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An "Errorful" Learning Deficit in Schizophrenia?

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Disturbances in learning are prominent in schizophrenia. The present study examined the effect of committing mistakes (errors) on learning in schizophrenia. Subjects included schizophrenia and schizoaffective disorder patients (n = 36) and healthy adults (n = 22) who were administered a word-stem completion task under "errorfree" (no guessing) and "errorful" (guessing) conditions. The data were analyzed using a 2 (group) 2 (order) 2 (condition) repeated-measures ANOVA and by comparing standard residualized scores between patients and controls. The results from the ANOVA revealed a significant group condition interaction with patients showing greater impairment relative to controls on the errorful versus errorfree condition. Similarly, contrasts of standard residualized scores revealed patients' scores on the errorful condition to be deviant from that of healthy adults. The findings implicate problems in the ability to self-correct and suggest that rehabilitation efforts incorporating errorless learning methods may benefit persons with schizophrenia.

Introduction

It is widely held that disturbances in neurocognitive functioning are central to schizophrenia, and that these disturbances are, for the most part, not consequent to psychotic symptoms, adverse effects of psychotropic medication, or chronic institutionalization. The significance of these deficits is tied to an expanding literature showing a relationship between neurocognition and functional outcome. In three reviews of the literature (Green, 1996; Green, Kern, Braff & Mintz, 2000; Green, Kern & Heaton, 2004), neurocognitive functions involving secondary verbal memory, working memory, visual vigilance, and executive functioning were found to be related to levels of community functioning, social problem-solving ability, and psychosocial rehabilitation. Of the neurocognitive functions included in these reviews, verbal learning showed the most oft-replicated concurrent and prospective ties.

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Against a backdrop of generalized neurocognitive impairment, the disturbances in verbal learning may be most severe (Heinrichs & Zakzanis, 1998; Saykin et al. 1991). Disturbances in learning as evidenced by performance on list learning tests are commonly characterized by: (1) a shallow learning slope, (2) an under-utilization of efficient processing strategies such as grouping words by taxonomic category to facilitate recall, (3) a passive response pattern, recalling more words from the end of the list than from the beginning or middle, and (4) numerous learning "errors" such as intrusions and perseverations (Aleman, Hijman, de Haan & Kahn, 1999, Gold, Randolph, Carpenter, Goldberg & Weinberger, 1992; Gold et al., 2000; Paulsen et al., 1995).

A portion of the problems in learning in schizophrenia may be tied to difficulties in the ability to self-correct. It is commonly observed that many persons with schizophrenia fail to benefit from past mistakes, to use past behavior to guide subsequent behavior. Instead, making mistakes appears to interfere with the establishment of desired ties. For example, on the Wisconsin Card Sorting Test, a widely used test of concept formation and problem-solving, patients' performance is commonly characterized by numerous perseverative errors (Goldberg, Weinberger, Berman, Pliskin, & Podd, 1987). Despite receiving recurring feedback about correct and incorrect responses, patients fail to put this information to use to guide future sorts. Of clinical relevance, self-correction problems extend beyond neurocognitive tests. Parallels can be found in the observation of patients participating in rehabilitation programs, the ward behavior of inpatients, and the reports of outpatients living in the community (Becker et al., 1998; Corrigan, Schade & Liberman, 1992; McGlashan, 1988; Silverstein, Hitzel, & Schenkel, 1998).

If learning in schizophrenia is indeed compromised by failures in being able to self-correct, then patients should perform better under conditions in which errors or mistakes are removed. In the present study, we tested this hypothesis by comparing a group of schizophrenia and schizoaffective disorder outpatients versus a group of healthy adults on a stem-completion learning task administered under two conditions (errorful vs. errorfree). The paradigm has been used in previous studies with memory-impaired patients (Baddeley & Wilson, 1994; Tailby & Haslam, 2003). For the present study, we expected patients to be differentially impaired relative to healthy adults on the condition requiring self-correction.

Methods

Subjects

The study included 36 outpatients diagnosed with schizophrenia or schizoaffective disorder and 22 healthy adults. All patients met DSM-IV criteria for schizophrenia or schizoaffective disorder and were recruited from the VA Greater Los Angeles and San Fernando Mental Health Centers. Psychiatric diagnosis was determined following administration of the Structured Clinical Interview for DSM-IV (SCID-I/P; First, Spitzer, Gibbon, & Williams, 1996) by an interviewer trained by the Diagnosis and Psychopathology Unit (DPU) of the UCLA Clinical Research Center (CRC) for the Study of Schizophrenia. A minimum kappa of .75 for rating the presence of psychotic and mood items is required for certification. The outpatients were clinically stable (no psychiatric hospitalizations in the past six months, same antipsychotic medication for past three months). Antipsychotic medication type and dose were not controlled in the study, but were left to the discretion of the subjects' treating physician. The healthy adults were recruited from the community via a newspaper advertisement and were screened for exclusion criteria using a structured phone interview. All subjects were between the ages of 18–55, completed a minimum of

10 years of education, and could understand spoken and written English. Exclusion criteria for all subjects included evidence of current or past neurological disorder (e.g., epilepsy), history of head trauma with loss of consciousness exceeding one hour, mental retardation, and substance dependence within the past three months. For healthy adult subjects, the following additional exclusion criteria applied: (1) current or past treatment for DSM-IV Axis I mood or psychotic disorders, (2) diagnosed schizophrenia spectrum disorder in a first degree relative, (3) education greater than 16 years. Table 1 presents the characteristics of the patient and healthy adult groups. After complete description of the study to subjects, written informed consent was obtained.

Materials

The stem completion list learning task employed in the present study followed that described previously by Baddeley and Wilson (1994). Two decks of 20 five-letter word stems were developed. For each word stem, the first two letters were provided and the remaining three letters were left blank (e.g. BR _ _ _). All word-stems were printed in black 64-point arial font and centered on 4" × 6" non-lined index cards.

The 40 word-stems and their corresponding targets were selected based on the number of possible completions to the stem and how common the completions were in the English language, respectively. All word-stems yielded seven or more possible completions. All target words were concrete nouns and were selected from the American Heritage Word Frequency Book (Carroll, Davies, & Richman, 1971) that provides a word frequency index (standard frequency index; SFI) for the most commonly used words in the English language. The SFI is based on how frequently a word appears across multiple media sources (e.g., books, journals, magazines, newspapers). All target words were selected from the middle third of possible completions to the word stem to avoid solutions that would be too easy or too difficult to generate. Each target word yielded a SFI that fell between 30.0 and 75.0, indicating common usage. None of the 40 word stems began with

Table 1
Demographic Characteristics of the Schizophrenia and Healthy Adult Groups

Variable	Schizophrenia patients (N = 36)	Healthy adults (N = 22)
Age (yrs.)	42.2 (10.3)	40.6 (8.7)
Education (yrs.)[a]	13.1 (1.6)	14.9 (1.2)
Parental education (yrs.)	14.0 (2.3)	14.3 (2.6)
Gender (% male)	63.9%	68.2%
Ethnicity (% Caucasian)	55.5%	68.2%
Psych. dx (% schizophrenia)	63.9%	
Years since 1st hospitalization	17.4 (10.1)	
Percent on atypicals	83.3%	
Percent on anticholinergics	19.4%	
BPRS total	45.5 (12.8)	
BPRS positive	7.3 (4.1)	
BPRS negative	6.1 (3.1)	

[a]Significant group differences in education, t (56) = 4.46, $p < .0001$.

the same initial letter pair (e.g., ba, ch, do, etc.) and none of the target words included potentially offensive or affect-laden connotations (e.g., blood). The above procedure resulted in two highly comparable decks of word stems (20 in each). The mean SFI for deck 1 was 52.85 (sd = 9.28) and the mean SFI for deck 2 was 52.93 (sd = 6.98).

Procedures

Testing for a differential deficit requires a number of methodological considerations. Chapman and Chapman (1978) suggest that contrasted tasks or conditions need to be matched on level of difficulty, variance, and reliability. The proposed method requires item analysis of a pool of test items in a representative normative sample. The procedure does not lend itself easily to list learning tasks and others that do not have item independence because recall of any selected item is inextricably linked to its position on the list. Subsequently, these authors proposed an alternative strategy that uses standard residualized scores to compare performance levels between groups across tasks. In the present study we used this method in the analyses. We also roughly matched the errorful and errorfree conditions on difficulty level by including a different number of word stems in the two conditions. Based on pilot data from our lab, we estimated that 15 word-stems for the errorful condition and 20 for the errorfree condition would yield optimal performance levels for testing a differential deficit.

In the present study, subjects were sequentially assigned to receive the task under one of four counterbalanced conditions. Order and deck were counterbalanced across subjects. The four orders were: errorful (deck A) – errorfree (deck B), errorfree (deck A) – errorful (deck B), errorful (deck B) – errorfree (deck A), errorfree (deck B) – errorful (deck A). In the errorful condition, subjects were instructed to try to guess the completion of the word stem. Subjects were presented with word-stem index cards one at a time (e.g., TR_ _ _) and asked to guess what the target word might be. Subjects were provided 25 seconds to guess the correct completion to the stem. After 25 seconds elapsed, the correct completion was provided and subjects were instructed to print this word on a piece of paper placed in front of them. Subjects were told to try to remember the correct completion to the stem because they would be asked to recall it later. After subjects finished printing the word, the paper was removed and replaced with a clean blank one for the succeeding item. When a subject correctly guessed the target word on the first try, there was a back-up word that was used as the correct target. In the event a subject failed to generate any guesses during the 25-second response period, the tester provided an incorrect completion followed by the correct one. This way all subjects generated or heard at least one incorrect completion to the stem. All subjects were presented 15 word stems in the errorful condition.

In the errorfree condition, subjects were presented word-stem index cards individually, but were immediately provided the correct completion. As in the errorful condition, subjects were instructed to print each correct completion on a piece of paper and were told to try to remember it as best as they could because later they would be asked to recall it. The piece of paper was removed after each card presentation and a clean piece of paper was provided for each new word stem. All subjects received 20 word stems for the errorfree condition.

Following presentation of the word stems, be it under errorfree or errorful conditions, subjects were administered three recall trials. As administered initially, subjects were presented word stems individually and asked to say aloud the correct completion. Selective reminding procedures were employed during the recall trials. If the subject completed the word stem with the correct completion, the next card was presented. If the subject

responded incorrectly, the tester told the subject that their response was incorrect and provided the correct completion. The dependent measure was the total number correct over the three recall trials. This score was converted to a percent score for the data analyses.

Statistical Analyses

To assess differential levels of ability between patients and healthy adults on the errorfree versus errorful conditions, the data were analyzed in two ways. First, we analyzed the data using a 2 (groups: patients vs. controls) × 2 (order: errorfree-errorful vs. errorful-errorfree) × 2 (conditions: errorfree vs. errorful) repeated-measures ANOVA with the SAS general linear models procedure (Cary, 1990). There were two between-subjects factors, group and order, and one within-subjects factor, condition. Of primary interest was the group × condition interaction to measure differential ability between patients and controls on the errorfree vs. errorful tasks. Second, we compared errorful learning with errorfree learning using standard residualized scores (Chapman & Chapman, 1989). In using this approach, the investigator is asking, "To what extent is a subject's score on Task B deviant, given that subject's score on Task A?" For each schizophrenia patient, a predicted score on Task B is calculated using the equation for the regression of Task B on Task A for normal subjects included in the study. For group comparisons, deviation from the mean standard residualized score for normals is interpreted as aberrant. By definition, the mean standard residualized score for normals is zero. This procedure avoids some of the psychometric problems tied to using simple raw score differences, and is optimally used with tasks that are highly correlated with one another. The correlation between performance on the errorfree condition and errorful condition in normals was measured using a Pearson *r*.

Results

For the 2 × 2 × 2 repeated-measures ANOVA, there were significant main effects of group, $F(1, 54) = 8.18$, $p = .006$, and condition, $F(1, 54) = 22.76$, $p < .0001$, but not order, $F(1, 54) = 0.01$, $p = .90$. As expected, controls showed better overall recall of the stem completions than patients, and subjects in general performed better on the errorfree than the errorful task. Of primary interest, the group × condition interaction was significant, $F(1, 54) = 5.57$, $p = .02$ (see Figure 1). No other two-way interactions were significant, all $ps > .20$, and the three-way interaction was also non-significant, $p > .35$. Follow-up contrasts of the group × condition interaction revealed that patients differed from controls at a trend level on the errorfree condition ($t(56) = 1.65$, $p = .10$.), but differed significantly on the errorful condition with normals showing the better performance ($t(56) = 3.49$, $p = .001$).

For the analyses with standard residualized scores, the results indicated an errorful learning deficit with respect to errorfree learning in patients. Standard residualized scores for errorful learning regressed on errorfree learning were lower for patients compared to controls, $F(1, 56) = 6.84$, $p = .01$.

A Peason *r* calculated for the correlation between errorfree and errorful performance in normals was significant, $r(20) = .825$, $p < .0001$. Performance on the two conditions was highly related with one another.

Discussion

The data from this study indicate that the commission of errors during learning is differentially more problematic for persons with schizophrenia and schizoaffective disorder than

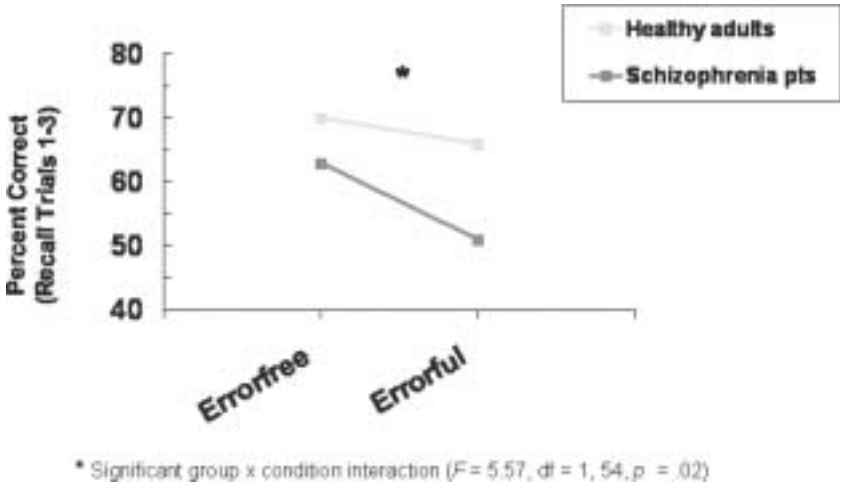

Figure 1.

healthy adults. Patients' recall of to-be-remembered word stem completions was significantly worse than healthy adults on the experimental condition that involved guessing. The data for the errorfree (no guessing) condition are more ambiguous. Patients differed from healthy adults at a trend level. Preventing errors from occurring did not eradicate patients' learning impairment. However, the magnitude of the level of impairment between patients and healthy adults was substantially increased in the errorful condition. The findings are best interpreted vis-à-vis a generalized deficit model of neurocognitive functioning in schizophrenia.

The present study addressed a number of concerns involved in testing differential deficits. Consideration was given to the Chapman and Chapman (1978) criteria that suggest contrasted conditions be matched by equating them on difficulty level, variance, and internal consistency. These criteria were proposed to address scaling influences and measurement instability that can confound interpretation of results. Unfortunately, these procedures are not easily adapted for most neurocognitive tests. Most tests do not have item independence, a necessary characteristic for measuring internal consistency and coefficient alpha. For list learning tasks of the type used in the present study the assessment of difficulty level for individual test items is linked to the item's position on the list (i.e., primacy and recency effects). Because of these limitations, we addressed condition comparability by alternative means. To address concerns regarding scaling influences, we manipulated the length of the word lists to minimize ceiling effects in the healthy adult group and floor effects in patients. To address concerns regarding differences in difficulty levels, the two conditions were made roughly comparable by including more items in the errorfree condition (n = 20) and fewer in the errorful (n = 15) condition. In addition, procedures were put in place to maximize the likelihood of the two decks of target words' comparability on an index of word frequency. These decks were counterbalanced across conditions. Lastly, we employed an additional statistical procedure suggested by Chapman and Chapman (1989) as an alternate strategy for examining differential deficits.

The results from the present study are in keeping with a report by O'Carroll, Russell, Lawrie & Johnstone (1999) who also employed the Baddeley and Wilson paradigm (Baddeley & Wilson, 1994) in a sample of schizophrenia patients and healthy adults. Patients were classified as memory-impaired or memory-unimpaired based on

performance on the Rivermead Behavioural Memory Test. On the errorful condition, the memory-impaired schizophrenia group performed worse than the healthy adult group and differed at a trend level from the memory-unimpaired schizophrenia group. On the error-free condition however, the memory-impaired schizophrenia group did not differ from either the healthy adult or memory-unimpaired schizophrenia group. Though the findings are provocative, interpretation is complicated by the following: (1) no procedures were included to equate the comparison conditions on difficulty level, and (2) the administration of a small number of word stems resulted in healthy adults and memory-unimpaired patients performing near ceiling by the second recall trial regardless of experimental condition. Despite these limitations, the findings suggest that the commission of errors is problematic for at least a subset of patients with schizophrenia.

Why do persons with schizophrenia have difficulties in learning? It would be an over-simplification to presume that the difficulties in learning for persons with schizophrenia are tied solely to error commission and problems in being able to self-correct. It is widely held that learning is a multi-faceted process influenced by a number of factors including selective attention, working memory capacity, vulnerability to distraction, motivation, and organizational processes. The findings from the present study may be understood within the framework of an information- processing model. In its simplest form, the findings suggest that patients with schizophrenia have problems in the processing of to-be-learned information, manifested as a failure to discriminate signal from noise (i.e., attend to relevant and disregard irrelevant stimuli). The disturbance could be due to inaccuracies or instability in the encoding of incoming information, a failure in the activation of long-term memory for contextual processing, or a failure in the control of voluntary attention to make relevant information the focus of attention (Nuechterlein, Dawson & Green 1994). Our findings of differential impairment on the errorful condition are consistent with signal-to-noise discrimination problems. In the errorful condition, the stem becomes associated with several possible completions, only one of which is correct. The task requires selective filtering of correct from incorrect solutions. Patients in the present study appeared to have particular difficulty selectively recalling correct (target) stem completions in the context of filtering those solutions from self-generated wrong ones.

The timeless studies by Koh and colleagues shed some light on ways that the processing of information can be effectively channeled to facilitate learning. Patients can perform comparable to healthy adults when word lists are manipulated so that words from the same taxonomic category (e.g., fruits, articles of clothing) are clustered together during presentation (Koh, Kayton & Berry, 1973; Koh & Kayton, 1974. In a separate study, Koh, Kayton & Peterson (1976) showed that patients performed similar to healthy adults when they were instructed to make ratings about the pleasantness vs. unpleasantness of a set of to-be-learned words. One interpretation of these findings is that the procedures served to increase the intensity of the signal (i.e., the to-be-remembered words), either by imposing an organizational structure or by instructing subjects to process the material in a certain way. These findings suggest that the processing abnormalities of schizophrenia patients can be manipulated to improve performance on tests of learning and memory.

From a different perspective, the findings might be explained by consideration of the relative integrity of implicit vs. explicit memory systems in schizophrenia (Clare, McKenna, Mortimer, & Baddeley, 1993; Danion, Meulemans, Kauffmann-Muller, Vermaath, 2001; Kern, Green, & Wallace, 1997). Though the literature is far from definitive, there is some support for the claim that implicit memory is relatively intact in schizophrenia. In contrast, disturbances in explicit memory are pronounced and undisputed. As recall performance would be largely dictated by the learning of stimulus-response associations, and would not

be mediated by filtering the correctness of responses, a previously presented stimulus would elicit a number of solutions in the errorful condition. In this way, persons with schizophrenia may have implicitly remembered their previous incorrect guesses and may have been unable to differentiate them from correct answers. Despite the attractiveness of the hypothesis, to date there is little empirical evidence to support the role of implicit memory in errorless learning (Hunkin, Squires, Parkin, & Tidy, 1998).

The limitations regarding interpretation of findings warrant some discussion. First, many investigators recognize schizophrenia as a disorder characterized by generalized deficits in neurocognitive functioning. The present findings do not challenge that interpretation of the literature. The primary claim made of these data is that the commission of errors adds to the problems in learning for persons with schizophrenia. Elimination of errors does not appear to eradicate the deficit as evidenced by nearly significant group differences on the errorfree condition. Elimination of errors does however, appear to reduce one source of problems involved in learning, namely reducing the cognitive burden of differentiating signal from noise. Second, we would be remiss without acknowledging that we could only approximate the guidelines held by Chapman and Chapman for testing a differential deficit. Hence, the study may have yielded slightly different findings if we had been able to perfectly match the two testing conditions. Third, the sample size was modest and though the predicted group $\times$ condition interaction was found, the trend for group differences on the errorfree condition may have been significant with a larger sample. Fourth, though the groups were comparable in age, gender, and parental education, formal matching procedures were not employed to ensure stringent control over key demographic variables that could have influenced the study's findings. Despite these limitations, the findings from the present study in large part support the claim that the commission of errors is problematic to learning in schizophrenia.

The results from the present study hold obvious implications for rehabilitation. Interventions aimed at reducing or eliminating errors during learning are currently being tested to improve work and social functioning in persons with schizophrenia (Kern, Liberman, Kopelowicz, Mintz & Green, 2002; Kern, Green, Mitchell, Kopelowicz, Mintz & Liberman, 2005). These results do not support conventional teaching methods for use in schizophrenia, methods predicated on didactic instruction and corrective feedback. Learning failures may be especially frustrating for persons with schizophrenia and may thwart subsequent efforts to habilitate. Continued efforts to improve rehabilitation in schizophrenia are sorely needed as work and social outcome are far from optimal (Scott & Lehman, 1998; Xie, Dain, Becker & Drake, 1997). Efforts to improve teaching methods for key work and social skills are necessary to reduce the magnitude of disability associated with schizophrenia.

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