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ABSTRACT

Objective : The possibility that delusion of influence could be related to abnormal recognition of one's own actions was investigated in persons with schizophrenia.

Method : Influenced (N=6) and non-influenced (N=18) patients with schizophrenia were compared to normal subjects (N=29) in an action recognition task. The image of a virtual right hand holding a joystick was presented to the subjects through a mirror so that it was superimposed to their real hand holding a real joystick. Subjects executed discrete movements in different directions. Angular biases and temporal delays were randomly introduced in some trials, such that the movements of the virtual hand departed from the movement executed by the subjects. After each trial, subjects had to decide whether the movement they saw was their own or not.

Results: Compared to the comparison subjects, both patient groups made significantly more recognition errors in trials with temporal delays. In trials with angular biases, the error rate of influenced patients significantly differed from that of comparison subjects and from that of the non-influenced patients.

Conclusions : These findings support the hypothesis that delusion of influence is associated with a quantifiable difficulty in attributing actions to their author. This difficulty may be related to a specific impairment of a neural action attribution system.

INTRODUCTION

Among the wide range of manifestations characterizing schizophrenia, some of the positive symptoms have been considered critical for the diagnosis of this disease. According to Schneider (1), first-rank symptoms refer to a state where patients interpret their own thoughts or actions as due to the influence of alien forces or to other people. The fact that these symptoms, when narrowly defined (2), can be considered as specific to schizophrenia, together with their relative homogeneity across patients, raises an important point. Indeed, first-rank symptoms might reflect the disruption of a mechanism which normally generates consciousness of one's own actions and thoughts and allows their correct attribution to their author. Thus a study of attribution behavior in schizophrenic patients would not only shed light on this critical function but also help understanding the factors responsible for misattribution in the patients.

Previous studies have examined the monitoring of actions in schizophrenia: patients with positive symptoms are impaired when tested, in the absence of visual feedback, in error-correcting tasks (3,4), or in a drawing task using a joystick or the keys of a keyboard (5). These results, however, cannot disentangle between the factors responsible for this impaired performance in the absence of visual control, whether it relies on an altered representation of the action to be performed, or a defect in the sensorimotor loops normally used to control movement execution.

The hypothesis of an altered representation seems the most likely one. Indeed, patients with delusion of influence, for example, tend to deny being the authors of the decisions to perform their own actions, even if they have actually performed these actions, suggesting that they cannot match an executed action with the corresponding representation or intention. This hypothesis can be directly tested in studying patients' ability to distinguish between actions that they have performed and actions performed by others. In a pioneering experiment (6), normal subjects were presented with movements of an uncertain origin: they were shown the image of an actor's hand visually superimposed to (and undistinguishable from) their own hand. Movements performed by the actor's hand could either be in concordance or in discordance with the subjects' own movements. Even in the latter case, subjects experienced the actor's hand as theirs without regard to obvious discrepancies between the self-generated and the seen movements: they simply reported feelings of strangeness or impressions of having their hand pulled by some external force.

Daprati et al (7) extended this paradigm to schizophrenic patients. Subjects performed simple manual gestures with their right hand that they monitored via a video camera. At times, the image of the subject's hand was unknowingly substituted by that of an experimenter performing the same or a different gesture. At the end of each trial, subjects gave a verbal agency judgement about whether the hand they had seen was their own hand or another hand. In the most "difficult" trials where they saw another hand performing the same movement as they had performed, normal subjects misjudged the alien hand as theirs in about 30% of cases. The error rate amounted to 80% in patients with delusion of control, whereas in patients without delusion of control, it was around 57%.

These experiments, although they demonstrate that the clinical difficulty in identifying the origin of an action can be experimentally provoked, did not allow to determine the cues used by the comparison subjects to give correct attribution responses, that were missing in the influenced patients. The present experiment was therefore designed to answer this question. Using a situation similar to that of Daprati et al (7), a realistic virtual hand was used, instead of the hand of an experimenter, which was superimposed to the subject's hand. Not only did this device allow more standard experimental conditions; it also allowed systematically distorting the movements of the virtual hand with respect to those of the subjects' hand. The results fully support the existence of impaired attributions of action in schizophrenia, especially in influenced patients.

METHODS

Subjects

Twenty-nine patients with schizophrenia (twenty-three males and 6 females; mean age=34.6, SD=11.0) and 29 normal subjects (twenty males and 9 females; mean age=36.7, SD=11.5) participated in the study. Patients as well as comparison subjects were naive as to the purpose of the experiment. This study was approved by the local ethical committee (CCPPRB Léon Bérard, Lyon). After a complete description of the study, all participants provided written consent.

Patients were selected according to the DSM-IV criteria. None of them presented any additional diagnoses. Comparison subjects were recruited from maintenance staff of two hospitals. Exclusion criteria in both groups were visual and auditory disorders, history of neurological illness or trauma, alcohol and drug dependence according to the DSM-IV criteria, age superior to 65 or inferior to 18. The patient and comparison groups did not differ significantly for age, sex, laterality and educational level.

Seventeen of the 29 patients were hospitalized at the time of the experiment. Twelve patients met the criteria for paranoid, 3 for disorganized, 11 for undifferentiated and 3 for residual schizophrenia. All but 3 patients were right-handed according to the Edinburgh Inventory (8). The mean average disease duration was 11.3 years (SD=9.0; range=1-33). All patients were under treatment with antipsychotic medication (principally risperidone, olanzapine, clozapine and levomepromazine), and were clinically stable at the time of testing. No information exists in the literature on possible effects of medications on tasks like that used in the present work, or on motor tasks in general.

Neuropsychological testing was used to assess patients' spatial perception abilities and intellectual performance, using the Birmingham Object Recognition Battery (BORB) (9) and the Raven Progressive Matrices PM47. The BORB investigates the abilities to process basic features of simple or geometric pictures. The patients' performances were within normal range in the six tests used (Line Match Test A = 26.7; cut-off point 22; Circle Match Test A=26.7, cut-off point 19; Line Orientation Match Test A=24.5, cut-off point 18; Position of Gap Match Test A=34.7, cut-off point 24; Minimal Feature View Task=24.4, cut-off point 18.5; Item Match Task=31.5, cut-off point 24). The PM47 examines the effectiveness of visuo-spatial reasoning and may detect low intellectual performance. Patients' mean score at this test was within normal performance for their age (28.4, SD=2.3; range=24-31) (10).

All patients underwent clinical assessment with the Scale for Assessment of Positive Symptoms (SAPS) (11) and the Scale for Assessment of Negative Symptoms (SANS) (12). Mean scores were 24.7 for the SAPS (SD=12.3; range=8-60), and 41.3 for the SANS (SD=19.9; range=6-85). In addition, a passivity phenomena sub-scale score was defined, which consisted in items 15 to 19 of the SAPS. This sub-scale allowed classifying the patients as influenced or non-influenced. At the time of testing, 6 patients presenting a passivity phenomena sub-scale score superior to 2 (mean=6.3, SD=2.8, range=3-9) were classified as "influenced". The remaining 23 "non-influenced" patients scored 2 or less at this sub-scale. No differences between the two samples of patients were found on t-tests regarding educational level, intellectual level, clinical features (SAPS and SANS total scores) and 5 tests from the BORB. Mean age in influenced patients (25.2 years, SD=3.5) was significantly lower than in non-influenced patients (37.1 years, SD=11.0; t=-2.6, df=27, p=0.015). Performance on the BORB Item Match was significantly lower in influenced (mean score=29.7, SD=3.9) than in non-influenced patients (mean score=31.9, SD=0.3; t=-2.7, df=27, p=0.013) but still in the normal range.

During the experiment itself, 5 non-influenced patients revealed unable to correctly perform the task. For this reason, it was decided not to include them in the comparative analysis. The behavior of these 5 patients during the task will be described at the beginning of the results section. They did not differ from the other non-influenced patients for their age, illness duration, educational level, intellectual performance, perceptual abilities (BORB), or total SAPS score (t-tests). By contrast, their total SANS score was significantly superior (58.2, SD=16.5) to that of the other non-influenced patients (36.0, SD=18.8; t=2.38, df=21, p=0.027).

Materials

During the experiment the image of an electronically reconstructed hand was presented to the subjects on a high refresh rate computer screen. A specially designed program synthesized pictures of a hand holding a joystick according to the real position of a joystick actually held by the subject and connected to the computer. This design allowed the dynamic representation of the movements of the joystick held by the subject with an intrinsic delay inferior to 30 msec. Temporal or angular biases could be introduced in this representation (see below), modifying the apparent direction or the degree of synchrony of the movement actually performed by the subject with respect to the movement displayed on the computer screen.

The computer screen was placed face down on a metallic support. A horizontal mirror, located 18 centimeters below the screen, reflected the image. The joystick was placed below the mirror on the table supporting the apparatus. The distance between the table and the mirror was 31 cm, so that the subject’s hand holding the joystick was located approximately 18 cm below the mirror. Thus, when subjects looked at the mirror, they saw the image of a virtual hand moving a joystick just above their own hand actually doing that.

Procedure

Subjects sat comfortably in front of the apparatus with their forehead leaning on a foam cushion. They held the joystick with their right hand, with their elbow resting on the table. The position of their forearm was adjusted so as to coincide with the direction of the virtual forearm seen in the mirror. Subjects were instructed to maintain fixed the position of their fingers on the joystick and to restrict their movements to the wrist joint.

The task consisted in executing a series of simple movements with the joystick. Each trial started with a dark screen. A green spot (1 cm diameter) was displayed for 1 second on the left, on the right or on the top of the screen. The image of the virtual hand then appeared for 2 seconds during which the subjects had to execute a movement of the joystick in the direction indicated by the position of the green spot. Immediately after the trial, subjects had to answer the question: “Did the movement you saw on the screen exactly correspond to that you have made with your hand”? They had to answer YES or NO.

Three categories of trials were used: 1. Neutral trials: movements of the virtual hand exactly replicated those made by the joystick. 2. Trials with angular biases: movements of the virtual hand were deviated by a given angular value with respect to those made by the joystick. Seven values of angular bias (5°, 10°, 15°, 20°, 25°, 30°, 40°) either to the right or to the left were used. 3. Trials with temporal biases: movements of the virtual hand were delayed by a given time with respect to those made by the joystick. Seven values of temporal bias (50, 100, 150, 200, 300, 400, and 500msec) were used. Each trial with a temporal bias was run 4 times for each of the three directions of movement (N=84); trials with angular bias were run two times with a bias to the right and 2 times with a bias to the left for each of the three directions of movement (N=84). Finally, neutral trials were run 12 times. Each subject therefore executed a total of 180 trials. The order of presentation of the 180 trials was randomized before the participation of each subject. Identical trials could not be presented twice in a row.

A 5 minutes break was provided after 90 trials. Missed trials were repeated if necessary. Before the experiment, each subject ran a training session during which the instruction was to freely move the joystick. During the first 30sec, no bias was used; then, a 500msec bias was introduced; finally a 30° bias was introduced.

Data Analysis

Verbal responses of the subjects were recorded. According to whether trials were with or without bias, subjects could potentially make 2 types of errors: YES responses in trials with a bias, and NO responses in neutral trials. The maximum number of errors was 12 for the neutral trials and 84 for the trials with an angular or a temporal bias. Presentation of the results below will focus on the YES responses which reflect the subjects’ ability to recognize a movement as their own.

Non-parametric statistics were used because the scores were not normally distributed. For statistical comparison between the comparison group and two subgroups of patients (influenced and non-influenced) the Median test and pairwise comparisons (Mann-Whitney U-test) were used.

RESULTS

Descriptive analysis

Comparison subjects and patients gave YES (correct) responses in nearly all neutral trials. The median value of erroneous NO responses was equally small (N=1) for all three groups. The distribution of YES responses for the biased trials, although it clearly differed between groups as will be shown below, kept a relatively similar pattern across groups. In both comparison subjects and patients, the number of YES responses was higher for the smaller temporal and angular biases, and became lower as the biases increased. In other words, only the slope of the curve differed between groups. This was not the case, however, for five of the 29 patients, who showed no trend for a decay of YES responses in trials with angular biases, even for the larger values of biases. Instead, they kept giving YES responses at nearly the maximum rate for all biases. These patients, who gave more than 90% of YES responses in the last three classes of angular biases (25°, 30° and 40°), were considered as non-responsive to this experimental variable. For this reason, they were not included in the comparison analysis. None of them were influenced nor hallucinated.

Between-Group Analysis

1 - Global differences

Influenced schizophrenic patients gave globally more YES responses than non-influenced schizophrenic patients and comparison subjects in both the trials with angular (median values, influenced patients: 56.5; non-influenced patients: 39; comparison subjects: 33) and temporal biases (median values, influenced patients: 53.5; non-influenced patients: 49.5; comparison subjects: 29). The Median test on YES responses revealed that the differences between groups were significant for both the trials with angular biases (χ^2=7.67, df=2, p=0.022) and with temporal biases (χ^2=20.49, df=2, p<0.001). The Mann-Whitney U-tests on global scores of responses revealed that, whereas influenced patients produced significantly more errors than comparison subjects in both trials with angular (U=19.5, Z=-2.95, N=35, p=0.003) and temporal biases (U=16.5, Z=-3.09, N=35, p=0.002), non-influenced patients significantly differed from comparison subjects in trials with temporal biases only (U=73.0, Z=-4.11, N=47, p<0.001). There was a trend toward significance in trials with angular biases (U=178.5, Z=-1.80, N=47, p=0.071). However, a significant difference between the two groups of patients for the trials with an angular bias was present (U=23.5, Z=2.03, N=24, p=0.042). No correlation was found between patients' global scores in the experiment and age, sex, illness duration and BORB performances, as well as between normal subjects' global scores and age and sex.

2 - Pairwise comparisons

Figure 1 reveal a further important characteristic of these results, namely that the differences between the comparison group and the two patients groups varied as a function of the amplitude of the biases. Figure 1A shows the number of YES responses for trials with an angular bias. Whereas non-influenced patients show a sharp decrease in erroneous YES responses (down to 50% of maximum number of errors) already for a bias between 15° and 20°, a value not very different from that of controls, influenced patients do not reach the same score until the bias increased to 30°- 40°. Figure 1B illustrates the data for trials with a temporal bias. Whereas comparison subjects show a clear decrease in YES responses for a relatively small bias (100-150msec), both influenced and non-influenced patients follow a similar trend and do not show a decrease in the rate of YES responses until the bias reaches 300msec.

Pairwise comparisons for each class of trials were performed using the Mann-Whitney U-test. This comparison showed that both groups of patients produced significantly more errors than the comparison group in the trials with a temporal bias for delays longer than 100 msec (Table 1). In the trials with an angular bias, the difference with the comparison group was significant for angles larger than 10° for the influenced patients, and for the 30° and 40° angles only for the non-influenced patients (Table 2).

The two groups of patients differed significantly from each other only for the trials with a 10° bias (Table 2). For most of the other angles, the differences were close to significance. For the trials with a temporal bias, no significant differences were observed (Table 1).

DISCUSSION

The present results demonstrate that experimental manipulations of the appearance of one's own movements impair the correct self-attribution of these movements; and that this effect is dramatically increased in patients with schizophrenia..

Comparison subjects still recognize as their own a movement delayed by up to 150 msec with respect to the movement they actually executed. Similarly, if normal subjects see their movement rotated from its actual trajectory by about 15°, they still accept it as their own. This result shows that the accuracy for detecting the features of one's own movement is limited, and that this limitation is far above perceptual thresholds of the visual system for detecting temporal gaps or angular deviations. The limits reported here for detecting differences between self-produced and externally produced movements should rather be those of a specific neural system devoted to perception of biological movements. The existence of such a system is indeed suggested by several psychophysical experiments (13,14,15).

In the present experiment, the patients were clearly worse than comparison subjects at recognizing as distinct from their own, movements that were delayed or deviated. Five of them, who were not included in the comparison study, revealed unable to execute half of the task: they gave the same response in all trials with angular biases as if they were unable to "see" this type of bias. This behavior might be explained by the fact that trials with temporal and angular biases were randomized: these patients might have been unable to consciously monitor the existence of 2 types of biases. One can only conjecture that they would have behaved differently in an experiment with blocked, instead of randomized trials. Indeed, these patients had performed correctly in the training session where the two types of biases were presented separately.

All the other 24 schizophrenic patients responded at chance when a time delay up to 300msec was introduced. For angular deviations, only the influenced patients responded at chance up to 30° whereas non-influenced patients presented an error rate comparable to comparison subjects, i.e., they became aware of the angle around 15°. Before this lower self-attribution threshold in patients can be related to a specific impairment, however, we have to exclude the possibility that it could be explained by unrelated factors, such as defective perceptual or attentional mechanisms. In the case of angular biases, this possibility seems to be ruled out by the fact that all patients (including the influenced ones) performed well in the BORB test (9), indicating that they had retained a normal ability to discriminate small angular differences. In the case of temporal biases, one could argue that schizophrenic patients are known to be slow in many tasks and that their reaction times are globally increased, a feature which can be categorized among the negative symptoms (16).

In fact, our temporal delay condition is quite different from a reaction time task, and the patients' impairment is different from slowness to respond; it expresses a difficulty in the perception of slight temporal differences. Recent findings on the difficulty of patients with schizophrenia to discriminate moving visual stimuli might represent a rationale for the difficulty met by the patients from the present study (17, 18). Although this impairment in resolving temporal delays probably contributes to the high rate of misattributions observed here, it may not represent the core of the problem, for the reason that it does not differentiate the two subgroups of patients.

By contrast, the deficit in the detection of movement direction, might represent a critical factor in misattributing actions. An impairment in trajectory judgements was reported in schizophrenics (19), but without relating it to the clinical symptoms of the patients. The novelty of our finding is that only influenced patients were impaired in attributing movements with angular biases. Perceiving the direction of a movement is indeed a critical information for an observer to understand the action of the agent of this movement: the arm points to the goal of the action and its direction reveals the intention of the agent. It is thus not surprising that a patient deprived of this information will misinterpret the intention displayed by others in their movements, and that this will have consequences on understanding interactions between people. The fact that, in the present study, influenced patients attributed to themselves movements different from those they had performed suggests that they could attribute to themselves movements performed by others : hence the feeling of being influenced by other agents.

An interesting hypothesis (20, 21) proposes that understanding an action performed by an external agent could be based on internally simulating that action. By placing himself "in the shoes of the agent", the observer would experience the same feelings and build a representation of the observed action. This theory is supported by two types of arguments. First, the different modalities of action representation all have in common a subliminal activation of the motor system, which can be measured by a similar increased excitability of motor cortex (22, 23, 24). Second, functional imaging studies show that cerebral activity during imagination, preparation and observation of a given action involves largely overlapping patterns of activation (25, 26, 27). The network common to all conditions involves the inferior parietal lobule (area 40), part of the

SMA and the ventral premotor area. The location and amplitude of cerebral activation produced by the representation of an action would thus enable a subject to determine the origin of that action. A functional imagery study in influenced schizophrenic patients (28) supports this hypothesis.

Finally the present results should be interpreted cautiously and confirmed by further experiments due to the small size of the influenced sample and the fact that many individual statistics have been carried consequently to the distributions of the results. Moreover it will be necessary to obtain information about patterns of performance of non-schizophrenic psychiatric patients.

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FIGURE CAPTIONS

Figure 1.

Number of self-attribution responses reported by patients (influenced, red line ; non-influenced, green line) and normal control subjects (blue line) as a function of angular bias between the movements of the virtual hand and those performed by the subjects (A), and as a function of temporal delay between the movements of the virtual hand and those performed by the subjects (B).