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CROSS-MODAL MATCHING BY AMNESIC SUBJECTS

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Abstract—The present study examined the performance of two groups of amnesic subjects on a cross-modal identification task. It was found that subjects with Korsakoff's disease did not differ from alcoholic controls on their ability to match the tactile feel of an arc with the visual appearance of the full circle from which the arc was taken. The postencephalitic subjects were, however, impaired on this same task. All groups performed normally on two intramodal control tasks. The postencephalitic group, like the Korsakoff subjects, were also poor at identifying common objects from tactile cues. The results are consistent with the notion that limbic regions in the temporal lobe are important for cross-modal associations.

INTRODUCTION

INTEREST in the ability of amnesic patients to perform cross-modal associations arises from evidence that the amygdala may be necessary for this function. It has been shown that extensive lesions of the amygdala can produce a very severe tactile-to-visual cross-modal recognition impairment in monkeys [17]. This severe deficit contrasted with the normal or near-normal performance of the same animals on intramodal versions of the task, i.e. visual or tactile delayed nonmatching-to-sample [17]. No evidence was found that hippocampectomy affected the cross-modal version of the task [17]. These findings provide important evidence that the primate amygdala might be necessary for integrating the different sensory components of a complex, multimodal stimulus; a role consistent with its extensive cortical connections [1, 4, 5, 23].

In an attempt to replicate this result in humans a recent study compared cross-modal recognition before and after bilateral amygdalotomy [14]. This study, which was deliberately modelled on the procedure used with monkeys, failed to find any evidence of an impairment in either tactile-to-visual or visual-to-tactile associations [14]. One problem with this study was, however, the failure to eliminate verbal cues. Although the stimuli were nonsense paperboard forms differing in size and shape, it is unclear whether this was sufficient to exclude verbal mediation by the subject. In addition, the presence of ceiling effects may have obscured any mild deficit following the surgery. For these reasons it was decided to reinvestigate cross-model matching using a slightly different procedure.

The present study examined the performance of two groups of amnesic subjects, a postencephalitic group and an alcoholic Korsakoff group, on the "Arc–Circle test" devised by NEBES [18, 19]. In this task the subject blindly explores with his or her fingers an arc taken from one of three sizes of complete circle lying in free view before the subject. The subject then

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indicates which of the circles corresponds to the arc that had been felt. The advantage of this test is that the use of almost identical shapes helps minimize the value of any verbal cues [18]. Furthermore, the test involves no retention delay which might penalize the amnesic subjects. The subjects were also asked to identify a series of common items by touch alone. Although this is not an explicit cross-modal task, it is likely that for many stimuli textural cues are insufficient and the ability to envisage the three-dimensional shape of an object will help identification; hence the task will draw on cross-modal associations.

The postencephalitic group were of interest because the herpes simplex virus primarily affects limbic structures and related cortical regions in the temporal and frontal lobes. Although the extent of damage can be highly variable, one of the regions most consistently involved is the amygdala [8, 9, 10, 12]. Other structures damaged by this disease include the hippocampal formation, the perirhinal cortex, the anterior insula cortex, the posterior orbitofrontal cortex, and the anterior cingulate cortex [8, 9, 10, 12].

Although Korsakoff's disease is not associated with lesions in the amygdala, there is clear evidence that regions directly connected with the amygdala may be affected. Of particular interest is the likely presence of damage in the thalamic nucleus medialis dorsalis [16, 21, 31], a nucleus which receives a direct input from the amygdala [3, 13, 22]. Indeed there is evidence that the amygdala, in concert with diencephalic structures such as nucleus medialis dorsalis, may form a neural system involved in memory functions and that damage to this system may contribute to certain amnesic syndromes including Korsakoff's disease [2, 6, 16]. Evidence of a cross-modal association deficit in patients with Korsakoff's disease might therefore indicate that the amygdalo-thalamic pathway is involved in such functions, or that there is an amygdaloid dysfunction in this disease which is not revealed by conventional neuropathological methods.

METHOD

Subjects

The amnesic group diagnosed as suffering from viral encephalitis consisted of four men. Their ages ranged from 19 to 59 years (mean = 42) and the interval between the onset of the disease and testing ranged from 18 months, in the youngest subject, to 14 years in the oldest. Subjects were assessed with the WAIS and the NART [20] to evaluate IQ, and with the WECHSLER [26] memory scale (WMS) and the WARRINGTON [25] word and face recognition tests. One subject (G.H.) who had a speech impediment did not attempt the NART. The group mean scores (ranges in parentheses) were as follows: WAIS full-scale IQ 97.3 (91–104), premorbid IQ estimated from NART 106 (103–110), Wechsler memory quotient 84.8 (76–97), Warrington word and face scores (each out of 50), 35.3 (32–43) and 33.8 (27–41).

All of the postencephalitic subjects suffered from memory problems which had forced them out of work. A detailed case history of one of the subjects (B.D.), who appears to suffer from a semantic memory loss for living things, has already been published [12]. This subject did, however, display a normal ability to identify inanimate objects visually [12]. One of the other postencephalitic subjects (J.T.) was left-handed while two suffered from epilepsy. In none of the cases was there precise information regarding the location and extent of brain damage.

The control group for the postencephalitic subjects consisted of 20 normal subjects, the large majority of whom were employees at the University of Durham. This group, which was made up of 16 men and four women, contained three left-handers (two male, one female). The control group was matched for age (mean 39.3, range 20–59) with the postencephalitic group. Psychometric assessment was limited to the NART, and the mean IQ full score estimate was 115.2 (range 105–125).

A total of eight subjects, six men and two women, diagnosed as suffering from Korsakoff's disease were also tested. Their mean age at the time of testing was 57.9 years (range 48–63). All had a history of alcohol abuse and had been resident in psychiatric hospitals or hostels for at least 1 year. The control group (seven men, mean age 50.6 years, range 45–65) also had similar long histories of alcohol abuse, but did not present memory difficulties and had abstained from drinking for at least several weeks before testing. These subjects were reliant on institutional support, such as sheltered workshops and Salvation Army hostels.

The mean psychometric scores (range in parentheses) for the Korsakoff group were as follows: WAIS full score IQ

99 (85–105), NART 105.1 (92–119), Wechsler memory quotient 79.6 (70–88), Warrington words and faces (each out of 50) 28.6 (24–31), 32.3 (28–38). One of the Korsakoff subjects refused to complete the WAIS. The corresponding scores of the alcoholic controls were: WAIS full score IQ 98.7 (83–116), NART 105.5 (92–115), Wechsler memory quotient 96.9 (88–116), Warrington words and faces 41.1 (38–46), 41.0 (35–47). One alcoholic control subject who had a speech impediment did not attempt the NART.

The two-point discrimination threshold of every subject was measured on the forefinger of the preferred hand. There was no difference between the mean thresholds of the normal controls and the postencephalitic group (respective means 2.8 and 3.0 mm, $t < 1$), there was, however, a difference between the alcoholic controls and the Korsakoff subjects [respective means 3.0 and 4.6 mm, $t\ (13) = 2.14$, $P < 0.05$]. This finding was not unexpected as Korsakoff's disease is often accompanied by peripheral neuropathies which affect the arms and hands [24].

Procedure

The basic task was modelled on the Arc–Circle test [19], in which the subject is required to make a simultaneous cross-modal match between an arc and the circle from which it is taken. The circle stimuli consisted of aluminium rings (3 × 3 mm square cross section) with inner diameters of 1.9, 2.5, 3.2, 3.8 and 4.4 cm. There were two identical copies of each circle. In addition, there were four arcs from each of the five circles of 280, 180, 120 and 80 degrees. All circles and arcs were painted matt black and mounted on white card, 10.2 cm square.

The subject was seated within arms length of a wooden screen 38 cm high and 65 cm wide. The bottom 17.5 cm of the screen consisted of a black cloth partition in which were two slits, one on either side. These slits were so arranged that the subject could comfortably place either the right or left hand through the gaps in the cloth, but at the same time could not see beyond the cloth partition.

In the cross-modal task three complete circles (inner diameters 1.9, 3.2 and 4.4 cm) were displayed upright on a rack at eye level in front of the test screen. The subject then placed his or her preferred hand through the screen and felt the test stimulus with just the forefinger. The test stimulus was either one of the three complete circles or one of the four arcs which belonged to the same circles. The subjects could feel each stimulus for as long as they wished before indicating which circle on the front of the screen corresponded to the arc or circle they had felt. Each test arc or circle was presented twice in a standard, balanced sequence making a total of 30 trials. During the test the subjects received no feedback as regards the accuracy of their responses.

In the visual–visual control task three complete comparison circles were once again displayed at eye level on the front of the screen. This time, however, the test stimuli were also in full view being placed one at a time, on a flat surface immediately in front of the base of the screen. Once again the subject had to indicate which of the three comparison circles corresponded to the test arc (360°, 280°, 180°, 120°, or 80°). In order to equate difficulty with the cross-modal task the test circles were more similar in size (inner diameters, 2.5, 3.2 and 3.8 cm). Although the subjects were not allowed to touch the stimuli the rest of the testing procedure was identical to that used with the cross-modal task.

The tactile–tactile control task used the same stimuli as those in the cross-modal task. But in this version two stimuli were presented, one immediately after the other, to the subject's hand behind the screen. The first stimulus was always a complete comparison circle while the second was one of the test arcs or circles. The subject, who felt the complete circle and then the test shape with his or her forefinger, made a same/different judgement with respect to the sizes of the circles represented by the two stimuli. The subjects were allowed to take as long as they wished, and could go back to the comparison circle before making a decision. Once again each subject received 30 trials. All subjects were first tested on the cross-modal task, followed by the visual–visual task, and lastly the tactile–tactile task.

The subjects were also asked to identify a total of 37 common objects by feel alone. These objects, which were placed in the subjects' preferred palm, included items such as a stick of chalk, a cotton reel, soap, a toy animal, a potato, a golf ball, and a shell. This time the subject could use any part of his or her hand to help identification. If the subject could not name the object he or she was encouraged to describe what the object was used for and to guess a name. Accurate descriptions of function, e.g. "for tying thread around" (cotton reel), were scored as correct responses. If the subject could not identify the object he or she was allowed to look at it and then name the object. Two of the Normal control subjects, both male, were not tested on this task.

RESULTS

The performances of the amnesic and control subjects on the three matching tasks are shown in Figs 1 and 2. Each of the three tests were examined initially in separate analyses of variance in which the factors were "Groups" and "Arc Size", the second factor reflecting the scores from each of the five different test arcs (360°–80°), and hence the difficulty of the task.

An analysis of the scores from the tactile–visual task revealed clear evidence of a Group effect [$F\ (3, 35) = 4.98$, $P < 0.01$] and of Arc Size [$F\ (4, 140) = 13.84$, $P < 0.001$], there was,

however, no interaction between these factors ($F<1$; Fig. 2). Pairwise comparisons revealed that although the Korsakoff group did not differ from the alcoholic controls ($F<1$), the postencephalitic subjects did differ from the normal controls [$F(1, 22)=7.43$, $P<0.025$].

Similar analyses of the other two tasks failed to provide any evidence of a difference between the four groups [visual–visual, $F<1$; tactile–tactile, $F(3, 35)=1.66$, $P>0.1$]. As expected the factor Arc Size was highly significant in both tasks [visual–visual, $F(4, 140)=75.43$, $P<0.001$; tactile–tactile, $F(4, 140)=39.93$, $P<0.001$; Fig. 2], that is, as the angle of the arc decreased so performance became became poorer. There was, however, no evidence of a Group × Arc Size interaction ($F<1$, both tasks; Fig. 2). It may be noted that these analyses were not invalidated by ceiling or floor effects and that the cross-modal and visual–visual tasks proved to be of very similar overall difficulty (Fig. 1).

In an additional analysis the performances of the postencephalitic and normal control subjects were examined over both the tactile–visual and visual–tactile tasks. This analysis revealed a significant Group × Task interaction [$F(1, 22)=4.51$, $P<0.05$] between the normal controls and the four postencephalitic subjects. This interaction reflected the normal performance of the postencephalitic group on the visual control task which contrasted with their poor performance on the tactile–visual task (Fig. 1).

No evidence was found for an effect of either gender or handedness on the tactile–visual task. The mean score of the 16 males in the normal control group was 24.3 compared with a mean of 22.8 for the four females [$t(18)=1.23$]. Similarly, the mean of the 17 right-handed subjects was 23.9 while that of the three left-handed subjects was 24.3. This latter result is of interest as evidence has been published that left-handers may perform more poorly on this task [19]. Lastly, there was no evidence of a correlation between performance on the tactile–visual task and NART score among the 20 normal controls (Spearman rank $r=0.08$).

Clear-cut group differences emerged when the subjects were asked to identify 37 objects by feel alone (Fig. 1), the results being expressed as percentages as a few subjects were unable to name certain objects when allowed to look. These items were therefore removed from the total set of objects for that subject. The analyses, which used non-parametric statistics in response to the ceiling effect shown by the normal controls, revealed highly significant differences between the normal controls and the postencephalitic group (Mann–Whitney U 4, 18 = 1, $P<0.001$), and between the Korsakoff subjects and the alcoholic controls (U 7, 8 = 8, $P=0.01$). The postencephalitic group were also poorer than the alcoholic controls at object identification (U 4, 7 = 5, $P=0.055$).

The variability in the two-point discrimination thresholds of the Korsakoff subjects made it possible to determine whether tactile insensitivity, as measured by this threshold, correlated with poor performance on the experimental tasks. Although there was no such correlation on the tactile–visual form of the Arc–Circle test ($r_s=0.31$), there was evidence that tactile insensitivity impaired object identification ($r_s=0.58$, $0.1>P>0.05$).

DISCUSSION

The present study considered whether humans exhibit a cross-modal recognition deficit similar to that observed in monkeys following amygdalectomy [17]. The Arc–Circle test [18, 19] was used as it places no particular memory load on the subject and yet taxes cross-modal identification. Furthermore, the use of very similar shapes helps minimize verbal mediation and eliminates ceiling effects [18]. As the Arc–Circle test taxes the ability to link

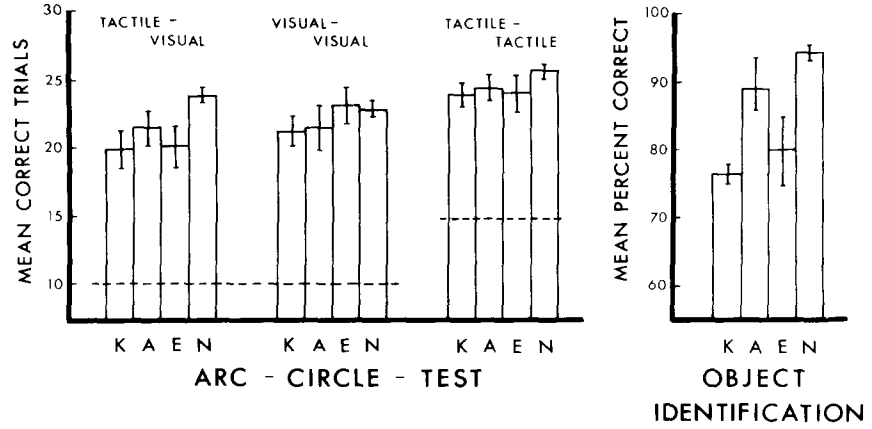

Fig. 1. Left: mean performance of the Korsakoff (K), alcoholic (A), postencephalitic (E), and normal control (N) subjects on the three versions of the Arc–Circle test [18]. Right: ability of the four groups to identify 37 common objects from tactile cues. Vertical bars show SEM.

the feel of an arc with its visual appearance the test draws upon associations formed when handling everyday circular items such as coins, cups and bottles; associations formed long before the onset of the amnesic syndrome. This is an important feature of the test as the cross-modal task given to monkeys employed a limited set of objects which were experienced both visually and tactually, over and over again prior to surgery, so giving the monkeys considerable opportunity to develop cross-modal associations [17].

The group of postencephalitic subjects displayed a significant deficit on the cross-modal version of the Arc–Circle test which contrasted with their normal performance on the two intramodal control tasks. For these reasons it seems most unlikely that this deficit can be directly related to a sensory impairment within either the visual or tactile modalities. Furthermore, the significant interaction between the tactile–visual task and the visual control task showed that the postencephalitic subjects fully understood the demands of the tasks and under some circumstances were able to perform most accurately. This conclusion is consistent with their normal pattern of performance with different sizes of arc (Fig. 2).

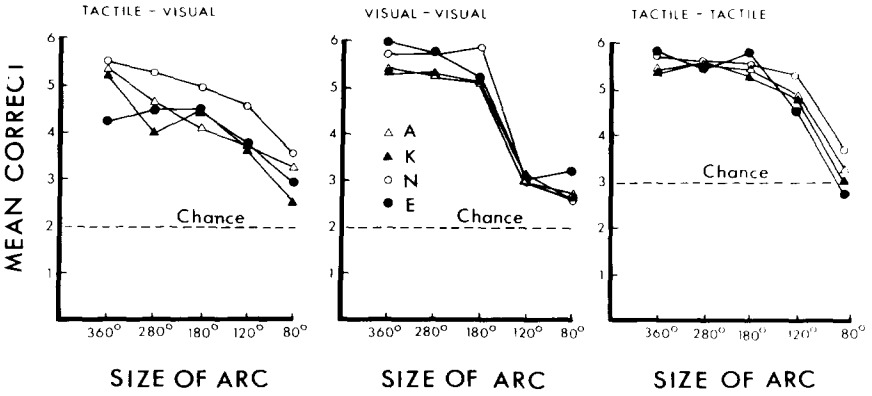

Fig. 2. Mean score (maximum 6) of the alcoholic (A), Korsakoff (K), postencephalitic (E), and normal control (N) subjects on the different sizes of test arc used in the three versions of the Arc–Circle test.

Although the patients with Korsakoff's disease were impaired on the Arc–Circle test when compared with normal controls, there was no evidence of a deficit when compared with the alcoholic controls. It is this latter comparison which is the most important as the alcoholic controls were closely matched, except for the profound memory losses characteristic of Korsakoff's disease. Factors which may have affected the performance of both groups with respect to the normal controls include age, motivation, and any neurological effects of chronic alcohol abuse [15]. This finding provides evidence that damage in those regions associated with the amnesia of Korsakoff's disease, namely the mammillary bodies and the medial dorsal nucleus of the thalamus [7, 24], does not disrupt the Arc–Circle test.

In a second test it was found that both the postencephalitic subjects and the Korsakoff subjects were impaired at identifying objects by touch. As any object that could not be identified by sight was excluded this difference is unlikely to reflect a semantic memory loss, unless this loss is peculiar to tactile information. For the postencephalitic group this possibility cannot, as yet, be excluded given that damage may occur in regions such as the insular cortex. For the Korsakoff group it is likely that their loss of tactile sensitivity contributed to their deficit. In addition, the Korsakoff subjects had been resident in institutions for a number of years and would have had far less recent experience of many of the test objects. For these reasons it is felt that the poor performance of this group did not reflect a specific cross-modal deficit. It should be added that no clear pattern could be discerned among those items that the subjects from either amnesic group most consistently failed to identify.

While it was intended that the Arc–Circle test should tax the same abilities assessed by the tactile-to-visual delayed nonmatching-to-sample task given to monkeys [17], some potentially important procedural differences may be present. One difference lies in the use of a short delay (10 sec) in the monkey test [17], whereas no equivalent delay was used in the current study. There was, however, no evidence from analogous intramodal tasks that this short delay was an important feature of the deficit observed after amygdalectomy [17]. Furthermore, the use of delay in the present study might have differentially affected the amnesic subjects due to an increase in the memory load and not because of the cross-modal nature of task. In addition, a delay between sample and test would have encouraged subjects to rehearse whether the arc came from the "large", "medium", or "small" circle, and so introduce an unwanted verbal component.

The performance of the amnesic postencephalitic subjects adds credence to the view that temporal lobe damage can produce a cross-modal deficit, even when comparable intramodal tasks are unimpaired. The results of the object identification task are consistent with this view. Although these preliminary findings cannot directly point to any specific contributory brain region they are consistent with the notion that limbic structures in the medial temporal lobe are involved. Further evidence comes from an additional subject who although diagnosed as having viral encephalitis did not suffer from anterograde amnesia. This subject, who presumably lacked any marked, bilateral damage in the medial temporal lobes, achieved one of the highest scores on the cross-modal version of the Arc–Circle test and had a normal score (94%) on the object identification task. These results provide additional, indirect evidence for a link between limbic damage and cross-modal recognition.

In their account of the cross-modal deficit seen in monkeys following amygdalectomy [17] emphasis was placed on the possible involvement of cortico–amygdalo–cortical pathways for the linking together of information from different senses from the same stimulus. The present study cannot make so precise a claim given the variability in the extent and location

of the pathology in viral encephalitis [8, 9, 10, 12]. Nevertheless, the performances of the two amnesic groups in the present study is seen as consistent with these views although confirmation will have to wait for studies on those very few subjects with focal, defined bilateral damage.

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