The effects of sensory input and concentration on post-amputation phantom limb pain

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The nature of the post-amputation limb phantom has been the subject of much speculation. Its existence as a clinical problem centres around the troublesome pain with which it is sometimes associated, and it is out of attempts made to deal with this pain that the majority of investigations have arisen. Therapy has generally focused on the stump and its centripetal pathways: the percussion treatment of Russell and Spalding (1950), the stump injections described by Leriche (1950), various local surgical manoeuvres mentioned by Gillis (1954), or tractotomy, as described by Falconer (1953). Where these have failed there have been attempts to alter central nervous events of a higher order by leucotomy so as to change the patient's general reaction to pain, operations which were evaluated by Elithorn, Glithero, and Slater in 1958.

Apart from leucotomy, these are all direct attempts to interfere with sensations conducted centrally from the stump. Sensations can, however, be modified in many other ways. There is a whole literature concerned with the distracting effects of sensory stimuli upon each other. In 1899 Heymans derived a number of laws which govern the effects of strong sensations on threshold sensations in the same modality from his experiments. Jacobson added more experimental data in his review of 'Experiments on the inhibition of sensations' in 1911. He had investigated the experimental effects of a strong sensation on judgments of moderately intense sensations both in the same and in different modalities, and found that the distracting stimulus always reduced the apparent intensity of the experimental stimulus.

Since then the literature in this field has grown enormously. Beecher reviewed the 'Measurement of pain' in 1957, and cites many experiments which amplify this point. The main directions taken by work on the psychology of sensory distractions are illustrated by Hardy, Wolff, and Goodell, who showed in 1940, for instance, that locally induced pain is accompanied by a general rise in the threshold of pain elsewhere; by Libman (1934), who lists a

variety of emotional and other states which may affect the pain threshold; by Ischlonsky (1949) who has investigated the relationships between sensory thresholds and motor activity, and by the work of Bender, Fink, and Green (1951) on simultaneous sensory stimulation in normal and brain-damaged subjects. The common factor in all these experiments is that sensory judgments are modified by making alternate claims on the subject's attention.

The experiments to be reported in the present paper deal with the effects of attention and sensory distraction on post-amputation phantom limb and sensations in the stump. They are not, however, concerned as much with immediate changes in these sensations, as with the cumulative effects which follow repeated and prolonged distraction. This is part of a general investigation into the nature of post-amputation pain, and the subjects who took part in the experiments suffered from an intractable form of this pain. It was argued that if a situation was devised in which externally applied stimuli had to be ignored in order to perform a difficult task, this might generalize to include the sensations from the stump or from the phantom limb, whether painful or otherwise. The two main differences between this study and much of the previous work are that it is concerned with spontaneously occurring, and not with experimentally induced, sensations and that practise effects as well as immediate changes are examined.

METHODS

The conditions of this experiment were that the subject should concentrate so intensively on his task that he becomes oblivious to a whole barrage of distracting stimuli. In general, the subjects were given tasks which demanded their closest attention, and while performing these were exposed to a wide range of sensory distractions which they learned to ignore so as to pursue their work.

It was argued that a successful block of all sensory stimuli irrelevant to the task would also include the phantom sensations. If the phantom sensations could thus be suppressed experimentally, intensive practise

might lead to enduring changes, and, in the patients involved in this study, to relief from the phantom limb pain. An attempt was thus made to carry out a kind of sensory deconditioning comparable to the deconditioning procedures used for the relief of motor habits, e.g., tics or writer's cramp.

Accordingly a number of sensory-motor tasks were selected to engage the subject's attention, and these included a tracking drum, a pursuit rotor, a variety of pencil mazes, and a peg board. Most of these tasks were first learned using the right hand, then the left hand, and later, while performing the tasks, the subject's hands were shielded and he controlled his actions as reflected in a mirror. Any one task occupied at least five and usually 10 or more minutes of concentrated attention.

While the patient was performing these tasks sensory distractions were provided by (1) a light flashing at frequent but irregular intervals; (2) a noise delivered through earphones at irregular intervals, not synchronized with the light; (3) mild electric shocks to the wrists or to the intact leg operated by the same switch as the light; (4) a pressure cuff applied to the arm or to the intact leg and inflated intermittently to a pressure of 180 to 220 mm. Hg. All these stimuli were of moderate intensity, so that the patient could not fail to be aware of them when first applied but none were more than uncomfortable. They were regulated according to subjective reports of the stimulus intensity.

SUBJECTS

Observations were made on four subjects who had experienced phantom limb pain for periods of three to eight years after amputation of a limb without obtaining lasting relief. They are described in the accompanying table and the case histories which follow:

To avoid contaminating the results by changes which might be due to psychotherapy (of the analytic type), no psychological interpretations were offered to the patient nor were there any attempts to deal with possible emotional conflicts. Conversations which took place were deliberately kept to general topics.

There was no common pattern in the social, economic, and emotional circumstances of the patients. The circumstances of the amputation were equally varied:

one was the immediate result of war damage, another a delayed effect of war service; two were civilian injuries, one involving compensation, the other without compensation. They were chosen in this way because selection for a uniform background would have made it difficult to generalize from such a small number of patients. The experiment was made in order to investigate how to change the phantom limb sensations, irrespective of their source, and interest was focused on this change in sensation and not on the aetiology.

CASE REPORTS

CASE 1 P.S. is 46 years old. He suffered a traumatic bilateral amputation above the knee while on active service at the age of 26 years. This was followed by intermittent bilateral phantom limb pain for 19 years and continuous pain for three years.

Both parents died of cancer. His mother was addicted to alcohol. He has one sister who is happily married and two brothers who lead unsuccessful private lives. His childhood was disturbed due to his mother's alcoholism but this was offset by school, where he boarded happily from the age of 7 onwards. He married shortly before enlisting in 1939 but was divorced due to his wife's unfaithfulness in 1947. His second marriage is completely successful and he has two children.

Medical history He has congenital myopia. He suffered from duodenal ulcer after demobilization in 1944 and from recurrent diarrhoea and occasional vomiting and fibrositis during the past year.

Personality He is stable, active, and successful at work and in his personal relationships, in spite of his pain and the drugs he takes for it.

Amputation While serving in the desert in 1942 he was blown up by a bomb he was dismantling. He was unconscious for half a minute and retains a clear memory of the event. At the time of injury he had severe pain from general abrasions and from hand and eye injuries, but no pain from the legs. Immediate surgery was to close the bilateral wounds above the knee stumps and numerous other superficial wounds. He had two further operations in the next two weeks.

Post-amputation pain This was completely controlled by morphia for the first four weeks, but became intense

TABLE
SUMMARY OF CASES DESCRIBED

	Patient P.S.	N.N.	N.H.T.	W.E.W.
Nature of amputation	Bilateral, above knee	Right, below knee	Right, below knee	Left, below knee
Status of patient	Service	Civilian	Service	Civilian
Compensation	100%	Nil	70%	Inadequate
Age at amputation (yr.)	26	48	28	54
Age on admission (yr.)	46	56	36	57
Duration of continuous pain (yr.)	5	6	8	3
Off work (yr.)	3	1	1	1
Phantom	R. and L., painful	Painful	Painful	Never felt
Stump	Occasional severe pain	Rare severe pain	Occasional pain; tender	Constant severe pain
Result of previous treatments	No change	Brief improvements	Temporary improvement	No change
Response to present course	Temporary but complete loss of pain	Complete loss of pain	Lasting improvement	Temporary but complete loss of pain

when it was discontinued. Later the pain was most effectively controlled by alcohol. Both phantom and stump pain decreased during the next six months, and had almost ceased when he returned to England at this time.

Regression of the phantoms Six months after amputation the phantoms were of 'normal' length and regressed very slightly, so that 19 years later the feet were about nine inches off the ground. When pain was severe the phantoms resumed their full length, but when extreme they could not be localized. He had occasional bouts of pain of crippling intensity between 1943 and 1953 which lasted from one to 36 hours. In 1953, he fractured the left thigh and was introduced to pethidine by his physician. The pains became less intense but more frequent. In 1958, he was changed to physeptone to avoid addiction to pethidine, of which he took up to 300 mg. in 24 hours if the pain was severe. In 1959 he began to take barbiturates to enable him to sleep, again, owing to pain in the phantoms. He had been off work the greater part of that year on account of the pain, and stopped work altogether at the end of 1959. Alcohol was his most potent analgesic, and his consumption was about one and a half bottles of spirits and some wine and beer each week.

On admission, an ordinary day may be described as follows: On waking there is a sensation of heat and of tingling of the toes only (especially in the great toes and the second toes). As the day continues so the sensations increase. The phantom feet appear to be 9 inches below the knees, which are bent at right angles, though there is little sensation from the rest of the legs. Both 'feet' are smaller than 'normal' and the left foot can be everted. Otherwise there is no difference in sensations on the two sides. At 2 p.m. there has been a steady increase in discomfort. 'There is now considerable pressure and heat, and tingling, like pins and needles . . . Discomfort is now obvious, and the phantoms are painful, mainly in the toes and fore part of the instep, and on the outside of both feet'. After he had walked about for some minutes he said that 'there is now more heat, and the tingling and pressure around the toes and instep and side of the foot have increased'. The discomfort continues to increase and by 4 p.m. the feet were really uncomfortable so that he could do nothing to take his attention from them. Drugs were taken at 6 p.m. (two codeine tablets). At 10 p.m. he took $1\frac{1}{2}$ grains nembutal and repeated the dose at 11 p.m. All these drugs gave some relief, and he slept intermittently from midnight, waking at times with stabbing pain in the right foot. At 2 a.m. he woke completely because of the phantom pain. He took two panadol and one codeine tablets and smoked a cigarette. After taking a further panadol tablet at 3 a.m. he slept until 6 a.m.

Clinical progress after start of 'sensory deconditioning' On the first day the distracting stimuli were of very mild intensity when compared with the sensations in the phantom limbs even early in the day. He noticed the light, the sound, the shocks to the wrists, and the cuff, but none of them appeared to distract from his task as much as the phantom limbs. He was, however, only aware of the 'feet' intermittently during the task performance. At the end of the afternoon session on the fifth day he was only just aware of the 'feet'. By 7 p.m.

however, they were once more tingling intensely, and the night was disturbed by pain. By the tenth day it was becoming more and more difficult to move the left foot. On the fourteenth day: 'The feet leave me baffled; sometimes they are clearly at the "knees", and then five seconds later, I cannot be sure where they are. It is very hard to say where the sensations come from: they might almost be at the ends of the stumps (12 noon); the foot sensation is very mild now'. Later in the afternoon (4 p.m. after the second session) 'there is just a feeling of mild heat and pressure in my feet.' He was no longer taking analgesics, even in the evenings at home. The nights were less interrupted now and he was sleeping with barbiturates only. By the sixteenth day phantom pain has been replaced by stump pain during the nights but the amount of sleep obtained during the nights is increasing. That morning the stumps felt painful, 'but while I am concentrating I am not nearly so conscious of them'. The phantom feet were still felt at the beginning of the afternoon session but after working for 10 minutes with a pursuit rotor he was 'not conscious of the feet now'. It was five minutes before there was any return of foot sensations. At night the sensation in the feet was beginning to merge with that of the stumps. By the seventeenth day there had been a considerable change in the phantom sensations: as before they were mild in the morning but persisting, so that even at 5 p.m. 'there is just the (now) usual mild cold, rather than hot, sensation, and a waxing and waning of pressure which is not painful, in the toes and slightly down the outside of the feet. The feet are not so completely at the stump as, say, last night, but they are very close to them'. While engaged in tasks demanding concentration he was not aware of either the stumps or of the phantom feet. A week later both in the morning and in the afternoon, the feet were only represented by tingling feelings, semi-attached to the stumps, and by cold sensations, the most prominent being the latter. In the evenings there was usually some severe discomfort at about 10 o'clock, when the 'stumps ached like hell' for 40 minutes. He slept well, however, after taking $1\frac{1}{2}$ grains of nembutal. On the 29th day there were no longer any distinct sensations from the toes or from the outside of the feet at any time and the patient could not re-create the feelings he used to have. The varying pressure in his 'feet' had been completely replaced by a steady tingling. Three days later: 'Last night there were some jabs in the stumps; just a few, nothing continuous.' Throughout the day the phantom sensations were mild. On the 38th day he was completely comfortable in the morning; after luncheon he fell asleep while sitting in his chair. This had never happened since the amputations, as the phantom feet would be too irritating to allow him to sleep. At 5 p.m., after mirror drawing, there were no sensations in the right foot or stump at all and tingling, only of a slight intensity, in the left 'foot'. On the 41st day there was just a mild tingling in the feet as though he were being touched with a feather (at 5 p.m.). In the evening he felt a series of jabs in the right foot, but slept soundly when he went to bed. When he examined the sensations closely, he felt the lateral part of the left foot, but could not follow this round to the toes; very occasionally there were tingling

sensations in other bits of the foot, but 'if I can feel one bit, I cannot feel the rest'. Three days later the phantom sensations had diminished in extent so that 'it is as though the toes were amputated, and there is just tingling on the ends of the foot, but not in the toes. These feelings are very hard to describe, as there are separate sensations in the stump and in the foot which appear to come from the same point. Occasionally there is just a feeling like a touch of iced water on the outside of the feet, like a tiny, gentle spray; this is not even uncomfortable'. This diminution in size of the phantom feet was irrespective of the quality and intensity of sensations. On the 47th day he went to bed at lunch time owing to a feverish cold. He slept fitfully, owing to showers of painless electric shocks in the stumps, which stopped spontaneously. On the 51st day the stumps of the big toes of his phantom feet were a little uncomfortable after luncheon but not so intense as to stop an afternoon nap. His nights were now undisturbed but he continued to take 3 grains of nembutal in divided doses in the evening, and there were no further changes in sensations during the week ending on the 58th day of treatment.

The patient's treatment was complicated by severe bouts of abdominal pain and diarrhoea (fourth to ninth day), a feverish cold (11th-26th day), and fibrositis of the neck (27th-32nd day).

After discharge he maintained complete freedom from any discomfort for 17 days. He then had two bouts of severe, recurrent lancing pain in his 'feet' within a week, and after this there was a return of some discomfort in his feet. The phantoms have continued to shrink in spite of this, and are now about the size of a postage stamp, at or near the ends of the stumps, but still separate from them. The discomfort is never enough to warrant taking analgesics.

A further course of six weeks' exercises once more removed the discomfort but he suffered badly from fibrositis of the neck.

CASE 2 N.N. is 56 years old. When he was 48 he had a traumatic amputation of the right ankle after an accident at work. He had phantom pain since the operation. There was no question of compensation.

His mother died aged 75 after 15 years of ill health. His father is alive; he is 86 years old and is described as a quiet, kindly man. N.N. had one non-identical twin brother who committed suicide when he was 22. His childhood was happy and his family united. He had no neurotic traits and was well adjusted at school and later, at work, staying for many years at any one job. He married at 24 and is well suited to his wife. There are no children.

Medical history Mild left congenital hemi-smallness was noted presumably from birth injury but was not relevant to his condition.

Personality He is a quiet, active man, socially and emotionally well adjusted.

Amputation He fell into a bailing machine while working on his smallholding in 1954 and suffered traumatic amputation of the right ankle. There was no loss of consciousness, and his memory for the accident is complete. 'There was no pain at the time. It was like a powerful, blunt blow to the ankle.' He waited two hours for the ambulance to arrive and had some pain during transport to hospital, but nothing severe.

Post-amputation pain This began immediately on waking from the anaesthetic, and consisted of intense pressure, burning, and tingling in the phantom foot, with intermittent sharp cutting pains and jactitation of the stump. Analgesics gave partial relief from pain, which has remained essentially unchanged for the past eight years.

Regression of the phantom The 'foot' remained at the same level as the left foot and the constant, continuous pain forced him to give up work one year ago.

Treatments These were percussion, ultrasonic vibration, sciatic nerve resection, hypnosis, E.C.T., and injections of the stump but the only one to give any relief was the sciatic nerve resection, after which the worst, the jactitating, pains were almost abolished.

On admission, the phantom sensations were confined to the toes, the instep, and the 'bone under the arch of the foot'. There was then a gap which was only filled in when pain was very severe. Sensations consisted of a feeling of intense compression, congestion, and a deep-seated soreness mainly in the bone under the arch of the foot; superficially there was also tingling pain. The foot was always painfully cold. At times the 'great toe' felt as though it were being twisted outwards painfully. Pain was present on waking in the morning and then increased steadily throughout the day so that it was always worst at night. It was exaggerated by walking, and getting up frequently from a chair was particularly irritating. He always walked with a stick and removed the prosthesis whenever he could as it gives him more pain to wear it. Before going to bed he bathed his stump in warm water as this reduced some of the cold pain.

Clinical progress after start of 'sensory deconditioning' On the first day the pain was consistently less during the tasks demanding concentration. On the fourth day the site of pain was diminishing; it had receded up the ankle and was confined to the bone at the base of the ankle and on the following day he stopped using his sticks for walking. By the seventh day relief from pain was complete during the session, and lasted throughout the evening. He could now walk short distances without getting pain, and the next day he was free of pain for 10 minutes after a bath, for the first time since the amputation. Pain was now relieved by walking, as well as by the distracting exercises. There was no relief of pain, however, if the distractions were omitted. By the ninth day pain was clearly more notable when sitting than when walking, and he experienced no discomfort during the tasks with distractions demanding concentration. Two days later all pain had disappeared during the day and night leaving only discomfort, chiefly when sitting down.

By the fourteenth day he had started full weight bearing which was much more comfortable. The phantom foot was regressing, so that instead of feeling the feet at the same level, the right foot seems to be half-way down

the shin, between the ankle and the knee. He now preferred to be with the leg rather than without it. Sensations in the stump were becoming apparent as feelings of warmth or of constriction. Two days later he ran a short distance. Stump sensations were then stronger than phantom sensations, as the phantom was reduced to a mild tingling only. By the eighteenth day there had been no further pain in the phantom and the stump was always warm, even in bed at night. The phantom continued to regress, especially while walking. On the 24th day he walked three miles across country with no discomfort at the time or afterwards, and the next day the phantom was like a mildly tight shoe on a small foot at the level of the upper third of the shin. No further change was seen at the end of a month's treatment.

This patient's progress was uncomplicated by any incidental disorders. After discharge, there has been no recurrence of pain. He works nine to 11 hours, standing at a machine, and one year later reports continued regression of the phantom into the stump.

CASE 3 N.H.T. is 36 years old. At the age of 28, he had an amputation below the knee of the right leg for chronic osseomyelitis. He was awarded a 70% pension as the infection followed a bayonet wound during army service.

His father is 78 and is described as a narrow minded, rather strict person with whom the patient had very little contact. His mother died when he was born. He has eight siblings from the father's second marriage. His childhood was quite happy, the only neurotic trait being nail biting which persists to the present. He was good at sports and indifferent as a scholar. He enjoyed school and held 11 different jobs in the following 21 years.

Medical history There is nothing relevant apart from the present history.

Personality He is a histrionic, aggressive person, of the barrack room lawyer type.

Amputation Osteomyelitis was contracted from a bayonet wound while serving in the Middle East in 1952. An elective amputation of the right leg below the knee was performed in 1954 because the wound failed to heal. He felt no pre-amputation pain but severe phantom pain from the time of waking from the anaesthetic. This changed little in the following eight years.

Treatments From 1954 to 1955 he was given drugs by a general practitioner but with little relief. In 1957, he was given a stump injection which gave complete relief for six months when a second injection was given but with no relief. Ultrasonic vibration and percussion gave temporary relief during application of the treatment. Excision of a neuroma gave short a period of relief. He had six hospital admissions in five years.

On admission, he had not worn his prosthesis until two days before because the stump was too painful. All the 'toes' were screwed up, with a gap somewhere which could not be localized precisely. This was like a painful cramp. The ankle felt as though someone were kicking it while he walked, giving a long-lasting ache. He could move his toes, but only to increase the tightness. Occasionally, but not that time, he had a pain at the back of the shin. The stump was only tender if he put any

pressure on it and he only felt the pain of the phantom. The stump was painful again when he removed the prosthesis. There was one area of hyperaesthesia on the dorsolateral aspect of the stump; pressure there resulted in a painful tingling sensation in the ankle. When he straightened or when he relaxed the leg, there was a shooting sensation in the foot, also felt when pressure was applied to the front of the knee. The latter also results in uncontrollable jactitations of the stump.

Clinical progress after start of 'sensory deconditioning' On the first day the stimuli applied during the task made no difference to his performance; they did not distract him and the task made no difference to his phantom pain. For the next two days the patient was in bed with a cold and complained of severe phantom pain. On the seventh day he experienced severe pain for one hour in the morning with cramp in the foot, the toes curling up under him, and he dared not put any weight on the foot. After concentration on a task with different sensory distractions, he was pain free. The pain returned after a short walk, but went at the end of the next task demanding concentration. At the end of the session he said that some phantom pain remained 'but of an intensity I can live with'. By the next day he was beginning to be able to go downstairs with a normal leg action, and after the third task there was no phantom sensation left at all. On the thirteenth day he had the worst night since coming into hospital, suffering severe jactitations but in the morning he could stand on the right leg for five seconds unsupported. By the 21st day he had no further jactitations. The phantom was now merely niggly, and of an intensity he could live with. His gait had now become near perfect. On the 24th day he went home for the weekend and had no trouble from his leg. 'If it never gets any worse I shall be a happy man'. His walking was impeccable. He took part in dances, games, and all other ward activities. Pain was now a stump sensation and not in the phantom, which was, however, still present. Five weeks after discharge (103rd day after the start of treatment) the phantom was of variable length but he could not put his hand at the level of the foot. The pain in the stump was of a tolerable intensity. There were times when he was completely free of pain.

This patient's treatment was complicated by colds, sore throats, and feelings of malaise. After discharge he returned to work (he had not worked for almost one year) and continues to do so six months later. He does not complain of pain in the phantom but of pain in his left knee.

CASE 4 W.E.W. is 58 years old. He had a delayed amputation of the left leg below the knee after a motor bicycle accident, and he considered the compensation awarded inadequate.

His mother died when he was 3 years old and his father remarried. The father was a kind, placid man who died of coronary thrombosis at 65 years of age. His stepmother died aged 81; the cause is not known. He has one sister who was close to him until the stepmother's death. He was a quiet child and was very fond of his

stepmother. At school he was good and was liked by masters and other children. He worked as a cook until 10 years ago, when he changed to being a storeman as he developed ulcer pains. He continued to work for one year after the accident but then stopped because of the pain. He married at 24. His wife is a kind, anxious woman, by whom he has two children.

Medical history He had a duodenal ulcer when aged 43 but no other relevant illness apart from the present history.

Personality He is a quiet, shy, retiring man, apprehensive of new situations and tending to panic easily. Once he has learned a task he does it well.

Amputation He was knocked off his motor bicycle while going to work in 1958. He was unconscious for three-quarters of an hour and had a brief amnesia for preceding events. On waking he was in severe pain from the left leg. Immediate measures were to put the leg in plaster, but because the bone did not unite and the loss of skin was extensive, amputation of the left leg below the knee was performed six weeks later. The pain did not change and has persisted until the present.

Treatment Neither injection of the stump, ultrasonic vibration, local heat, or percussion made any difference to the pain.

On admission, a dull, steady, diffuse, pain pervaded the stump up to the knee and in addition he experienced a gnawing, nagging pain at the end of the stump. The stump was tender and felt worse with the prosthesis on. Walking was agonizing, and he could only creep around with the help of a stick unable to put any weight on the left leg. There were no phantom sensations and there had never been any.

Clinical progress after start of 'sensory deconditioning' On the first day he said, 'I know that the light and the sound are there, but they do not disturb me.' He tried to stand on the left leg but fell towards the other side because it was so painful. On the second day it took him 30 minutes to walk from his ward to the treatment room and he needed 10 minutes' sitting to revive before he could do any work. There was no change in the sensations in the stump after the task but it gave very little trouble that evening. By the fourth day he had little trouble on waking but the pain intensified within half an hour, and on the following day concentration on the task reduced the intensity of sensations in the stump but they returned at the end of the task. The muscles also relaxed and remained so. The leg improved during the afternoon session on the seventh day. Filling up a peg board relaxed his muscles but the pursuit rotor, which is a much more difficult task, did not. By the 21st day there were no further writhing movements of the stump and sensations were a mild, gnawing ache at the back of the stump only. A week later he started to walk up stairs with normal leg action. On the 33rd day: 'I am so concentrated on the task that I really forget the leg,' and three days later he could walk up stairs and was beginning to learn to descend. There was no pain in the stump during the task. By the 39th day pain had localized to one spot and the rest of the stump was free of pain. On the 44th day he walked outside in the street for 10 minutes without assistance. Although during the week the stump went

numb it was unpleasant but painless. Five days later: 'If the stump remained like this I could work perfectly well.' Standing and walking now eased the pain, which was more noticeable when he was sitting down. By the 53rd day he had no discomfort all day and four days later he began weight bearing on the end of the stump. For a short time, walking with end weight bearing took all the pain from the stump but it returned on sitting down, and two days later the pain was worse with the prosthesis off than on. On the 64th day the walk from the ward to the treatment room took five minutes. On the 78th day he went home for the weekend and he was pretty well free of pain. He went shopping in the local town for the first time since the amputation. The stump was tense but not painful although some pain returned on reaching home. By the 101st day the leg was relaxed and comfortable. He did a lot of walking on the previous day and the pressure area on the end of the stump was sore but it was comfortable at the end of the day. There was no change during the last week of observation.

This patient had a number of minor colds and sore throats while in hospital. After discharge, he was offered a different job which he had already once failed to master. He developed ulcer pains and had to rest in bed for a time. On getting up, the roads were icy and he did very little walking. Three months later there was some pain in the stump 'but nothing one can complain of'. He now walks well but has not yet found a job.

DISCUSSION

In all these cases a profound change in the sensations in the phantom and in the stump was achieved, but without acting on the stump or on its afferent pathways. In the method used, the patients were required to concentrate on a task, to learn to ignore sensory distractions, and to work intensively for two hours each day for a number of weeks. The contributions made by each of these factors demands separate consideration.

Concentration on a task is in itself a recognized way of altering concurrent sensory experiences, as in the situations described by Ischlonsky (1949). On the other hand, all the patients had found that the type of concentration involved, for instance in their work, was not only inadequate to reduce the phantom sensations but had actively increased the pain so much that work had become impossible. Sensory distraction by itself also occurs in situations of everyday life—driving a motor car or working in noisy surroundings—but there is no indication that these had any kind of ameliorating action on the phantom limb sensations. It has, however, been reported that under certain circumstances stimuli applied in a rhythmic manner may have a strong soporific action. This is described by Oswald (1960)

and has been used as a therapeutic narcosis by Teplov (1959). Where stimuli have been used to achieve this effect, they have been intense and repeated at strictly regular intervals, whereas in the above experiment the stimuli were mild and given at irregular intervals. None of the subjects reported any kind of hypnotic action from the stimuli, but, as Oswald points out, repeated stimulation may invoke 'this phenomenon of habituation or cessation of response . . . which is a property of stimulus response mechanisms of all degrees of complexity'. The extent to which applied stimuli may suppress other sensations is well demonstrated by the use of intense auditory stimulation with which Gardner, Licklider, and Weisz (1960) suppressed the pain of dental operations, so that separate analgesics were not required by 65% of patients who had previously needed these for comparable operations. Here, also, the subject's concentration was invoked but directed at the applied stimuli which he controlled in intensity so as to suppress the pain of the operation.

In the present experiments there seemed to be a qualitative change in activity when these were united. Concentration and distraction together have displaced the phantom limb sensations and relieved the pain, when either alone was not effective. It is no simple effect, however, as it takes time to emerge and then increases in its effect with further practise. This is a characteristic of learned reactions, and it seems that whatever process is involved in reducing the phantom sensations in these circumstances, it can be acquired or reinforced by constant repetition.

The actual changes in sensation were in the size of the phantom limb, in the quality of the sensations, and in their intensity; there were also changes in the character of the sensations in the stump, and it was possible to record alterations which took place in the phantoms of two limbs amputated at the same level.

The intensity of the sensations altered first, temporarily during the course of the sessions, and later for increasing periods until there was a lasting reduction in the whole range of the sensations. In this respect there was no significant difference in the reaction of painful and painless sensations. Next, there was a reduction in the size of the phantom limbs. The onset of this phase was abrupt and surprising to the patient. Once the regression in the size had started, it continued at varying rates. The regressing phantom rarely seemed to remain at any particular length for any period but seemed to be highly subject to alteration according to changing circumstances, the patient standing, sitting, active, or relaxed. This shortening was accompanied by alterations in the sensations in the stump. As the

phantom began to regress, so the patient became aware of sensations in the stump. These were at times actively pleasant, sometimes uncomfortable, and occasionally painful. The stump sensations did not replace the phantom sensations, but remained in some measure independent of the phantom sensations. At the same time, it may be significant that two of the patients noted that the cold feeling (to the touch) of the stumps which had been particularly unpleasant in bed, disappeared and the stumps became pleasantly warm.

Much the same applied to the sensations in the stump where these were the only source of the patient's discomfort. From being generalized throughout the stump they became localized in a small area at first and then disappeared. The suggestion is that whatever the form of the subjective experience, *i.e.*, as a phantom limb or as stump sensations, the modification that is undergone in this situation is the same. The possible inference follows that the difference between the two is not one of subjective interpretation but that they are two manifestations of the same underlying process.

In case 1, the overall pattern of change on the two sides was similar; the phantom limbs were always of the same length and had the same topographical components but they differed in details. One side might burn or itch or it might be made up of pins and needles, while the other was hardly noticeable. On the other hand, both may be similarly intense—mild or strong—and there might be tingling in the instep on one side and in a toe on the other. There is therefore no simultaneous, dual representation of the sensations from the two stumps, but there are patterns which are broadly related and yet retain some measure of independence. This is much the same relationship which obtains for the sensations from the stump and from the phantom limb.

The similarity between the regression phenomena reported in the course of this experiment and those generally described by amputees makes it unlikely that there is any difference in the underlying events, although what took place in weeks in this series of cases usually requires months or years. It is therefore suggested that the general habituation to sensory stimuli should be accorded some measure of attention when explaining the regression phenomena.

In conclusion it may be said that the sensory events which make up a phantom limb can be modified by events at a high level of central nervous organization by a process of sensory distraction. The manner of action can only be guessed at, but it is compatible with the type of theory which invokes reticular suppression of impulses at the periphery, as demonstrated by Hernández-Péon, Shcerer, and Jouvett (1956) in the case of visual suppression of

auditory stimuli in the cat, together with some form of central habituation to stimulation.

SUMMARY

Sensory distraction is a potent means of modifying sensations. An experimental situation is described in the course of which post-amputation phantom limb sensations as well as stump pain were temporarily dispersed. This occurred while sensory distractions were applied to a subject concentrating on a variety of sensory-motor tasks. The distractions avoided the afferent nervous pathways from the stump. The changes which occurred were in the apparent size and intensity and in the constituent sensations of the phantom limb. Similar alterations were found in a patient with stump pain only. The role played by the experimental variables and some theoretical implications of these results are discussed.

I wish to thank Col. E. Wheatley and Dr. T. Ritchie for their encouragement in undertaking this work, and for permission to have access to patients at the limb-fitting centre, Roehampton; Mr. L. Gillis, Dr. M. Shepherd, and Dr. D. Bennett for permission to work with patients

under their care; and Dr. M. Vitali and Miss R. Greenfield for invaluable discussions in planning the work and writing the paper. The research project is being financed by a special grant from the Ministry of Health.

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