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Experimental Studies on Adversive Movement

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Abstract

Adversive movement was first reported in 1870 by Fritsch and Hitzig when they said that when gyrus Sylvii was stimulated electrically the eyes moved to the opposite side of the stimulation. Vogt and Foerster made a detailed report on adversive movement, which is a rotary motion of the head, trunk and both eyes. But in their report, they did not make it clear what tracts the stimulation took. Mitsueda, who iS under Hayashi, defined the cortical area of the eye balls and the eye lids. He reported that they were of the extrapyramidal kind. Russel reported that when the cerebellum was stimulated the eye balls moved to the side of the stimulation, but did not say anything about adveraive movements which concerned the movement of the head and the trunk. Therefore, to ascertain the center of adversive movement and its tract the following experiments were performed. For stimulation electrical ones and chemical ones using metrazol (cardiazol) were used. As Ishizuka, who is under Hayashi, has proved excitement is only seen when cardiazol is injected among the nerve cells at a certain concentration, and it is not seen when injected among the nerve fibres.

Experimental Studies on Adversive Movement

By

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Part I. Studies on the Center and Conduction Tract of Adversive Movement

Introduction

Adversive movement was first reported in 1870 by *Fritsch* and *Hitzig* when they said that when gyrus *Sylvii* was stimulated electrically the eyes moved to the opposite side of the stimulation. *Vogt* and *Foerster* made a detailed report on adversive movement, which is a rotary motion of the head, trunk and both eyes. But in their report, they did not make it clear what tracts the stimulation took. *Mitsueda*, who is under *Hayashi*, defined the cortical area of the eye balls and the eye lids. He reported that they were of the extrapyramidal kind. *Russel* reported that when the cerebellum was stimulated the eye balls moved to the side of the stimulation, but did not say anything about adversive movements which concerned the movement of the head and the trunk.

Therefore, to ascertain the center of adversive movement and its tract the following experiments were performed. For stimulation electrical ones and chemical ones using metrazol (cardiazol) were used. As *Ishizuka*, who is under *Hayashi*, has proved excitement is only seen when cardiazol is injected among the nerve cells at a certain concentration, and it is not seen when injected among the nerve fibres.

Experimental Methods

A. Experimental animals and their medication.

Dogs weighing about 10 kgm. were used. 3% morphine-HCl was given at the rate of 0.5 cc. per kgm. for medication.

B. Methods of trepanation, stimulation and removal of the cortex.

1) Exposure of the cerebral cortex: The incision of the skin

was made along the saggital line from the nasion to the inion. The muscle was cut, exfoliated and turned over to one side. A hole was burred into the skull and then was widen with a rongeur to reach the dura.

2) Exposure of the cerebellar cortex: The skin was cut as stated in (1) which reached the posterior part of the cerebral semisphere. Two approaches were used. The indirect approach is performed by opening the tentorium to reach the cerebellar cortex. The direct approach is performed by going through the posterior part of the skull to reach the cerebellar cortex.

3) Stimulation of the caudate nucleus and its removal: A 1.5 cm. incision was made along sulcus entolateralis. When this was pushed downward vertically for about 2 cm. it reaches the lateral ventricle and the white fimbria hippocampi, choroid plexus and the grey caudate nucleus could be seen when opened. This grey bulge was stimulated with a needle, and its removal was performed with a small oval curette or with a bent narrow spatula.

4) Stimulation of the thalamus and its removal: The lateral ventricle was reached as stated previously and to stimulate the thalamus, a needle was stuck through the fornix or through the fimbria. An incision was made along the fornix from the anterior to the posterior direction, then the thalamus with the fornix was removed by using a curette or a spatula from the posterior lateral to the anterior medial direction.

5) Stimulation of the lenticular nucleus and its removal: A needle was stuck 8 to 11 mm. vertically from the surface of the arachnoidal membrane at sulcus sylviaticus to stimulate it. For its removal, a small incision was made on the arachnoidal membrane and a curette with a narrow handle (5×2 mm.) was inserted 11 mm. vertically from the surface. The point of the curette moved from the anterior to the posterior direction for 14 mm. horizontally and 11 mm. vertically, which form into an oval shape.

6) Stimulation and removal of colliculus superior of corpora quadrigemina and stimulation of the tegmentum: The occipital lobe was exposed with a spatula and colliculus superior of corpora quadrigemina was seen when the occipital lobe was pushed anteriorly upward. Colliculus superior and the tegmentum were both stimulated. When nucleus niger was aimed for, a needle was stuck 10 mm. from the middle of colliculus superior. When

nucleus ruber was aimed for, the needle was stuck 6 mm. near the *Sylvian* aqueduct. When the oculomotor nucleus was aimed for, it was stuck 4 mm. Colliculus superior was removed with a curette.

7) Stimulation of various motor nuclei in the pons and medulla oblongata: By the direct method to expose the occipital lobe, the cerebellum was exposed and was pushed upward. A needle was stuck at various motor nuclei in the 4th ventricle for stimulating purpose.

8) Cutting brachium conjunctivum cerebelli: Brachium conjunctivum cerebelli was exposed easily by first exposing the anterior face of the cerebellum according to the previously stated method in (2). It was cut with a small knife used in eye surgery.

9) Longitudinal section between both cerebral hemisphere, interruption between both thalamus and cutting of corpus callosum: Cerebral cortex was exposed as stated in (1). A spatula was used to cut to the base of the brain at the midline of corpus callosum and moved in the longitudinal direction (from anterior to the posterior), and the connection between both hemisphere was cut. The posterior limit of this cutting stopped when the connection between both thalamus was cut and this interruption did not involve the midbraid. Sectioning between both thalamus and cutting corpus callosum were performed in the similar way.

C. *Methods for stimulation.*

1) When stimulation was done with cardiazol (metrazol), a 4 mm. square filtering paper soaked with 0.02 - 0.05 cc. of 10% cardiazol was used. These were pasted on the cortex for 5 to 15 sec. When stimulation was done in places other than the cortex, cardiazol mixed with 1/5 amount of India ink was injected with a tuberculin syringe using a 1/5 mm. diameter needle. The amount injected was 0.04 to 0.05 cc.

2) When stimulating was done with electricity, a 6 volt alternating current with an induction coil was used. The distance between poles was 10 cm. and the length of stimulation was 3 to 5 sec. The electrode was bi-polor with a distance of 1 mm.

D. *Observation.*

Adversive movement is recognized as a cooperative movement of both eye balls, head and trunk. A typical adversive movement

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always has an eye ball movement. So a rotary movement of only the head and the trunk was not considered here as an adversive movement. When the eye balls moved slightly laterally upward or laterally downward it was included in the adversive movement.

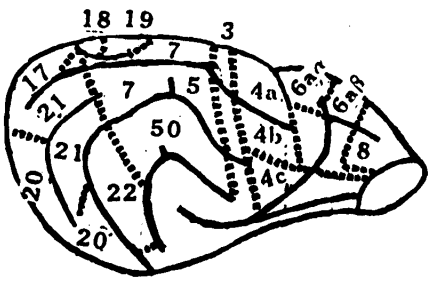
Experimental Results

A. On the center of adversive movement.

1) The center in the cerebral cortex is as follows.

Kind of stimulation / Cortical area	Electrical stimulation	Cardiazol stimulation
8	(±) 7 cases	(−) 7 cases
6aβ	(+) 10 „	(+) 7 „
6aα	(+) 1 „ (−) 8 „	(−) 6 „
4a	(+) 1 „ (−) 9 „	(+) 1 „ (−) 5 „
4b	(+) 1 „ (−) 5 „	(+) 1 „ (−) 5 „
4c	(+) 6 „ (−) 3 „	(+) 5 „ (−) 2 „
5	(+) 10 „	(+) 10 „
7	(+) 7 „	(+) 7 „
19	(+) 5 „ (−) 1 „	(+) 5 „ (−) 2 „
22	(+) 7 „	(+) 5 „ (−) 1 „
18	(+) 1 „ (−) 6 „	(+) 1 „ (−) 4 „
17	(+) 1 „ (−) 4 „	(−) 4 „
21	(−) 3 cases	(−) 3 cases
50	(+) 1 „ (−) 3 „	(−) 3 „
3	(+) 1 „ (−) 7 „	(−) 7 „
20	(−) 2 „	(−) 2 „

Fig. 1.



2) The center in the subcortical nuclei and thalamus.

Nucl. caudatus	(+) 5 cases (−) 2 „
Nucl. lenticularis	(+) 4 „ (−) 2 „

Thalamus	Nucl. anterior		(+) (−)	1 cases 4 „
	Nucl. intermedius group	……Nucl. medialis	(+)	5 „
		……Nucl. ventralis		
		……Nucl. lateralis	(−)	2 „
	Nucl. posterior		(+) (−)	5 „ 0 „

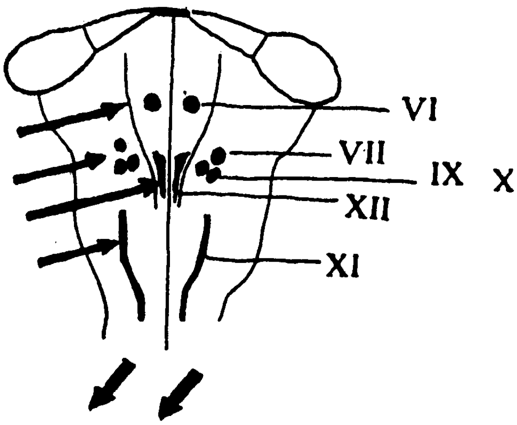
3) The center in the midbrain.

Colliculus superior of corpora quadrigemina		(+) (−)	4 cases 1 „
Colliculus inferior of corpora quadrigemina		(+) (−)	0 „ 3 „
Corpus geniculatum laterale		(+) (−)	0 „ 2 „
Tegmentum	Nucl. oculomotorius (depth 4 mm.)	(+) (−)	2 „ 0 „
	Nucl. ruber (depth 6 mm.)	(+) (−)	0 „ 2 „
	Nucl. niger (depth 10 mm.)	(+) (−)	0 „ 2 „

4) Center in various motor nuclei of the pons and medulla oblongata.

VI	(+) 2 cases	IX, X, XII	(+) 5 cases (−) 1 „
VII	(+) 1 „ (−) 1 „	XI	(+) 2 „

Fig. 2.



5) Center in the cerebellar cortex.

Lobus lunatus inf. ...	(+)	2 cases	Lobus lunatus ant. ...	(−)	2 cases
L. semilunaris sup. ...	(+)	3 "	L. centralis	(−)	2 "
L. semilunaris inf. ...	(+)	3 "	Culmen	(−)	4 "
L. cuneiformis	(+) (−)	3 " 1 "	Declive	(−)	5 "
			Pyramis	(−)	4 "

6) Center in the cerebellar nuclei.

When India ink added with cardiazol was injected into nucleus dentatus, the results were as follows.

Amount of injection	Result	No. of case
0.03 cc.	(−)	2
0.1 cc.	(+) (−)	1 2
0.2 cc.	(+)	3

7) Preliminary summary.

a) The parts that initiates adversive movement in cerebrum were areas 8, 6aβ, 4c, 5, 7, 19 and 22, caudate nucleus, lenticular nucleus, thalamus (intermedial nuclei group, posterior nucleus), colliculus superior of corpora quadrigemina, tegmentum (vicinity of nucleus oculomotorius) and various motor nuclei from nucleus abducentus to nucleus accessorius. In the cerebellum they were l. lunatus inf., l. semilunaris sup. et inf., l. cuneiformis, and nucleus dentatus.

b) In only area 8 the eye balls turned to the opposite side, while the trunk and the head did not show any rotary movements.

c) Adversive movement caused by stimulation of motor nuclei in the pons and of the cerebellum moved to the side of the stimulation.

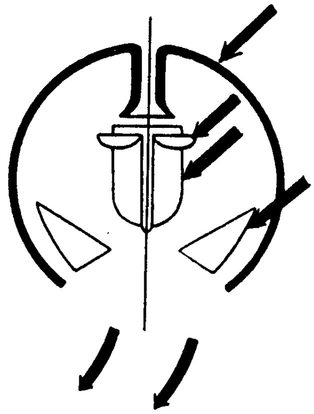
d) Area 8 reacted to electrical stimulation but did not react to cardiazol stimulation. When stimulating cerebellar cortex and nucleus dentatus they reacted very well to electrical stimulation, but showed no action to small amounts of cardiazol and needed a large dose to do so.

B. Conduction tract of adversive movement.

1) Conduction tract of adversive movement from the cerebral cortex.

i) Longitudinal section of the cerebral hemisphere: When the space between both cerebral hemisphere was sectioned with the connection between both thalamus adversive movement was seen in all cases when cortical adversive fields 6aβ and 5, caudate nucleus, lenticular nucleus, thalamus (intermedial nuclei group, posterior nucleus) were stimulated. (Fig. 3.)

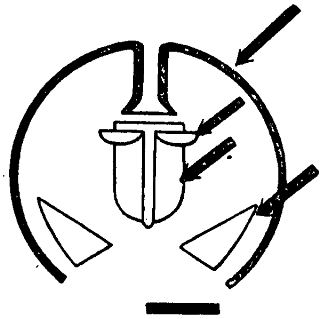
Fig. 3.



ii) Sectioning the immediate upper part of colliculus superior of corpora quadrigemina; The immediate upper part of colliculus superior of corpora quadrigemina of one side was sectioned and when the adversive field (areas 6aβ and 5), the caudate nucleus, the lenticular nucleus and the thalamus (intermedial nuclei group) of the side that was sectioned were stimulated in 2 cases for each part, adversive movement was missing in all cases. (Fig. 4.)

Fig. 4.

Adversive movement (−)



From the experiments stated above, it was found that adversive movements caused from the adversive field, caudate nucleus, lenticular nucleus and the thalamus (intermedial nuclei) did not cross to the other side at any place above colliculus superior of corpora quadrigemina.

iii) Cortical stimulation after removal of the thalamus of one side: When cortical areas 8, 6aβ, 5, 7, 19 and 22 were stimulated after removing the thalamus of the same side the results were as in the following table. (Fig. 5.)

8, 6aβ	(−)	6	cases
5	(+)	3	"
7, 19	(+)	4	"
	(−)	2	"
22	(+)	3	"

When area 4c was stimulated ad-

Fig. 5.

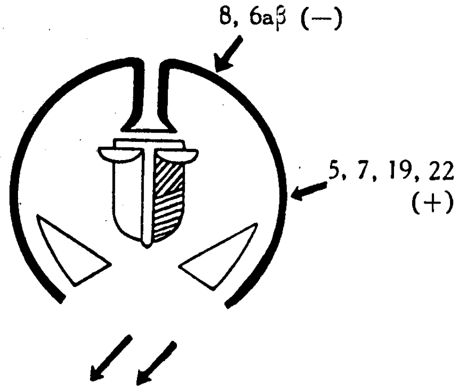
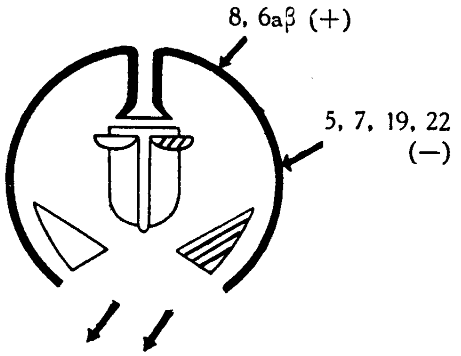


Fig. 6.



versive movement was irregular, so it was excluded from here.

iv) Cortical stimulation after removal of the caudate nucleus of one side : Nucleus caudatus of one side was removed and later areas 5, 7, 19 and 22 of the same side were stimulated in two cases for each area. In all cases, adversive movement was not observed. When areas 8 and 6aβ were stimulated, adversive movement was seen in all cases. (Fig. 6.)

v) Cortical stimulation after removal of the lenticular nucleus : When nucleus lenticularis was removed from one side and later areas 5, 7, 19 and 22 of the same side were stimulated in two cases for each area no adversive movements were observed. But when areas 8, 6aβ were stimulated adversive movements were observed in all cases. (Fig. 6.)

vi) After removing nucleus lenticularis and later when nucleus caudatus of the same side was stimulated no adversive movement was observed.

From the stated experiments, adversive movements from areas 5, 7, 19 and 22 first passes through the caudate nucleus of the same side. Then it passes through the lenticular nucleus, but does not pass the thalamus of the same side. Adversive movement from areas 8 and 6aβ passes through the thalamus, but not through nuclei caudatus nor lenticularis.

vii) Stimulating the thalamus after removal of nucleus lenticularis or caudatus of one side : After nucleus caudatus of one side was removed in two cases, the thalamus of the same side was stimulated. Adversive movement was seen in both cases (Fig. 7).

In another two cases, nucleus lenticularis of one side was removed and then the thalamus of the same side was stimulated, and in both cases adversive movement was seen (Fig. 8).

From this, adversive movement from areas 8 and 6aβ does not pass through nuclei caudatus and lenticularis after passing through the thalamus.

viii) Cortical stimulation after removal of colliculus superior of corpora quadrigemina: After removal of colliculus superior of one side adversive movement was seen in two cases when the adversive field (area 5) was stimulated (Fig. 9).

When getting the previous results together, it is presumed that the conduction tracts from areas 8 and 6aβ passes through the thalamus of the same side, and those from areas 5, 7, 19 and 22 pass through nuclus caudatus and lenticularis of the same side. And these two tracts reach colliculus superior or the tegmentum of the same side. From here, they cross to the opposite side and is presumed to reach the motor nuclei from the VIth to the XIth cranial nerve in the pons and medulla oblongata.

2. Conduction tract of adversive movement from cerebellar cortex.

i) Cerebellar stimulation after removal of the thalamus of one side: After the thalamus of one side was removed adversive movement was seen when nucleus dentatus and the cerebellar cortex of the opposite side were stimulated (Fig. 10). In these cases its degree was light and returned to the original condition immediately. The movements in these cases

Fig. 7.

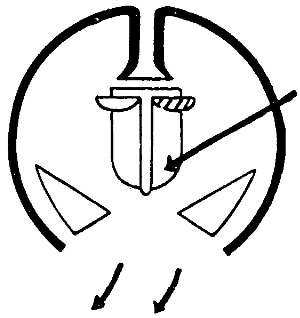


Fig. 8.

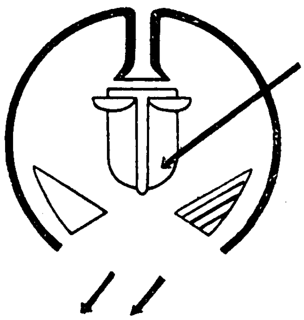


Fig. 9.

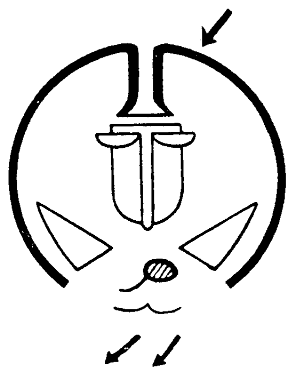


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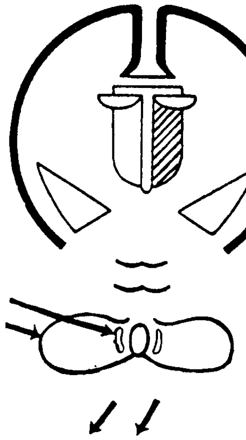
Fig. 10.



were very weak and their continuation were just a third in comparison to others. From these results, it can be thought that the conduction tract from the cerebellum reaches colliculus superior and the tegmentum besides the thalamus. Next, after the thalamus of one side was removed, and the cerebellum of the same side (one case for l. lunatus inf., one case for nucleus dentatus) was stimulated, adversive movements were all towards the side of the stimulation.

ii) Cerebellar stimulation after cutting brachium conjunctivum cerebelli of one side : When brachium conjunctivum cerebelli of one side was cut and the cerebellar cortex (l. lunatus inf. and nucleus dentatus) of the same side was stimulated, they did not show any adversive movements (Fig. 11).

Fig. 11.

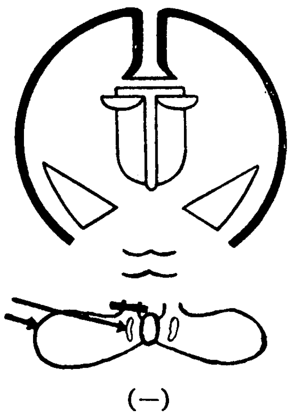
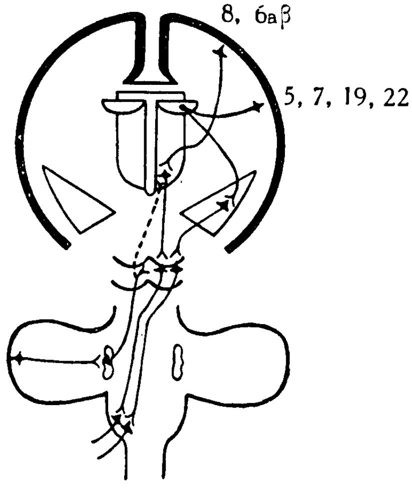


Fig. 12.



3) Preliminary summary.

Conduction tract of the adversive movement is as shown in Fig. 12. Conduction tracts from areas 8 and 6aβ passes through the thalamus of the same side while those from areas 5, 7, 19 and 22 pass through nucleus lenticularis following nucleus caudatus of the same side. In the cerebral hemisphere they descend without crossing and reach colliculus superior of corpora quadrigemina or the tegmentum, and after that they cross to the opposite side. It is thought that they end in the motor nuclei of those between the abducens and the accessorius nuclei in the pons and medulla oblongata (it is thought that they also reach nucleus oculomotorius and nucleus trochlearis, but as it is hard to experiment on them, they have been omitted here.).

Those from the cerebellar cortex are thought to pass through nucleus dentatus and brachium conjunctivum cerebelli of the same side, then cross to the tegmentum and the thalamus of the opposite side and connect with those descending from the cerebral cortex.

From the experiment on the center of adversive movement, nucleus caudatus, nucleus lenticularis, thalamus and tegmentum including colliculus superior of corpora quadrigemina, nucleus dentatus, the motor nuclei in the pons and medulla oblongata causes adversive movement when they were stimulated with cardiazol. Therefore, it can be understood, that there are synapses at these nuclei.

Conclusion

1) When the cerebral cortex is stimulated with electricity or cardiazol adversive movement occurs from areas 6aβ, 5, 7, 19, 22 and 4c.

2) In the cerebellar cortex adversive movement occurs when lobus lunatus inf., l. semilunaris sup. et inf., or l. cuneiformis were stimulated and they turn towards the side of the stimulation.

3) Conduction tracts of the adversive movement from the cerebral and cerebellar cortex to the motor nuclei in the pons and the medulla oblongata were decided as stated previously.

Part II. Studies on Adversive Movement with Intravenously Injected Cardiazol

Introduction

Studies on adversive movement in part I were aimed to find its centers and its conduction tract and experiments were performed with direct stimulation. The relation between adversive movement during epileptic convulsion and the adversive field in cortex have not ever been discussed yet. Also, in literatures, the relations between the two have not been throughly discussed. *Penfield* and *Dandy* have said that adversive movement during epileptic convulsion turns to the opposite side of the focus. While *Davis* said that it turns to the side of the focus. From clinical experience by provocating convulsions with cardiazol in idiopathic epileptics, *Jinnai* and *Kawamata* have pointed out that the side to which the adversive movement turns first has the meaning in deciding the side of the focus. and after the adversive field with the focus was removed the adversive movement turns to the opposite side when convulsion was provocated by cardiazol injection. When convulsion is provocated you will experience that movement does not always turn to just one side, but will alternate from left to right by time. To explain this mechanism which is often seen during clinical observation the following experiments were performed.

Experimental Methods

A. Stimulation below threshold in the cerebral cortex ; Anesthesia and removal of the cortex.

1) For cortical stimulation a stimulation below threshold, that is, a kind that will not produce convulsion or adversive movements must be given. For this, a 1 mm. square filtering paper, soaked with 0.01 cc. of 10% cardiazol was pasted on the surface of the cortex for about 4 seconds. Or a 6 volt alternating current with an induction coil was used. The tube distance was 10 cm. and electricity was passed for 2 seconds (the electrode was bipolor with a distance of 1 mm.).

2) Cortical anesthesia : To anesthetize a part of the adversive field a round filtering paper with a diameter of 1 cm. was soaked with 0.1 cc. of 1% novocaine and pasted on the surface of the cortex for 10 sec. This was changed three times.

3) Removal of the cortex : A metal spatula was used to remove the entire layer of the cortex.

B. Convulsive provocation.

A dog was fixed to a supporting rack and 1.0 cc. of 10% cardiazol was injected into V. digitorum communis of the lower leg in 10 seconds. When no convulsion occurred in 30 sec. another 0.5 cc. was added in 5 sec. Other parts of the experiment were as in part I.

Experimental Results

A. Developing area of adversive movement in the cerebral cortex when provocated with cardiazol.

1) Experiments in contrast animals: After trepanation on a healthy dog, convulsion was provocated with cardiazol. In this case, both eyes, head and trunk looked straight forward and no adversive movement was observed.

2) Developing area of adversive movement by stimulation below threshold: When cardiazol was injected intravenously to provocate convulsion after stimulating the adversive field of one side with electricity or cardiazol which has a stimulating effect and which is below threshold, adversive movement turned towards the opposite side of the stimulation. The place where adversive movement was seen (+) and where it was not seen (—) are shown in the following table.

Cortical area	Stimulation below threshold		Cortical area	Stimulation below threshold	
	Electrical stimulation below threshold	Cardiazol stimulation below threshold		Electrical stimulation below threshold	Cardiazol stimulation below threshold
8	(−) 5 cases	(—) 5 cases	22	(+) 4 cases	(+) 3 cases
6aβ	(+) 5 "	(+) 4 "	4a	(—) 7 "	(—) 5 "
5	(+) 7 "	(+) 5 "	4b	(—) 4 "	(—) 5 "
7	(+) 3 "	(+) 4 "	4c	(+) 4 " (—) 1 "	(+) 5 " (—) 1 "
19	(+) 4 "	(+) 4 "			

3) Developing area of adversive movement when the cortex is anesthetized: After one of the adversive field of one side was anesthetized with novocaine, cardiazol was injected intravenously to provocated convulsion. At this time, the movement was seen first turning toward the anesthetized side. Where such movement was seen (+) and where it was not seen (—) are shown in the following table.

Area 8	(−) 4 cases	Area 22	(+) 3 cases
„ 6aβ	(+) 5 „	„ 4a	(−) 5 „
„ 5	(+) 4 „	„ 4b	(−) 5 „
„ 7	(+) 5 „	„ 4c	(+) 4 „ (−) 3 „
„ 19	(+) 3 „		

4) Adversive movement with removal of cortex : After areas 6aβ or 5 were removed convulsion was provocated with cardiazol from the 3rd day to the 21st day after removal and the direction of the adversive movement was observed. Its results were as follows.

No. of days after removal	Removed area	
	6aβ	5
to the 3rd day	opposite to the side of removal	opposite to the side of removal
4th to 6th day	nearly towards the center	nearly towards the center
7th to 8th day	to the side of the removal	to the side of the removal
9th to 16th day	to the side of the removal	to the side of the removal
17th to 21st day	to the side of the removal	to the side of the removal

B. Adversive movement provocated by cardiazol injection and interception of its conduction tract.

In the experiment explained in the previous section, it became known that adversive movement can be provocated by injecting cardiazol intravenously when there is a difference of irritability between the adversive fields of both sides. To see what effects could be seen in the adversive movement provocated by intravenously injected cardiazol the following experiments were performed when the caudate nucleus, the lenticular nucleus, the thalamus and other nuclei which has relation with adversive movement showed difference in their irritability and when the conduction tract from the cortex to these nuclei were intercepted.

1) Subcortical cutting : After performing subcortical cutting in adversive fields 6aβ, 5 or 7, convulsion was provocated by injecting cardiazol intravenously and in all cases adversive movement was seen turning toward the side of the cutting (Fig. 13).

2) Removal of nucleus caudatus: After removal of nucleus caudatus on one side, convulsion was provocated by injecting cardiazol intravenously and in all 3 cases adversive movement was seen turning towards the side of the removal. (Fig. 14.)

Fig. 13.

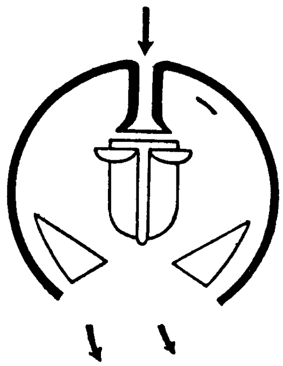


Fig. 14.

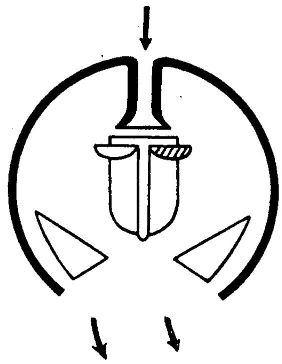
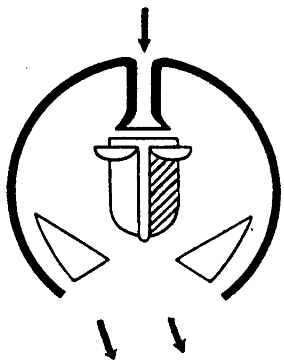


Fig. 15.



3) Removal of the thalamus: After removal of the thalamus of one side convulsion was provocated by injecting cardiazol intravenously and in all 4 cases, adversive movement was seen turning towards the side of the removal. (Fig. 15.)

Fig. 16.

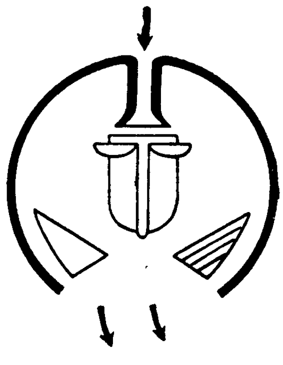
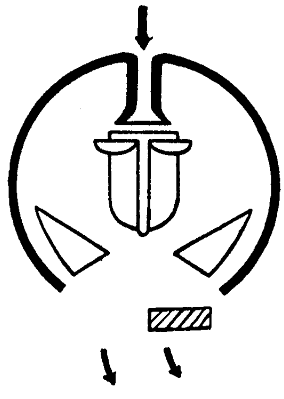


Fig. 17.



4) Removal of nucleus lenticularis: After removal of nucleus lenticularis of one side, convulsion was provocated by injecting cardiazol intravenously and in all 3 cases adversive movement was seen turning towards the side of the removal. (Fig. 16.)

5) Cutting the immediate upper part of colliculus superior of corpora quadrigemina : After cutting the immediate upper part of colliculus superior of corpora quadrigemina, convulsion was provocated by injecting cardiazol intravenously and in all 4 cases adversive movement was seen turning towards the side of the cutting. (Fig. 17.)

Discussion

From the previously stated results, when no procedures were performed on the cerebral cortex, namely, when both cerebral hemispheres were kept in equal condition, no adversive movements were observed. But when a stimulation below threshold was given to one of the adversive field, an adversive movement which first turn toward the opposite side of the stimulation was observed. On the other hand, when a part was anesthetized with novocaine or was removed, a movement turning towards the side of the lesion was seen. When a procedure was performed on the cortical adversive field 8 and on the non-adversive fields 4a and 4b, no effects were seen.

This fact was the same not only on the cortical adversive field but also in the subcortical nuclei. These facts show that the fundamental conditions that produce adversive movement is the difference of irritability between both cerebral hemispheres and when convulsion is induced by injecting cardiazol intravenously under such condition this convulsion becomes the provocating cause of the adversive movement, because when there is no convulsions there is no adversive movement. This is explained in part III.

The side to which the adversive movement turn is thought to come from the difference of irritability between both cerebral hemispheres. The place of irritability may be in the cortical adversive field, subcortical nuclei or the thalamus. And whatever side the irritability may be dominant, it starts to excite itself first and a movement turning to the opposite side is caused. We have experienced that when there is a continuance in the convulsion the adversive movement turns to the opposite of the first one. Assuming that a convulsion is always needed for the arising of adversive movement, it is presumed that this convulsion becomes to be a new provocating condition and the side which became excited first and had caused adversive movement starts to show fatigue or a condition of suppression. This produces an unbalance and the opposite side becomes relatively dominant as it was previously on the other side.

Conclusion

1) When there is no difference in the irritability between both adversive fields, no adversive movement is seen when convulsion is provocated with intravenously injected cardiazol.

2) When there is a difference in the irritability of areas 6aβ, 5, 7, 19, 22 or 4c of both sides, an adversive movement is seen when convulsion is provocated with intravenously injected cardiazol. As the dominant side of the irritability works first the direction of the rotation is towards the opposite side first, then to the other.

3) When a difference of irritability in areas 8, 4a and 4b of both sides are made, no adversive movement is seen even after convulsion is provocated with intravenously injected cardiazol.

4) Removal of subcortical nuclei (nucleus lenticularis, and nucleus caudatus) and thalamus or interception of the conduction tract of the adversive movement on one side would produce a difference in irritability between both cerebral hemisphere. An adversive movement is seen when convulsion is provocated in such condition with intravenously injected cardiazol.

Part III. Studies on the Relation between Secondary Adversive Movement and Convulsion

Introduction

In adversive movement caused by cortical stimulation or in those induced by intravenously injected cardiazol, they do not always constantly turn to one side. As the convulsion progresses, it has been observed by many authorities (*Penfield, Foerster, Jinnai & Kawamata, Nakata*) that the direction of the movement changes from right to left or from right to left then back to right again.

From studies on adversive movement induced by intravenously injected cardiazol in Part II, it is thought that the change of direction in the adversive movement is caused by the difference of irritability between both cerebral hemispheres which makes an unbalance of tension. This initiates the dominant side to cause the adversive movement. Following this initial movement, a state of fatigue or suppression is then caused on the dominant side and the previously inferior side now becomes dominant. It is presumed for this reason that the direction of the adversive movement changes and turns to the opposite side. I would like to call this movement secondary adversive movement to the first one which would be called initial or primary adversive movement.

On the other hand, it has been observed by *Vogt, Foerster* and others that when cortical adversive field is stimulated, convulsion is seen besides adversive movement. Therefore, I have given a stimulation which is over certain strength to the cortical adversive field to produce convulsion besides adversive movement and made an experiment on the secondary adversive movement which comes after the convulsion to see what is its arising mechanism and to see what relations it has with convulsion.

Experimental Method

The strength of stimulation given in Part I was enough to just cause adversive movement and not convulsion, but in this part a stronger stimulation was needed to produce convulsion.

1) When electric stimulation was used, a 6 volt alternating current was connected with an induction coil, the tube distance was 7 cm. A bipolar electrode with a distance of 1 mm. was used to give a stimulation for 4 to 6 seconds.

2) When chemical stimulation was used, a tuberculin syringe with a needle having a diameter of 1/5 mm. was used. And 0.01 cc. to 0.03 cc. of 10% cardiazol was injected. To stimulated the subcortical nuclei and the thalamus 0.05 cc. to 0.07 cc. (added with 1/5 amount of India ink) was injected. The other procedures were as same as in other parts.

Experimental Results

1) When the adversive field was stimulated with a weak stimulation, only the adversive movement was seen and returned to normal without causing convulsion. But once the stimulation was strenghened over a certain degree, an adversive movement which was followed by a convulsion appeared when any of the adversive fields except area 8 was stimulated. After the convul-

sion a movement, which turned to the same side of the stimulation occurred (Table 1).

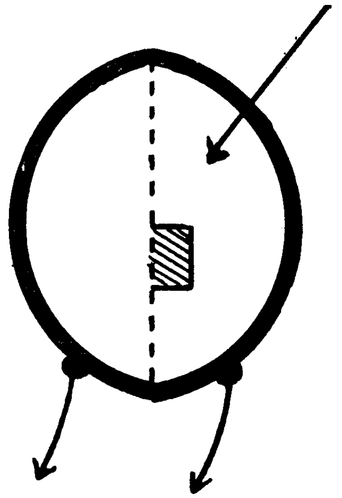
Table 1

Kind of stimulation	Electric stimulation			Cardiazol stimulation		
Kind of movement / Place of stimulation (areas)	primary adversive movement	convulsion	secondary adversive movement	primary adversive movement	convulsion	secondary adversive movement
8	(+)	(−)	(−) 3 cases	(−)	(−)	(−) 3 cases
6aβ	(+)	(+)	(+) 2 "	(+)	(+)	(+) 2 "
5	(+)	(+)	(+) 4 "	(+)	(+)	(+) 3 "
	(+)	(−)	(−) 1 "	(+)	(−)	(−) 1 "
7	(+)	(+)	(+) 2 "	(+)	(+)	(+) 3 "
19	(+)	(+)	(+) 1 "	(+)	(+)	(+) 1 "
				(+)	(−)	(−) 1 "
22	(+)	(+)	(+) 2 "	(+)	(+)	(+) 2 "
	(+)	(−)	(−) 1 "			
4c	(+)	(+)	(+) 3 "	(+)	(+)	(+) 2 "
	(+)	(−)	(−) 1 "	(+)	(−)	(−) 2 "

2) When any adversive field except 8 was stimulated with cardiazol which was below threshold and did not cause convulsion, the adversive movement first turned to the opposite side when cardiazol is injected intravenously, then the convulsion occurred which was followed by a movement turning to the side of the stimulation.

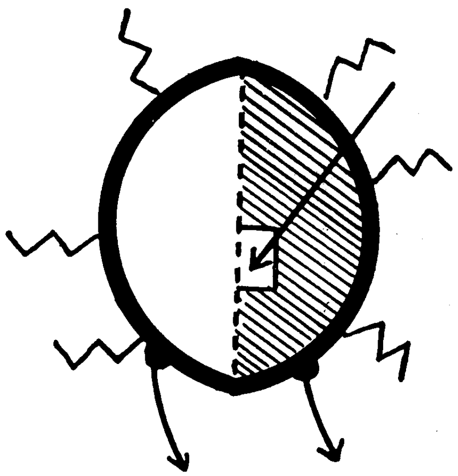
3) When any adversive field, except area 8, is paralyzed by painting novocaine or by being removed, the appearance of adversive movement is opposite from the previous case when cardiazol is injected intravenously, that is, it first turns to the side of the stimulation, and then convulsion occurs which is followed by a

Fig. 18.



Primary adversive movement (+)
Convulsion (—)
Secondary adversive movement (—)

Fig. 19.



Primary adversive movement (—)
Convulsion (+)
Secondary adversive movement (+)

movement turning to the opposite side.

In these cases when continuence of the convulsion is prolonged a third turning is often seen. The first adversive movement is the initial or primary adversive movement and the next one which turns to the other side is the secondary adversive movement.

4) When motor cortex 4a and 4b are stimulated with a weak stimulation, only convulsion occurs and there is no adversive movement.

5) When the motor cortex of one side is removed, and if the cortical adversive field of the same side is stimulated with whatever strength of stimulation, only the primary adversive movement occurs and the convulsion and the secondary adversive movement are missing. (Fig. 18.)

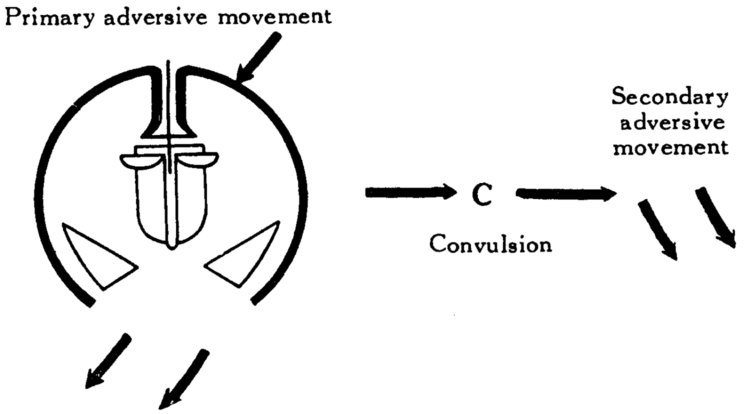
6) When the motor cortex was left alone and all the adversive fields of one side were anesthetized by painting novocaine the primary adversive movement disappearred, but when the motor cortex which was left alone was stimulated the convulsion and the secondary adversive movement were seen. (Fig. 19.)

From these facts, it is clear that convulsion is related with the motor cortex and adversive movement is controlled by the cortical adversive field. Both are different and can be divided. The reason why convulsion is seen when the cortical adversive area is stimulated with a strong stimulation, is because this stimulation is giving an influence to the motor cortex.

Next, from the fact that secondary adversive movement follows convulsion, it can be thought that convulsion becomes a new provocating condition for this secondary adversive movement. And as the primary adversive movement has occurred on the side of the stimulation and it is now in the state of suppression, and there is an unbalance between both sides which makes the opposite side becomes dominant and the movement turns to the opposite side. It is known that for the secondary adversive movement to occur convulsion is needed. If so, is it the convulsion itself that is needed or is it the spread of its influence to the opposite hemisphere that is needed? To clear this, the following experiment was performed.

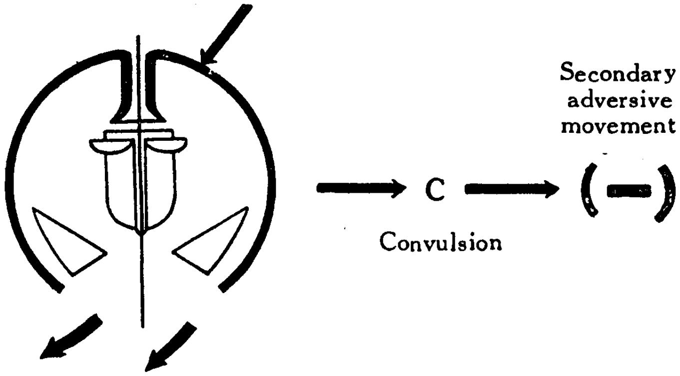
7) Even when corpus callosum was cut there was no change in the phenomenon of primary adversive movement, convulsion and secondary adversive movement. (Fig. 20.)

Fig. 20.



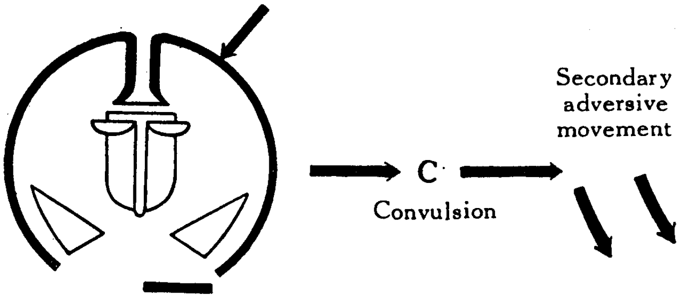
8) When longitudinal section between both cerebral hemispheres was performed without touching the midbrain and parts below it, the primary adversive movement and the convulsion were seen while the secondary adversive movement was missing, when the adversive field of one side was stimulated. (Fig. 21.)

Fig. 21.



9) When the immediate upper part of colliculus superior of corpora quadrigemina of one side was sectioned and when the adversive field of the same side was stimulated, the primary adversive movement did not occur but the convulsion and the secondary adversive movement were seen. (Fig. 22.)

Fig. 22.

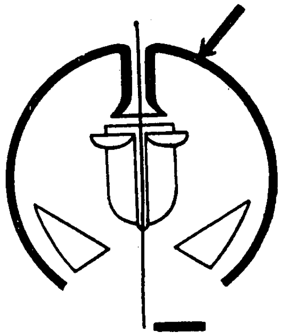


10) When a longitudinal section between both cerebral hemispheres with the cutting of the immediate upper part of colliculus superior of corpora quadrigemina of one side was performed and neither the primary adversive movement, convulsion nor the secondary adversive movement were seen when the adversive field of the same side was stimulated. (Fig. 23.)

11) When nucleus caudatus, nucleus lenticularis and the thalamus were stimulated, the primary adversive movement followed by convulsion and secondary adversive movement were seen. But

when the posterior nucleus of the thalamus was stimulated only the primary adversive movement was seen and the convulsion and the secondary adversive movement did not appear. When nucleus caudatus or nucleus lenticularis were stimulated similar cases were seen, but cases which had a secondary adversive movement always had a convulsion. (Table 2.)

Fig. 23.



Primary adversive movement (—)
Convulsion (—)
Secondary adversive movement (—)

12) After the immediate upper part of colliculus superior of corpora quadrigemina was cut and when nucleus caudatus or nucleus lenticularis or the thalamus were stimulated, the primary adversive movement failed to appear, but the convulsion and the secondary adversive movement were seen.

Table 2

Place of stimulation	Kind of movement		
	Primary adversive movement	Convulsion	Secondary adversive movement
Nucleus caudatus (6 cases) …	3 cases (+)	(+)	(+)
	2 „ (+)	(—)	(—)
	1 „ (—)	(—)	(—)
Nucleus lenticularis (8 cases)	3 cases (+)	(+)	(+)
	3 „ (+)	(—)	(—)
	2 „ (—)	(—)	(—)
Thalamus: intermedial nuclei group (5 cases)	5 cases (+)	(+)	(+)
Thalamus: nucleus posterior (5 cases)	5 cases (+)	(—)	(—)

The secondary adversive movement seen when nucleus caudatus, nucleus lenticularis or the thalamus were stimulated, is also caused by the spreading of volley of impluses from the convulsion through the conduction tract of adversive movement to the other hemisphere.

Discussion and Conclusion

From these facts, secondary adversive movement is caused by transmission of volley of impluses from the convulsion to the opposite cerebral hemisphere through the conduction tract of the primary adversive movement in the other side. This transmission is done in the part upper than colliculus superior of corpora quadrigemina. It is thought that it does not pass through corpus callosum but between both thalami.

It is plain that, the spreading tract of the volley of impulses from the convulsion to the other hemisphere takes the conduction tract of the convulsion. This secondary adversive movement is absolutely the same thing as the primary one and it is thought that it also takes the same conduction tract.

From experiments in these three parts the conduction tract of the adversive movement was decided and a very interesting view concerning the relation between convulsion and adversive movement was found. Furthermore, the mechanism of secondary adversive movement was studied and the mechanism of convulsive attacks which is seen clinically was understood and explained to some extent.

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