, neuropsychological functioning has been a main consideration in both research and medical settings in regard to confirmation, management and treatment of major brain injuries, and neurological and developmental disorders (Allott et al., 2013; Johnstone et al, 1997). In recent years, however, the utility of neuropsychological assessment has been increasingly seen as useful in psychology and psychiatry. This includes early classification of cognitive deficits and their potentially predictive nature (Lee et al., 2015), markers for specific disorders such as bipolar disorder (Cosway et al., 2000; Lee et al., 2014), and serious clinical symptoms such as suicidal ideation (Gorlyn et al., 2015; Marzuk et al., 2005; Westheide et al., 2008).

Previous reviews have suggested that research into cognitive deficits and neuropsychological profiles is not always consistent and these

*Abbreviations:* ADD, attention deficit disorder; ADHD, attention deficit hyperactivity disorder; AST, attention switching task; APS, attenuated psychosis syndrome; CANTAB, Cambridge neuropsychological test automated battery; DSM-IV, diagnostic and statistical manual of mental disorders; EDNOS, eating disorder not otherwise specified; GAD, generalized anxiety disorder; K10, Kessler psychological distress scale; MDD, major depressive disorder; MOT, motor screening task; NA, not applicable; NEET, not in education, employment or training; OASIS, overall anxiety severity and impairment scale; PAL, paired associations learning task; QIDS-16, quick inventory of depressive symptomatology; RVP, rapid visual processing task; SIDAS, suicidal ideation attributes scale; SPHERE, somatic and psychological health report; VRM, verbal recognition memory

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deficits are more prevalent in wider age ranges than in specifically young cohorts (Castaneda et al., 2008). Neuropsychological assessments have often been used to objectively determine or verify current cognitive deficits objectively, yet they are typically used on an as-needed basis as opposed to a routine assessment for all inpatients. While it is extensive and comprehensive, it can also be expensive, time consuming (approximately 3–4 h overall) (Thomas Gualtieri, 2004), and come later in diagnostic planning and treatment of a patient rather than earlier.

Thomas Gualtieri (2004) examined the employment of computerized neurocognitive testing (in psychiatry) for its usefulness in psychiatry using repeated administration and at more frequent time points. This study (Thomas Gualtieri, 2004) concluded that cognitive assessment should be routine in initial psychiatric evaluation. Furthermore, Keefe (1995) noted the importance of having objective data available in mental illness diagnosis and assessment of symptoms (Keefe, 1995). Importantly, pilot studies have previously demonstrated the usefulness of routine cognitive screening for a small sample size of inpatients with affective disorders (Tickell et al., 2019), suggesting further examination in a larger sample size would be prudent.

Neuropsychological subgroups and clusters have been assessed in previous studies (Hermens et al., 2011; Lee et al., 2013; Tickell et al., 2019) and proven to be helpful in prediction of functional outcomes (Lee et al., 2013), as well as clearly distinguishing neuropsychological impairments and their relationship to symptoms and diagnoses (Hermens et al., 2011). In regard to symptoms, research has demonstrated a potential relationship between cognitive impairments and suicidal ideation in patients with affective disorder diagnoses (i.e. major depressive disorder (MDD)) (Gorlyn et al., 2015; Marzuk et al., 2005; Westheide et al., 2008). Unfortunately, the literature does not specifically examine this association in a clearly defined young adult cohort. Furthermore, as noted by Westheide et al. (2008), these studies use relatively small sample sizes (Gorlyn et al., 2015; Marzuk et al., 2005; Westheide et al., 2008).

We believe further examination of neurocognitive performance and clinical outcomes is necessary. Previous studies have demonstrated research into cognitive clusters and profiles is of clinical importance due to the clear delineation of said profiles in regard to illness severity and differences in symptoms (Hermens et al., 2011; Levy and Weiss, 2010; Sweeney et al., (2000). Thus, the argument in support of an initial neurocognitive assessment (i.e. screener) in a young adult inpatient cohort (i.e. comparatively more severe than a community sample) as standard practice is strong.

The purpose of this study is to expand on a previous smaller sample pilot study (Tickell et al., 2019) and to further demonstrate the feasibility of routine neurocognitive screening as standard clinical care in an inpatient unit. It further aims to explore the cognitive and clinical profiles of a current inpatient sample, as well as assess whether a clustering model is meaningful when assessed against external validators. Considering various literature stating the strength in prediction of social and vocational outcomes (Lee et al., 2015; Metzler et al., 2014), we expect that neurocognitive profiles and socio-occupational functioning will be especially helpful predictors in a younger age inpatient facility, providing excellent information on appropriate immediate interventions. We also hypothesize a potential link, in accordance with previous literature, between cognitive dysfunction and more severe negative clinical outcomes (such as suicidal ideation).

## 2. Methods

This study was approved by the University of Sydney and St Vincent's Hospital Human Research Ethics Committees. Following confirmation that potential participants were of mental and intellectual capacity to give informed consent, a complete description of the study was discussed and, those under the age of 18 having their parent or guardian also consent, written consent was obtained.

### 2.1. Patients and design

Inclusion criteria comprized of: (i) patients currently admitted to the Young Adult Mental Health Unit (Uspace); and (ii) current presentation of a severe affective episode (i.e. depressive, manic, anxiety; including those with psychotic features). Exclusion criteria for this study were: (i) insufficient fluency in the English language to participate in the cognitive testing; (ii) unable to consent due to intellectual impairment (for example, IQ < 70) or severity of mental illness (as determined by the treating psychiatrist/psychologist); and (iii) refusal to provide informed consent. Comorbid or pre-existing childhood-onset conditions (for example Attention Deficit Hyperactivity Disorder (ADHD) and conduct disorder), as well as alcohol or other substance misuse or autistic spectrum disorders were not exclusion criteria. The sampling used in this project is consistent with the 'Research Domain Criteria' (RDoC) approach (Casey et al., 2013) as a means of classifying mental disorders based on neurobiological (in this case, cognitive) measures. Furthermore, this study utilizes a subject sample (i.e. across the inpatient unit) with the appropriate variance as advocated by proponents of the RDoC approach (Casey et al., 2013).

#### 2.1.1. Patient cohort

Active recruitment of patients was between May 2016 and December 2017. Primary diagnosis for patients ($n = 103$) were as follows: $n = 88$ with a depressive disorder [MDD ($n = 86$); MDD with psychotic features ($n = 2$)]; $n = 8$ with an anxiety disorder (AD) [obsessive compulsive disorder (OCD) ($n = 3$); generalized anxiety disorder (GAD) ($n = 5$)]; $n = 7$ with a bipolar disorder [bipolar disorder I (BD I) ($n = 2$); bipolar disorder II (BD II) ($n = 5$)].

### 2.2. Settings, and cognitive screen

The Young Adult Mental Health Unit (Uspace), St Vincent's Private Hospital Sydney, Australia is a voluntary private mental health service, targeted to the needs of young adults (16–30 years of age). Patients are referred for the assessment of mental health problems; with a mission to promote recovery and psychological well-being of young adults with severe and emerging mental health problems. Patients were determined to have a primary diagnosis of an affective disorder. At Uspace, these included depressive disorder, anxiety disorder, or bipolar disorder through consensus diagnosis; that is, via multidisciplinary clinical assessment (by psychiatrists, psychologists and allied health professionals) St Vincent's Private Hospital. A total of 149 patients were approached to participate (69% consented to participate and completed the full protocol). The remaining non-consenting patients did not want to participate for the following reasons: (i) 'not feeling they were in a good enough headspace' ($n = 9$); (ii) feeling the study did not appeal to them ($n = 19$); (iii) disruptive symptomatology (e.g., high anxiety and nervousness surrounding possible performance, participation and/or results) ($n = 2$); (iv) did not get parent/guardian to sign consent form/forgetting to sign consent form themselves ($n = 4$); and/or (v) 'embarrassed' or concerned about potential results due to mental illness or felt they wouldn't be able to complete testing due to current symptoms ($n = 4$). Several patients were also unable to be followed up for the informed consent process due to being discharged early or being transferred to a different hospital due to medical reasons ($n = 7$).

Cognitive testing and self-report assessments were completed on 103 young inpatients. On average, patients were in hospital for 17 days, and neurocognitive screening was completed 2 days following admission.

### 2.3. Measures

#### 2.3.1. Self-report questionnaire

Patients completed self-report questionnaires, on a touchscreen tablet (iPad), as part of the Mental Health e-Clinic (Iorfino et al., 2017), Brain & Mind Centre (BMC), University of Sydney. Initial questions obtain key demographic and clinical information, focusing on critical illness course variables (for example, onset of symptoms, hospitalizations, age of first help seeking). Standardized questionnaires included the 10-item Kessler Psychological Distress Scale (K-10) (Kessler et al., 2002) to detect psychological distress, with scores ranging between 10 and 50 (a score over 30 representing a likely severe mental disorder); Quick Inventory of Depressive Symptomatology (QIDS-16) (Rush et al., 2003) to assess severity of depressive symptoms, with scores ranging between 1 and 27 (a higher score representing greater severity of depression); Overall Anxiety Severity and Impairment Scale (OASIS), a 5-item measure for assessment of severity and impairment in regard to anxiety symptoms (Norman et al., 2006), with scores ranging between 0 and 20 (a higher score representing a higher frequency and severity of anxiety (across anxiety disorders); Psychosis Screener derived from Community Assessment of Psychic Experiences (CAPE) (Stefanis et al., 2002), a positive symptoms scale and psychosis screener, developed to measure the lifetime prevalence of psychotic-like experiences in the general population; Hypomania Screener derived from the Altman Self-Rating Mania Scale (ASRM) (Altman et al., 1997), a 5-item self-rating scale to assess the severity of manic symptoms, a higher score (five or more) indicating a high probability of a manic or hypomanic condition; Suicidal Ideation Attributes Scale (SIDAS) (van Spijker et al., 2014), a 5-item scale to screen participants for suicidal thoughts and severity of these thoughts, with scores ranging between 0 and 50 (a higher score representing more severe suicidal thoughts (a score over 21 being in the high risk category)); and, the Somatic and Psychological Health Report (SPHERE-12) (Hickie et al., 2001), a 12-item measure to screen for current depression and/or anxiety-like symptoms (a score of two or more on the psychological subscale and a score of three or more on the somatic subscale indicating current depression and/or anxiety-like symptoms). Self-reported, non-structured, standardized questions in regard to the patient's own sense of cognition was assessed prior to testing (for example, changes in everyday thinking skills and neurocognitive abilities).

All electronic data files were retained in a secured SQL eResearch platform (and database) hosted by the BMC, University of Sydney. Once completed, the data from the self-report assessment is collated, and displays a detailed and immediate dashboard of results. This information is available to the trained research psychologist (AT) immediately upon the patients' completion of the self-report assessment.

#### *2.3.2. Neurocognitive screening*

A trained research psychologist (AT) conducted the cognitive testing battery, which included computerized assessments. First, premorbid intellectual functioning ('predicted IQ') was estimated on the basis of performance on the Wechsler Test of Adult Reading (Wechsler, 2001). Following this, patients completed tests from the Cambridge Neuropsychological Test Automated Battery (CANTAB) (Sahakian and Owen, 1992). CANTAB tests have the advantage of being largely nonverbal (i.e. language-independent, culture-free) and have been described in detail elsewhere (Hermens et al., 2011; Sahakian and Owen, 1992; Sweeney et al., 2000). Five tasks were included in this study: the Motor Screening Task (MOT), an introductory task to prepare patients for testing (i.e. not included in overall results) using induction of sensorimotor and comprehension; the Verbal Recognition Memory task (VRM immediate and recall/delayed) assessing 'verbal memory and new learning' indexed by the encoding and subsequent retrieval of verbal information scores; the Attention Switching Task (AST) assessing 'mental flexibility' and indexed by the total adjusted score; the Paired Association Learning task (PAL) assessing 'visuo-spatial learning and memory' indexed by the total adjusted errors score from; and, the Rapid Visual Processing task (RVP) assessing 'sustained attention' and indexed by the RVP A prime (sensitivity to the target).

Patients' individual, normed results were calculated by a trained research psychologist (AT) within two to three days of completion of cognitive testing battery. Calculation of CANTAB z-scores were completed for each patient. While each patient's predicted IQ is assessed in the cognitive screener, this is specifically to personalize results based on each patient's age, education and background, compared to 'demographically corrected' standardized scores (z-scores) using an internal normative database of healthy controls (http://www.camocog.com).

### *2.4. Procedure*

Through consecutive referral, patients (16–30 years of age) who were newly admitted to Uspace were given a Participant Information Sheet and Consent Form and followed-up by the researcher (AT) for informed consent, no less than 24 h later. Following informed, written consent (and parent or guardian written consent for patients under the age of 18), patients were booked in to complete neurocognitive testing and self-report questionnaires. Patients availability and booking schedule was based around their own routine appointments and groups as inpatients, with most patients being booked within four days of admission. Neurocognitive testing (CANTAB) was completed on an iPad, taking between 35 and 45 min. The self-report questionnaire was completed the day after neurocognitive testing, taking 45–60 min, and depending on the patient.

### *2.5. Statistical analyses*

Statistical analyses were performed using Statistical Package for the Social Sciences Version 24.0 (SPSS). To control for the effects of age, cognitive variable raw scores were converted to 'demographically corrected' standardized scores (z-scores) using an internal normative database of healthy controls (http://www.camocog.com), and each patient's predicted IQ score. Any deviation from instruction, distraction or refusal to complete any one task during CANTAB testing was invalid for that specific variable. Prior to analyses, while all outliers were confirmed to be statistical (i.e. not artifacts), outliers beyond $\pm$ 4.0 z-scores for each neuropsychological variable were curtailed to values of $+4.0$ or $-4.0$. As this is a hospitalized sample of current patients, we believe curtailing of $+4.0$ or $-4.0$ more appropriately captures the severity of impairment, compared to the usual $+3.0$ or $-3.0$ curtailing. There were no more than 7% of cases in any group with a z-score of beyond $\pm$ 4.0 across variables.

A hierarchical cluster analysis utilising Ward's method of minimum variance with a squared Euclidean distance measure was conducted to identify patterns of impairment across four key neuropsychological variables (i.e. AST, RVPA, PAL and VRM). Cluster analysis was used for this study due to its ability to assess natural groupings within data, and the heterogeneous class of this inpatient cohort. The rationale being, the importance of examining distinctive and clear differences in an inpatient sample based on meaningful grouping. Furthermore, of the clustering techniques and algorithms, hierarchical clustering offers a more informative and structured analysis. Cluster analysis techniques were based on previous similar studies (Delano-Wood et al., 2009; Goldstein, 1990; Hermann et al.,2007; Hermens et al., 2011) and statistical recommendations (Norusis, 2010). The agglomerative hierarchical method was used as it does not impose preconceived notions regarding the number of clusters. Changes in agglomeration coefficients were used to determine a demarcation point. Unlike other statistical techniques (e.g., factor analysis), cluster analysis does not identify a particular statistical model (Norusis, 2010); that is, a classification technique for forming homogeneous groups within complex data sets (Borgen and Barnett, 1987). While there are no specific rules about the number of cases (and the corresponding number of variables) required for cluster analysis, hierarchical clustering is recommended for smaller data sets (Norusis, 2010); the type and number of variables are typically chosen on theoretical grounds (Delano-Wood et al., 2009; Goldstein, 1990). Ideally, a good cluster solution is when the data segregates into theoretically meaningful subsets (Delano-Wood et al., 2009) and this is usually achieved by examining cluster characteristics at consecutive steps until a reasonable number of relatively homogenous groups is obtained (Norusis, 2010).

Pearson's correlations were used to examine associations between functional/clinical variables (K-10, QIDS-16, OASIS, Psychosis screener, Hypomania screener, and SPHERE) and key neuropsychological variables (AST, RVPA, PAL and VRM) for the entire sample of subjects. Given the number of correlations conducted (32), and to further minimize the likelihood of type 1 errors, only correlations at $p < .01$ were considered to be significant.

One-way between-subject analysis of variance (ANOVA) was used to assess differences in demographic, clinical and functional, and neuropsychological variables among cluster groups. Scheffé's tests were used to determine post-hoc pair-wise comparisons. The chi-square test was used to compare the ratio of females to males across cluster groups. Significance levels were set at $p<.05$. Based on a similar methodology (Delano-Wood et al., 2009) we also conducted a confirmatory (standard) discriminant function analysis (DFA) to determine which combinations of the neuropsychological variables best distinguishes the cluster groups and whether these combinations could reliably predict cluster-group membership (Hermens et al., 2015, 2011).

## 3. Results

The average age of the cohort ($n = 103$) was 19.2 ± 3.1 years (72% female). The average predicted IQ was 105.5 ± 7.7, as well as 41.5% of patients not being in current education, employment or training (NEET status).

Due to technical difficulties there is missing self-report data worth noting (18.4%). A total of 78 patients (75%) had fully completed self-report data with a further 6 patients (5.8%) partially completed. Therefore, a total of 84 patients (81.6%) had some quantity self-report data.

### 3.1. Cluster characteristics (n = 103)

Agglomeration coefficients generated by cluster analysis revealed a demarcation point between three cluster solutions; this was confirmed by inspection of the dendrogram. Thus, the three groups were made up of $n = 17$ (cluster 1), $n = 59$ (cluster 2), and $n = 27$ (cluster 3) patients. Six patients were missing at least one neuropsychological variable (i.e. due to the patient being distracted during testing); their scores were replaced with averages of the specific group variable. ANOVA determined statistical significance of 'cluster group' for two neurocognitive variables (PAL and RVP), as well as one clinical variable (SIDAS).

Table 1 shows medication categories were relatively well distributed across the three cluster groups. According to chi-square analysis the three clusters did not significantly differ ($p > .05$) in regard to medication status. Chi-square and post-hoc Scheffe's analysis further showed no statistical differences based on diagnosis between the three clusters.

### 3.2. Cluster profiles (n = 103)

Fig. 1 demonstrates all three clusters were characterized by poor performance; however, of the four neurocognitive variables, two were found to be significantly different between the three clusters. As seen in Table 2, PAL and RVP were both significant ($p < .05$). Due to adjustments of predicted IQ scores in CANTAB testing, corresponding ANCOVAs controlling for predicted IQ demonstrated that the same significant differences for both PAL and RVP remained. Post-hoc comparisons using the Tukey HSD (honestly significant difference) test indicated the mean scores for PAL variables significantly differed between all cluster solutions (i.e. 1, 2 and 3), confirmed further by Scheffe's test with RVPA between cluster 1 and 2 showing no statistical significance. Tukey DSH tests showed RVP variables were significantly different between cluster 1 and 3, and cluster 2 and 3. Significance was found between three cluster groups in one clinical variable only (SIDAS), as shown in Table 3; post-hoc Scheffe's test confirming this significant between clusters 2 and 3. Significant differences were found between clusters in age and predicted IQ, with cluster 1 having the lowest predicted IQ scores, and cluster 3 being the eldest (by almost 2 years).

Discriminant function analysis (DFA) confirmed a single function accounting all (100%) of the variance among the two significant clusters [Wilk's $\lambda = 0.062$, $p < .000$]. Furthermore, the structure matrix revealed a clear delineation for verbal learning (PAL, $r = 0.936$), and sustained attention (RVP; $r = 0.707$), with the two remaining variables not significant. The DFA showed an overall correct classification result of 99.0%; that is, 100% of cluster 1, 98.3% of cluster 2 cases, and 100% of cluster 3 cases were correctly classified. Cross-validation confirmed the stability of these classification results with the same overall correct classification as the original grouped cases (i.e., 98.1%).

### 3.3. Correlations between neuropsychological performance and self-reported symptoms (n = 103)

Table 4 shows the correlation coefficients for the four neuropsychological scores and clinical variables for the entire sample. One significant ($p < 0.01$) correlation was revealed: RVP-A was associated with SIDAS ($r = -0.297$). Importantly, a scatterplot of this significant correlation showed a segregation of the three cluster groups, whereby cluster 1 individuals appear at the lower end of this spectrum.

## 4. Discussion

As expected, this inpatient sample ($n = 103$) showed varying levels of cognitive deficits, with three neurocognitive profiles being revealed. Cluster 1 was characterized by a more impaired neurocognitive profile overall (except for attention shifting), followed by Cluster 2, and Cluster 3 having the least impaired neurocognitive profile comparatively, but showing the most impairment in attention switching. There was a significant statistical difference between the three clusters in two of the four neurocognitive variables; verbal learning (PAL) showed the most differences between clusters (i.e. cluster 1 having the most impaired scores, and cluster 3 with the best scores, with cluster 2 being intermediate), followed by sustained attention (RVP); with clusters 1 and 2 (both compared separately to cluster 3) showing the most impairment. Of note, suicidal ideation was found to be the only clinical variable that was significantly different between clusters, with cluster 1

**Table 1**
Cross-tabulation of cluster by medication category of Uspace sample (%), as tested by chi-square.

| Current medication | Cluster 1 (N = 17) | Cluster 2 (N = 59) | Cluster 3 (N = 27) | Significance test ($x^2$) |
|---|---|---|---|---|
| Nil (%) | 17.6% | 13.6% | 0% | $x^2$ (1, 103) = 4.606 [.100] |
| Antidepressant (%) | 64.7% | 74.6% | 85.2% | $x^2$ (1, 103) = 2.480 [.289] |
| Antipsychotic (%) | 41.2% | 30.5% | 37.0% | $x^2$ (1, 103) = 0.822 [.663] |
| Mood stabilizer (%) | 23.5% | 27.1% | 25.9% | $x^2$ (1, 103) = 0.089 [.956] |

Abbreviations: AST = attention switching task; PAL = paired associations learning task; RVP = rapid visual processing task; VRM = verbal recognition memory.

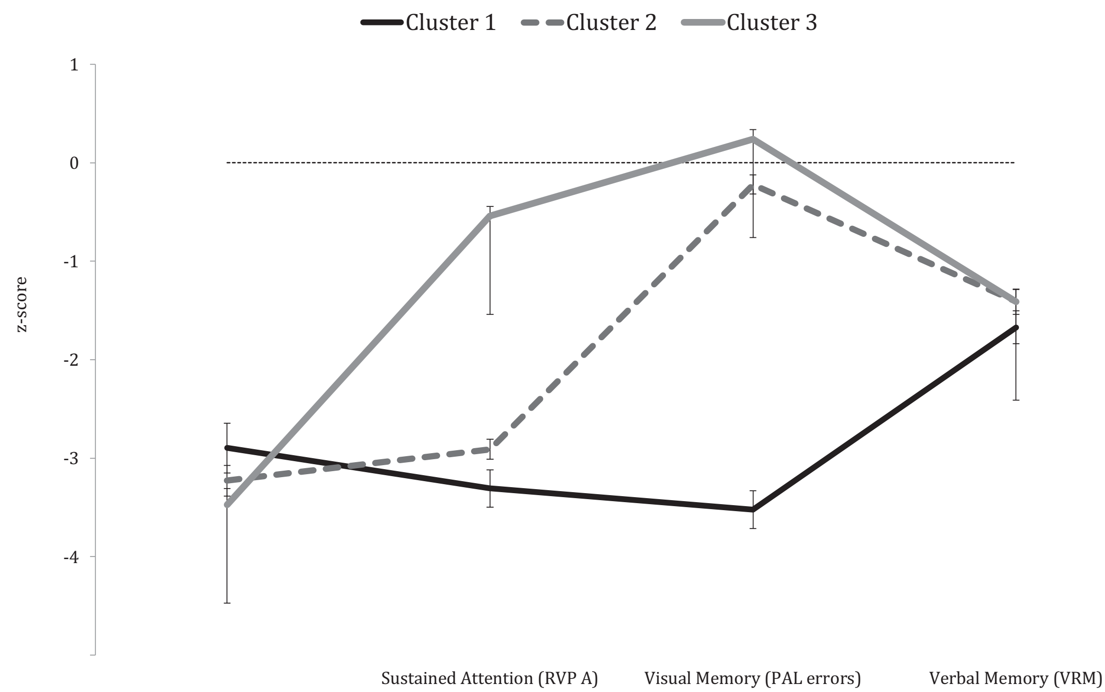


**Fig. 1.** Profile ($n$ = 103) of mean z-scores (with standard error bars and dashed line representing the standardized norm (equivalent of 0 z-score)) for neurocognitive measures across cluster groups: cluster 1 ($n$ = 17), cluster 2 ($n$ = 59), and cluster 3 ($n$ = 27).

**Table 2**
Mean z-scores ( ± standard deviation) for neurocognitive variables across the three clusters with corresponding results for ANOVA.

| | *Cluster 1 (N = 17)* | *Cluster 2 (N = 59)* | *Cluster3 (N = 27)* | *Significance Test [p]* | *Post-Hoc* 1v2 | 1v3 | 2v3 |
|---|---|---|---|---|---|---|---|
| AST | −2.90 ± 1.04 | −3.23 ± 1.20 | −3.47 ± 0.85 | F (2, 102) = 1.4 [.242] | | | |
| PAL | −3.52 ± 0.77 | −0.22 ± 0.75 | 0.24 ± 0.50 | **F (2, 102) = 176.1 [.000]** | * | * | * |
| RVPA | −3.31 ± 0.78 | −2.91 ± 0.78 | −0.54 ± 0.52 | **F (2, 102) = 117.3 [.000]** | | * | * |
| VRM | −1.67 ± 0.69 | −1.41 ± 0.98 | −1.41 ± 0.64 | F (2, 102) = 0.7 [.524] | | | |

Abbreviations: AST = attention switching task; PAL = paired associations learning task; RVP = rapid visual processing task; VRM = verbal recognition memory;.
*Note*: the four cognitive tests (VRM, AST, PAL, RVP) were all performed via touchscreen computer (CANTAB); standardized scores are presented.
*Note:* Significance levels for each Scheffé's post-hoc comparison is depicted by: *$p < .05$.

**Table 3**
Mean scores ( ± standard deviation) for demographic and clinical variables across the three clusters; between group differences were tested by chi-square or ANOVA.

| | *Cluster 1 (N = 17)* | *Cluster 2 (N = 59)* | *Cluster 3 (N = 27)* | *Significance Test [p]* | *Post-Hoc* 1v2 | 1v3 | 2v3 |
|---|---|---|---|---|---|---|---|
| Sex (f) | 15 (83.2%) | 42 (71.2%) | 18 (66.7%) | χ2 (1, 103) = 2.637 [.268] | | | |
| Age, years | 19.5 ± 3.3 | 18.6 ± 2.8 | 20.4 ± 3.2 | ***F* (2, 102) = 3.5 [.034]** | | | * |
| Predicted IQ | 100.9 ± 6.8 | 105.9 ± 8.0 | 107.4 ± 7.5 | ***F* (2, 95) = 3.5 [.034]** | | * | |
| K-10 Total | 39.1 ± 5.3 | 36.1 ± 6.1 | 35.7 ± 7.2 | *F* (2, 76) = 1.3 [.288] | | | |
| QIDS-16 Total | 19.2 ± 4.6 | 17.7 ± 4.7 | 15.4 ± 5.7 | *F* (2, 68) = 2.6 [.082] | | | |
| OASIS Total | 13.2 ± 3.5 | 11.5 ± 3.5 | 10.5 ± 4.1 | *F* (2, 59) = 1.6 [.201] | | | |
| Psychosis Screener | 1.6 ± 1.6 | 2.7 ± 2.6 | 1.7 ± 1.9 | *F* (2, 73) = 1.8 [.167] | | | |
| Hypomania Screener | 2.4 ± 2.3 | 2.8 ± 2.1 | 1.7 ± 2.0 | *F* (2, 72) = 1.9 [.157] | | | |
| SIDAS | 29.3 ± 15.7 | 28.0 ± 15.5 | 17.0 ± 17.7 | ***F* (2, 74) = 3.9 [.025]** | | | * |
| SPHERE Psyc | 8.0 ± 2.5 | 6.6 ± 3.6 | 5.9 ± 3.2 | *F* (2, 66) = 1.2 [.317] | | | |
| SPHERE Soma | 6.5 ± 2.7 | 5.9 ± 3.1 | 5.8 ± 2.9 | *F* (2, 72) = 02 [.837] | | | |

Abbreviations: AST = attention switching task; PAL = paired associations learning task; RVP = rapid visual processing task; VRM = verbal recognition memory.
Note: the four cognitive tests (VRM, AST, PAL, RVP) were all performed via touchscreen computer (CANTAB); standardized scores are presented.
*Note:* Significance levels for each Scheffé's post-hoc comparison is depicted by: *$p<.05$.

having the highest scores, suggesting more severe suicidal ideation, and both clusters 1 and 2 averaging in the 'high risk' category (i.e. a score over 21).

In this current study we have found an association between cognition and suicidal ideation, which is in accordance with previous studies examining cognition and suicidal ideation in MDD. Pu et al. (2017) examined cognitive deficits and suicidal ideation (with or without) using a neuropsychological battery in 233 outpatients, aged between 17 and 76 years of age, with a diagnosis of MDD. While this study used a specific brief cognitive measure of schizophrenia, it is one of the first studies to suggest an association between neurocognitive performance and suicidal ideation in patients with MDD (Pu et al., 2017). Overall,

**Table 4**
Pearsons correlation coefficients ($p < .01$) between functional/clinical versus key neurocognitive variables for the entire Uspace sample ($N = 103$).

| | AST | RVP A | PAL | VRM |
|---|---|---|---|---|
| K-10 Total | −0.035 | −0.090 | −0.208 | −0.252 |
| QIDS-16 Total | −0.017 | −0.211 | −0.112 | −0.126 |
| OASIS Total | 0.121 | −0.126 | −0.178 | −0.242 |
| Psychosis Screener | 0.046 | −0.031 | 0.087 | 0.015 |
| Hypomania Screener | −0.006 | −0.092 | −0.043 | 0.144 |
| SIDAS | −0.039 | **−0.297*** | −0.151 | −0.132 |
| SPHERE Psyc | 0.062 | −0.136 | −0.136 | −0.151 |
| SPHERE Soma | 0.024 | −0.077 | −0.077 | −0.288 |

Abbreviations: AST = attention switching task; PAL = paired associations learning task; RVP = rapid visual processing task; VRM = verbal recognition memory.

* $p < .01$

outpatients with suicidal ideation (i.e. 59% of the 233 sample) demonstrated significantly more severe cognitive deficits (i.e. performed worse on the neuropsychological battery), compared to outpatients without suicidal ideation; furthermore, executive function was a main player in this association (Pu et al., 2017). Previous studies have demonstrated a strong link between cognitive dysfunction and the presence of suicidal ideation in patients with MDD (compared to those without suicidal ideation), with neurocognitive deficits (or rigidity) being referred to as a possible risk factor for suicidal ideation and behavior (Gorlyn et al., 2015; Marzuk et al., 2005; Westheide et al., 2008). Marzuk et al. (2005) examined 33 current MDD inpatients (5 with suicidal ideation, and 28 without) (Marzuk et al., 2005). While the small sample size and uneven groups need to be taken into consideration, this study demonstrated current inpatients with suicidal ideation performed significantly worse in executive function, and also showed more global impairments, compared to those inpatients without suicidal ideation (Marzuk et al., 2005). Likewise, Westheide et al. (2008) compared inpatient groups with MDD based on suicidal ideation (mean age of 34.3 years with suicidal ideation, and 40.4 years without suicidal ideation), and found impaired executive function in those inpatients with suicidal ideation, compared to those without (Westheide et al., 2008). The studies from Pu et al. (2017), Marzuk et al. (2005) and Westheide et al. (2008) as well as this current study, further validate the importance of cognitive function, and value of cognitive testing and modelling (Stip et al., 2017) in regard to collaborative, integrated, and personalized care. Clinically speaking, neurocognitive dysfunction could be helpful in establishing contributing factors to certain clinical domains, in this instance, suicidal ideation. Importantly, we have gained further knowledge in regard to the logistics of neurocognitive testing as standard clinical care in an inpatient facility, as well as capturing a representative, albeit heterogeneous, sample of patients in an inpatient unit. Importantly, the literature in this area is not always clear and sometimes studies combine suicidal ideation and suicidal attempt status. Despite this, Richard-Devantoy et al's (Richard-Devantoy et al., 2012) meta-analysis of suicidal behaviours (i.e. inclusive of both ideation and/or attempts) in affective disordered patients demonstrated eight out of nine analysed studies found a link between cognitive dysfunction and suicide attempt (Richard-Devantoy et al., 2012). While the large age ranges across the studies included (i.e. 18 to 86 years) may be a limitation in terms of younger cohorts, this study does not make a clear distinction between suicidal ideation and attempt. Suicidal behaviour is examined as a symptom including both ideation and attempt (as opposed to separate states) and linked to executive function and depression. On the other hand, some literature has suggested that cognitive deficits are associated with suicide attempt and not suicidal ideation (Keilp et al., 2013). Clearly, future studies in young patients with affective disorders need to differentiate suicidal ideation from suicide attempts and examine their unique relationships with cognition.

There are some limitations worth mentioning in this study. Firstly, there has been disagreement surrounding the potential effects of acute psychiatric symptoms' impact on cognitive testing performance. However, there are various factors that have the ability to influence cognitive performance, for example quality and quantity of sleep, and time of testing (i.e. morning or evening). Various factors need to be taken into consideration in order for this assessment to be representative of personalized care (i.e. catering to an individual). Secondly, this study relies heavily on technology. While it is true the CANTAB program itself initially relies on an internet connection, this is only to switch the device to being offline active; this means, while testing is commencing there is no reliance on internet connection (i.e. drop outs do not impact testing). The self-report questionnaire, however, is reliant on a persistent internet connection, and unfortunately, due to technical problems with the hospital setting itself, 45% of patients were unable to access and complete all modules of the self-report questionnaire. Lastly, due to the heterogeneous nature of this sample a hierarchical cluster analysis was employed in order to examine inpatient cohort groupings. However, a model-based approach such as mixture modeling or examining measures as a set of potential predictor variables, may also be an option for future research.

We believe this study is novel in its aims of assessing a younger, more severe cohort of current inpatients and the utility of technology and neurocognitive testing as standard clinical care in an inpatient unit. Future directions of this work as standard clinical care at Uspace have seen updates in protocol, and further discussion in regard to a neurocognitive battery that fits the needs of the unit (i.e. time, usability and automatic report generation), and the addition of a psychoeducational group as part of the inpatient hospital program. On a more general scale, this study of an inpatient cohort shows clear neurocognitive clusters, which further strengthens the idea of neurocognitive screening being useful in intervention, care and management.

## Disclosure statement

The authors report no conflicts of interest.

## Availability of data and material

The dataset generated and/or analysed during the current study are not publicly available due to individual privacy, and the nature of the studies, but are available from the corresponding author on reasonable request.

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## CRediT authorship contribution statement

**Ashleigh M. Tickell:** Data curation, Formal analysis, Writing - review & editing, Investigation, Validation, Writing - original draft, Formal analysis. **Elizabeth M. Scott:** Writing - review & editing, Data curation, Formal analysis, Validation. **Tracey Davenport:** Writing - review & editing, Data curation, Formal analysis. **Frank Iorfino:** Writing - review & editing, Data curation, Formal analysis. **Laura Ospina-Pinillos:** Writing - review & editing, Data curation, Formal analysis. **Django White:** Writing - review & editing, Data curation, Formal analysis. **Kate Harel:** Writing - review & editing, Data curation, Formal analysis. **Lisa Parker:** Writing - review & editing, Formal analysis. **Ian B. Hickie:** Conceptualization, Writing - review & editing, Data curation, Formal analysis. **Daniel F. Hermens:** Conceptualization, Writing - review & editing, Data curation, Formal analysis.

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## Compliance with ethical standards

Ethicalapproval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informedconsent: Informed consent was obtained from all individual participants included in the study.

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