

CUTANEOUS SENSITIVITY OF UNILATERAL ARM AMPUTEES¹

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ABSTRACT

Measures of tactual acuity and heat and pain sensitivity were obtained from 20 subjects with unilateral arm amputations. The measures were taken 3 in. above the stump and on a homologous area of the intact arm. Corresponding areas were tested in 20 matched controls. The tactual acuity of the stump was significantly greater than that of the intact limb or of either limb of the controls. For heat and pain sensitivity there was no significant difference between the stump and the intact arm. However, both arms of the amputees were significantly less sensitive to heat and pain than either arm of the controls. The results are related to current theories of cutaneous sensitivity.

IN A RECENT EXPERIMENT (Aftanas & Zubek, 1963a), it was shown that isolation of a circumscribed area of the skin of the forearm for a week results in a significant increase in tactual acuity, a change which was still present several days after the removal of the occluding cup. Temperature and pain sensitivity, on the other hand, were not affected. The purpose of the present experiment was to determine whether similar cutaneous effects would occur at the stump in unilateral arm amputees, subjects who may be viewed as possessing a limited degree of cutaneous deprivation. Several studies have already demonstrated an increased tactile sensitivity (light pressure, two-point threshold, and point localization) at the stump as compared with the homologous area of the intact limb (Haber, 1955; Katz, 1920; Teuber, Krieger, & Bender, 1949; Wilson, Wilson, & Swinyard, 1962). However, none of these has investigated temperature and pain sensitivity.

METHOD

A group of 20 unilateral traumatic amputees, 18 males and 2 females, with a mean age of 39.2 yrs., were used as experimental Ss. Eleven of the amputations were below the elbow and nine above. The mean duration of amputation was 14.3 yrs. Twenty right-handed non-amputees, matched for age, sex, and general occupational background, served as controls. Three measures of cutaneous sensitivity were used, tactual acuity and heat and pain sensitivity. Tactual acuity was determined by means of a "flicker" technique, described in detail in an earlier publication (Shewchuk & Zubek

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1960). This method utilizes an interrupted jet of air at a specified pressure whose frequency can be systematically increased until S reports a sensation of constant pressure or fusion. This threshold value is referred to as the c.f.p. or critical frequency of percussion. After a practice session, 4 experimental trials were given on each arm. All stimuli were presented in an ascending order and at a tank pressure of 30 lb. The heat and pain thresholds were measured by the Hardy, Wolff, and Goodell dolorimeter (Model ER 2-ES 2, Williamson Development Co.), using the time method. The basal setting for the instrument was 100 m. cal./cm²/sec. for a skin temperature of 34°C. A correction was made in the basal setting if the skin temperature differed from 34°C. by more than ± 0.50 degrees. Ss were asked to indicate when they experienced the first trace of warmth, and, subsequently, when they felt the first trace of pricking pain. The latency, in seconds, was measured by a Hunter Klockounter and a Standard high speed timer. Both instruments were activated by the onset of the radiant heat stimulus. After a practice session, 4 heat and 4 pain trials were given on each arm, in alternate order, with the trials separated by a 1-min. interval. In all cases the heat and pain thresholds were taken after the tactual acuity thresholds.

The three measures of cutaneous sensitivity were taken on the volar surface of the arm, 3 in. from the end of the stump, and also from a homologous skin area of the intact arm. Since most of the amputees wore prosthetic devices, an interval of 15 min. was allowed between prosthetic removal and beginning of testing. This was deemed necessary to eliminate, or at least minimize, the effects of stimulation of the stump by the prosthetic device. The three measures were also taken on corresponding arm areas of the non-amputees.

RESULTS

The mean scores of the 20 amputee and 20 non-amputee control subjects on the three measures of cutaneous sensitivity are summarized in Table I. A *t*-test analysis (two-tailed) of the data of the controls revealed that on none of the cutaneous measures was there a significant difference between the left and right arms or between the same arm as the stump *versus* the other arm. However, the tactual acuity above the stump of the amputees was significantly better than that of the homologous area of their intact arm ($p < .001$) as well as that of the arms of the controls (p 's $< .001$). Of the 20 amputees, 18 were more sensitive on the stump than on

TABLE I
CUTANEOUS SENSITIVITY OF THE ARMS OF MATCHED AMPUTEE AND NON-AMPUTEE SUBJECTS

Test	Amputees		Non-amputee controls			
	Stump	Intact	Same arm as stump	Same arm as intact	Left arm	Right arm
Acuity (c.f.p.)	23.2 (6.1)*	18.8 (4.2)	17.4 (3.5)	17.8 (3.5)	7.8 (3.6)	17.4 (3.3)
Heat (sec.)	9.2 (5.8)	8.5 (4.7)	5.2 (2.7)	4.8 (2.6)	4.7 (2.6)	5.3 (2.7)
Pain (sec.)	17.7 (5.9)	15.9 (4.2)	12.5 (2.1)	12.4 (2.2)	12.4 (2.2)	12.5 (2.1)

*The scores in parentheses are standard deviations.

the intact arm. No significant differences existed between the acuity of the intact arm and the arms of the controls.

In contrast to tactual acuity, the results of Table I suggest that the stump is less sensitive than the intact arm to heat and pain. Neither of these differences is statistically reliable, however, although the results for pain sensitivity border on significance ($.10 > p > .05$). Although the differences between the arms of the amputees are not significant, it is interesting to note that both the stump and the intact arm are significantly less sensitive to heat and pain than the arms of the controls ($p's < .01$).

DISCUSSION

The results on tactual acuity are in agreement with the work of previous investigators who have all reported a superior two-point threshold discrimination at the stump as compared with the homologous area of the intact limb or with either limb of non-amputee controls. This increase in sensitivity to touch also occurs in normal subjects after experimental occlusion of a circumscribed area of the forearm (Aftanas & Zubek, 1963a, 1963b). This similarity might be expected since in both cases a reduced sensory input to the forearm area of the somesthetic cortex probably occurs. Although it is generally agreed that the tactile sensitivity of the stump is heightened, the results, in so far as the intact limb is concerned, are contradictory. Recently, Wilson, *et al.* (1962) reported that the tactile sensitivity of both the amputated and the intact limbs is greater than that of either limb of non-amputees. However, neither in the present study nor in that of Haber (1955) was there any evidence of a heightened sensitivity of the intact limb. This discrepancy is probably due to differences in sample. Wilson, *et al.* employed child congenital amputees whereas the other studies used adult traumatic amputees.

The increased tactile sensitivity of the stump has generally been attributed to central rather than to peripheral mechanisms. Of the various central theories postulated (Haber, 1955; Teuber, Krieger, & Bender, 1949; Wilson, Wilson & Swinyard, 1962), the "differential input" hypothesis of Wilson, *et al.* is favoured as an explanation of our results on tactual acuity. According to this theory the loss of a limb results in a reduced input to the somesthetic cortex. Neural impulses arising from stimulation of the stump now enter the somesthetic cortex against a reduced background level of nervous activity as compared with the undiminished level on the contralateral side. Therefore, an intermittent

tactile stimulus applied to the stump will be more readily discriminated than an equivalent stimulus to the homologous area of the intact limb.

Although tactual acuity is increased, the results indicate that a unilateral arm amputation serves to decrease the heat and pain sensitivity of both arms. Furthermore, some exploratory research at this laboratory strongly suggests that this decreased sensitivity may extend to the legs. These widespread effects are undoubtedly mediated by central mechanisms. These results, however, are at variance with those of Korin, *et al.* (1963) who reported an increase in pain sensitivity in a group of unilateral leg amputees. This discrepancy may be due partly to their use of recent amputees and the measurement of deep tissue rather than superficial pain. A more important variable, however, is their use of a mechanical deformation method for producing pain. Since amputees are known to be more sensitive to pressure, a deformation method is probably not appropriate for use with amputees. The possibility exists that they may have reacted more to pressure than to pain. If they did, an increase in sensitivity might be expected. Our results, however, do confirm a recent theory of pain perception postulated by Melzack and Wall (1962). These investigators state that "a large number of active fibres might well be one of the conditions for producing the central patterns that may evoke pain." Furthermore, "any procedure that cuts down the number of active fibres, including tractotomies, sympathectomy, and analgesic drugs would serve to reduce pain perception and response." Since amputation involves a reduction in the number of fibres in the limb and thus probably affects the central patterns of impulses, a decrease in pain sensitivity might be expected. A similar explanation may apply to heat sensitivity especially since the same skin area was tested and with the same radiant heat technique. Furthermore, the fact that the C-fibres of the skin seem to possess both thermal and pain mediating functions may also be relevant (Douglas & Rich's, 1957). This theory also accounts for our earlier finding that heat and pain sensitivity are not affected by temporary experimental occlusion of a limb. The procedure does not reduce the number of fibres and hence does not affect the central patterns of impulses.

Résumé

Etude de l'acuité tactile et de la sensibilité thermique et algique chez 20 sujets amputés d'un bras. Les mesures sont prises à 3 po. au-dessus du moignon et sur la région homologue du bras intact. Les mêmes mesures sont prises sur les régions anatomiques correspondantes de vingt sujets de contrôle. L'acuité tactile du moignon s'avère significativement plus grande que celle du membre intact ou de chacun des membres des sujets de contrôle. Quant à la sensibilité thermique et algique, on

n'observe pas de différence significative entre le moignon et le bras intact. Toutefois, les deux bras des amputés sont significativement moins sensibles à la chaleur et à la douleur que chacun des bras des sujets de contrôle. Les résultats sont examinés à la lumière des théories actuelles sur la sensibilité cutanée.

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