# Processing of Ambiguous Sentences in Schizophrenics

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## Abstract

*The characteristics of 17 schizophrenic patients in the processing of polysemous and ambiguous sentences were examined. Japanese-language equivalents of sentences such as "Arnold hit Bill who shot Charley with a gun" were visually presented to the patients, and they were requested to select answers to prepared questions such as "Who held the gun?" by pressing a button. Tracings of fixation points were recorded as a physiological index while the patients carried out the task. The response selections, response times, initial read-through times and post-read-through times were analyzed. The response selections of the patients for polysemous sentences were different from those of normal subjects. It can be inferred that schizophrenics do not resolve the ambiguity of sentences in terms of the correlation of word meanings; instead they tend to analyze the sentences in accordance with normally expected sentence structures. In addition, it was ascertained that the prolongation in the response time of the patients for certain stimulus sentences was due to the prolongation in the post-read-through time. In many cases, the initial read-through time of the patients was somewhat shorter than that of normal subjects, and we can speculate that during the initial read-through, the patients process sentences at a shallow level.*

## 1. Introduction

Schizophrenics are believed to have problems with basic cognitive and behavioral functions[3),6)]. However, these deficits are thought to be manifested in different ways depending on the information to be processed. It may be speculated from our clinical findings that these difficulties tend to be manifested especially in the processing of ambiguous information[4)].

We investigated the characteristics exhibited by schizophrenics in the analysis of polysemous and ambiguous sentences, a type of information in which the level of ambi

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guity can easily be controlled by the examiner. Tracings of fixation points were recorded as a physiological index so that the characteristics of the information processing of schizophrenics could be investigated. This study was conducted with the approval of the Research Ethics Board of the University of Tokyo, Faculty of Medicine. Prior to the investigation, the informed consent of the examinees was obtained in written form after the aims of the investigation were explained to them.

## 2. Subjects and Methods

Since the subjects and methods used in this study were the same as those employed in our previous study, only an outline is presented here.

***Subjects***

The patients participating in this study were 17 outpatients who satisfied the diagnostic criteria for schizophrenic disorders as defined by the DSM-III-R. Most of the 17 patients, 10 males and 7 females, were relatively stable in terms of symptoms. Their ages ranged from 23 to 60 (average age, 42.7 $\pm$ 10.9 SD). As controls, 10 normal subjects, 8 males and 2 females, were also tested. The ages of the control group ranged from 20 to 25, with an average age of 22.4 $\pm$ 1.7 SD.

***Methods***

As stimuli, we used ambiguous sentences such as "Arnold hit Bill who shot Charley with a gun," or "Arnold hit Bill who was watching Charley with binoculars." The basic sentence pattern of these sentences in Japanese was as follows: (person 1) wa (noun) de (person 2) wo (verb 1) shita (person 3) wo (verb 2) shita. Here, wa, de, wo in Japanese represent postpositional words functioning as auxiliaries to main words (wa, de, and wo) and ta in shita is a conjugated inflectional suffix to verbs. Wa comes after the subject, de comes after a word which shows the means by which the action of the verb is accomplished, and wo comes after the word which functions as the grammatical object. During the test, the question "Who held the gun (or binoculars)?" was asked, and the stimulus sentence was presented to the subjects on a CRT display while records of the tracing of the fixation points were made by means of an eye-mark recorder (NAC Eye-mark Recorder V). The subjects were asked to respond to the question with either "Arnold," "Bill" or "Charley" by pushing the button that represented the person of their choice.

In the present study, there were six stimulus sentence patterns containing a variable correlation of meaning among verb 1, verb 2 and noun as shown in Table 1.

In sentence I, for example, the verb of the embedded clause (verb 1), the verb of the main clause (verb 2), and the noun are related in terms of meaning, and the answer to the aforementioned question can be either Arnold or Bill; thus, the sentences are polysemous and ambiguous.

As described above, (noun) was either "gun" or "binoculars". (Verb 1) and (Verb 2) could be "shot," "hit" or "was watching" in the gun series, and "was watching," "hit" or "called" in the binocular series. The names Arnold, Bill, and Charley can be used for the

three personal names in any order. Accordingly, the number of stimulus sentence is 18 for each series. These sentences are presented in random order in each series.

The stimulus sentence patterns differed from each other in terms of the strength of the relationship among (verb 1), (verb 2) and (noun). Specifically, in sentence I of the gun series, verb 1 and verb 2 were "shot" and "hit," respectively; here, the relationship between (verb 1) and "gun" was strong, and that between (verb 2) and "gun" was moderately strong. Similarly, in sentence II the relationship between "shot" and "gun" was strong, while that between "was watching" and "gun" was weak. In sentence III, there was a moderately strong relationship between "hit" and "gun," and a strong relationship between "shot" and "gun." In sentence IV, the relationship with "gun" was moderately strong for "hit" and weak for "was watching," but in sentence V, it was weak for "was watching" and strong for "shot." Finally, in sentence VI, the relationship with gun was weak for "was watching" and moderately strong for "hit." Thus, the changes of relationship between (verb 1), (verb 2)-(noun) in sentences I, II, III, IV, V and VI were strong-moderately strong, strong-weak, moderately strong, moderately strong-weak, weak-strong, and weak-moderately strong, respectively, in both the gun and the binocular series. Because "who held the gun (or binoculars)" was judged on the basis of the degree of relationship among (verb 1), (verb 2) and (noun), these differences in strength of relationship governed the polysemy and ambiguity of the stimulus sentences.

The size of the CRT display was 348(W) x 278(H) mm, the distance between the eye mark recorder and the CRT was 570 mm, and the size of the characters on the display was 8(W) x 8(H) mm at a visual angle of 0.8°. The space between characters was 16 mm, and the total length of the stimulus sentences ranged from 280 to 312 mm.

The position and output of the optical apparatus were adjusted using a standard stimulus pattern after every nine trials to correct for the mechanical shift of the apparatus.

## 3. Experimental Results

### 1) Examples of fixation point tracings

Figure 1 shows examples of fixation point tracings for the six normal subjects. The vertical axis shows the time (1 graduation represents 1 second), and the end of the record represents the time at which a response was made by pressing the button. Figure 2 shows examples of the three schizophrenic patients' records in the same format.

The backtracking in the tracings of the fixation points can be explained as follows. Two kinds of sentence structure could correspond to the ambiguous stimulus sentences. If the initially selected sentence structure could not be applied to the sentence because of the weak meaning correlation of between (verb 1) and (noun) and between (verb 2) and (noun), then the sentence was reanalyzed, and this is reflected in the backtracking in the tracing of the fixation points.

### 2) Analyzed indices

Analyzed indices are the distribution of the response selections, the time required to select the response by pressing the button, the initial read-through time and the post-

read-through time, the presence or absence of pauses in fixation (pause in fixation at the same point for over 2 seconds), and the relation between the symptoms and the indices just mentioned.

The indices were defined as follows. The initial read-through time is the period until the fixation point reached the last word for the first time. A pause in fixation meant that the eye fixation point stayed at the same place for over 2 seconds, because 2 seconds is the shortest round number which exceeds the duration of the fixation of all the normal subjects. The initial read-through time is shown in Figure 3 as "a". The post-read-through time is the time shown in Figure 3 as "b", which can be obtained by "RT (response time)" minus "a". Among the fixation point tracing records, cases in which judgment was difficult were excluded (10 records were excluded in both normal subjects and schizophrenics, although the number varied depending on the type of sentence). Brief Psychiatric Rating Scale (BPRS) points at the time of the examination were adopted for evaluation of symptoms.

**3) Response selections**

First, we analyzed the differences between the normal subjects and the schizophrenics with respect to response selections. The result of a $x^2$ test showed that in the sentences of the "gun" series, there was a difference between the two groups in terms of the response selections for sentences I, II, and IV, as shown in Table 2. The subject of the main clause and the object in the embedded clause (especially the subject of the main clause) were selected with a significantly greater degree of frequency in the patient group. Also in the "binoculars" series (See Table 2), the patient group selected the subject of the main clause significantly more often than did the controls in the case of sentences I and II. In the case of sentence V, on the other hand, the normal subjects often selected the subject of the main clause, while the patient group selected the subject of the embedded clause. In sentence IV, the patient group selected the object of the inserted clause with a significantly greater degree of frequency.

**4) Response time (until the button was pushed), initial read-through time and post-read-through time**

These indices were considered to be easily influenced by the age of the examinees. Therefore, the dependent variables in the analysis of covariance were the response time, the initial read-through time and the post-read-through time. Age was a covariate, and group (patients or normal subjects), sex (male or female), noun ("gun" or "binoculars") and sentence pattern (I-VI) were the independent variables. According to the results of the analysis of covariance, the main effect of group after adjustment for age was significant with regard to response time ($F(1, 730)=76.322$, $p<0.001$), initial read-through time ($F(1, 730)=3.855$, $p=0.05$) and post-read-through time ($F(1, 730)=78.740$, $p<0.001$). Also, the interaction of the factors diagnosis and sentence pattern was significant with respect to reaction time ($F(5, 730)=2.261$, $p=0.047$) and post-read-through time ($F(5, 730)=2.505$, $p=0.029$). This means that although there was a difference in age between the patient group and the normal subjects, there was also a difference between the two groups in terms of the response time, the initial read-through time and the post-read-through time, regardless of age. Furthermore, we can speculate that the differences in the

response time and the post-read-through time between the two groups depended on the type of sentence. Therefore, we compared the two groups using t-tests for each sentence in the "gun" and "binoculars" series.

Table 3 show the response time, the initial read-through time and the post-read-through time in each group for the "gun" and the "binoculars" series.

When the two groups were compared in terms of response time, the response time of the patient group was found to be significantly prolonged in the case of sentence V in both the "gun" series and the "binoculars" series. However, there was no difference in initial read-through time between the two groups in either series. The post-read-through time of the patient group was significantly prolonged in sentence V in the "gun" series and in sentences II and V in the "binoculars" series.

**5) Pauses in fixation**

Next, we analyzed the pauses in fixation, which we defined as a fixation on the same point for over 2 seconds. Figure 4 shows an example of the fixation pauses for one patient. Fixation on the same point for over 2 seconds was observed for at least one stimulus sentence in 6 out of the 17 patients. Patients who paused in reading took an average of 10.97 seconds (SD 3.19) to respond by pressing the button, while those who did not pause took an average of 7.25 sec (SD 3.02). Thus response time was significantly prolonged when there were pauses in fixation.

**6) Relationship with the symptoms**

The relationship between the symptoms evaluated by the BPRS and the response selections, the response time, the initial read-through time and the presence or absence of pauses in fixation was investigated, but no significant correlation was observed.

## Discussion

**1) Analysis of fixation point tracings**

Normal subjects' processing of information contained in sentences has been investigated in terms of fixation point tracings, but there have been no previous investigations of sentence processing in schizophrenics as far as we know. Tinker,[7] using records of eye movement, reported that sentences were processed by normals in "chunks," that fixation points did not move smoothly from one word to another but jumped from one phrase to another, and that the length of each jump became greater as the sentences became easier. McConkie et al.[2] reported that the length of the jump increased after a long word was fixated upon, or when a long word was positioned on the right-hand side of a fixated word. They also found that the length of the jump was shortened when a misspelling existed near the fixation point, or the fixation came at an important part in the sentence. Rayner et al.[5] reported that in sentence processing the duration of fixation was prolonged at the part of the sentence which gave the reader a bias in understanding. These investigations show that fixation point tracings are useful in understanding the processing of sentences through reading.

However, in the recording of fixation point tracings, care must be exercised with

regard to the accuracy of the information on the fixation points in the sentence; i.e., the points at which the information is actually being taken in. The reasons for this are that (1) the recording system can err; and (2) there is a certain range to the area from which information can properly be taken in through fixation. With respect to the former reason, we have taken steps to correct for possible slippage during the recording as we mentioned in the "Method" section of this report. With regard to the second reason, it should be noted that under the conditions of this examination, the visual angle of each character was 0.8° and several characters were probably recognized within a visual field. Therefore, it was sometimes difficult to accurately determine which clause was being fixated upon, or when the fixation point reached the last clause, which was the criterion for determining the initial read-through time. In this investigation, the fixated clause was automatically determined on the basis of the location of the fixation point.

**2) The characteristics of response selection (method of reducing ambiguity) in the schizophrenic patients**

The pattern of the responses, which were considered to result from the processing of polysemous and ambiguous stimuli, was characteristic in the patients. There were significant differences between the patient group and the normal subject group in the case of sentence patterns I, II and IV in both the "gun" series and the "binoculars" series. In these sentence patterns, the relationships between the (noun) and (verb of the embedded clause), and the (noun) and (verb of the main clause) were strong-moderate, strong-weak and moderate-weak in sentences I, II and IV, respectively. In these sentences, the verb of the embedded clause was relatively strongly related to the noun in terms of meaning (in all the other sentences, the verb of the main clause was strongly related to the noun). When the examinees reading sentences I, II and IV came to the verb of the embedded clause, they tended to think that these sentences should be parsed at the point before the noun, due to the characteristics mentioned above. Most of the normal subjects tended to select the verb of the embedded clause as their response. In sentences III, V and VI, the verbs of the embedded clause and the nouns were relatively weakly related in terms of meaning. Therefore, the examinees tended to think that the owner of (noun) was (name 1) at the point where they had read as far as (verb 1), and this is the reason why they did not think any contradiction existed when they read to the end of the sentence. Thus, sentence patterns III, V and VI could be said to be low in polysemy and ambiguity.

From the results of our study, we can speculate that the semantic processing of highly polysemous or ambiguous sentences is confused in schizophrenics, who tend to either analyze such sentences as ordinary simple sentences, or else partially randomly select a response, such as the object of the embedded clause. However, we can infer that the response selections of the patient group are not wholly random, and that they do not always select the subject of the main clause, on the basis of the following facts. (1) In many cases, there was a big difference between the percentage of patients selecting the subject of the main clause and the percentage of those selecting the object of the embedded clause (for example, in sentence I in the "gun" series, the subject of the main clause was selected by 28% of the patients, while the subject of the embedded clause was selected by 66%). (2) In sentence V in the "binoculars" series, there was a large inclination for

the patients to select the subject of the embedded clause; in the normal group, the subject of the main clause was selected by 97%, and the subject of the embedded clause by 3%, while in the patient group, the subject of the main clause was selected by 56% and the subject of the embedded clause by 41%. However, it is not clear why the patients were inclined to select the subject of the embedded clause in sentence V in the "binoculars" series.

On the basis of the above results, it can be inferred that schizophrenic patients do not resolve the ambiguity of sentences in terms of the correlation of word meanings: instead they tend to adopt a method of analyzing the sentences in terms of the sentence structure they would ordinarily expect to see.

**3) Cause of the delayed response in the patients**

Delayed responses among schizophrenic patients have been observed in many investigations[1]. In this investigation, the response time of the patients was significantly longer than that of the normal subjects in the case of sentence V. When this response time is divided into the initial read-time and the post-read-through time on the basis of the fixation point tracings, it can be observed that the delayed response time was due to the prolongation of the post-read-through time. The initial read-through time is not differ from that of normal subjects for any type of sentence. There were many cases in which the average initial read-through time in patients was a little shorter than that in the normal subjects, as shown in Table 3. This can be considered to have resulted from the fact that the level of sentence processing in terms of meaning was shallow in the schizophrenics during the initial read-through, and that patients backtracked fewer times during the initial read-through than did the normal subjects. This point warrants further investigation. The cause of the prolongation of the post-read-through time can be considered to lie in such factors as frequent rereading and backtracking after the initial read-through, a slow processing of the sentence within short-term memory due to confusion, and pauses during information processing.

The causes of the prolongation in response time and initial read-through time in the case of sentence V have still not been determined. We intend to continue analyzing the fixation point tracings. At the same time, since the subjects in this investigation exhibited relatively mild symptoms, the correlation obtained between each testing index and the symptoms was not that prominent. We believe that an analysis of the results of patients with heavier symptoms would yield clearer evidence of a relationship between schizophrenia and difficulty in the processing of ambiguous sentences.

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Table 1 Examples of the stimulus sentences used in the examination

| | |
|---|---|
| <gun series> | |
| I: | (Arnold) wa (gun) de (Charley) wo (shot) shita (Bill) wo (hit) shita.<br>(Arnold hit Bill who shot Charley with a gun.) |
| II: | (Arnold) wa (gun) de (Charley) wo (hit) shita (Bill) wo (watching) shita.<br>(Arnold was watching Bill who hit Charley with a gun.) |
| III: | (Arnold) wa (gun) de (Charley) wo (hit) shita (Bill) wo (shot) shita.<br>(Arnold shot Bill who hit Charley with a gun.) |
| IV: | (Arnold) wa (gun) de (Charley) wo (hit) shita (Bill) wo (watching) shita.<br>(Arnold was watching Bill who hit Charley with a gun.) |
| V: | (Arnold) wa (gun) de (Charley) wo (watching) shita (Bill) wo (shot) shita.<br>(Arnold shot Bill who was watching Charley with a gun.) |
| VI: | (Arnold) wa (gun) de (Charley) wo (watching) shita (Bill) wo (hit) shita.<br>(Arnold hit Bill who was watching Charley with a gun.) |
| <binocular series> | |
| I: | (Arnold) wa (binoculars) de (Charley) wo (watching) shita (Bill) wo (hit) shita.<br>(Arnold hit Bill who was watching Charley with the binoculars.) |
| II: | (Arnold) wa (binoculars) de (Charley) wo (watching) shita (Bill) wo (call) shita.<br>(Arnold called Bill who was watching Charley with the binoculars. |
| III: | (Arnold) wa (binoculars) de (Charley) wo (hit) shita (Bill) wo (watching) shita.<br>(Arnold was watching Bill who hit Charley with the binoculars. |
| IV: | (Arnold) wa (binoculars) de (Charley) wo (hit) shita (Bill) wo (call) shita.<br>(Arnold called Bill who hit Charley with the binoculars. |
| V: | (Arnold) wa (binoculars) de (Charley) wo (call) shita (Bill) wo (watching) shita.<br>(Arnold was watching Bill who called Charley with the binoculars. |
| VI: | (Arnold) wa (binoculars) de (Charley) wo (call) shita (Bill) wo (hit) shita.<br>(Arnold hit Bill who called Charley with the binoculars. |

Note: These are examples of the polysemous and ambiguous stimulus sentences used in our examination. The sentences are divided into two groups, the "gun" and the "binoculars" series. Each series consists of six sentence types (I - VI). Each sentence type includes three sentences, with the names of the persons interchanged. A total of eighteen sentences comprise one series.

Table 2 Response distribution patterns in the "gun" and "binoculars" series (name 1: subject of main clause; name 2: object of embedded clause; name 3: subject of embedded clause: con: controls; pat: patients: unit: number of trials; numbers in parentheses = %)

| | "gun" series | | | | "binoculars" series | | | |
|---|---|---|---|---|---|---|---|---|
| sentence | (name 1) | (name 2) | (name 3) | remarks | (name 1) | (name 2) | (name 3) | remarks |
| I: con | 1 (3) | 2 (6) | 27 (90) | $x^2$=7.54 | 2 (7) | 0 (0) | 28 (93) | $x^2$=14.2 |
| pat | 14 (28) | 3 (6) | 33 (66) | p=0.023 | 17 (35) | 2 (4) | 29 (60) | p<0.001 |
| II: con | 0 (0) | 0 (0) | 30(100) | $x^2$=6.09 | 1 (3) | 0 (0) | 29 (97) | $x^2$=7.32 |
| pat | 5 (10) | 4 (8) | 41 (82) | p=0.047 | 10 (26) | 1 (3) | 28 (72) | p=0.025 |
| III:con | 24 (80) | 1 (3) | 5 (17) | | 23 (77) | 0 (0) | 7 (23) | |
| pat | 44 (86) | 2 (4) | 5 (10) | n.s. | 19 (49) | 3 (8) | 17 (44) | n.s. |
| IV: con | 0 (0) | 0 (0) | 30(100) | $x^2$=7.65 | 0 (0) | 0 (0) | 30(100) | $x^2$=4.89 |
| pat | 7 (14) | 4 (8) | 39 (78) | p=0.022 | 6 (15) | 0 (0) | 33 (85) | p=0.026 |
| V: con | 28 (93) | 0 (0) | 2 (7) | | 29 (97) | 0 (0) | 1 (3) | $x^2$=14.3 |
| pat | 49 (96) | 1 (2) | 1 (2) | n.s. | 22 (56) | 1 (3) | 16 (41) | p<0.001 |
| VI: con | 29 (97) | 0 (0) | 1 (3) | | 28 (93) | 0 (0) | 2 (7) | |
| pat | 46 (92) | 2 (4) | 2 (4) | n.s. | 30 (77) | 3 (8) | 6 (15) | n.s. |

Note: Trials in which fixation point tracings were incorrectly recorded are not counted.

Table 3 Response time (time until button wa pushed), initial read-through time, post-read-through time in the "gun" and "binoculars" series

| | | "gun" series | | "binoculars" series | |
|---|---|---|---|---|---|
| sentence | time | controls | patients | controls | patients |
| I: | response | 7.0 ± 3.2 | 7.9 ± 3.6 | 6.8 ± 3.5 | 7.6 ± 4.6 |
| | read-through | 3.5 ± 1.7 | 3.4 ± 2.4 | 3.6 ± 1.5 | 3.7 ± 2.8 |
| | post-read-through | 3.9 ± 2.9 | 4.6 ± 3.4 | 2.9 ± 2.3 | 4.2 ± 3.4 |
| II: | response | 7.0 ± 3.2 | 7.7 ± 4.4 | 5.9 ± 2.4 | 7.2 ± 4.4 |
| | read-through | 4.0 ± 2.4 | 3.4 ± 2.3 | 3.9 ± 2.2 | 3.5 ± 2.7 |
| | post-read-through | 3.4 ± 2.6 | 4.6 ± 3.5 | 2.3 ± 1.6 | 4.0 ± 3.6* p=.016 |
| III: | response | 8.4 ± 3.2 | 8.3 ± 5.6 | 6.6 ± 2.9 | 7.4 ± 5.5 |
| | read-through | 4.3 ± 3.1 | 3.4 ± 2.1 | 3.5 ± 1.8 | 3.5 ± 2.7 |
| | post-read-through | 3.9 ± 2.9 | 4.6 ± 3.5 | 2.2 ± 2.9 | 4.2 ± 5.0 |
| IV: | response | 7.4 ± 4.8 | 7.7 ± 4.5 | 7.8 ± 4.3 | 7.1 ± 4.5 |
| | read-through | 3.5 ± 2.0 | 3.5 ± 2.3 | 3.6 ± 1.5 | 3.4 ± 2.1 |
| | post-read-through | 4.4 ± 4.3 | 4.1 ± 3.5 | 4.3 ± 3.9 | 4.1 ± 4.1 |
| V: | response | 6.4 ± 2.3 | 9.1 ± 8.3* P=.031 | 5.6 ± 2.5 | 8.3 ± 4.8* p=.003 |
| | read-through | 3.6 ± 1.6 | 3.1 ± 2.2 | 3.0 ± 1.0 | 3.4 ± 2.9 |
| | post-read-through | 3.3 ± 2.7 | 5.4 ± 4.9* P=.002 | 2.6 ± 2.1 | 5.2 ± 4.0* p=.002 |
| VI: | response | 6.6 ± 3.1 | 8.2 ± 5.6 | 7.1 ± 3.4 | 7.5 ± 6.9 |
| | read-through | 3.7 ± 1.9 | 3.2 ± 2.4 | 3.2 ± 1.8 | 3.8 ± 2.9 |
| | post-read-through | 3.3 ± 2.7 | 5.4 ± 4.9 | 4.0 ± 3.2 | 6.2 ± 5.8 |

Note: In the case of the initial read-through time and the post-read-through time, only trials in which it was possible to determine these periods from the fixation point tracings are counted.

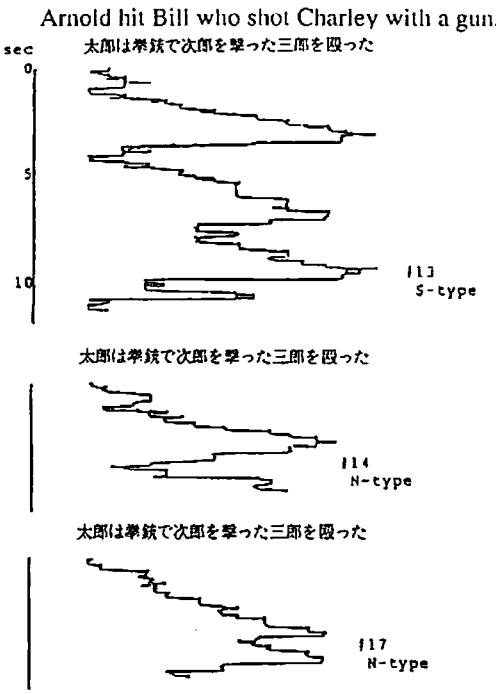


Figure 1 Examples of fixation point tracings in three normal subjects (the vertical axis shows time (1 graduation represents 1 second). The end of the record shows the time at which the button was pressed

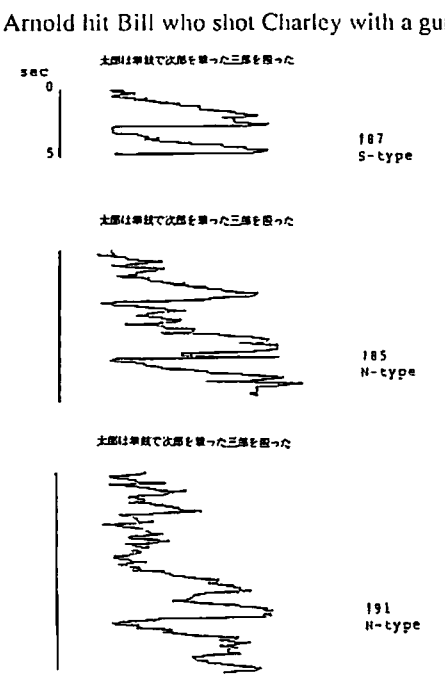


Figure 2 Example of fixation point tracings in three schizophrenics, shown in the same format as in Fig. 1

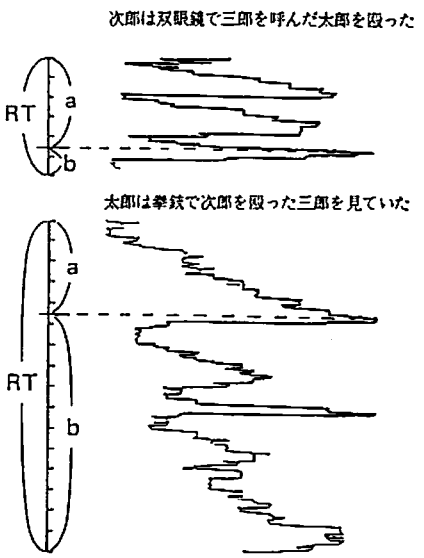


Figure 3 Definitions of response time (time until button was pushed), initial read-through time and post-read-through time, by way of example. RT: response time; a: initial read-through time; b: post-read-through time

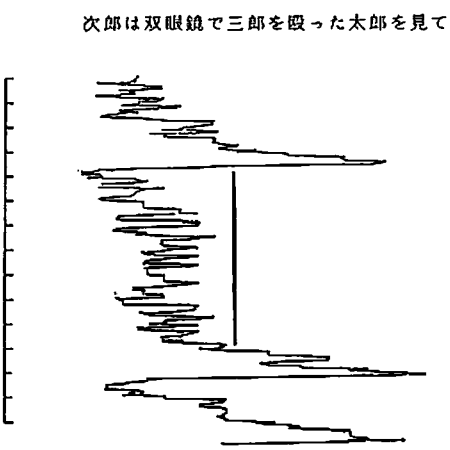


Figure 4 An example of a pause in eye fixation in a schizophrenic patient. After the beginning of the stimulus, fixation stayed at approximately the same point (the part indicated by the vertical line) for 4 to 11 sec.; hence, this was determined to be a pause in fixation