Can disorganisation of semantic memory account for the abnormalities of thought in schizophrenia – a controlled experimental study ?

Can semantic memory impairments explain thought process disorders in schizophrenia – a controlled experimental study.

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Abstract

Background

Disorganisation of semantic memory provides a cognitive account of the disturbances of thinking and reasoning in schizophrenia. In this study we directly test this explanation by identifying patients with disorganised semantic categories and then examine how they use their knowledge about these same categories in an inductive reasoning task.

Method

Experiment 1 utilised a semantic category sorting task to identify patients with disorganisation of semantic memory. In Experiment 2 the patients with disorganised categories carried out a category based inductive reasoning task. Accurate performance on this task requires access to well organised semantic knowledge about the objects and categories used in Experiment 1.

Results

Patients with disorganised semantic categories in Experiment 1 did not demonstrate any difficulties or unusual responses when reasoning about the same categories in Experiment 2.

Conclusion

Disorganisation of semantic memory may not be the primary cause of disturbed reasoning or thought in schizophrenia. Patients with schizophrenia tend to generate ad hoc categories, which are unsuited to the current context. Impaired performance on semantic memory tasks can arise from a misunderstanding of social context.

Key Words

Semantic network

Overinclusion

Schizophrenia

Concepts

Context

Inductive Reasoning

Introduction

Semantic memory is the long term memory store of meanings of words, objects and relations between entities in the world (e.g. cars have engines). Semantic memory dysfunction has been frequently reported in some patients with schizophrenia using diverse methodologies including verbal fluency (Allen et al 1983, Goldberg et al 1998), semantic priming (Aloia et al 1998, Spitzer et al 1993), semantic categorisation tasks (e.g. Chen et al 1994, McKenna et al 1994,) and lexical processing (Salisbury et al 2000). Evidence would also suggest that semantic memory dysfunction could account for the characteristic disorders of thinking processes in schizophrenia, namely formal thought disorder (e.g. Goldberg et al 1998; Aloia et al 1996; Spitzer et al 1994), and delusions (Rossell et al 1998,1999), as well as schizophrenic–like language disturbances in psychiatrically well subjects (Moritz et al 1999).

Semantic memory impairment in schizophrenia has been contrasted with that in DAT. In schizophrenia impairment results from disorganisation of the category based structure of semantic memory (Goldberg et al 1998, Sumiyoshi et al 2001, Elvevag et al 2002) rather than loss of semantic knowledge per se. However, in DAT semantic memory impairment is consistent for the same items across tests. This pattern indicates a loss of semantic knowledge about specific concepts rather than a failure of access (Chertkow and Bub 1990).

Although disorganisation of semantic memory in schizophrenia may vary with illness state (Goldberg et al, year? 1998???), one would predict that patterns of disorganisation of semantic memory in schizophrenia should be consistent across cognitive tasks that depend on accessing semantic memories.

Aloia et al (1998) point out that the value of cognitive models of schizophrenia lie in providing an explanation rather than a redescription of the phenomena. In the study reported here, we performed a controlled experimental study to see whether disorganised semantic memory directly influences thinking and reasoning about the same disorganised concepts. If it does then it would provide firm evidence that disorganisation in semantic memory is the primary cause of disorders of thought process in schizophrenia.

Experiment 1 – Category Generation Test

Method

Participants

Thirty Two patients (26 male, 6 female) with a diagnosis of schizophrenia took part in this study. Diagnoses were established by the participant's consultant psychiatrist according to DSM IV criteria. All had a minimum duration of illness of 2 years. The mean age of the group was 45 years, ranging from 25 to 68 years. The mean estimated premorbid IQ, as measured by the NART (Nelson 1982) for this group was 105.54, ranging from 91 to 119. The Quick Test (Ammons and Ammons 1962), which provides an IQ based on picture vocabulary, indicated mean current IQ = 97 (range = 75-116). A brief clinical assessment, the 12 item Montgomery Schizophrenia Rating Scale (Montgomery et al 1978), was administered close to the time of testing. This scale provides good information about first rank symptoms (Mellor 1970), but not negative symptoms or thought disorder. 70% of the patients were rated as having ≥ 1 definite/pervasive first rank symptoms, 10% showing ≥ 1 moderate symptoms, and 20% showing no first rank symptoms. Approximately two thirds of the sample were taking atypical antipsychotic medication at the time of testing, with the majority of these being prescribed Clozapine. The remainder were on conventional neuroleptics.

In addition, normative data were collected from 15 control participants (6 male, 9 female) without psychiatric history. The mean age of the group was 27 (range 19-38) years, mean NART IQ = 119.3 (range 111-124), Quick Test based mean IQ = 102 (range = 77-116).

The Category Generation Test (CGT)

The CGT utilised a card sorting method similar to that adopted in many early studies of overinclusive thinking in schizophrenia (e.g. Payne and Hewlett 1960, Chapman 1958). Sorting of pictured objects into semantic categories is now a subtest of at least one semantic memory test battery and is sensitive enough to reveal semantic memory impairments (Hodges et al 1992).

Materials

49 line drawings were selected from the Snodgrass and Vanderwart (1980) corpus. These were chosen on the basis that they were all familiar items that could be considered to fall clearly into distinct, familiar, everyday categories. Since norms for both name (Snodgrass and Vanderwart 1980) and typicality (Battig and Montague 1969) were published more than 20 years ago, 20 undergraduates from the University of Hertfordshire were required to both name these items and provide a rating of how typical each item was of its category. Forty-five items (9 items in each of 5 clear categories) were then selected on the grounds of good name agreement. These were printed on individual cards. A full list of the items used can be seen in Appendix A, along

with details of the degree of name agreement and the mean typicality ratings collected from the students.

Procedure

Each participant was asked to name all of the 45 line drawings, to ensure that they could be easily identified. They were then asked to "Sort the cards into groups of items that go together, making as many or as few groups as you want, with any number of cards in each group". When this task was completed, the item groups were recorded. Where a subject had made a grouping, which did not correspond to the nine items in one of the five semantic (i.e. taxonomic) categories, s/he was asked " Why have you put this item in this category?" and the response was recorded.

Data Analysis

Overinclusive thinking was operationally defined by Cutting (1985) as "the number of unusual items included in a category during an object sorting test". Each grouping made by a participant was classified as one of the following:

i) *Normative category* – all 9 items from each of the 5 taxonomic categories are grouped together.

ii) *Overinclusive* – where items from more than one semantic category are grouped together (e.g. horse and tiger grouped with the vehicles).

iii) *Underinclusive* – where one or more members of a semantic category have been grouped separately to the remainder of the category members (e.g. car, bus and train grouped together but the other six vehicles in a separate group).

Each participant was subsequently classified as an overincluder, an underincluder or a normal sorter. An overincluder was someone who produced ≥ 1 overinclusive categories. An underincluder was someone who produced ≥ 1 underinclusive categories and a normal sorter was someone who produced normative categories. No participant met the criteria for both overincluder and underincluder.

Results

5 of the 15 healthy controls were classified as underincluders, but none of them formed any overinclusive categories. In all 5 cases of underinclusion the participants had grouped roller skates, sledge and bicycle separately to the other vehicles. When asked their reasons for this they all gave similar answers, indicating that these were toys rather than vehicles. In one case, animals and fruits were split into indigenous and non-indigenous. Where these particular sorts were also seen in the patients' data they were classified as 'normative' categories. Of the 32 patients with a diagnosis of schizophrenia, 9 were then identified as overincluders, 11 as underincluders and the remaining 12 as normal sorters.

Experiment 2 – Category Based Inductive Reasoning by Over- and Underincluding patients.

Background

Inductive reasoning refers to the process by which people are willing to make a generalised conclusion from premises that describe particular instances (Eysenck and Keane 1991). In category based inductive reasoning tasks (Sloman 1993; Osherson et al 1990) participants have to judge whether a state of affairs is true about other members of a semantic category when they are previously told that it is true for specific members of the same semantic category. Participants are presented with an argument that consists of two premises that they are told to accept as true (e.g. 'Shirts are manufactured in Mr.Smith's factory', 'Belts are manufactured in Mr Smith's factory'). A conclusion is then given (e.g. 'Shoes are manufactured in Mr Smith's factory') and the participant is asked to evaluate the probability that the conclusion is true (Sloman 1993; Osherson et al 1990). The predicate used in both premises and conclusion (i.e. are manufactured in Mr Smith's factory), is called a 'blank predicate' since it provides novel information. As a consequence, semantic similarity is the overriding influence on judging the probability that the conclusion is true (Osherson et al 1990). Strong semantic similarity between the items in premises (i.e. shirts and belts) and conclusion (i.e. shoes) elicit high estimates of probability, whereas weak semantic similarity results in low estimates of probability. On this basis we can now formulate a hypothesis about the performance of patients who overincluded or underincluded in the CGT.

Hypothesis 1:

In a category based inductive reasoning task, overincluders (or underincluders) will be less likely to believe the conclusion if it specifies an item that was sorted out of category in the CGT, in comparison to healthy controls.

Part 1: Category based inductive reasoning about disorganised semantic categories.

Method

Category Based Induction Test

In a pilot study a category based induction test was developed using the same format as Osherson et al (1990). On each trial patients were presented with a card on which two premises were printed above a line and a conclusion below the line. Participants were asked to estimate the likelihood that the conclusion was true given the truth of the two premises. A 5-point Likert-type scale was provided for patients to indicate their estimate of likelihood. However it became clear from this pilot study that patients found the layout of each card confusing and the instructions difficult to follow. As a result we had to change the format of Osherson et al's task. Instead of the premises ('Shirts are manufactured in Mr. Smith's factory' and 'Belts are manufactured in Mr Smith's factory') and a conclusion ('Shoes are manufactured in Mr Smith's factory'), the following verbal argument was presented:

"Mr Smith owns a factory. In this factory he manufactures shirts and belts. How likely is it that Mr. Smith will also manufacture shoes in his factory?"

The opening sentence avoided the confusing request of asking the patients to believe the truth of the two premises. The two premises were combined in the next sentence (premise sentence), which is a more familiar mode of expression in natural language. The final sentence (conclusion sentence) explicitly asks the participant to evaluate the truth of the conclusion.

Materials

For each of the five categories used in the CGT, a standard argument was constructed (see Appendix B). Two blanks spaces were provided in the premise sentence and a single blank space in the conclusion sentence.

At the beginning of this experiment, participants were provided with a laminated white card of 6X4 inches on which they indicated their response. On the card was drawn a Likert-type rating scale of 1-5. Underneath the numeral

‘1’ was printed ‘Definitely will’, and underneath ‘5’ was printed ‘Definitely will not’.

Procedure

For each patient who had been identified as an overincluder or underincluder in the CGT, the categories that had produced sorting errors were selected for the category based inductive reasoning task (hereon referred to as the inductive reasoning task for brevity). If more than two categories had generated missorting errors in the CGT then two were randomly selected by the experimenter. Test and control trials were then formed in the following ways. The two blank spaces in the premise sentence were always filled with items that the patient had *correctly* sorted in the CGT. In the test trials, the blank space in the conclusion sentence was filled with an item that had been *missorted* (i.e. over or undercluded) in the CGT. In the control trials the blank space in the conclusion sentence was filled by an item that had been *correctly* sorted in the CGT. For example suppose that an overincluder in the CGT had missorted ‘hat’ together with the nine body parts. Then a test trial presented to this patient would be of the form:

“ Mr Smith owns a factory. In this factory he manufactures *shirts* and *belts*. How likely is it that Mr. Smith will also manufacture *hats* in his factory?”

For the control trial 'hats' would be replaced by another of the eight clothing items which had been correctly sorted.

Using this procedure, trials on the inductive reasoning task were constructed on a patient –by –patient basis.

On each trial the participant indicated their response by pointing to a number on the Likert scale or by saying a number out loud, to indicate the likelihood that the conclusion was true.

Participants

29/32 patients and all of the 15 controls who completed the CGT also completed the inductive reasoning task. Each patient had already been identified as an overincluder,underincluder or normal sorter.

Data Analysis

Because the verbal arguments were tailored to suit the individual sorting pattern of each patient, there were in all 142 individual trials. Normative data was collected from 10 healthy controls for each test and control trial. Control participants followed the standard instructions given to patients but completed the test in their own time.

Given the qualitative difference between patients who overinclude or underinclude, separate analyses were conducted. For both overincluders and underincluders, if hypothesis 1 were true, patients would be expected to give lower likelihood scores (i.e. higher values on the Likert-type scale) for the test trials than the control trials, whereas healthy controls would provide similar ratings for both versions. In other words the study is designed to test for a classic interaction in an analysis of variance model. Thus a mixed ANOVA design was used in which the repeated measure was the mean likelihood ratings for the test and control trials (Trial factor). Scores for the patients and healthy controls made up the between Groups factor.

Results

1. Internal validity

Given that we made substantial revisions to the original version of Osherson et al's (1990) task, it was necessary to provide a validation that semantic similarity was a critical ingredient in this inductive reasoning task. Typicality ratings of an item are a measure of how close the meaning of an item is to the central meaning of a category (Rosch et al 1976). In Osherson et al's (1990) task, category based induction was greatly influenced by item typicality, which indicated that semantic similarity was the overriding influence on performance. Internal validity would be obtained if the typicality of items in the conclusion correlated with their likelihood ratings. In our study typicality ratings correlated highly with these likelihood ratings ($r= -.732$, $p <.001$). This would indicate that despite the changes to the original design of Osherson et al (1990), semantic category structure remains the overriding influence on category based inductive reasoning. In addition, such a high correlation should mean that the task is sensitive enough to detect any effect of disordered semantic memory on inductive reasoning.

2. Evaluation of Hypothesis 1

i) Overincluders v's Healthy Controls

Mean (SD) scores for test and control trials respectively were 3.06(1.18) and 1.85(0.97) for overincluders compared to 3.44(0.33) and 2.78(0.22) for healthy controls. A significant main effect was found for Trial Type (F (1, 10)= 8.87, p= .014). However, there was no significant group effect (F (1, 10) = 3.98, p =.074). In addition, the critical interaction between the Group and Trial Type factors produced an insignificant F-ratio (F (1, 10) =0.76, p =.403). Thus the healthy controls and the overincluders produced a similar pattern. Higher likelihood ratings were provided for control trials compared to test trials.

ii) Underincluders v's Healthy Controls

Mean (SD) for test and control trials were 3.62(1.43) and 2.26(0.95) for underincluders compared to 3.30(0.61) and 2.50(0.28) for the controls. A significant main effect was found for Trial Type (F (1,20) =12.16, p=. 002). There were no significant differences between the overall means for the two groups, (F (1,20) = .027, p=.87). The critical interaction between the Group and Trial

Type factors also produced an insignificant F-ratio ($F(1,20) = .819$, $p = .376$) contrary to the prediction of the hypothesis. Like the overincluders, the underincluders produced a similar pattern of likelihood scores as the healthy controls.

Discussion

Two interesting conclusions follow from the ANOVAs for both the overincluders and the underincluders. Firstly, even healthy control participants are less likely to transfer beliefs from premises to the conclusion for items which patients are likely to missort in the CGT. Secondly items which caused patients to be overincluders or underincluders on the CGT did not produce lower likelihood scores by these same patients in the category based inductive reasoning task. These data provide a refutation of Hypothesis 1. Missorted items in the CGT were treated by patients in a normative way during the inductive reasoning task.

Part 2: Category Based Inductive Reasoning with overinclusive categories.

Background

Using the definition of Cutting (1985) overinclusive categories on the CGT were identified where cards sorted together included items from 2 or more semantic categories (e.g. horse sorted with vehicles). This could result from an abnormal organisation of categories in semantic memory, such that items from different taxonomic categories have merged to become members of a new overinclusive category. On this basis we can formulate a second hypothesis:

Hypothesis 2:

Overincluded items (e.g. horse sorted with vehicles rather than animals) will have stronger semantic ties with other members of the overinclusive category (i.e. vehicles) for overincluders than they do for healthy controls. This will be reflected in the likelihood ratings in a category based inductive reasoning task.

Method

A category based inductive reasoning task similar to that described in Part 1.

Materials

As for Part 1, except that the standard argument for the principal taxonomic category (e.g. vehicles) within the overincluded catgeory was used.

Example

Patient B was an overincluder. One overinclusive category was made up of horse sorted with the 9 vehicles in the CGT. The argument presented in test trials would be of the form:

"A new lubricant called DDX makes *cars* and *trains* go faster. Do you think it will also make *horses* go faster?

For control trials the conclusion sentence was filled with a correctly sorted item from the principal taxonomic category (i.e. another vehicle).

Procedure

As for Part 1.

Results

It would be predicted from Hypothesis 2 that overincluders should give higher likelihood scores (i.e. lower ratings on the Likert scale) on test trials compared to healthy controls. Mean (SD) scores for test and control trials were 5.0(0.0) and 1.85(0.97) for the overincluders compared to 4.61(0.09) and 2.78(0.22) for the healthy controls. The universal response of overincluders was the *maximum* rating (i.e. conclusion definitely does *not* follow from premises). No conventional statistical test was applicable since all likelihood ratings were ties. Given that semantic similarity is expected to be the overriding factor influencing judgements on a category based inductive reasoning task, this finding indicates a total reluctance by overincluders to find any semantic similarity between the 'overincluded' item in the conclusion and other members of the overinclusive category.

General Discussion

In Experiment 1, the Category Generation Test (CGT) was used to identify 9 overincluders (i.e. sorted items into the wrong semantic category) and 11 'underincluders' (i.e. sorting items into subcategories). Both sorting patterns suggest disorganisation in semantic space for those categories that elicited over-/underinclusion errors. In Experiment 2, the category based inductive reasoning task required the generalisation of semantic knowledge from premises to the conclusion. Internal validation was demonstrated. Item typicality accounted for 50% of performance variance on this task.

Categories with disorganised semantic structure revealed in the CGT did not affect category based inductive reasoning in Experiment 2, contrary to the prediction. Patterns of over/underinclusion in Experiment 1 appeared not to affect reasoning about those same categories in Experiment 2. One possible explanation could be that these tests have poor reliability so that a correlation would not be expected between Experiments 1 and 2. This is unlikely since Experiment 1 produced highly reliable patterns of sorting behaviour for all 45 items in control participants. For Experiment 2 Osherson et al (1990) demonstrated a major contribution from item typicality. This was also found in the adapted version used in the current study.

Conclusion

Disorganisation of semantic memory in schizophrenia has been explained by anatomical theories suggesting abnormal patterns of connectivity (e.g. Seigmeier and Hoffman 2002). Abnormal connectivity would then lead to a reduction in the automatic spread of activation to semantically related concepts, whereas activation of weak semantic associates remains unaffected (Goldberg et al 1998; Aloia et al 1998). This explanation has been underpinned by neuropathological evidence for reduced corticocortical or dendritic connectivity in schizophrenia (e.g. Feinberg 1982, Glantz and Lewis 2000). According to this explanation one would expect that patterns of disorganised semantic structure would be consistent between memory tests and reasoning tasks requiring on-line access to semantics. This is not supported by the findings of the present study.

Process theories of disorganised semantic memory in schizophrenia have included impaired selective attention (Nestor et al 2001), or dysexecutive theories (e.g. Allen et al 1994, Ragland et al 2001). These could account for different patterns across tests if attentional or executive demands differ in a consistent way across these tests. But these seem unlikely explanations for the results reported here. Attentional or executive demands appear to be less when the semantic errors were high (i.e. on the CGT). Sorting cards into taxonomic categories can be achieved by 7 year olds (Smiley and Brown 1979), whereas the inductive reasoning task was too difficult in its original form and had to be simplified. Thus, it is more likely that the cognitive demands of the inductive reasoning task exceeded those of the CGT, yet patients who overincluded or underincluded on the CGT performed within normal limits on the inductive reasoning task.

The strong conclusion that can be drawn from these findings is that abnormal semantic memory may not be the primary cause of disturbances of reasoning and decision making in patients with schizophrenia. If we can assume that category based inductive reasoning provides a good model for on-line access to semantic memory, then semantic memory dysfunction does not appear to affect the thought process of these patients. An alternative explanation has been suggested by Goldberg et al (1998). Goldberg et al suggested that semantic memory problems in patients with schizophrenia can lead to misjudging the meaning or context of social situations, or failure to comprehend the significance of certain acts. This would provide a good explanation for some of the definitions given by overincluders and underincluders for their sorts on the CGT. For example, one overincluder who sorted lips and hands together with fruits reported, "You use your hands and lips when you eat fruit." This ad hoc explanation could well be plausible in a different context, but it demonstrates a misunderstanding of the demands of the context in which the CGT was being conducted. The category based inductive reasoning task provided greater specification of the context and in particular the respects (Medin et al 1993) by which semantic similarity should be judged. This would explain why the disorganisation of semantic categories apparent in Experiment 1 did not influence inductive reasoning in Experiment 2.

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Appendix A (i) - Mean Typicality Ratings for Items in the Category Generation Test

Vehicles		**Clothing**		**Fruits**		**Animals**		**Body Parts**	
Item	**Mean**	**Item**	**Mean**	**Item**	**Mean**	**Item**	**Mean**	**Item**	**Mean**
car	9	shirt	8.7	apple	8.9	dog	8.95	arm	8.95
bus	8.75	trousers	8.65	banana	8.9	cat	8.95	leg	8.95
lorry	8.25	dress	8.45	orange	8.85	horse	8.6	eye	8.6
train	7.9	coat	8.3	strawberry	8.6	elephant	8.45	foot	8.6
airplane	7.05	sock	7.45	grapes	8.5	monkey	8.2	hand	8.5
helicopter	6.3	waistcoat	7.3	pear	8.5	cow	8.15	ear	8.2
bicycle	6.05	shoe	6.35	pineapple	8.05	camel	7.75	thumb	7.75
sledge	3.8	hat	6.1	melon	7.45	tiger	7.75	elbow	7.7
roller skates	3.1	belt	6	lemon	6.95	tortoise	6.7	lips	7.55
	6.69		**7.48**		**8.30**		**8.17**		**8.31**

Appendix A (ii) – Name Agreement for Items in the Category Generation Test

Item name	**% agreement**	**Other responses (% of sample giving response)**
Aeroplane	70	Plane (25), Airplane (5)
Ankle *	80	Heel (20)
Apple	100	
Arm	100	
Banana	100	
Belt	90	Bracelet (5), Collar (5)
Bike	55	Bicycle (45)
Bus	100	
Camel	100	
Car	100	
Cat	100	
Coat	60	Jacket (35), Long coat (5)
Cow	80	Bull (20)
Dog	100	
Dress	95	Top and Skirt (5)
Ear	100	
Elbow	85	Arm (15)
Elephant	100	
Eye	100	
Fingernail *	35	Finger (25), Fingertip (25), Nail (15)
Foot	100	
Grapes	80	Bunch of Grapes (15), Berries (5)
Hand	95	Right Hand (5)
Hat	100	
Helicopter	95	Chopper (5)
Horse	100	
Jumper *	95	Sweat shirt (5)
Leg	90	Bottom half of leg (5), Knee (5)
Lemon	95	Fruit (5)
Lips	95	Mouth (5)
Lorry	95	Truck (5)
Melon	70	Slice of watermelon (15), Melon slice (15)
Monkey	100	
Motorbike *	90	Motorcycle (10)
Orange	100	
Pear	100	
Pineapple	100	
Roller Skate	70	Skate (25), Tricycle (5)
Shirt	100	
Shoe	100	
Sledge	85	Sleigh (5), Skis (5), Ski pulley (5)
Sock	100	
Strawberry	100	
Thumb	100	
Tiger	95	Cat (5)
Tortoise	80	Turtle (20)
Train	100	
Trousers	100	
Waistcoat	100	

* indicates items discarded in favour of alternatives showing higher name agreement.

Appendix B – Standard Arguments used in Experiment 2.

Semantic Category - Vehicles

A new lubricant called DDX makes …….. and …………. go faster. Do you think it will also make …………… go faster?

Semantic Category - Clothing

Mr Smith owns a factory. In his factory he manufactures ………… and ……………….. Do you think he will also manufacture ……………….. in his factory?

Semantic Category - Fruits

Exotic birds in London Zoo like to eat ……….. and ………. Do you think they will also like to eat …………?

Semantic Category - Animals

A vet has discovered that ………….. and …………….. get sick when they eat a certain type of grass called Tetsy Grass. Do you think …………….. will also get sick when they eat Tetsy Grass?

Semantic Category – Body Parts.

A Dr. has just discovered a new chemical called HTP, which is found in ……………. and ……………… . Do you think the Dr will also find the chemical HTP in ………………… ?