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Word production in schizophrenia and its relationship to positive symptoms

John G. Kerns, Howard Berenbaum*, Deanna M. Barch, Marie T. Banich, Neal Stolar

Department of Psychology, University of Illinois at Urbana-Champaign, 603 E. Daniel Street, Champaign, IL 61820, USA

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Abstract

We explored relationships between positive symptoms of schizophrenia and neurocognitive functions (language and memory). The semantic and phonemic associations among words produced in a verbal fluency task by 26 participants diagnosed with DSM-III-R schizophrenia were examined. Formal thought disorder was associated with producing fewer contextually related words and with producing more unrelated words. In contrast, hallucinations were associated with producing more related words. Our results suggest associations between formal thought disorder and impaired memory, and between hallucinations and increased lexical activation/excessive synaptic pruning. © 1999 Published by Elsevier Science Ireland Ltd. All rights reserved.

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1. Introduction

Two neurocognitive functions that are potentially important for understanding schizophrenia are language and memory (e.g. Hoffman, 1986; McKay et al., 1996). One way to explore language and memory functioning is to examine semantic and phonemic associations between each successive pair of words produced in a verbal fluency (VF) task (Raskin et al., 1992). For example, changes in either the activation levels (e.g. David, 1994; Spitzer, 1997) or the integrity of stored information (e.g. Hoffman, 1987) should be reflected in the number and types of associations among words produced in a VF task (e.g. Rohrer et al., 1995). Using the VF task, we tested several hypotheses concerning relationships between language and memory processes and two positive

* Corresponding author. Tel.: +1-217-333-9624; fax: +1-217-244-5876.

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symptoms of schizophrenia: hallucinations and formal thought disorder (FTD).

In this study, we examined predictions of two models that posit that aberrant language activation produces hallucinations. One hypothesis, suggested by David (1994), posits that hallucinations are the result of overactivated lexical items unintentionally exceeding a threshold level of activation. Furthermore, according to cognitive theory (e.g. Dell and O'Seaghdha, 1991), increased activation should spread primarily to words sharing multiple semantic and/or phonemic associations. A second hypothesis, suggested by Hoffman and colleagues (Hoffman et al., 1995, 1997, 1999), posits that hallucinations result from excessive synaptic pruning (the removal of weak and moderate synaptic connections) reducing the activation of lexical competitors and making activated lexical items highly discriminable. Furthermore, because of the paucity of weak and moderate synaptic connections, activation should spread primarily to semantically and phonemically related words. Hence, both David's and Hoffman and colleagues' hypotheses predict that people with hallucinations should have increased spreading activation between semantically and phonemically related words. Therefore, we predicted that in a VF task, hallucinations would be positively associated with producing semantically and phonemically related words.

In addition to examining hallucinations, we also tested three hypotheses concerning FTD. The first FTD hypothesis, which we will refer to as the disorganized memory hypothesis, is based on neural network simulations and theorizing by Hoffman (1987) in which he proposed that people with FTD have disorganized connections within semantic memory. The second hypothesis is that people with FTD have an increase in the amount of spreading activation within lexical networks (Spitzer et al., 1994). The third hypothesis is that people with FTD have a loss of semantic information.

The three FTD hypotheses make different predictions about the associations between FTD and the number of semantically and phonemically related words produced in a VF task. The disorganized memory hypothesis predicts that FTD should be positively associated with producing unrelated words because of the increased number of disorganized connections between items. The spreading activation hypothesis makes an opposite prediction: that FTD should be positively associated with producing related words. The loss of semantic information hypothesis predicts that FTD should be negatively associated with semantically related words. However, if the loss of semantic information is not extreme, then only relationships that are based on a relatively small number of semantic connections should be affected (McRae et al., 1997; Devlin et al., 1998). Therefore, FTD should only be negatively associated with contextually related words (e.g. 'restaurant'–'wine') because these words share few semantic connections. In contrast, FTD should not be associated with categorically related words (e.g. 'dog'–'cat') because these words share many semantic connections.

2. Method

2.1. Participants

Participants were 26 hospitalized individuals with DSM-III-R diagnoses of schizophrenia (mean age = 36, median education = high school graduate, 81% Caucasian, 78% male, mean length of current hospitalization = 267 days with range from 4 to 1295 days, mean duration since first psychiatric hospitalization = 14.4 years with range from less than 1 to 34 years, mean chlorpromazine equivalent antipsychotic medication level = 1231 with range from 0 to 4625). Diagnoses for the schizophrenic participants were based on interviews conducted using the psychotic and mood disorders sections of the Structured Clinical Interview for DSM-III-R (Spitzer et al., 1992) and a review of participants' clinical records. The interviewers were a Ph.D.-level clinical psychologist and an advanced doctoral candidate in clinical psychology, both of whom had extensive prior experience employing a range of different clinical rating scales and structured clinical interviews. The patient sample presented in this article is composed of 26 of the 27 schizophrenic participants from the study reported by Stolar et al. (1994).[1]

2.2. Procedure

As part of the schizophrenic patients' participation in the study reported by Stolar et al. (1994), hallucinations and formal thought disorder were rated using the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen, 1984). We used SAPS global scores to measure hallucinations. FTD was measured by summing across the following SAPS items, all of which are examples of disturbances in fluency and discourse coherence (Berenbaum and Barch, 1995): incoherence, derailment, tangentiality, and clanging. The internal consistency of this FTD scale, measured using Cronbach's alpha, was 0.76.

2.2.1. Relatedness ratings

The schizophrenic participants wrote as many words as possible within 5 min that began with the letter 's' and as many four-letter words as possible within 4 min that began with the letter 'c'. Following Raskin et al. (1992), two judges independently rated lists of written words for whether the successive pairs of words were related semantically, phonemically, or both semantically and phonemically.[2]

Semantic relations were coded in four different ways. Following Drews (1987), Koivisto and Laine (1995), and Moss et al. (1995), we distinguished between two types of semantic relations: categorically related words and contextually related words. For example, 'swordfish' and 'shark' are related categorically, as they both are 'animals', whereas 'oven' and 'potato' are related contextually as they occur together in the world. Identical to the design used by Moss et al. (1995), contextually related words included pairs that either have a functional relationship (e.g. 'ship' — 'sailing') or that tend to be present together in a spatial and/or temporal context (e.g. 'ship' — 'sailor'). A category-word score and a context-word score were computed by summing the number of words produced for each type of semantic relationship.[3]

Judges rated three different phonemic relations. Two were examined by Raskin et al. (1992): rhymes (e.g. 'stall', 'small') and words sharing the same second phoneme (e.g. 'start', 'stop'). A third, words sharing the same syllable (e.g. 'normal', 'enormous'), was added in this study.

In addition, we calculated four composite relatedness scores: (a) semantically related score (the total number of words that belonged to any of the four types of semantic relations); (b) phonemically related score (number of phonemically related words produced); (c) related total score (number of words that were semantically and/or phonemically related); and (d) unrelated total score (number of words that were neither semantically nor phonemically related). Mean and S.D. values for the relatedness scores and for symptoms are presented in Table 1.

Interrater reliabilities of the two judges, measured using intraclass correlations (Shrout and Fleiss, 1979), treating the raters as random effects and the mean of the two raters as the unit of reliability, were: semantically related: 0.88; category word: 0.73; context word: 0.85; phonemically related: 0.96; unrelated total: 0.97; related total: 0.96.

2.2.2. Residual scores

In order to obtain statistically purer measures of the tendency to produce either related or unrelated words, we computed two residual scores based on a series of multiple regressions. One residual score, the related residual, measured the variance shared between the phonemically

[1]One person's data could not be used because the order in which he produced words was not recorded.

[2]There are other measures of relatedness (e.g. measuring the degree of coherence for all words). However, we thought successive pairs of words would be most likely to reflect relatively automatic (non-strategic) processes (Neely, 1991).

[3]Judges also rated two other types of semantic relatedness that have been examined in previous research (Brownell et al., 1984): synonyms and antonyms. However, they were produced too infrequently to compute meaningful correlations with symptom measures.

Table 1
Mean and S.D. values for symptoms and relatedness scores

Variable	Mean	S.D.
Symptoms		
FTD	3.3	3.8
Hallucinations	2.2	1.7
Relatedness scores		
Category word	1.9	2.6
Context word	1.5	2.3
Semantically related	3.8	3.9
Phonemically related	7.6	6.3
Related total	10.2	8.1
Unrelated total	17.6	9.8
Total word	27.8	15.0

related and semantically related scores, but not shared with the unrelated total score. The second residual score, the unrelated residual, measured the variance accounted for by the unrelated total score that was not shared with the phonemically related and semantically related scores (see Appendix A for computational details.)

2.2.3. *Proportion scores*

In order to control for possible individual differences in the number of words produced, we calculated proportion scores by dividing each participant's relatedness scores by the total number of words she/he produced. We did not compute an unrelated total proportion score because an unrelated total proportion score would merely be the inverse of the related total proportion score (i.e. an unrelated total proportion score would be perfectly correlated ($r = -1.0$) with the related total proportion score). We also did not compute related residual and unrelated residual proportion scores because the computations of the residual scores already removed shared variance with a variety of word production scores, reducing the likelihood that the residual scores would merely reflect global verbosity; in fact, the computation of residual scores can itself be considered a strategy to try to reduce shared variance with the total number of words produced.

3. Results

First, we examined the correlations between the raw relatedness score variables and the symptom measures. Given previous research and our own hypotheses, all statistical tests were one-tailed. As can be seen in Table 2, the severity of FTD was positively correlated with the two unrelated raw scores and tended to be negatively correlated with the relatedness raw scores. Inter-

Table 2
Correlations between symptoms and relatedness scores

	FTD		Hallucinations	
	Raw score	Proportion score	Raw score	Proportion score
Category word	0.04	0.05	0.27	0.37*
Context word	−0.48**	−0.46**	0.39*	0.37*
Semantically related	−0.23	−0.20	0.40*	0.47**
Phonemically related	−0.08	−0.08	0.37*	0.40*
Related total	−0.21	−0.27	0.41*	0.46**
Related residual	−0.35*	–	0.44*	–
Unrelated total	0.34*	–	−0.08	–
Unrelated residual	0.43*	–	−0.09	–

*$P < 0.05$.
**$P < 0.01$.

estingly, FTD had a different association with the number of context than the number of category words produced. Levels of FTD were significantly negatively correlated with the number of context-related words, whereas there was a very weak positive correlation between FTD and the number of category-related words. On the basis of the formula recommended by Meng et al. (1992), these two correlations were found to differ significantly, $Z = 2.17$, $P < 0.05$.

Next, we computed partial correlations to examine whether FTD was uniquely associated with more than one type of fluency score. We examined whether the different fluency scores that were associated with FTD continued to be associated after removing shared variance with the other fluency scores that were associated with FTD. The partial correlation between the context-word score and FTD was relatively unchanged after partialling out shared variance with the unrelated-residual score ($r = -0.47$). Similarly, the partial correlation between the unrelated-residual score and FTD was unchanged after partialling out shared variance with the context-word score ($r = 0.43$). In contrast, the related-residual score was no longer significantly associated with FTD after partialling out either the context-word score ($r = 0.03$) or the unrelated-residual score ($r = -0.22$), suggesting that the correlation between FTD and the related-residual score can be explained by the associations between FTD and the context-word score and the unrelated-residual score. When context-word scores and unrelated-residual scores were entered simultaneously as predictors of FTD in a multiple regression analysis, they accounted for slightly more than one-third of the variance, $R = 0.61$, $P < 0.01$, with both predictor variables having statistically significant beta weights. These results suggest that FTD is uniquely associated with two types of relatedness scores: contextually related and unrelated.

The pattern of correlations between FTD and the relatedness scores was quite different from the pattern of correlations between hallucinations and the relatedness scores. As can be seen in Table 2, severity of hallucinations was positively correlated with all of the relatedness raw scores. The related-residual score had the strongest association with hallucinations. In contrast, the severity of hallucinations was not positively correlated with the unrelated raw scores. Next, we examined whether the associations between hallucinations and relatedness measures could be accounted for by one common factor measuring overall lexical activation. All partial correlations between relatedness measures and hallucinations, after removing shared variance with the relatedness residual score, became very small (all r values < 0.10), suggesting that one common lexical activation factor can account for the associations between hallucinations and the relatedness measures.

In order to control for possible individual differences in the number of words produced, we examined associations between symptoms and proportion scores. As can be seen in Table 2, all previously significant results remained significant. In addition, one previously non-significant correlation (between hallucinations and category-related words) was now significant.

The major findings of the previous analyses were that hallucinations were associated with producing related words[4] and that FTD was associated with producing fewer context words and more unrelated words. To explore whether these results reflected specific processes associated with the relatedness measures and were not artifacts of verbal intelligence, shared variance with WAIS-R Vocabulary scores was partialled out of these correlations. Partialling out verbal intelligence produced very small changes in the correlations: the correlation between hallucinations and the related-total proportion score changed from 0.46 to 0.43, the correlation between FTD and the context-word proportion score changed from -0.46 to -0.44, and the correlation between FTD and the unrelated-residual score changed from 0.43 to 0.46. These partial correlations suggest that the symptoms and the relatedness scores

[4]In a test of the specificity of the association between hallucinations and relatedness scores, exploratory analyses did not reveal any associations between delusions and relatedness scores, suggesting a specific association with hallucinations and not with reality distortion in general.

were not associated only because of their mutual association with verbal intelligence.

4. Discussion

As predicted by both the lexical overactivation and the excessive synaptic pruning models, hallucinations were associated with producing more related words. Thus, our results support both models. Although it is beyond the scope of this paper, these two models are not necessarily mutually exclusive. For example, depending on assumptions in the model, excessive pruning might result in overactivation of lexical items.

Our results and the models of David and Hoffman and colleagues suggest two potentially important mechanisms for the occurrence of hallucinations. First, both models include a mechanism for auditory imagery to occur unintentionally (either by exceeding a threshold value of activation or lexical items becoming highly discriminable). Second, both models suggest that the unintentional auditory imagery should have some recognizable lexical order, exhibiting relatedness semantically, phonemically, and possibly syntactically as well. Our finding of an association between hallucinations and the production of related words is consistent with previous research by Hoffman and colleagues. They found that hallucinations have comparable semantic organization to the organization of extended discourse in schizophrenia (Hoffman et al., 1994). In addition, in a neural network simulation of the effects of excessive pruning, they found that hallucinations produced by the simulated network exhibited syntactic and semantic regularity (Hoffman et al., 1997). Unintentional and organized auditory imagery might likely be attributed to external sources and experienced as auditory hallucinations.

The findings of this study are consistent with the available evidence concerning the functional anatomy of hallucinations and VF performance. Since VF tasks are associated with activity in temporal lobe regions (as well as frontal regions, e.g. Frith et al., 1991; Martin et al., 1994), and hallucinations have been most often associated with activity in left temporal lobe regions (e.g. David et al., 1996; Frith, 1999; however, the results of previous research exploring the neuroanatomy of hallucinations have not been particularly clear or consistent, e.g. see Frith, 1999, for a review of difficulties in the functional imaging of hallucinations), it is not surprising that we found a link between some aspects of VF performance and hallucinations. Presumably, lexical overactivation would be associated with activity in the temporal lobe, and excessive synaptic pruning could take place within temporal lobe regions or between temporal and frontal lobe regions (Hoffman et al., 1997), which might account for why hallucinations have been found to be associated with activity in temporal lobe regions.

As predicted by the disorganized memory hypothesis (Hoffman, 1987), FTD was positively associated with producing more unrelated words. This is not the first study to obtain evidence consistent with the hypothesis that FTD is associated with a disturbance in memory organization (see Chen et al., 1994). As predicted by the loss of semantic information hypothesis, FTD was associated with producing fewer context words but was not associated with producing category words. A differential impairment of context processing is consistent with theorizing and research on semantic memory concerning the effects of a loss of semantic information (McRae et al., 1997; Devlin et al., 1998). Essentially, contextually related words should be a more sensitive indicator of semantic memory impairment than categorically related words. This is expected because of the relatively greater number of associative connections between category words than between context words. Therefore, category relations should be less affected by semantic memory impairment than context relations.

The two VF task trials in this study, producing all words that begin with ‘s’ and producing only four-letter words that begin with ‘c’, also might be differentially sensitive to semantic memory impairment because the ‘c’ trial is far more restrictive. In fact, the associations between FTD and the number of semantically related words did vary depending upon the VF trial, $r = -0.03$ for ‘s’ and $r = -0.56$ for ‘c’ (in contrast, associations between FTD and phonemically related words did not vary by trial, $r = -0.07$ for 's' and $r = -0.08$ for 'c'). Our results suggest that a loss of semantic information might be present in people with FTD and that it will be most evident on demanding semantic memory tasks. This is consistent with the study by Aloia et al. (1998) who also found evidence of semantic memory impairment in people with FTD. Note that although we favor a loss of information interpretation, our results do not completely rule out an explanation based on deficient retrieval of semantic information (Rapp and Caramazza, 1993). Either way, our results do suggest deficient semantic processing in people with FTD.

In contrast to the predictions from the disorganized memory and loss of information hypotheses, the prediction we generated based on the spreading activation hypothesis (that FTD would be positively associated with the number of related words) was not supported by the results. It is possible, however, that automatic spreading activation is increased to such an extent that activation quickly extends beyond the scope of normal semantic and phonemic associations (Spitzer, 1997), which would account for the positive correlation between FTD and the number of unrelated words produced. However, there are two reasons we believe the spreading activation hypothesis cannot fully explain the results of this study. First, it is not clear why the spreading activation would be limited to only unrelated words and would not include increased activation for related words (which would have led to a positive correlation between FTD and the number of related words produced, when we, in fact, found a negative correlation between FTD and the number of related words produced). Second, previous priming research that presumably most directly measures automatic spreading activation (i.e. using either a low proportion of related items or a word pronunciation task) has not found support for the spreading activation hypothesis (Barch et al., 1996; Passerieux et al., 1997; Aloia et al., 1998). Therefore, we interpret the positive correlation between FTD and unrelated words, and the negative correlation between FTD and related words, as more consistent with the disorganized memory hypothesis than the spreading activation hypothesis. At the very least, our results suggest that increased spreading activation alone is unlikely to characterize the relationship between semantic memory and FTD.

The findings of this study are consistent with the available evidence concerning the functional anatomy of FTD and VF performance. Since VF tasks are associated with activity in temporal and frontal lobe regions (e.g. Frith et al., 1991; Martin et al., 1994), and FTD has been most often associated with decreased volume of frontal and temporal lobe regions (e.g. Petty et al., 1995), it is not surprising that we found a link between some aspects of VF performance and FTD. Presumably, disorganized memory and loss of semantic information reflect anatomical changes in the left temporal lobe and/or impaired modulation of left temporal lobe activity by the frontal lobe, which might account for why FTD has been found to be associated with frontal and temporal lobe regions.

The goal of this study was to determine which, if any, neurocognitive processes are specifically associated with which, if any, schizophrenic symptoms. It is important to point out that the inclusion of a control group could not have altered our finding that FTD in schizophrenia is associated with memory processes, and that hallucinations are associated with levels of lexical activation. In the absence of a control group, however, this study cannot tell us how deviant, if at all, are the memory processes of schizophrenic patients exhibiting FTD, nor how deviant, if at all, are the patterns of lexical activation of schizophrenic patients with hallucinations. If, for example, the memory processes of schizophrenic patients exhibiting FTD do not differ markedly from the memory processes of non-psychiatric controls, it would not alter our finding that those memory processes are implicated in FTD; such a finding would suggest, however, that the memory processes alone are unlikely to account for FTD. Therefore, it will be important for future research, at least some of which should employ non-schizophrenia control groups, to further delineate the nature of the associations between FTD and memory processes, and between hallucinations and lexical activation.

In this study, we have found evidence for different roles of language and memory processes in different symptoms of schizophrenia. The conclusions we have drawn based on our results should be considered tentative, however, because of the modest sample size and the lack of statistical power to enable us to use corrections for the number of statistical tests conducted. Nonetheless, our results suggest that an impairment in semantic memory may foster incoherent speech plans and word retrieval difficulties, thereby contributing to disturbed speech. Conversely, an overactivation of items in memory and/or an excessive pruning of synaptic connections may foster the perception of organized inner speech, thereby contributing to the development of hallucinations. Continued research employing the research strategy utilized in this study, comparing and contrasting different symptoms and their correlates, should further elucidate the relationships between symptoms and neurocognitive functions (David, 1993).

Appendix A. Computation of residual scores

A.1. Related-residual scores

There were moderately positive correlations between all relatedness scores [e.g. the correlation between the semantically related (SR) score and the unrelated-total (UR) score was 0.30], presumably reflecting a factor related to word production in general. Therefore, we first computed multiple regressions with UR as the predictor variable and SR and the phonemically related score (PR) as the dependent variables: $SR = B1(UR) + K$; $PR = B2(UR) + K$, where K is a constant and B1 and B2 are beta weights. Then, we used these beta weights to partial out the variance from UR: $SRR = SR - B1(UR)$; $PRR = PR - B2(UR)$, where SRR and PRR are new residual scores. Next, we used these new residual scores as predictors of each other: $SRR = B3(PRR) + K$; $PRR = B4(SRR) + K$. Finally, we used these new beta weights to calculate the related-residual score (RRR): $RRR = B3(PRR) + B4(SRR)$. Hence, the related-residual score is a measure of the variance shared between phonemically and semantically related words, removing variance unique to either phonemically or semantically related words as well as variance common to word production in general.

A.2. Unrelated-residual scores

First, we computed a multiple regression with UR as the dependent variable and SR and PR as the predictor variables: $UR = B5(SR) + B6(PR) + K$. Then, we used these beta weights to calculate the unrelated-residual score (URR): $URR = UR - B5(SR) - B6(PR) - K$. Hence, the unrelated-residual score is the number of unrelated words with the variance shared with semantically and phonemically related words removed.

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