Anthropological Review • Vol 61, pp. 3–30, Poznań 1998

Studying tactile sensitivity – population approach*

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Abstract

The purpose of this study was to investigate the basic characteristics of threshold tactile sensitivity in man. The study involved the examination of over 1500 people aged from 7 to 85 years, including 300 adult subjects aged over 21 years. 55% of the population under study were females. Digital pulps of the subjects were examined with the Semmes-Weinstein monofilaments aesthesiometer. The variability range of touch sensation was determined and the mean value and standard deviations of tactile threshold in sex and age classes were calculated. The relationship of touch with age, sex, body mass and height and with social and economic factors was investigated by means of the analysis of variance. An attempt to assess the inheritability of tactile sensitivity was made. Finally, the adaptive meaning of the sense of touch in man was discussed.

Agnieszka Kozlowska 1998; *Anthropological Review*, vol. 61, Poznań 1998, pp. 3–30, figs 18, tables 11. ISBN 83-86969-35-0, ISSN 0033-2003

The history and significance of the research on the sense of touch

First studies on the sense of touch were undertaken in the early 19th century. According to Sir Sidney Weinstein, one of the leading figures in this field of research, the earliest known scientific report on tactile sensitivity in man are the results of Weber's observations published in *Muller's Archives* in 1835 (!) [WEINSTEIN 1968]. Weber tested the two-point tactile threshold. His report fails to give the data on the age and sex of the subjects (subject?), on the side of the body or the size of the sample. It is most likely did not presume that these variables could impact the result of the test. In spite of all these shortcomings, his observations on the lack of uniformity of tactile sensitivity (he found out it was different in different parts of the body) proved correct. Weinstein noted that Weber's drawing illustrating the two-point discrimination test results shows a distinct proximal-distal sensitivity gradient: sensitivity increases starting from the trunk towards the distal parts of the extremities. Later studies indicated also certain differentiation of tactile sensitivity depending on the side of the body. The left side turned out to be more sensitive, which was at that time associated with the predominance of the left cerebral hemisphere. At the break of the 1950s and 1960s researchers such as L. Ghent, J. Semmes, S. Weinstein, H. L. Teuber, E. A. Sersen [KENSHALO 1968] described and attempted to explain the phenomenon of lateralisation of tactile

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* The studies were financed from the Committee for Scientific Research grant (KBN) No. 6P04C 025/10

sensitivity. At that time the topography of the primary somesthetic cortex was being explored. As a result, a hypothesis was set forth, according to which parts of the body, more sensitive than its other areas, such as lips or hands, have more extensive cerebral cortex representations than the less sensitive areas.

In early 1960s Sidney Weinstein decided to test this hypothesis experimentally and to verify the validity of some other convictions concerning the tactile sensitivity of man, such as the conviction about the higher sensitivity of the left side of the human body. He subjected to scrupulous scrutiny 24 dextromanual men and 24 dextromanual women. He described the results of his studies in the chapter on "Intensive and extensive aspects of tactile sensitivity as a function of body part, sex and laterality" in a widely known and popular book by KENSHALO [1968] *The Skin Senses*. Up to these days his studies are one of the basic source of knowledge on tactile sensitivity in man.

Weinstein's subjects were adults, mainly students. Their tactile pressure threshold (the so-called intensive investigation of touch), and two-point discrimination and point localisation (the so-called extensive or spatial investigation of touch) were measured in different parts of the body, symmetrically at its both sides. The results of the analysis of variance indicated that the sex of the subject produced an effect solely on their threshold sensitivity (women turned out to be more sensitive in this test). In all the types of measurements, results clearly depended on the studied area of the body, while in some of them also the side of the body was of certain importance. In the threshold test, the face proved to be the most sensitive in both sexes. The trunk and upper extremities (fingers) came next. In the two-point discrimination test, fingers were the most sensitive part of the body, with the face and feet positioned at the second and third place, respectively. In the point localisation test, fingers, the face and great toe, in this order, showed the greatest sensitivity.

The previously mentioned sensitivity gradient was also partly confirmed. The more distal location of a given area of the body, the higher its sensitivity. Fingers were more sensitive than the palm, which, in turn, was more sensitive than the forearm, etc. However, this regularity was observed only in extensive studies – in two-point discrimination and localisation tests. The threshold test did not confirm the gradient hypothesis. Similarly, the conviction about higher sensitivity of the left part of the body did not find corroboration in the results of the tests. The hypothesis on the positive correlation between the size of the primary cerebral cortex representations of particular parts of the body and their sensitivity to touch was corroborated for the two-point discrimination and localisation tests, but not for the threshold measurement.

Over the next 30 years there were conducted more such studies, e.g. research by WEINSTEIN [1977], THORNBURY *ET AL.* [1981], DELLON AND KALLMAN [1983], KENSHALO [1986], BELL-KROTOSKI *ET AL.* [1993], GRUENER & DYCK [1994], HAGE *ET AL.* [1995], KETS *ET AL.* [1996], as well as numerous clinical studies, mainly of diagnostic nature, such as research by BELL-KROTOSKI, TOMANCIK [1987], AL-QATTAN [1995], MIELKE *ET AL.* [1996], DELLON *ET AL.* [1993], LIPTON *ET AL.* [1990], PLATZ [1996], CASELLI [1991], KING [1997].

Numerous new models of aesthesiometers and other equipment for measuring tactile sensitivity became available at that time. Several researchers ventured investigations on a larger than usual scale, involving tens of subjects. These studies resulted in the confirmation of the relationship of the sense of touch with the sex of subjects and in the discovery of a link between tactile threshold and the age of the subjects tested [WEINSTEIN 1993, BELL-KROTOSKI *ET AL.* 1993, THORNBURY 1981].

All in all, these studies did not contribute a lot the existing body of data. Similarly, they failed to resolve numerous doubts on the structural background of tactile sensitivity and perception [BOŻIŁOW 1986]. These problems were taken over by physiologists and scientists in related fields of study [JOHANSON, VALLABO 1979, BURTON, SINCLAIR 1996].

The doubts concerning the morphological background of tactile sensations are a serious obstacle in the progress of anthropological studies. This is so, because they restrict the field of study. Nevertheless, one can imagine populational studies of tactile threshold, taking into account the behaviour of this trait depending on selected biological and social factors.

Investigating the adaptive function of touch sensation one can use a living human population and carry out the analysis of variability of a trait, searching for factors modifying this variability. We can only speculate on whether the same factors operated in the past, whether variability was similar and what was its significance for the selection processes. Population studies form a basis, become a starting point for such discussions. For this reason I decided to supplement the normative studies initiated by Weinstein, organising population research on the touch sensitivity.

Assumptions and purpose of the study

The general purpose of the study was to interpret tactile sensitivity (tactile threshold) of man with regard to its adaptive significance. This objective could be achieved only through basic population studies involving testing the tactile sensitivity variability range and its distribution in the population under study.

Upon the analysis of the literature and having conducted a pilot study on a group of 600 children and youths I singled out the following factors that could contribute to the variability of tactile threshold:

- biological factors, such as age, height and mass of the body, state of health, thickness of epidermis measured by occupation;
- mental factors, such as intelligence measured with school marks in children and with the level of education in adults, and care received from parents;
- social factors, such as the level of education of the subjects' parents, number of children in the family, material status of the family.

I assumed that an in-depth analysis of variability combined with the assessment of the eco-sensitivity of the trait and of inheritability index, would be a good basis for the discussion on the adaptive meaning of tactile sensitivity. My study covered 1553 individuals aged from 7 to 85 years; approximately 55% of them were female individuals, 45% – male individuals. Majority of the subjects – over 1250 individuals – were children and youths, aged from 7 to 21 years. Out of the total number of subjects, 300 were adults, the number including approximately 56% of women.

Majority of the studied population was inhabitants of the commune of Barciany (mostly pupils of primary schools in Barciany, Winda and Krelikejmy), others were students of the Grammar School No. 6 in Poznań and children from the orphanage at Pamiątkowa Street also in Poznań.

The data being the basis for assigning subjects to a certain category of a given variable were obtained from the head masters of the schools, form masters, from school files and pupils' medical records. A school nurse working in the communal health centre and in the primary schools situated within the commune participated in the study, which facilitated access to the data on social and economic situation of the subjects and on the state of their health. This enabled me to eliminate from the sample persons suffering from diseases known to considerably disturb the sensation of touch, such as peripheral neuropathies (e.g. in diabetes, carpal tunnel syndrome), or fractures [WEINSTEIN *ET AL.* 1996, KUMAR *ET AL.*, 1991]). The group of adult subjects was made up of local administration clerks, labourers and representatives of other occupations.

From among several options of tactile sensitivity tests I chose the measurement of tactile pressure threshold being the most basic and explicitly defined aspect of touch sensation. In truth, tactile threshold is fairly distant from the common understanding of the trait but it complies with its biological definition: in the threshold pressure investigations a stimulus means delicate, mechanical deformation of skin.

Measuring instrument chosen for this study, the Semmes-Weinstein aesthesiometer, is a simple apparatus. The criteria of the reception of the stimulus are known in advance and clear: the subject either senses the touch or not. Owing to the high repeatability of measurements taken with the apparatus, its simplicity of operation and reasonable price, the S-W aesthesiometer is commonly used for threshold pressure tests performed in university hospitals and scientific institutions.

Due to considerable differences between tactile thresholds measured at different areas of the skin, I decided to select a single easily accessible and sensitive area, if possible, susceptible to environmental changes (such as cultural changes related to the subject's occupation). These requirements were satisfied by digital pulps of the hand, used daily for the exploration of the environment and considered by some to be the proper touch organs.

Threshold sensitivity – the dependent variable

The variable investigated in this work was the threshold sensitivity to touch understood as constant touch or pressure. It is most likely that irritation of the skin with the nylon fibres of the aesthesiometer stimulates Merkel's tactile discs located in the bottom layers of epidermis. The plates are seated at the ends of large, slowly adapting, myelin covered fibres, classed as A_{beta} type fibre [LEVIN *ET AL.* 1978]. Meissner's corpuscles located in the papilla of the dermis react rather to dynamic stimuli, such as moving touch [DELLON, KALLMAN 1983; GRUENER, DYCK 1994]. There are scientists who disagree with this view, maintaining that skin deformation rather than a single, concrete type of receptors, stimulates receptors of various types (including the temperature ones), and that the resulting sensation of touch is a sum of them all [RUTKOWSKI 1965].

Digital pulps have very high density of tactile receptors (approximately 100-140/cm^2). Also, they are covered with epidermis of varying thickness. Next to the facial skin, digital pulps are the most sensitive areas of the human body. This may be due to the high density of tactile receptors correlating with the size of the cerebral cortex representation: the higher the density of receptors within a given area of the skin, the larger the representation area in the cortex. Regions of the body showing little sensitivity to touch have low density of receptors and, at the same time, small cerebral cortex representation [TRACZYK 1989].

The threshold tactile sensitivity of an individual was measured on the digital pulps of the little finger and the index finger of the left hand. The fingers were chosen taking into account the innervation of the palm side of the hand (see Figs. 1, 2), and the results of the pilot studies indicating that particular fingers do not differ with respect to their sensitivity [KOZŁOWSKA 1993]. The choice of the side of the body was determined by the literature data indicating higher sensitivity of the left hand [WEINSTEIN 1963, 1968]. Only the little finger material was selected for analysis.

The distribution of the tactile threshold values (Fig. 3) for the little finger was strongly skew, in spite of a normalisation procedure applied by the manufacturer of the aesthesiometer [DELLON *ET AL.* 1993a, b]. However, we should remember, that Weinstein, like the majority of his followers investigating threshold tactile sensitivity, based his research on a distribution made up of sensitivity measurements taken in various places of the body, while in the present work measurements were taken exclusively from

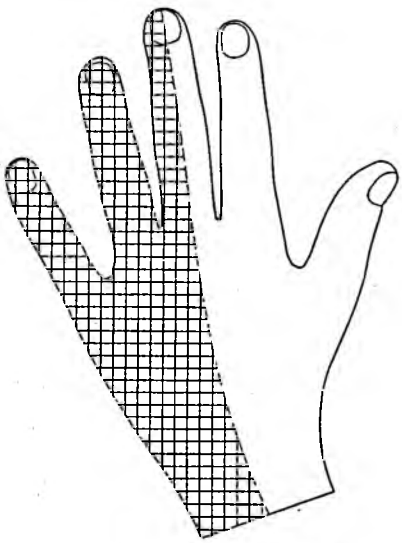

Fig. 1. Innervation of the hand. Dorsal surface of the left hand. Grated field – radial nerve, rest – ulnar nerve

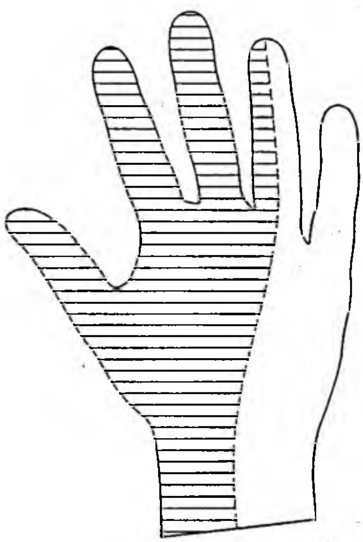

Fig. 2. Innervation of the hand. Palmar surface of the left hand. Lined field – median nerve, rest – ulnar nerve

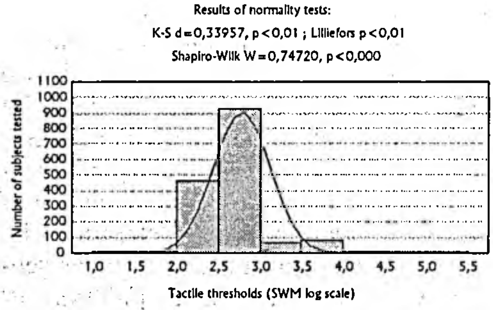

Fig. 3. Distribution of light pressure thresholds (SWM log scale) for the 1553 little fingers and results of normality test for the distribution

a single, selected area (digital pulps). The fixed area of measurements made it possible to capture inter-individual differentiation of tactile sensitivity. Owing to the considerable size of the sample the result is likely to reflect the reality – majority of the individuals show the level of sensitivity close to the left edge of the distribution, i.e. higher than the population mean.

Factors that may influence the sense of touch – independent variables

Age. The phenomenon of „weakening" of the senses with age is well known. Vision, hearing and sensitivity to touch deteriorate with age. VERILLO [1996], who studied the changes in the threshold of vibration, taking place with age noted statistically significant lowering of tactile sensitivity in aged persons.

Contrary to the appearances, these changes are not obvious. With age, human skin becomes increasingly thinner, which implies that the sense of touch (similarly to the sense of temperature) could be an exception to the general tendency of the senses to weaken in the process of ageing [THORNBURY, MISTRETTA 1981]. Furthermore, the relationship between the thickness of the skin and the tactile threshold level is still unclear: the most sensitive areas of the body, such as the face and digital pulps differ considerably with regard to the thickness of the skin.

When grouping the subjects into age classes, I took into account their number and the course of their ontogeny. Since the size of the sample was large enough, I isolated narrow age categories (one-year interval) for peripubescence and wide age categories within the adult group (Fig. 4).

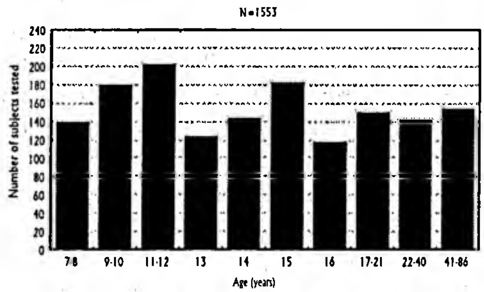

Fig. 4. Age distribution among study subjects

Sex. According to the authors of the book *Brain Sex. The Real Differences Between Men and Women* [MOIR, JESSEL 1993], differences between men and women are manifested also in the make-up and the function of the nervous system. Quoting the works by Garai and Scheinfield, as well as by McGuinness, they maintain that women are more sensitive to touch than men. They claim the difference to be so great that the variability ranges for both sexes hardly ever overlap. Unfortunately, the book does not specify which exactly aspect of touch sensation was measured and in by what method. Women's skin is thinner than men's skin. Their occupations (at least in our culture) involve more light and precise works. If the sensitivity of females were determined mainly by the cultural factor, higher sensitivity could be observed already in small girls, as the authors of *Brain Sex* suggest referring to McGuinness' study. However, if a biological factor (e.g. a hormonal one) is responsible for the increased sensitivity of women the differences should appear only in adults, or in postpubescent children.

Body height and mass. Dimensions of the body may affect tactile sensitivity in a variety of ways. Firstly, with the fixed number of receptors, increased height and mass of the body results in the lower density of receptors per surface area unit. Secondly, body height and mass, being highly eco-sensitive traits reflecting the level of biological development may also reflect the effect of numerous environmental factors modifying a given feature. Having assumed that higher sensitivity to touch is related to higher density of receptors, the number of which is established in perinatal period and declines with age, obese children should be less sensitive than their slimmer peers.

Since the height and mass of the body are age and sex-related traits, I carried out all the calculations of these variables separately for each sex on sets standardised according to age. For the purposes of the analysis of variance, I created 3 classes for both variables. From the standardised sets I isolated individuals falling between the range of +0.5 and –0.5 of standard deviation. They formed a middle class. The two extreme categories including individuals with the values of above 0.5 of standard deviation and below 0.5 of standard deviation formed two further categories. In order to capture the effect of body dimensions on the tactile sensitivity variance, I calculated the BMI (*Body Mass Index*) according to the formula: mass [kg]/(height [m])^2. I standardised the resulting index in sex and age classes, and subsequently categorised it similarly to the body height and mass.

Occupation. It is a common belief that the sensation of touch depends upon the thickness (hardness) of the skin and epidermis. Unfortunately, there are only few works on the relationship between tactile sensitivity and skin thickness. Handbook *The Skin Senses* [KENSHALO 1968] gives an example of the increased sensitivity in women employed in spinning rooms of a cotton mill. As a result of their occupation they developed extremely thin digital pulp epidermis. However, this isolated example cannot be treated as a proof for the existence of such a dependency, especially that the above-mentioned handbook describes also counterexamples.

Table 1 shows the criteria applied in this work for grouping subjects into categories, depending on the presumed effect of occupation on the thickness of epidermis.

Education. Education is the best indicator of the social status. At least it is so in Poland [KACZMAREK 1995]. It is also an easily determined, explicit and precise factor. In Poland, the level of education is a feature of small mobility. It, so to say, "descends through generations" This trend is very strong and persistent, in spite of attempts to counteract it. Today, only every 80-th university student comes from a farming family. Thus, education reflects not only intelligence (it would be unreasonable to think that the Poles with rural background are less intelligent than their countrymen born in urban areas) and the financial status of an individual (of his/her family)

Table 1. Variable: *Occupation* in categories. Criteria of classification

Category	Characteristics of category	Occupations included
1	light indoor works, e.g. office works; precise works	an official in charge of administration; a shop attendant; a social administrator; a house-keeper; an accountant; a librarian; a tailor; a steward; out-of-work women
2	light outdoor works; light indoor labour works	a car mechanic; a caretaker; a driver; an upholsterer; a carpenter; a cook; a store-keeper; a baker; a cook assistant; out-of-work men; pensioners
3	hard labour indoor works; light labour outdoor works	a turner; a labour worker, pensioners who used to work very hard for a long time
4	hard labour outdoor works; very hard labour indoor works	a tractor-driver; a farmer; a milkmaid

but also, and maybe even primarily, certain model of social behaviour.

I split the *education* variable into *education of the subjects* (applicable to adult subjects) and *education of the parents* (applicable to children and adolescents).

Classifying parents' education, I adopted the mother's education as a criterion of assignment to particular groups. When the level of father's education was higher by more than one category than the level of mother's education I averaged the data. My adoption of this mode of classification of this variable stems from the results of Polish anthropological studies of the recent decades, proving the decisive influence of the mother's education on the biological development of her children [WALISZKO *ET AL.* 1987].

Material status. Similarly to the *education* variable, *material status* is an important component of the social status. In this work, the material status of the subjects or, in the case of children, of their families was established by means of interviews. Due to the fact, that in the region under study the unemployment rate was high, and the unemployed lived either on unemployment benefit or on the assistance of their relatives, I tried to establish the living condition of the families rather than the level of their income. Families living on social benefit, inhabiting extremely modest dwellings (such as a single-room flat for a family consisting of several people), or those with children receiving free meals at school, which could not afford some school handbooks or basic clothes for children were considered poor or very poor and classified in category three. Families whose status, compared with other families, was average (at least one of the parents had a job, they lived in a several-room flat providing minimum privacy for the children (separate beds, room for study) and for other members of the family, were classified in category two. Families whose living conditions and employment situation were better than average in this region of Poland and labelled as good (a flat the with density of at most 2 people per room, frequently a car, working parents) or very good (a house or a large apartment, a car, high income) were classified as category one families.

Number of children in the family. This variable was chosen due to its significant effect on the social status. Apart from that, the information on the number of children in the family, in the case of similar dwelling conditions, may be an indication of the density of inhabitants in a dwelling, which probably produces an effect on the frequency of tactile communication. In spite of the fact, that the material status of families with many children is frequently worse than the status of other families, and that parents have less time to devote to each child, social development of children coming from these families may be better than that of single children. This may be ascribed to the fact that, customarily elder siblings take over certain parental (caretaking) functions. I isolated 4 categories of the variable, containing more or less the same number of subjects. These were: families with 1–2 children, 3 children, 4–5 children, and 6–10 children.

Parental care. Data that enabled me to split this variable into classes were gathered by way of interviews with form masters, head masters, and the district nurse. Children were grouped into classes. The first class included children receiving good parental care – where parents took good care of their child, regularly attended parents-teacher meetings, participated in school events and ensured the child a good rest during holidays. The second class grouped children receiving average care. The third group included slightly neglected children or children from single-parent families (brought up by one of the parents or by grandparents). The fourth category grouped the children from pathological families.

School marks. The effectiveness of information processing in people can be measured in a variety of ways. In the case of school children, school results (average marks) may be one of the indicators of the intelligence. Education may be considered an indicator of intellectual skills in adults, especially in the lower categories of the variable.

Average marks were calculated for almost 120 pupils. These were all the tested in 1993 or 1996 pupils of the Primary School in Barciany, who in the year of study were attending at least the fifth form. Pupils whose average mark (in scale from 1 to 6) was above 3.75 (out of 5) were classified as category one, pupils with the average mark below 3.0 and the ones attending compensation classes made up category three. All other children formed category two.

The above variables were supplemented with the *menarche* variable. It was treated as an auxiliary trait helpful in the assessment of the age of puberty and of the subjects' pace of development. It served as an indicator of puberty and a means for the explanation of tactile sensitivity differences between sexes. If the differences result from the increased quantities of female sex hormones in adult women in relation to girls, the comparison of menstruating girls with these that have not started menstruating yet should provide conclusive evidence.

Analysis of results

Prior to the main analysis I checked whether there is a significant difference between the sensitivity of the small and index finger (both fingers are innervated by separate nerves). I also measured the repeatability of tactile sensitivity measurements (Table 2). In Table 2 and other tables representing the descriptive statistics of the variables, I used the following symbols: N – numerical force, m – mean, me – median, v – variance, d – standard deviation, e – measuring error, S – skewness, K – kurtosis.

The results shown in the table indicate high repeatability of measurements (measuring errors for the little and index fingers are 7%). They also show there are no statistically significant differences between the sensitivity of the small finger and index finger. For this reason, having analysed the distributions of tac-

Table 2. Pearson correlation coefficients and error of measurements for the light pressure thresholds of little finger and forefinger. Significant results are marked with asterisk

Test	Tactile pressure thresholds – comparison between little finger and forefinger	Estimation of repeatability of measurements – comparison between two measurements of each individual N=17	
	N=1553	Little finger	Forefinger
Pearson correlation coefficient	r=0.87* t=69.62* p=0.00*	r=0.82* t=5.* p=0.000062*	r=0.86* t=6.* p=0.000011*
m, v, sd of differences in measurements		*m*= -0.0459 *v*=0.0358 *sd*=0.1892	*m*=0.0229 *v*=0.0280 *sd*=0.1672

tile sensitivity measured in various units, I have chosen the values expressed in SWM units (aesthesiometer monofilament markings) for further analysis. Since, tactile sensitivities of the little finger and the index finger showed great similarity (similar mean values), the values of thresholds for both of the fingers were strongly correlated and had very similar distributions. For my studies I chose the little finger, as the one less exposed to the modifying effect of the environment (for instance, for the pressure occurring in the course of physical work).

Descriptive statistics of the dependent variable

Basic statistics for the dependent variable, being tactile sensitivity measured on digital pulps, expressed in three different units that can be read on the aesthesiometer are shown in Table 3. The units mentioned are SWM, F – gramme, and P – g/mm^2.

Since, I chose only one finger for my investigation, I calculated the basic statistics of the dependent variable in sex and age classes, that is in classes in which I had standardised the *tactile sensitivity* variable only for the little finger. The results are shown in Table 4.

Relationships between factors – independent variables

As could be expected on the basis of the earlier anthropological studies, such as KOZŁOWSKA [1993], KACZMAREK [1995], the majority of the selected factors are interrelated. Tables 5 and 6 contain estimations of this co-variability by means of the χ^2 test and Goralski's coefficient of the strength of relationship [STRZAŁKO, ROŻNOWSKI 1992] that may be used for comparing pairs of variables characterised with a different number of categories.

With the pairs of variables describing children and adolescents I dealt similarly to the variables concerning the adult subjects. Chi-square test results, as well as the numerical force of the pairs and the Goralski's coefficient of the strength of relationship for the group of children are shown in Table 6.

The data in Table 6 indicate that in the group of children only the *sex* variable can be considered an independent factor – all other factors are related in a significant way with at least three other factors. With the exception of the relationships of *sex* and *parental care* with age, which in this case are likely to be an artefact resulting from the age distribution in the collected material, the interrelations that occurred between the variables can be rated as fairly common and they can be easily explained.

In the situation when independent variables are in fact dependent, interrelated in a variety of ways, it is more appropri-

Table 3. Descriptive statistics of tactile threshold sensitivity (N=1553)

Variable	Units of measurements*	*m*	*me*	*v*	*sd*	*e*	*S*	*K*
Little finger	SWM log scale	2.78	2.83	0.12	0.34	0.01	1.66	5.21
	Calculated force (g)	0.108	0.068	0.151	0.39	0.010	21.027	566.980
	Calculated stress (g/mm^2)	5.79	4.86	22.03	4.69	0.12	5.75	51.47
Forefinger	SWM log scale	2.80	2.83	0.12	0.34	0.01	1.42	3.42
	Calculated force (g)	0.108	0.068	0.062	0.250	0.006	11.732	199.000
	Calculated stress (g/mm^2)	5.95	4.86	19.51	4.42	0.11	4.55	13.82

* Adapted from LEWIN *ET AL.* [1977] and DELLON *ET AL.* [1993]

Table 4. Tactile threshold pressure. Means and standard deviations in groups of age and sex

Age group	Females				Males			
	N	*m*	*sd*	*me*	*N*	*m*	*sd*	*me*
7	68	2.57	0.298	2.44	74	2.65	0.209	2.83
9	94	2.57	0.220	2.44	87	2.65	0.208	2.83
11	97	2.57	0.237	2.44	107	2.68	0.255	2.83
13	60	2.65	0.199	2.83	66	2.75	0.219	2.83
14	80	2.79	0.260	2.83	66	2.84	0.310	2.83
15	102	2.78	0.174	2.83	82	2.83	0.150	2.83
16	67	2.80	0.259	2.83	52	2.90	0.231	2.83
18	112	2.75	0.199	2.83	40	2.87	0.302	2.83
30	86	2.75	0.248	2.83	57	2.90	0.291	2.83
60	82	3.18	0.538	2.83	74	3.42	0.495	3.61
Total	**848**	**2.74**	**0.323**		**705**	**2.83**	**0.351**	

Table 5. Chi-square test for variables for adults

Variable	Age	Sex	Education	Material status	Occupation
Sex	χ^2=1.73 p=0.18 N=299				
Education	χ^2=61.67* p=0.00000* N=300 r_p=0.45	χ^2=19.09* p=0.00007* N=300 r_p=0.35			
Material status	χ^2=0.67 p=0.7 N=281	χ^2=1.22 p=0.54 N=986	χ^2=31.57* p=0.00000* N=286 r_p=0.39		
Occupation	χ_2=41.07* p=0.04* N=303 r_p=0.40	χ^2=60.44* p=0.00000* N=303 r_p=0.58	χ^2=132.9* p=0.00000* N=300 r_p=0.68	χ^2=33.77* p=0.00001* N=288 r_p=0.40	
Health	χ^2=12.53 p=0.99 N=297	χ^2=8.35* p=0.04* N=297 r_p=0.23	χ^2=20.69* p=0.002* N=292 r_p=0.32	χ^2=14.26* p=0.03* N=285 r_p=0.27	χ^2=18.17* p=0.03* N=295 r_p=0.28

r_p – Góralski's coefficient of strength of relationship

ate to carry out factor analysis or multi-way variance analysis. Nevertheless, I decided that, one-way analysis could, if carried out first, be a source of useful information, regardless of the fact it describes a hypothetical situation, meaning a situation in which selected variables would act on tactile sensitivity under investigation independently from one another.

I carried out the analysis of variance and obtained very distinct results. Almost all factors, in statistically highly significant way (significance level at 0.001 and higher) produced an effect on the dependent variable.

A wide range of variability and cases

Table 6. Chi-square test for children (individuals aged under 21)

Variables	Age	Sex	BMI	Education of parents	Material status of the family	Number of children in the family	Parental care
Sex	χ^2=32.08* p=0.000* N=1254 r_p=0.22						
BMI	χ^2=12.28 p=0.83 N=1221	χ^2=3.10 p=0.21 N=1221					
Education of parents	χ^2=40.72* p=0.002* N=654 r_p=0.30	χ^2=1.45 p=0.48 N=654	χ^2=3.83 p=0.43 N=648				
Material status of the family	χ^2=35.31* p=0.001* N=711 r_p=0.27	χ^2=1.21 p=0.54 N=986	χ^2=14.28* p=0.006* N=689 r_p=0.17	χ^2=153.14* p=0.000* N=652 r_p=0.53			
Number of children in the family	χ^2=21.44 p=0.77 N=704	χ^2=1.06 p=0.66 N=704	χ^2=10.64 p=0.1 N=696	χ^2=72.1* p=0.000* N=652 r_p=0.39	χ^2=93.86* p=0.000* N=685 r_p=0.43		
Parental care	χ^2=106.18* p=0.000* N=698 r_p=0.42	χ^2=1.73 p=0.63 N=698	χ^2=18.28* p=0.006* N=691 r_p=0.20	χ^2=177.76 p=0.000* N=651 r_p=0.57	χ^2=349.41* p=0.000* N=691 r_p=0.71	χ^2=41.02* p=0.000* N=685 r_p=0.29	
School marks	χ^2=21.70 p=0.24 N=117	χ^2=4.17 p=0.12 N=117	χ^2=3.33 p=0.5 N=115	χ^2=47.51* p=0.000* N=116 r_p= 0.66	χ^2=28.98* p=0.000* N=117 r_p=0.55	χ^2=25.37* p=0.000* N=117 r_p=0.52	χ^2=40.05* p=0.000* N=117 r_p=0.62

r_p – Góralski's coefficient of strength of relationship

of the lack of uniformity of the variance of variables in particular categories made me modify the set. I repeated the one-way variance analysis on a set standardised according to age and sex (I made the previous analysis separately for each sex, on the set standardised according to age only). Due to the fact that I extended standardisation to cover also the sex variable, in the course of the analysis of particular variables I obtained higher numerical forces in classes. When re-standardising I increased the number of age classes within the adult group, which allowed me for more precise investigation of the changes of tactile sensitivity with age. Apart from that, with the use of the Q-Dixon test I excluded the individuals with extreme values of tactile threshold [STRZAŁKO, ROŻNOWSKI 1992]. The basic statistics for the modified set are shown in Tables 7 and 8.

Subsequently, I supplemented the variables making up the set with menarche. This variable is used for the comparison of the significance of the differences in tactile sensitivity between girls with differentiated level of female hormones in blood, that is girls that had experienced the menarche prior to the investigation and those that were still before the first menstrual period.

The analysis of variance on the modified set was carried out only for the variables satisfying the requirement of the uniformity of variances; the results where F value was statistically insignificant ($\alpha > 0,05$) were not interpreted.

Table 7. Descriptive statistics of tactile threshold pressure. Modified sample for N = 1544

Variable	Unit of measurement	*m*	*me*	*v*	*sd*	*e*	*S*	*K*
Little finger	SWM	2.78	2.83	0.11	0.33	0.01	1.71	5.50
	F (g)	0.106	0.068	0.150	0.38	0.009	21.291	576.030
	P(g/mm^2)	5.74	4.86	21.24	4.61	0.12	5.99	55.552
Forefinger	SWM	2.80	2.83	0.11	0.34	0.01	1.45	3.51
	F (g)	0.106	0.068	0.061	0.247	0.006	12.076	207.964
	P(g/mm^2)	5.90	4.86	18.81	4.34	0.11	4.69	38.43

Table 8. Tactile threshold pressure for modified sample

Age group	Females				Males			
	N	*m*	*sd*	*me*	N	*m*	*sd*	*me*
7	66	2.53	0.201	2.44	74	2.65	0.209	2.83
9	94	2.57	0.220	2.44	87	2.65	0.208	2.83
11	96	2.56	0.213	2.44	107	2.68	0.255	2.83
13	60	2.65	0.199	2.83	65	2.74	0.173	2.83
14	80	2.79	0.260	2.83	65	2.86	0.274	2.83
15	102	2.78	0.174	2.83	81	2.83	0.150	2.83
16	66	2.78	0.207	2.83	51	2.91	0.224	2.83
18	111	2.74	0.182	2.83	40	2.87	0.302	2.83
25	24	2.66	0.201	2.83	26	2.84	0.240	2.83
35	62	2.79	0.258	2.83	31	2.95	0.324	2.83
43	28	2.89	0.334	2.83	23	3.11	0.398	2.83
53	31	3.15	0.483	2.83	26	3.38	0.479	3.61
73	23	3.58	0.582	3.61	25	3.74	0.402	3.84
Total	843	2.73	0.314		701	2.83	0.351	

I started the analysis of variance with checking the *sex* and *age* variables. In accordance with the results obtained in earlier studies, quoted in numerous publications, these variables significantly differentiated the tactile sensitivity of the subjects. Fig. 5 shows the results of the analysis of variance by age. Here, clear differences can be observed in the tactile sensitivity of both sexes. One possible explanation of this result is the fact that women's skin is thinner, which, in turn, is conditioned hormonally. In order to verify this concept, I subjected to the analysis the girls that menstruated in the year of study and those before the first menstrual period. The F-test value in the analysis of variance ($F = 0.25$) did not allow for the rejection of the null hypothesis according to which the level of sex hormones in man has no effect on the tactile sensitivity of man.

The effect of the age factor on tactile sensitivity of man is equally evident. In spite of the fact that the curves of tactile sensitivity are not identical (Fig. 6 and 7) for women and for men, they are climbing for both sexes, with a characteristic protuberance in the peripubescent period. In the age categories of 43 years for women and 35 years for men the first leap illustrating the decline of sensitivity to touch may be observed. In each subsequent age category the weakening of the sense of touch is increasingly greater.

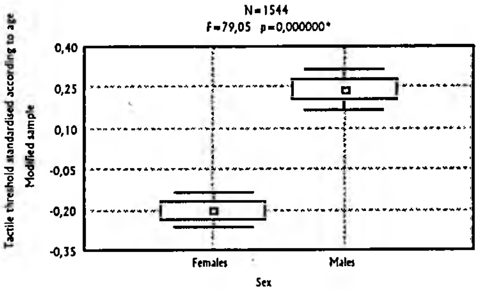

Fig. 5. Analysis of variance of tactile threshold according to sex

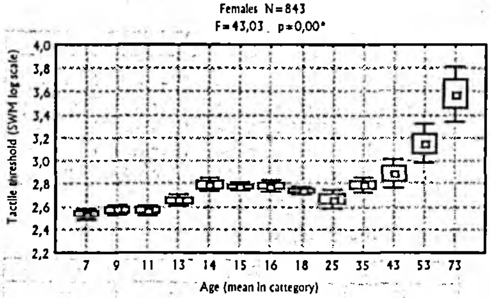

Fig. 6. Analysis of variance of tactile thresholds according to age, for females

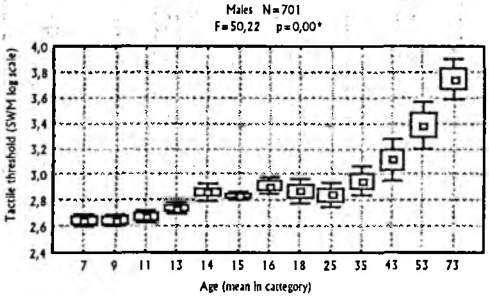

Fig. 7. Analysis of variance of tactile thresholds according to age, for males

Summing up the results obtained in the analysis of variance (Tab. 9), we can state that *age*, *sex*, *body mass index*, *school achievements*, *parental care*, *number of children in the family* as well as *material status*, *education* and *state of health* are variables that in a highly statistically significant way differentiate tactile threshold sensitivity. Definitely negative result was obtained only in the analysis of the *menarche* variable, while the *occupation* variable gave an ambiguous result. High statistical significance does not automatically entail a high share of a given variable in the explanation of the variance of the dependent variable. That is why, in Table 9 containing the most important results of one-way analysis of variance I included an estimation calculated on the basis of a relevant formula for the value of the variance explained with a given independent variable.

Obviously, due to the previously indicated interrelationships between the independent variables, the results represented in Table 9 cannot be treated as a basis for final conclusions.

In order to check, in what way the effects of potential interaction in the pairs of variables affect the picture of a variable under investigation I carried out the two-way analysis of variance. The multiway analysis would have been more useful, but it was impossible due to the size of the sample (1500 people). I split the calculations into two groups: children and adults. This division was imposed by the variables themselves, since part of them, such as *body mass*, *parental care* or *school marks* applied only to individuals under 21 years of age, while other variables, such as *occupation* or *state of health* applied exclusively to adults. I carried out this analysis on the set standardised according to sex and age.

The results were tabulated, separately for children and separately for adults (Tables 10 and 11).

As evident from Table 10, the effects of certain variables cancel each other in pairs. Thus, for instance *parental care* and level of their *education*, similarly to *parental care* and *material status*, since they occur together, have no effect on the variability of the dependent variable. In other pairs the effect of only one variable was noticeable. For instance, in the pair: *education of the parents* and *material status*, only the former variable had a significantly differentiating effect on tactile sensitivity, while in the pair: *school marks – number of children in the family*, only the latter variables produced a significant effect, at the level of $p<0,05$. The *menarche*, as expected,

Table 9. Analysis of variance of tactile thresholds (SWM log scale). Apart from variables Age and Sex, analysis for set standardised according to age and sex

Independent Variables	N	Homogeneity of variance	F	*p*-level	% of variance explained
Age – Females	843	no	43.03	0.001	73.37
Age – Males	701	no	50.22	0.001	49.24
Sex	1544	yes	79.048	0.000*	9.47
Menarche	422	yes	0.25	0.615	
BMI	1221	yes	4.12	0.016	1.26
Education	300	yes	14.79	0.000*	13.75
School marks	117	yes	11.21	0.000*	24.00
Education of parents	654	yes	9.04	0.000*	4.50
Number of children	704	yes	11.80	0.000*	6.91
Maternal care	698	yes	7.69	0.000*	4.97
Material status	705	yes	9.82	0.000*	4.41
Material status of subjects tested	146	yes	7.01	0.001	16.19
Occupation	N=303;	yes	5.25	0.002	9.43
Health	N=297	yes	5.88	0.016	14.99

Table 10. Two-way analysis of variance for children; p-level of *F* test for variable 1 (upper value), variable 2 (middle) and the interaction effect (bottom)

	Variable 2					
Variable 1	Education level of parents	Number of children in the family	Material status	Parental care	School mark	Menarche
BMI	**0.029161** **0.000092** **0.017461**	**0.000745** **0.000000** **0.018000**	**0.001254** **0.000086** 0.15562	**0.001314** **0.00004** 0.619389	**0.008355** **0.000004** 0.179404	0.170803 0.222472 0.345326
Education level of parents		0.06332 **0.000024** **0.046069**	**0.00123** 0.103965 0.694894	0.471912 0.060461 0.26768	0.335534 **0.02853** 0.488639	0.166933 0.941009 0.308579
Number of children in the family			**0.000227** 0.07115 0.687939	**0.000014** **0.002119** 0.22225	0.107052 **0.020856** 0.382987	0.061915 0.969995 0.750756
Material status				0.088777 0.218825 0.158293	**0.030728** **0.000231** 0.103918	0.272618 0.725758 0.840772
Parental care						0.110377 0.444473 0.335954
School marks						0.285562 0.888464 0.643421

Table 11. Two-way analysis of variance for adults; p-level of *F* test for variable 1 (upper value), variable 2 (middle) and the interaction effect (bottom)

	Variable 2		
Variable 1	Occupation	Material status	Health
Education	**0.025587*** 0.903933 0.075461	**0.003103*** **0.003396*** 0.774136	**0.000081*** 0.170784 **0.019041***
Occupation		0.304512 **0.001114*** 0.430952	0.371576 0.120285 0.386653
Material status			**0.003473*** **0.046420*** 0.271092

exerted no statistically significant influence on variability, neither in isolation nor in a pair with any other variable.

In the remaining pairs both variables exerted a statistically significant influence on the variance of tactile threshold. Among them there were two pairs producing an extra interaction effect. These were: the *Body Mass Index – Parents' education* pair and the *Body Mass Index* and *number of children in the family* pair. In a single case – in the pair including *education of the parents* and *number of children in the family* – only the latter variable had a significant effect on the variance of tactile threshold, but both variables when acting in concert, generated an additional effect significantly differentiating the sense of touch.

In the *BMI – number of children in the family* pair (Fig. 8) both variables differentiate the sensation of touch in a highly statistically significant way, producing additionally a strong interaction effect. This shows that the divergence of the mean values (the slimmer – the more sensitive) characteristic of *BMI* is present only in families with many children. This indicates that the fact that there are not many children in the family could have a stabilising effect on tactile sensitivity, maintaining it at a higher than the average level.

BMI behaves similarly in the pair with *education* (Fig. 9). In the families with parents having secondary or academic education, children of differentiated obesity (varying categories of *Body Mass Index*) are similarly sensitive, though, always sensitive above the average (only the mean value for more obese children approximates the value of the population mean). In turn, in the families where the parents obtained the lowest level – primary or incomplete primary education – *BMI* distinctly differentiates tactile sensitivity. Here, the slimmest individuals have the lowest sensitivity thresholds.

The *material status* and *average school marks* variables (Fig. 10) do not produce an additional interaction effect. In all the cases (categories) of material status, mean values of tactile sensitivity in the *school marks* category distribute in a similar way: better pupils are more sensitive than worse pupils. However, it is worthwhile noting that the lower the material status the lower the average sensitivity, even among the best pupils. In well-off families the best pupils deviated from the population mean of tactile sensitivity by 0.5 of standard deviation, while in the poorest families the best pupils' sensitivity was exactly average (the mean value in this group was in line with the population mean).

In the *number of children in the family – education of parents* pair of variables (Fig. 11) the former variable is the main factor influencing the variability of tactile sensitivity threshold. Its effect is enhanced by the interaction of the variables.

Figure 12 illustrates the interaction between *BMI* and *material status*. In well-to-do families BMI does not differentiate the sensation of touch – more obese children are only slightly less sensitive than other children. However, the worse the material status of the family, the stronger body mass affects the sensitivity threshold, lowering it in slimmer children. In the poorest families, though, even the most sensitive subjects (slim children) have the group mean oscillating around the population mean, while in well-off families the mean value for the most sensitive ones (the slim and medium built) is lower than the population mean.

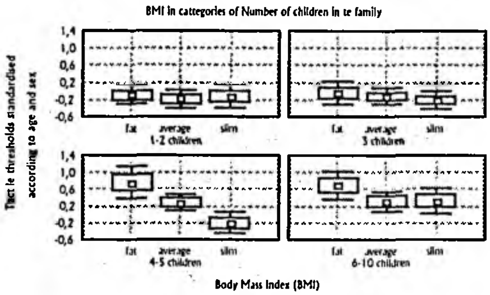

Fig. 8.

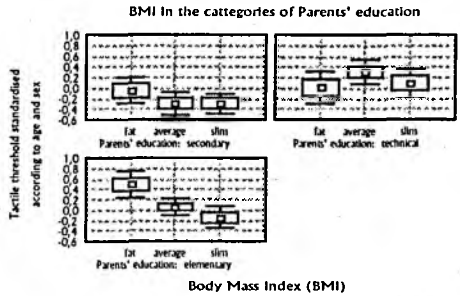

Fig. 9.

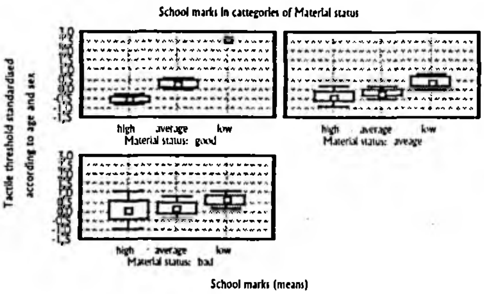

Fig. 10.

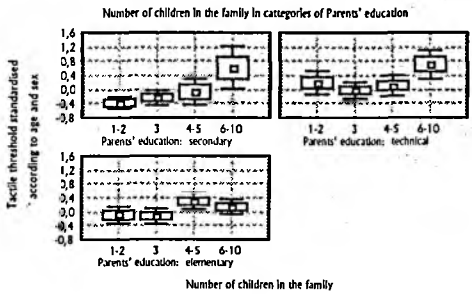

Fig. 11.

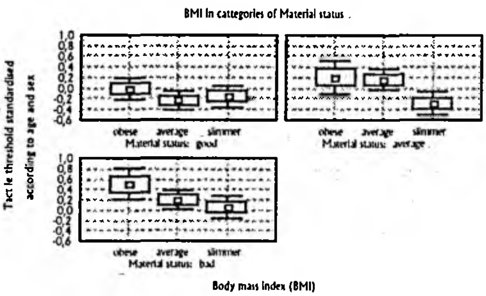

Fig. 12.

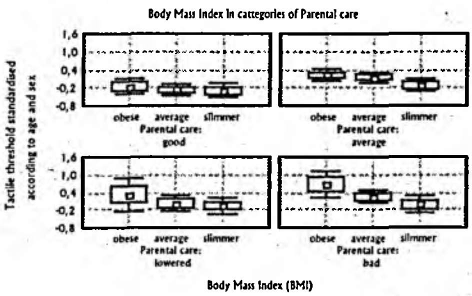

Fig. 13.

Figs. 8-13. Two-way analysis of variance of tactile treshold according to *BMI* and the *number of children in the family* (Fig. 8), *BMI* and *Parents' education* (Fig. 9), *school marks* and *material status* (Fig. 10), *number of children in the family* and *Parents' education* (Fig. 11), *BMI* and *material status* (Fig. 12) and *BMI* and *parential care* (Fig. 13)

The situation is similar in the case of *BMI* and *parental care* (Fig. 13): all the individuals classified under the highest category of *parental care*, regardless of their body mass show similar sensitivity, with approximately 0.2 of standard deviation from the population mean. In lower categories of *parental care*, *BMI* behaves according to the well-known pattern: slimmer individuals show greater sensitivity.

The diagram in Fig. 14 shows that the *school marks* variable, regardless of the individual's body mass, affects tactile sensitivity in all *BMI* categories, the individuals with the highest average school mark are the most sensitive. This effect is enhanced with the body mass factor in the following way: slimmer individuals with the highest average school marks are by more than one standard deviation more sensitive than more obese individuals achieving equally good school results.

The pair of variables represented in Fig. 15 shows a stabilising effect of *the number of children in the family* acting in concert with the *parental care* variable. Children from families with a low number of children, regardless of the quality of parental care, are more sensitive than children from large families. In small families only children from the families classified as pathological ones have the threshold mean oscillating around the population mean. Other children in this group are sensitive above the average. In large families, only children receiving good and very good parental care show average, or above average, sensitivity. The other categories of *parental care* in families with many children are characterised with the mean value exceeding the mean threshold value, which signalises a gradual weakening of sensitivity along with the decrease of the parental care standard and the increase of the number of children in the family.

In a similar way I carried out the two-way variance analysis for the group of adults. Its results are shown in Table 11 and illustrated with diagrams in Figures 16 to 18.

In all pairs with the *education* variable, the factor differentiates tactile sensitivity in a statistically significant way, being a weighty contribution to the effect (*occupation* and *state of health* factors occurring in the pair with *education* do not produce a significant effect on the threshold variability of touch). *Material status* is another factor producing a similarly clear effect. Its influence on tactile variance remains statistically significant in all the pairs of variables formed with its participation. *Occupation,* on the other hand, unlike in the one-way analysis, became neutral, while the *health* variable retained its ability to differentiate touch variance only in the pair with *material status*. An additional interaction effect occurred only in one combination of the pairs of variables, when *health* was combined with *education*.

The nature of these mutual relationships is shown in the diagrams in Figures 16 to 18.

It is evident from Figure 16 that in all categories of *education* well-off subjects are more sensitive than the subjects with average material status, and these subjects in turn are more sensitive than the individuals living in poverty. However, the mean values of tactile threshold in particular categories of *material status* are not identical at subsequent levels of *education*. The mean tactile threshold of well-educated and well-to-do individuals reaches the level of – 0.4 of standard deviation, while the mean for well-educated individuals living in bad conditions oscillates around the population mean.

In the pair of variables including *state of health* and *education,* the latter variable in healthy people differentiates the mean values according to the earlier observed pattern: the higher the education level, the lower the tactile threshold (higher sensitivity). Yet, in the group of ill individuals, this pattern was disturbed, most likely, by the distribution of frequency of particular diseases in categories of education.

When *health* and *material status* acts in concert it is evident that the group of healthy individuals is generally more sensitive than the ill in the same categories of *material status*. Nevertheless, it is

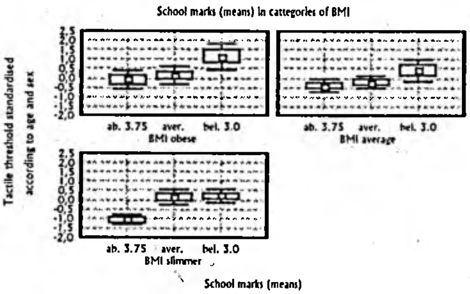

Fig. 14.

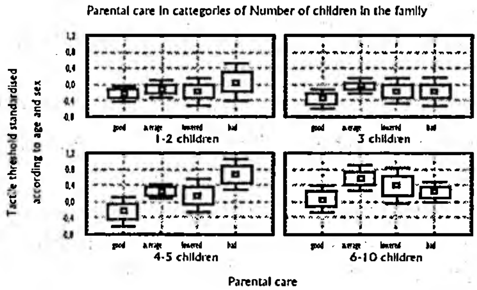

Fig. 15.

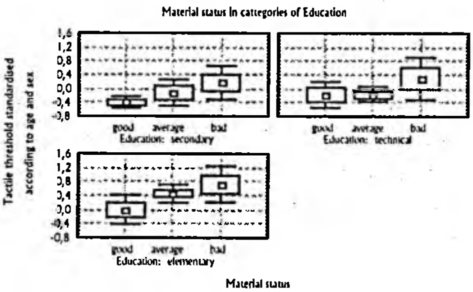

Fig. 16.

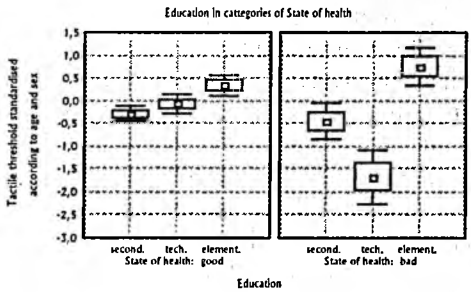

Fig. 17.

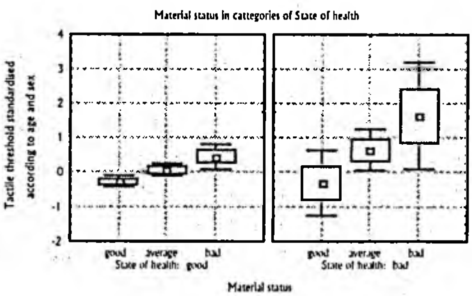

Fig. 18.

Figs. 14-18. Two-way analysis of variance of tactile threshold according to *school marks* and BMI, (Fig. 14), *parental care* and *numbe of children in the family* (Fig. 15), *material statius* and *education of subject tested* (Fig. 16), *education* and *state of health* (Fig. 17) and *material status* and *state of health* (Fig. 18)

worthwhile emphasising, that both ill and healthy individuals with good material status are similarly sensitive – only lower categories of *material status* are characterised with considerably lower, compared to the group of healthy individuals, mean values in corresponding categories.

Interrelationships between variables revealed as a result of the analysis and the additional differentiating effects resulting from the combined action of variables enable us to indicate the most important factors producing a decisive effect on the variability of tactile threshold. These are: for children: *BMI* (produced a significant effect in 4 pairs of variables, plus an interaction effect in two cases); *number of children in the family* (produced significant effects in 4 pairs of variables, and additionally an interaction effect in two cases); *school marks* (significant effects in 4 pairs of variaables); *education* of the parents (significant influences in two pairs, plus an interaction effect in two cases).

The *parental care* and *material status* variables produced the weakest modifying effect. It is most likely that variability they produce, detected in the one-way analysis, was to a high degree a result of the number of children in the family; while this last variable depends mainly on education.

The high position of the *school mark* variable is interesting. It may suggest a significant relationship of tactile sensitivity and intelligence. This may be inferred from the fact, that this result is in agreement with the result obtained in the pilot study in which pupils' mental skills were assessed on the basis of the form masters' opinions, rather than according to their school marks.

In the group of adults the ranking of the variables proving to produce the most distinct distinguishing effect is as follows: education of the subjects (producing statistically significant effects in all pairs plus one interaction effect); *material status* (producing statistically significant effects in all pairs).

The *health* variable produced a statistically significant effect on the variance of tactile threshold only in the pair with *education,* while *occupation* remained neutral in all the pairs formed. It is worthwhile noting that the *subjects' education* variable in adults is a counterpart of the *school mark* variable in children. A strong influence of *education* and *material status* (material status being a factor to a large extent determined by education) on the variability of tactile threshold may suggest two conclusions. On the one hand, it may suggest sensitivity of this feature to the level of an individual's intelligence, which opens a wide field for discussion on the relationship between sensory sensibility and intelligence. On the other hand, it may indicate its sensitivity to living conditions and lifestyle, which, in turn, is a convenient pretext for an anthropologist to start discussion on the importance of the influence living conditions exert on the biological development of man.

Discussion

Numerous dependencies revealed in the course of this work, such as decline of tactile sensitivity with age or higher sensitivity to touch in women are not surprising, even if in the literature one may come across works that do not reveal such relationships [HAGE *ET AL.* 1995]. The observed weakening of tactile sensitivity with age is in line with a conviction that ageing involves the deterioration of all senses, resulting from the progressing degeneration of the nervous system [MYŚLIWSKI 1998]. The mechanism behind the weakening of tactile sensitivity is unknown, though many authors relate this phenomenon the to the fact that the density of tactile receptors decreases with age. Unfortunately, the data available on this topic refer to Paccini's corpuscles [BOŻIŁOW 1965, 1987, VERILLO 1996] and to Meissner's corpuscles, and not to Merkel's tactile discs irritated in this study. For this reason, it is difficult to decide whether they can be extrapolated on all skin receptors. The only publication I managed to find, containing concrete, numerical data on the decrease of the density of tactile receptors (Meissner's corpuscles) with age was the work by BOLTON *ET AL.* [1965]. The authors of the contemporary publications on tactile sensitivity often refer to this work, which indicates that it is one of only a few available works on this topic. It seems that the population tests for the two-point threshold, conducted on a representative group of individuals of one sex in a selected area of the body, could be a verification of the hypothesis on the relationship between tactile sensitivity and the density of receptors. Being aware of the strong dependency of tactile sensitivity upon social factors, in order to restrict the size of the sample, one should conduct such research on a group of subjects similar with regard to social factors. This could be a group of university scientists who are characterised by the similarity of social variables, most important for touch, such as education, type of profession, material status. Due to the fact, that some study result published point out to significant changes in the tactile sensitivity of women in various phases of the sex cycle [WEINSTEIN 1963], it would be better to carry out the two-point discrimination test on men.

The strong dependency of tactile sensitivity on age may have adaptive meaning. If we assume that the level of tactile threshold determines the quantity of information accessing an individual from the environment, then a gradual lowering of tactile threshold would be beneficial both for the individual and for the entire system (population) he/she remains in. The ability to receive and process large quantities of information is indispensable especially in the period of intense development and learning – that is in childhood. This is so, firstly, because childhood is a period when an individual gets to know his/ her environment; secondly, because in the early stages of the ontogenesis in particular, the degree of sensory stimulation is decisive for the final shape of the nervous system – for the number of neurones and their junctions, the number of synapses, and, possibly, for the density of skin receptors. This may be the reason why in younger age categories tactile sensitivity was higher than in older age categories.

Both of the processes – the exploration of the environment and the shaping of the nervous system are closely interconnected and, staying in feedback, affect the central nervous system. This does not mean that the shape of the nervous system is determined exclusively by environmental factors, since it is strongly conditioned by the genetic resources of the individual. Nevertheless, the final shape that is assumed by the nervous system, whose development continues long after birth (e.g. myelination of nerve fibres is completed as late as in puberty), is a result of the interaction with the environment. In consequence, the genetic potential produces a variety of phenotypic effects, depending on the environment of the individual's development and the changes taking place in the course of this process are of adaptable – irreversible for each individual – character. The need for high sensory effectiveness does not vanish when the individual enters adulthood. This is due to the special significance of the communication system for the human evolution process. The ability to receive, analyse and transmit information, developed over millions of years, resulted in culture, treated by biologists as an adaptation instrument [STRZAŁKO *ET AL.* 1980, PIONTEK, WIERCIŃSKA 1993, STRZAŁKO, OSTOJA-ZAGÓRSKI 1995]. Tactile threshold sensitivity, which, in this respect, seems to be not different or less important than sensory sensitivity in other modalities, though on average weakens with age, with regard to the median value remains unchanged almost throughout the entire life. Disregarding the higher median in prepubescent girls, its value amounts to 2.83, to decrease only towards the end of life (in the categories with the mean of age of 73 years for women and 53 years for men). Significant and common lowering of tactile sensitivity towards the end of individual's life may stem from the fact that the achievements of our civilisation, in the field of medical science in particular, made it possible to considerably prolong human life, simultaneously failing to guarantee prolonged youth. Living on average 20 years longer than several centuries ago, man is exposed to longer senility with accompanying gradual decline of homeostasis and regulatory functions of the body. The fact that its median decreases only late in life may indicate a great importance of the maintenance of narrowly channelled tactile sensitivity throughout the whole life. The values of tactile threshold determining the boundaries of this channel are an effect of adaptation processes. It is worthwhile noting, that the distribution of tactile threshold is strongly skew. If high sensitivity promotes survival and if the low one decreases fitness, the skewness of the distribution of tactile threshold frequency seems to be justified. The sharply dropping curve of the distribution, related to the low threshold of tactile sensitivity, indicates the occurrence of some obstacle preventing the increase of tactile sensitivity. Since low values of tactile threshold are, in general, reserved for children, this obstacle could be associated with the fact that, with age the density of tactile receptors declines or with the fact that human skin (at least male one) thickens as a result of the activity of sex hormones. The suggestion that too high sensitivity could be harmful, leading to experiencing pain instead of touch, should be rejected for two reasons. Firstly, for the reason that there are skin areas (such as face) that are more sensitive than other places, secondly because, the receptors are unable to change their modality and suddenly start sending pain impulses instead of tactile ones, since the former are transmitted through free nerve endings reacting to tissue damage. Cases of hypersensitivity (hyperaesthesia) do not prove that tactile receptors change their function, since pain can still be received by free nerve endings and the changes may occur within the receptors themselves.

Discussing the adaptive meaning of a trait such as tactile threshold, one should know its parameters, such as phenotypic variance and inheritability coefficient. Due to the fact, the study material included both parents and children I attempted to estimate the inheritability coefficient h^2. The coefficient is used to determine the share of genetic origin variance in the overall variability of tactile threshold, being the dependent variable. Based on the official population censuses I have identified over 80 parent – child pairs in the study material. Since the sample was too small for the separation of the pairs of particular sexes, I calculated correlations for the set standardised for age and sex. Correlation coefficient obtained was $r = 0.1295$. It proved to be statistically insignificant at the adopted level of significance. The value of inheritability index estimated on this basis ($h^2 = 0.26$) [FALCONER 1974] indicates a slight chance for the natural selection to operate with regard to the trait under investigation. Most of the observed variances of the trait (over 70%) resulted from environmental factors, and only 26% constituted genetic (additive) variance. One may presume it to be a slightly genetically *differentiated* trait. Genotypes of people in the population under study are similar with regard to tactile sensitivity, which determines a low chance of natural selection to operate. In other words, acting on different variants of the phenotype, natural selection had only 26% of chances that it will change the genotype. For comparison, the inheritability coefficient for body mass, being a trait of recognised high eco-sensitivity, determined with the correlation method in family pairs was $h^2 = 0.64$ [HENNEBERG 1989]. For threshold tactile sensitivity the value of this coefficient amounts to half of the above value.

In order to calculate environmental plasticity of the trait under investigation I used equations proposed by HENNEBERG [1989]. With the value of phenotypic variance $Vp = 0.12$ and population mean of the dependent variable of 2.78, coefficient of variation CV was $CV = 12.46$. I calculated also the coefficient of genetic polymorphism, obtaining $P_g = 0{,}0634$, and the coefficient of eco-sensitiveness $D_c = 0{,}1073$.

Even though the above calculations are based on an insufficient number of observations to definitely resolve the issue of the degree of inheritability and eco-sensitivity of the trait under study, still they show that *tactile sensitivity* is a highly eco-sensitive trait. This does not mean that this feature is weakly determined genetically – because the inheritability coefficient obtained describes only the level of genetic variance. GAZZANIGA [1997] points out to the fact that *in general senses are not strictly determined by genetic mechanisms, but they develop through the mutual exchange of information with the external environment,* though the scope of the influence exerted by the environment is greatly overestimated. The nervous system reacts only to *certain* stimuli, which are *concurrent* in time for a given, developing structure. It does that in a strictly determined (genetically programmed) manner. According to Gazzaniga, the environment determines – through the selection – the choice of neurones, direction and the number of their junctions from the excess produced by the young nervous system, rather than modifies the developing structures of the nervous system. These processes are particularly active over the initial two years of the human life.

Due to the limited size of the family sample, the results on the degree of inheritability and threshold eco-sensitivity should be treated with caution when drawing conclusions on the adaptive function of touch. Benefits resulting for man from increased tactile sensitivity might have been insufficient for the selection pressure to occur (more sensitive individuals were not necessarily more fertile ones, though one can imagine that higher sensitivity to touch enhanced their sexual attractiveness). What is more, the fact of the tactile threshold median being close to the minimum may result from the linkage of the trait under investigation with another trait, subject to selection, such as the ability to process information (intelligence). The inheritability of intelligence, oscillating around 0.75, is much higher than the inheritability of touch. Thus, it could be a factor pulling the more eco-sensitive tactile sensitivity. In the sample under investigation, intelligence estimated on the basis of average school marks in children and education in adults, produced a highly statistically significant effect on the variability of tactile threshold. Whether or not this relationship is an artefact is subject to discussion. Better pupils or well-educated individuals may lead a different lifestyle, which makes their skin thinner. This, in turn, could be responsible for their higher sensitivity. One can also deliberate on whether school marks actually reflect the intelligence of the subjects, as it depends on the definition of intelligence. It seems that intelligence tests would be more reliable than *school mark* and *level of education* criteria, however even such tests fail to provide reliable information on the subject's intelligence, since the same individual may perform differently in different types of tests. He/she can also perfect his/8her test-solving skills, which results in the raising of the IQ by up to several points [SELIGMAN 1995]. Besides, the correlation of results between particular tests is far from 1, which may be related to the intellectual condition of the subjects on the day when the test is solved, but may also result from differences between the tests that, depending on their type, investigate a variety of the aspects of intelligence.

When discussing the relationship of tactile sensitivity with intelligence and its significance for the development of the communication process it is also useful to take into consideration an important issue debated by the representatives of medical sciences. It can be stated in the form of the following question: Is there a statistically significant correlation between tactile threshold as measured with the aesthesiometer and the efficiency of the hand as a manipulation and exploration instrument? If such correlation is non-existent, the consideration of the adaptive value of touch sensation based on the threshold study assumes a highly speculative character.

Prolonging lack of consensus on this issue, even though it alarms each researcher investigating touch sensation with the S-W aesthesiometer, stems from easily identifiable sources. The lack of standards for the assessment of the efficiency of the hand as an exploration instrument is the most important of them. Some scientists assume that it is sufficient to check if subjects recognise a few common objects, such as a paper clip or a toothbrush using their touch sense. Others use surfaces with complex textures, making subjects remember and then discriminate various types of surfaces with differentiated parameters (angles, distances) of patterns. It is evident, that in spite of the fact that during these tests the temperature of the objects is controlled (they are usually made of the same material), touch sensation or tactile threshold are not necessarily crucial for solving the test tasks. Intelligence of the subjects may be a key factor here. Discernment, recognition and comparison of surfaces – these operations take place in association areas, rather than in the primary somesthetic cortex adjusted for the reception of simple stimuli of a definite modality. This indicates that the significance of the level of tactile threshold for the quantity of information received should not be separated from the individual's ability to *process* the information. Throughout the evolution of the humankind, improving the access to information through the lowering of tactile thresholds of various modalities must have been linked with the increase of the central nervous system's ability to process the information. Otherwise, an information surfeit could occur, disturbing the environmental patterns stored in the brain and leading to the loss of control over the environment, and in consequence to the undermining of the exteriorisation process involving the incorporation of the environment into the system [STRZAŁKO *ET AL.* 1980].

Conclusion

The relationships of touch sensation with social factors, revealed in this work indicate a strong effect of these factors on the trait under investigation. This effect is not always direct – for instance, graduation does not entail a sudden increase of tactile sensitivity. The essence of the influence exerted by social factors is their role in the shaping of the environment of each individual under study, in the shaping of the environment differentiated with respect to the density and quality of information. Man is a social creature and his development requires constant confrontation and constant exchange of information with the environment. The quantity and quality of the information in the early stages of ontogeny decide about degree of realisation of genetic potential – in this case the genetically determined ability to reception and transform environmental stimuli.

The history of human development and the direction of the development of our civilisation prove that effective information management leading to the gradual extension of the area under control, spreading far beyond the human body, is crucial for the increase in the energy balance. Culture – both when it stores information in the form of dances and magic practised by a shaman and when it employs writing and multimedia databases – is the most adaptable trait of man understood both as a species and as a single individual. However, information is the main element of this culture.

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Streszczenie

Głównym celem pracy było przedyskutowanie adaptacyjnego znaczenia czucia dotyku u człowieka, i znalezienie odpowiedzi na następujące pytania. Czy wrażliwość na dotyk mogła mieć jakieś znaczenie dla ewolucji człowieka, a jeśli tak, to jakie? Czy ludzie różnią się wrażliwością dotykową, a jeśli tak, to czy ta różnica – w przeszłości – mogła być przyczyną zróżnicowanej płodności i stanowić fragment sita selekcji? Czy osadzona w konkretnym kanale wrażliwość dotykowa mogła być elementem zmieniającym prawdopodobieństwo przetrwania?

Badanie funkcji adaptacyjnej dotyku, a więc cechy, która nie ujawnia się w materiale kostnym, rodzi spore problemy. Można jedynie zbadać żyjącą populację ludzką i na podstawie analizy zmienności oraz współczynnika odziedziczalności cechy wnioskować o jej rozwoju, i ewentualnie uzupełnić takie badanie o porównawczą analizę behawioralną zwierząt w różnym stopniu spokrewnionych ewolucyjnie z człowiekiem. W pracy przeprowadzono badania populacyjne. Wrażliwość dotykową oceniano poprzez zmierzenie progu dotykowego estezjometrem Semmes-Weinsteina, powszechnie wykorzystywanym na zachodzie do diagnostyki czucia powierzchniowego. Ponieważ zmysł dotyku jest bardzo labilny – wrażliwość dotykowa różni się zależnie od miejsca na ciele, chcąc zbadać zmienność międzyosobniczą wrażliwości dotykowej, badano jedno, wybrane miejsce. Wybrano opuszki palców, jako jedne z najbardziej wrażliwych miejsc na ciele, i najczęściej używane do eksploracji otoczenia – niektórzy wręcz uważają że właściwym narządem dotykowym jest ręka, a konkretnie opuszki palców.

Celem pracy było zbadanie podstawowych cech wrażliwości dotykowej, określenie zakresu zmienności wrażliwości dotykowej i wyznaczenie normy dla badanej populacji. Zmierzono też stopień ekosensytywności cechy i podjęto próbę oszacowanie stopnia odziedziczalności cechy. Uzyskane wyniki interpretowano z punktu widzenia adaptacyjnego znaczenia wrażliwości dotykowej człowieka. Postawiono tezę, że progowa wrażliwość dotykowa będąca wynikiem interakcji czynników genetycznych i środowiskowych, wspólnie odpowiedzialnych za obserwowaną wariancję cechy, w przeszłości mogła mieć znaczenie adaptacyjne. Argumentami popierającymi lub odrzucającymi tezę miały być, z jednej strony, proporcje wariancji pochodzenia środowiskowego i genetycznego, a z drugiej strony przewidywana pozytywna i statystycznie istotna korelacja pomiędzy wrażliwością dotykową (progiem dotykowym) a umiejętnością przetwarzania informacji z otoczenia (inteligencją).

Badania objęły 1500 osób w wieku od 7 do 85 lat, z tego 300 osób dorosłych (powyżej 21 roku życia). Większość badanych zamieszkiwała gminę Barciany w północno-wschodniej Polsce. Kobiety stanowiły ok. 55% badanej populacji. Za potencjalne źródła wariancji uznano:

– czynniki biologiczne, jak: wiek, długość i masa ciała, stan zdrowia, grubość naskórka mierzona wykonywanym zawodem

– czynniki psychiczne, jak inteligencja, mierzona ocenami szkolnymi u dzieci i wykształceniem u dorosłych, oraz opieka otrzymywana ze strony rodziców;

– czynniki społeczne, jak: wykształcenie rodziców badanych, liczba dzieci w rodzinie, sytuacja materialna rodziny, opieka rodzicielska.

Wszystkie zmienne niezależne kategoryzowano, zgodnie z potrzebami analizy wariancji. W pierwszej kolejności obliczono rzetelność pomiarów oraz podstawowe statystyki zmiennej zależnej, czyli wrażliwości dotykowej. Następnie zmierzono współzależności miedzy wybranymi do analizy czynnikami, wykorzystując test Chi-kwadrat. Zbadano moc i kierunek tych współzależności. Kolejnym krokiem było skontrolowanie zależności dotyku od płci i wieku. Obliczono średnie wrażliwości progowej w grupach płci i wieku, tworząc w ten sposób normę dla populacji Polski. Przeprowadzono analizę wariancyjną 1-czynnikową, w celu wychwycenia najważniejszych tendencji i sposobów oddziały-

wania badanych czynników w hipotetycznej sytuacji – to znaczy takiej, gdyby były one rzeczywiście niezależne od siebie. Wszystkie badane czynniki, za wyjątkiem menarche i zawodu, w sposób wysoce istotny statystycznie oddziaływały na wrażliwość dotykową. Kierunek tych oddziaływań był następujący: wrażliwsi byli osobnicy młodsi, kobiety, szczuplejsi, lepiej wykształceni, lepiej uczący się, posiadający lepiej wykształconych rodziców, z mniej licznych rodzin, o lepszej opiece rodzicielskiej, lepszej sytuacji materialnej, nie chorujący na cukrzycę lub alkoholizm.

Biorąc pod uwagę liczbę istotnych statystycznie wpływów, i efektów interakcji wykrytych w analizie wariancji, za najistotniejsze dla wrażliwości dotykowej uznano następujące zmienne: w grupie dzieci: wskaźnik masy ciała, liczba dzieci w rodzinie, ocena szkolna, wykształcenie rodziców; w grupie dorosłych: wykształcenie badanych i sytuacja materialna. Oznacza to, że na wrażliwość dotykową istotnie wpływa zarówno budowa ciała, inteligencja, jak i status społeczny. W przeszłości zależność między umiejętnością przetwarzania informacji z otoczenia a wysokością progu dotykowego mogła prowadzić do stopniowego obniżania progu, aż do stanu dzisiejszego, o charakterystycznym, wyraźnie asymetrycznym rozkładzie czucia dotyku, przesuwającym się w stronę niskich wartości progu.

Wrażliwość dotykowa okazała się cechą bardzo wrażliwą na czynniki środowiskowe. Pozostało sprawdzić, w jakim stopniu jest odziedziczalna, aby można było ocenić sposobność doboru naturalnego do oddziaływania na tę cechę. Na ponad 80 parach rodzic–dziecko obliczono współczynnik odziedziczalności, uzyskując wartość $h^2 = 0,259$, co oznacza, ze sposobność do działania doboru naturalnego dla cechy wrażliwość dotykowa nie przekracza 26%. Ponieważ współczynnik odziedziczalności oszacowany był na małej próbie i w dodatku na wartościach standaryzowanych, nie można tej wartości przyjmować jako ostatecznej, ale fakt, że współczynnik korelacji był nieistotny statystycznie, jeszcze bardziej osłabia tezę o adaptacyjnym znaczeniu cechy. Z drugiej strony, powiązanie dotyku z inteligencją i budową ciała (w badanej populacji osobniki szczuplejsze, o wyższym wykształceniu lub średniej ocen były znacznie wrażliwsze od średniej populacyjnej) może oznaczać, że co prawda nie bezpośrednio, ale w sprzężeniu z tymi cechami i ośrodkami przetwarzającym informację (CUN), oddziałując także na atrakcyjność seksualną, wyższa wrażliwość dotykowa mogła podnosić *fitness* osobnika, i stopniowo obniżać próg dotykowy.

Bezpośrednio wrażliwość dotykowa nie miała żadnego znaczenia adaptacyjnego: wyniki przeprowadzonych badań wskazują, że genotyp w kwestii wrażliwości dotykowej pozostawia duży margines na oddziaływanie środowiska – należałoby więc mówić raczej o znaczeniu adaptabilnym tej cechy, niż adaptacyjnym. Wysoka wrażliwość środowiskowa dotyku może pełnić funkcję ochronną, dostosowując, poprzez podwyższanie lub obniżanie progu, ilość odbieranej informacji do możliwości jej przetwarzania. Jak wiadomo, ostatnie etapy kształtowania się struktur układu nerwowego są zależne od środowiska, a konkretnie od ilości i charakteru bodźców docierających do osobnika; w przypadku nasilenia bodźców nieprzyjemnych adaptabilnym zachowaniem jest podwyższenie progu, a w przypadku bodźców pozytywnych – obniżenie. To tłumaczyłoby różnice we wrażliwości osobników wzrastających w odmiennych warstwach społecznych.