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Verbal working memory in schizophrenia: The role of syntax in facilitating serial recall

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ABSTRACT

Background: Deficits in verbal working memory (VWM) have consistently been observed in schizophrenia, ranging from impairments in capacity, encoding, to irregular semantic organisation. However, syntactic deficits are less well-characterised, despite its crucial role in language construction. This study examines the role of simple syntactic structure (basis of the “sentence superiority effect”) in VWM of patients with psychotic disorders.

Methods: Patients with schizophrenia-spectrum disorders ($n = 40$) and healthy controls matched on age, sex and education ($n = 40$) were administered an auditory serial recall task containing word lists with low semantic coherence and either syntactically familiar structure (noun-verb-noun sequence) or syntactically unfamiliar structure. Other neurocognitive measures, symptoms and social functioning of patients were also assessed.

Results: A 4-way analysis of variance (group \times version \times list type \times serial position) indicated that patients had significantly worse performance overall, suggesting a generalised verbal memory impairment. In addition, a significant interaction was found for list type and Group, demonstrating that healthy controls, but not patients, had superior performance in syntactically familiar word lists. A subgroup analysis of high-performing patients revealed that the interaction was not an artefact of poor verbal memory, but a selective deficit in syntactic facilitation.

Conclusions: Our findings may suggest segregated mechanisms for maintenance and computational aspects of VWM, and show that even simple syntactic structure facilitates recall of syntactically unfamiliar words lists. Additionally, schizophrenic patients show difficulty utilising syntactic information, which highlights the need to understand the neuropsychological basis of working memory and linguistic impairments in psychosis.

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1. Introduction

Research on the linguistic patterns of schizophrenia has traditionally viewed deficits as a reflection of disordered thought (Bleuler, 1950; Kraepelin, 1904), with emphasis on the linguistic manifestations of positive symptoms, such as tangential speech or neologisms, hypothesised to result from deviant patterns of associations in the long term semantic store (Barrera et al., 2005; Brébion et al., 2004; Kareken et al., 1996).

However, advances in neuroimaging and psycholinguistics suggest that language disorder is likely a selective impairment. Evidence now links patients' linguistic disturbances with alterations in the language network, chiefly in inferior frontal and temporal cortices (Catani et al., 2011; Moro et al., 2015; Stevens et al., 1998), and in hemispheric lateralisation of language (Bleich-Cohen et al., 2009; Mitchell and

Crow, 2005). Further progress in the field thus requires examination of aspects of language that are selectively impaired in patients (Covington et al., 2005).

A central component of language comprehension is working memory (WM) (King and Just, 1991). In fact development of the phonological loop (Baddeley, 1992), the foundation of verbal WM (VWM), might be intrinsically related to the evolution of language in humans (Baddeley et al., 1998; Carpenter and Just, 1989). Current research provides evidence for schizophrenic patients' WM deficits (Lee and Park, 2005; Silver et al., 2003), potentially linked to restricted syntactic complexity in language production and comprehension (Morice and McNicol, 1985), even when auditory non-verbal performance is normal (Wexler et al., 1998). Despite being more prevalent, sentence processing and syntactic deficits are subtler and less well-documented than the semantic component of language in schizophrenia (Kuperberg, 2010). Given the presence of VWM impairments in prodromal, psychotic and chronic schizophrenic patients (Frommann et al., 2010) and their first-degree relatives (Conklin et al., 2000), further research is required

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to clarify the relationship between syntactic processing difficulties and WM deficits.

Despite their interconnection, investigating the relationship between WM and language is problematic: most standardised WM tests, like Digit and Letter Number Span, are stripped of semantic and syntactic content, and studies targeting language comprehension fail to isolate individual linguistic components. For instance, syntactic tasks often include a semantic component (Barch and Smith, 2008), hence performance may be influenced by the use of semantic encoding strategies, and sentence processing tasks cannot distinguish between the stages of WM processing: encoding, maintenance and retrieval (Bonhage et al., 2014). Since encoding and maintenance occur simultaneously, the origin of schizophrenic WM deficits cannot be traced to problems in accuracy, maintenance or interference control.

Concurrently, studies involving normal subjects have found a robust “sentence superiority effect” – the more lists approximated sentences, the better they were recalled (Miller and Selfridge, 1950). This effect is sustained under distraction and not dependent on effortful control of the central executive (Baddeley et al., 2009). Interestingly, Perham et al. (2009) found that VWM is sensitive to even rudimentary syntactic structure: semantically incongruent adjective-noun pairs were better recalled than noun-adjective pairs.

The present study examines, through a novel word recall task, the role of rudimentary syntactic structure in VWM of patients with psychosis. Through comparing patient and control performance on low-semantic-coherence word lists with and without syntactic structure, we investigate the extent syntactic deficits affect VWM and contribute to memory impairments seen in schizophrenia. We hypothesise that controls will perform better on syntactically familiar lists while in addition to an overall memory deficit, patients will display an attenuated sentence superiority effect and little differentiation between the two list types.

2. Methods

2.1. Subjects

Forty patients and forty healthy controls participated in the study. Patients were screened and recruited by clinicians from psychiatric inpatient and outpatient clinics of the Hong Kong West Cluster. Forty matched controls were recruited from the community. See Supplementary material 1 for inclusion/exclusion criteria for patients and controls and patient characteristics. The study was approved by the Hospital Authority (Hong Kong West Cluster) Institutional Review Board and all participants gave written informed consent. Parental informed consent was obtained for one 17-year-old patient. This study complies with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration.

2.2. Materials

Six-word lists were constructed with two sets of 36 Chinese words (24 nouns, 12 verbs). Words consisted of two syllables, and only concrete nouns were used. Sets were controlled for frequency, homophones and tone. Words in Sets A and B had mean frequencies per million of 18.81 (nouns 18.75, verbs 18.92) and 18.83 (nouns 19.04, verbs 18.42) respectively. To avoid effects of prosody, each word was recorded separately by a native speaker and digitally combined.

Each set produced 6 syntactically familiar and 6 syntactically unfamiliar lists utilising the same words, hereafter referred to as “syntactic” and “non-syntactic” lists. Syntactic word lists comprised of 2 sentence-like sequences “noun-verb-noun, noun-verb-noun (NVN-NVN)” with a 1 s-interval between the third and fourth word, after piloting indicated the pause was necessary for rehearsal of appropriate word groupings. A list length of 6 was thought appropriate given the constraints of NVN structure required lengths of multiples of 3, while avoiding

floor or ceiling effects in both groups. Rate of speech was maintained at 1 syllable per second. Including the pause between the third and fourth word, each list was around 13 s. Syntactic word lists were constructed to ensure that combinations of nouns and verbs were implausible and nonsensical, e.g. “seashell hesitate raven” instead of “nurse stroll park” to minimise semantic content. Corresponding non-syntactic lists had the same words but with verbs clustered at the beginning or end of the sentence-like sequences (Supplementary material 2), controlling for word frequency and imageability.

Regarding the use of verbs in word lists, previous research has compared recall of syntactically familiar constructions (e.g. adjective-noun) to non-familiar constructions (noun-adjective), in order to explore the effect of syntactic structure on memory (Perham et al., 2009). However, using constructions with verbs and nouns presents additional advantages in investigating recall and syntactic familiarity. For instance, evidence has shown that verbs play an important role in binding the rest of sentential elements together by placing constraints on both the structure and thematic roles of the sentence they appear in (Elman, 2009). Similar to English, Chinese favours constructions following the subject-verb-object (SVO) pattern (Tomlin, 2014), e.g. (S)他(V)是(O)醫生 (He is a doctor), fitting the NVN structure. According to previous research (Baddeley et al., 2009; Miller and Selfridge, 1950), regardless of semantic content, recall should be better in grammatically and syntactically familiar NVN lists than in a grammatical (NNV, VVN) lists, as the latter cannot accommodate a SVO pattern of thematic roles.

2.3. Design and procedure

Participants from each group were randomly assigned to either version of the paradigm: (1) Set A syntactic lists and Set B non-syntactic lists, (2) Set A non-syntactic lists and Set B syntactic lists. The study employed a repeated measures design with group (patient/control) and version (1/2) as between-participant variables and list type (syntactic/non-syntactic) and serial position (1 to 6) as within-participant variables. All participants were tested individually in a single session lasting approximately 20 min. Patients were given additional cognitive tests and a clinical interview.

2.3.1. Word recall task

Participants listened to 12 trials (versions 1 or 2, in a pseudo-randomised order) on a laptop computer's speakers. Participants were instructed to: (a) immediately recall words in correct serial order as much as possible after presentation of each list, (b) not use mnemonic strategies (e.g. composing stories) except mental rehearsal. The presentation order of lists and participants' responses were recorded and scored by a trained researcher.

Words were scored according to relative serial position, adapted from Baddeley et al. (2009): a word was correct if it was recalled along with at least one adjacent word, except for the first and last word, which were scored as correct only if they were recalled in those positions, e.g. if ABCDEF were recalled as DABCEF, all except A, D would be correct as A was not the first and D had no adjacent word. For ADEFBC, all words except F (not recalled last) would be correct because A was recalled first and others were recalled with at least one adjacent word.

2.4. Clinical and neurocognitive assessments

Patients' symptoms and functioning were assessed with the Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987) and the Social and Occupational Functioning Assessment Scale (SOFAS) (Goldman et al., 1992). Additionally, they completed neurocognitive tests: (a) Forward Digit Span; (b) Backward Digit Span; (c) Information from the Wechsler Adult Intelligence Scale – Revised (Hong Kong Psychological Society, 1989; Wechsler, 1981); (d) Modified Wisconsin Card Sorting Test (Nelson, 1976).

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