Fingertip skin conformance accounts, in part, for differences in tactile spatial acuity in young subjects, but not for the decline in spatial acuity with aging

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The ability of the skin to conform to the spatial details of a surface or an object is an essential part of our ability to discriminate fine spatial features haptically. In this study, we examined the extent to which differences in tactile acuity between subjects of the same age and between younger and older subjects can be accounted for by differences in the properties of the skin. We did so by measuring skin conformance and tactile spatial acuity in the glabrous skin at the fingertip in 18 younger (19–36 years old) and 9 older (61–69 years old) subjects. Skin conformance was measured as the degree to which the skin invaded the spaces in the psychophysical stimuli. There were several findings. First, skin conformance accounted for 50% of the variance in our measure of tactile spatial acuity (the threshold for grating orientation discrimination) between the younger subjects. The subjects with more compliant skin had substantially lower thresholds than did the subjects with stiffer skin. Second, the skin of the younger subjects was more compliant across than along the skin ridges, and this translated into significantly greater performance when the gratings were oriented along than when oriented across the skin. Third, skin conformance was virtually identical in the younger and the older subjects. Consequently, skin conformance cannot account for the loss of spatial acuity reported in earlier studies and confirmed in this study. We infer that the loss must be neural in origin.

It is well known that tactile spatial acuity at the fingertips (the ability to resolve fine spatial detail) varies significantly between subjects of the same age (Vega-Bermudez & Johnson, 2001; Vega-Bermudez, Johnson, & Hsiao, 1991) and between younger and older subjects (Stevens & Choo, 1996; Stevens & Patterson, 1995; Vega-Bermudez & Johnson, 2002), but the reason for this variation is not known. The variation is not due to the testing methods, because the grating orientation discrimination measure used in several of these studies has been shown to be highly repeatable (Van Boven & Johnson, 1994a). Other possibilities are differences in the central pathways leading to tactile perception, differences in afferent innervation density, which has a significant effect on spatial acuity (Van Boven & Johnson, 1994b), or differences in skin properties.

The skin property that is critical for the recognition of small objects or surface features is the skin's ability to conform to the object or the surface. If the skin fails to bend and follow the surface features or does so poorly, the mechano-

receptors responsible for conveying the spatial form of the stimulus cannot do so. The skin's ability to conform to a spatial pattern is functionally analogous to the eye's ability to focus an image on the retina. A major source of variation in the uncorrected visual acuity of young adults is variation in their ability to focus an image (i.e., variation in their lenses). The question addressed here is whether variation in skin conformance contributes to variation in tactile acuity.

The mechanics of contact between the skin and an object are complex (K. L. Johnson, 1985). In the only previous study (Woodward, 1993) in which measures of tactile spatial discrimination were compared with skin properties, the indentation produced by 10 g of force (i.e., compliance) was used as a measure, and no relationship was found. However, compliance does not measure the degree to which the skin bends and molds to the stimulus, which is the critical issue. A rigid surface, such as a plastic computer key, can be highly compliant. There is no conventional measure of conformance of which we are aware. Because we used mechanical gratings to measure tactile spatial acuity, we adopted the degree to which the skin invaded a slot exactly like the slots in the test grating as a measure of conformance.

In the present investigation, we measured skin conformance and the grating orientation threshold (GOT)—the finest grating that allowed reliable grating orientation discrimination—in the fingertips of subjects 19–69 years old. The study had two main aims. The first was to see whether the relatively large variation in tactile spatial acu-

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ity between subjects of the same age is due to differences in skin conformance. The second was to see whether the progressive decline in tactile acuity with age is related to a progressive change in the skin's ability to conform to the shape of a stimulus.

We confined our study to the tip of the index finger because it is the area of greatest tactile acuity and, like the fovea, most critical for fine form perception (Vega-Bermudez & Johnson, 2001). Tactile spatial acuity at the fingertip is very close to the limits imposed by neural innervation density (Phillips, Johnson, & Browne, 1983), and it may also be limited by skin mechanics—the skin's ability to conform.

We used gratings in this study because GOTs are closely correlated with the ability to discriminate complex shapes, such as raised letters (Vega-Bermudez & Johnson, 2001), they have been used in many studies (Craig & Lyle, 2001; Sathian & Zangaladze, 1996; Schlereth, Magerl, & Rolf-Detlef, 2001), and the test-retest variation for individual subjects over many testing sessions is only about 10% of the mean threshold value (Van Boven & Johnson, 1994a). We measured the skin's invasion of the grating slots because that is a direct measure of conformance.

METHOD

The subjects consisted of a younger group of 18 (5 females and 13 males) right-handed subjects, 19–36 years old, and an older group of 9 right-handed subjects (5 females and 4 males), 61–69 years old. None of the 27 subjects had a history of nerve injury, finger trauma, or learning disability, and the finger pad tested was free of calluses. Consent was obtained from each subject, and the Human Subjects Institutional Review Board of Johns Hopkins University approved the experiments.

Grating Orientation Discrimination

The subjects' ability to discriminate the orientation of a mechanical square-wave grating was tested with JVP dome gratings (Stoelting Co., Wood Dale, IL) with equal groove and ridge widths (0.35, 0.5, 0.75, 1.0, 1.2, 1.5, 2.0, and 3.0 mm) plus two domed gratings, made for this study, with groove and ridge widths of 4.0 and 5.0 mm. A grating was applied for 1–5 sec to the distal one third of the finger pad, with the grooves either along or across the finger axis, and the subjects were required to state the orientation. At this location, the skin ridges are orthogonal to the finger axis, so the two grating orientations were also parallel and orthogonal to the skin ridges.

The experiment started with a grating that was easily discriminated (3.0-mm grooves for younger subjects, 5.0-mm grooves for older subjects). All 9 older subjects judged the grating with 5.0-mm grooves to be easily resolved. Each grating was presented 20 times (10 times with ridges oriented along and 10 times across the finger axis) before moving to the next, finer grating. A computer-generated random table determined the orientation for each trial. Gradually, finer gratings were presented until the subjects' performance approached chance (50% correct responses). The GOT was defined as the groove width at which the performance was 75% correct. Interpolation between gratings spanning the 75% correct responses was used unless performance was exactly 75% for a particular grating.

Skin Conformance Measurement

Because the psychophysical stimuli were mechanical gratings with bars and slots, skin conformance was measured as the depth to which the skin invaded a slot just like the grating slots. Because most GOTs fall in the range from 1 to 3 mm, slots 1, 2, and 3 mm wide were

used. The invasion was measured with a 0.5-mm-diameter pin that protruded through the center of the slot to rest just above the plate. The pin was mounted on a balance beam with counterweights adjusted to produce a reaction force of 5 mg. The pin was depressed as the skin entered the slot, which raised a mirror on the other end of the balance beam. The mirror displacement (and, thus, the skin invasion) was measured with a laser Doppler displacement meter (2-nm resolution; Optodyne Inc., Compton, CA). The entire apparatus was mounted on a balance scale (Dial-o-gram balance; Ohaus Co., Florham Park, NJ) that was set to maintain a reaction force of 80 g when depressed. Preliminary tests showed that people use 30–130 g when pressing with a force of their own choosing and that force variations in this range have a minor effect on conformance (see the Results section).

Before each skin conformance measurement, the zero-reference displacement was obtained by placing a perfectly flat block over the slot (a gauge block; Phase II Co., Carlstadt, NJ) so that the top of the pin was flush with the surface of the contact plate (± 0.030 microns). Skin invasion into the slot was sampled every 2 msec, beginning 3–5 sec after initial skin contact (the time required for finger placement and for the force to stabilize at 80 g) and continuing for 5 sec. These samples were used to calculate the average skin invasion. Repeated measures of skin conformance showed that trial-to-trial variation from all sources was ± 2 microns (SD).

The skin region tested (distal one third of the finger pad), the slot widths (1, 2, and 3 mm), their orientations (parallel and perpendicular to the skin ridges), the timing (5 sec of contact, 10–20 sec between measurements), and the contact force were all selected to match as closely as possible the stimulus conditions in the grating orientation discrimination experiments.

Each measure of conformance was obtained by placing the subject's finger over the slot at approximately 45° relative to the plate, so that only the distal one third of the finger pad contacted the plate. We used the distal one third of the finger pad because this was the region tested psychophysically and because the skin ridges run in a single direction perpendicular to the long axis of the finger. Care was taken to use the same skin region for the measurement of conformance and the psychophysical testing. Each conformance measurement was repeated 5 times. Thus, each subject was tested 30 times (3 slot widths $\times$ 2 orientations $\times$ 5 repetitions).

RESULTS

Force Effects

The effects of contact force on skin invasion were measured in 4 subjects (Figure 1). Forces of 40, 80, and 120 g were selected to span the range of forces used by the subjects asked to press the gratings with whatever force felt most comfortable (see the Method section). The results show that the skin is highly conformable. Forces less than 40 g produce a large fraction of the conformation (slot invasion) of which the skin is capable. The effect of additional force depends on the width of the slot. A threefold increase in force from 40 to 120 g produced 107%, 57%, and 30% increases in skin invasion into the 1-, 2-, and 3-mm slots, respectively, when the slots were parallel to the skin ridges. The comparable percentages when the slots were perpendicular to the skin ridges were nearly identical (100%, 54%, and 33%). Because force had a secondary effect on conformance, all the subjects were tested at a single force, 80 g, near the middle of the range of typical forces.

GOT and Conformance in Younger Subjects

The data collected from the younger group are shown in Table 1. The average GOT for these subjects was 1.21 mm

Figure 1. Skin invasion versus force in 4 young subjects. Skin invasion was measured as the maximum skin protrusion into a slot whose width is illustrated at the right of each graph. Dashed lines represent skin invasion when the slot was oriented parallel to the skin ridges; solid lines, when it was perpendicular to the skin ridges. Error bars represent the standard error of the mean for each point.

(0.08 mm SE). The depth to which the skin invaded each slot for slots oriented parallel and perpendicular to the skin ridges is shown for each subject. A three-way analysis of variance (ANOVA) with subjects, slot width, and slot orientation as factors showed that all three had a highly significant effect on skin invasion [subjects, $F(17,87) = 7.69$; slot width, $F(2,87) = 1,006$; slot orientation, $F(1,87) = 30.16$; $p < .001$ for all three]. The skin conformance data for the younger subjects are plotted in Figure 2, which shows that there is a progressively increasing skin invasion with increasing slot size and that, on average, the skin ridges have a small but significant effect on conformance. The average differences in skin invasion between the parallel and the perpendicular orientations were 14, 62, and 106 microns for the 1-, 2-, and 3-mm slots, respectively.

The relationship between skin conformance and spatial acuity is illustrated in Figure 3. The index of skin conformance for each subject is the slope of the linear regression of skin invasion on slot size. The mean slope is 0.293 mm of skin invasion per millimeter increase in slot size (0.271 perpendicular and 0.317 parallel to skin ridges). The subjects with greater skin conformance had lower thresholds, and the correlation, $-.704$, accounted for 50% of the variance in the thresholds between subjects (Hoetelling's transform to normality, $z = 3.42$, $p < .001$; Sokal & Rohlf, 1969, pp. 516–518).

Effect of Orientation

The data so far suggest a relationship between conformance and the ability to discriminate grating orientation. If that is true, the difference in conformance with grating orientation should translate into a difference in subjects' performance. Because the skin conforms to the stimulus more when the skin ridges and gratings are parallel to one another, subjects should recognize that grating orientation

more accurately. Figure 4 shows that, in fact, the subjects were more accurate when the gratings were parallel to the skin ridges than when they were perpendicular. Over all presentations, the subjects judged the orientations of parallel and perpendicular orientations with 88.7% and 79.7% accuracy, and the difference was significant [$t(17) = 2.71$, $p = .015$]. If only the presentations of gratings close to threshold are used (the gratings immediately above and below threshold), the subjects' scores were 81.5% and 67.5% for parallel and perpendicular orientations [$t(17) = 3.22$, $p = .005$].

Response Bias

The greater accuracy when the gratings were parallel to the skin ridges (oriented across the finger axis) could have been due to a response bias. To control for this possibility, all the subjects judged the orientation of a very fine grating (0.35-mm slots and bars) for which performance was close to chance. If there was a general bias toward calling orientations orthogonal to the finger axis (parallel to the skin ridges), it should apply to these stimuli as well, but it did not: Gratings parallel and perpendicular to the skin ridges were discriminated correctly on 53.2% and 56.8% of the trials, and the difference was not significant [$t(17) = 1.36$, $p = .19$]. Thus, we infer that the difference in accuracy was due to a difference in skin conformance and not to bias.

GOT and Skin Conformance in Older Subjects

Next, we inquired whether differences in skin conformance could account for the decline in performance in older subjects, which has been widely reported (Stevens & Choo, 1996; Vega-Bermudez & Johnson, 2002) and which we confirmed in this study. The results for the 9 older subjects, 60–69 years in age, are shown in Table 2. As was expected, the older subjects had poorer spatial acuity than

Table 1
Skin Conformance and Tactile Acuity in Younger Subjects

Subject	Age	Sex	GOT	Parallel			Perpendicular		
				1 mm	2 mm	3 mm	1 mm	2 mm	3 mm
A1	19	m	1.10	125	385	755	97	303	596
A2	21	f	0.86	193	498	946	198	448	945
A3	21	m	0.96	140	423	740	125	399	702
A4	21	m	1.26	146	418	792	124	268	555
A5	22	m	0.88	138	431	914	150	412	751
A6	22	m	0.95	181	502	1,016	190	492	803
A7	22	m	1.00	135	440	751	96	253	544
A8	23	f	1.00	192	543	922	219	497	854
A9	23	m	1.20	96	342	709	73	251	596
A10	24	m	1.75	140	466	811	112	356	652
A11	25	m	1.10	255	553	873	195	371	684
A12	25	f	1.00	148	429	792	145	420	745
A13	26	f	1.09	137	391	739	126	417	753
A14	27	m	1.50	103	374	707	103	304	579
A15	31	m	1.80	210	407	696	276	372	664
A16	31	m	1.75	170	383	635	153	349	613
A17	35	m	1.70	160	397	701	118	376	588
A18	36	f	0.89	94	324	683	94	309	659
Mean	25.2		1.21	154	428	788	144	367	682

Note—GOT, grating orientation threshold.

did the younger subjects (Figure 5). The mean threshold in the older group, 1.97 mm, was significantly greater than the mean for the younger group, 1.2 mm [$t(25) = 4.06$, $p < .001$]. Although the GOT varied widely in this group, there was no significant relationship between GOT and skin conformance (correlation, .04). Thus, skin conformance accounted only for <1% of the variance. This correlation was significantly different from the value for the younger subjects (Hoetelling's transform to normality, $z = 2.03$, $p = .02$; Sokal & Rohlf, 1969, pp. 516–518). Unlike the younger subjects, there was no relationship between slot orientation and conformance [$t(8) = 0.43$, $p = .68$], and there was no significant difference in skin conformance between the younger and the older subjects [three-way ANOVA with age group, slot width, and orientation as factors; F ratio for age group effect, $F(1,157) = 0.238$, $p = .63$]. These similarities are illustrated in Figure 6.

DISCUSSION

The aim of this study of the correlation between grating orientation discrimination and skin conformance was to further our understanding of the mechanisms of tactile form perception. There were two main findings. First, skin conformance in the fingertip had a substantial effect on acuity within the younger group. The subjects with more conformant skin generally had lower orientation thresholds. The same was true of the subjects in the older group, but the effect accounted for a negligible fraction of the variance. Second, skin conformance in the older subjects was very similar to that in the younger subjects, even though their spatial acuity was much poorer. These data suggest that skin conformance and aging have significant but independent effects on spatial acuity. An interpretation that

accounts for these data is that the decline in acuity with age is due to neural effects that vary between subjects, which explains why skin conformance accounted for less of the variance between the older subjects.

There were two secondary findings. First, the skin is highly conformant. Most of the conformance of which the skin is capable occurs at forces less than 40 g. This accounts for the relatively small effects of contact force on tactile

Figure 2. Skin invasion versus slot width for all 18 younger subjects at 80 g of force. Dashed lines represent skin invasion when the slot was oriented parallel to the skin ridges; solid lines, when it was perpendicular to the skin ridges. Error bars represent the standard error of the mean for each point.

Figure 3. Grating orientation discrimination threshold versus skin conformance for the 18 young subjects. The threshold is the grating gap and groove size that produced 75% correct responses. Conformance is defined as the slope of the regression of skin invasion on slot width for each subject. The correlation between the two is -0.704 .

spatial perception and on the neural responses to spatial stimuli, as will be discussed below. Second, when the gratings were oriented so the skin was more conformant (parallel to the skin ridges), the younger subjects judged orientation more accurately. This corroborates the observation of a general correlation between skin conformance and acuity.

Acuity and Skin Conformance

Woodward (1993) used compliance, defined as the skin indentation produced by 10 g of force, and found no relationship between skin compliance and tactile acuity measured with two-point discrimination and a gap detection task. There are several explanations for the differences between her findings and ours. First, she measured compliance, not conformance. The ability of the skin to conform to the shape of the stimulus is clearly important for transducing the spatial form of the stimulus. There is no comparable, direct logic linking compliance with spatial acuity. Skin that has lost its collagen and elastin and, therefore, its ability to conform to a stimulus might still be quite compliant (e.g., because it overlies a bed of fatty tissue). Second, she lumped 104 subjects from 18 to 84 years of age into a single group. Even if compliance were correlated with acuity in young subjects, a correlation with acuity in the larger group would be lost. We showed, in the present study, that changes in skin mechanics cannot account for the large and variable loss in tactile spatial acuity. If we had lumped our younger and older subjects, we would have found no significant relationship between conformance and acuity. Third, Woodward measured skin compliance as the mean indentation produced by 8 presentations of two-point stimuli (separation range, 0.0–2.5 mm in 0.5-mm increments) and 13 presentations of gaps ranging from 0.0 to 4.5 mm. Averaging over 21 different stimuli and size

combinations may have obscured any relationship between compliance and acuity. Fourth, at least one of her measures of acuity (the two-point limen) is poorly suited to measuring acuity, and it produces highly variable measures between and within subjects (Craig & Johnson, 2000).

Neural Responses and Mechanical Anisotropy

Our observation that skin conformance is anisotropic is in agreement with work by Phillips and Johnson (1981a), who found that cutaneous mechanoreceptors represent the spatial details of a grating more effectively when the bars and slots are parallel to the skin ridges than when they are perpendicular. They suggested that “the dermal ridges may act like parallel rods in a sheet, making it stiff in one direction and flexible in the other” (Phillips & Johnson, 1981b, p. 1218). Wheat and Goodwin (2000) obtained essentially the same result in a more extensive study. They found that mechanoreceptors respond to a slot in a surface about twice as vigorously when a slot is parallel to the skin ridges than when it is orthogonal. The obvious interpretation of these results is that the mechanoreceptors represent the slots in a grating more effectively when the bars and slots are parallel to the skin ridges, because the skin is more conformant in that orientation. We believe that this accounts for the subject’s greater accuracy in identifying gratings when they were parallel to the skin ridges.

Acuity and Mechanical Anisotropy

The relationship between stimulus orientation and acuity has been studied by several investigators (Craig, 1999; Essock, Krebs, & Prather, 1992, 1997; Stevens & Patterson, 1995; Wheat & Goodwin, 2000). The results vary substantially between studies. The differences are accounted for

Figure 4. Percentages of correct responses for gratings oriented parallel (light gray) and perpendicular (dark gray) to the skin ridges. Values are shown for all responses, for responses near threshold (responses to the one or two grating gap and groove widths closest to threshold), and for responses below threshold (all gratings with groove and bar widths less than threshold). Bars represent standard errors of the mean.

Table 2
Skin Conformance and Tactile Acuity in Older Subjects

Subject	Age	Sex	GOT	Parallel			Perpendicular		
				1 mm	2 mm	3 mm	1 mm	2 mm	3 mm
B1	61	m	1.37	136	473	820	100	361	686
B2	67	m	2.50	119	370	787	132	423	764
B3	68	f	2.50	142	345	755	92	326	847
B4	69	m	2.00	80	280	556	109	254	486
B5	69	f	1.75	99	383	893	206	489	1,076
B6	63	f	2.50	141	418	822	104	570	805
B7	65	f	1.67	166	398	719	118	349	660
B8	61	f	1.58	184	471	882	160	468	848
B9	66	m	1.88	124	392	685	132	420	813
Mean	65.4		1.97	132	392	769	128	407	776

Note—GOT, grating orientation threshold.

by differences in the stimuli and how and where they were applied.

Wheat and Goodwin (2000) applied gratings to the distal part of the fingerpad, where the skin ridges are orthogonal to the finger axis, and they asked subjects to discriminate gratings (ridge width, 1.5 mm; slot width, 0.75 mm) from smooth surfaces. The subjects in their study, like those in ours, detected the gratings more readily when the ridges and slots were orthogonal to the finger axis (parallel to the skin ridges) than when they were parallel (orthogonal to the skin ridges).

In contrast, Craig (1999) used nearly identical stimuli and found no relationship with orientation relative to the finger axis, but he applied the stimuli at a more proximal location, where the skin ridges are circular. At this location, the skin conformance to the gratings would probably have been the same whether the gaps were oriented parallel or perpendicular to the finger axis.

Other studies have shown differences in tactile discrimination depending on stimulus orientation, but because they did not specify the stimulus location, it is impossible to say whether they are consistent with the anisotropy that we have reported here. Stevens and Patterson (1995) found stimulus orientation differences in two tests of discrimination on the fingertip. In one, subjects judging the orientation of two points were substantially more accurate when the points were oriented along the finger axis. In the other, subjects discriminated an edge from two points (separation equaling the line length) and were slightly better when the two were oriented across the finger axis. Essick et al. (1992, 1997) used stimuli similar to those in Wheat and Goodwin (2000) and Craig (1999) and found that the subjects detected the slots more readily when they were parallel to the finger axis.

Acuity and Aging

A decline in tactile sensory capacity in older subjects has been well documented for different tasks, such as tactile letter recognition (Vega-Bermudez & Johnson, 2002), grating orientation discrimination (Remblay, Backman, Cuenco, Vant, & Wassef, 2000), gap detection and point localization (Stevens & Choo, 1996), and vibratory detec-

tion (Gescheider, Bolanowski, Hall, Hoffman, & Verillo, 1994). The demonstration that skin conformability is the same in older and younger subjects is surprising in view of the changes in skin that occur with aging. Studies that have addressed changes in hairy skin mechanics (we are not aware of comparable studies in glabrous skin) with age suggest that there are changes in skin elasticity, hydration, thickness, and torsion extensibility (Berardesca, Farinelli, Rabbiosi, & Maibach, 1991; Escoffier et al., 1989). However, our results suggest that these changes do not affect the skin's ability to conform to the spatial features of the stimulus.

The lack of a change in conformability with aging suggests that the loss of tactile spatial acuity is accounted for by some loss in the neural mechanisms leading to perception. Loss of mechanoreceptor density is a possible reason for the loss of mechanoreceptive sensibility (Gescheider et al., 1994; Stevens & Choo, 1996; Stevens & Patterson, 1995). Several studies have shown that Pacinian, Meissner, and Merkel receptor density declines with age and that there are morphological changes in the receptors (Bruce,

Figure 5. Grating orientation discrimination threshold versus subject age.

Figure 6. Skin invasion versus slot width for younger and older subjects at 80 g of force. Dashed lines represent skin invasion when the slot was oriented parallel to the skin ridges; solid lines, when it was perpendicular to the skin ridges. Error bars represent the standard error of the mean for each point.

1980; Cauna, 1965). Since these mechanoreceptors have been linked to the afferent system that transmits tactile information (K. O. Johnson, 2001), one may expect that deterioration in the density of the receptor matrix would lead to deterioration in tactile spatial acuity.

Force and Conformance

The skin is extremely compliant and conformant. A very light force produces a large indentation (compliance); for example, when a flat surface presses on the skin of a fingerpad, a 30-g force produces 1.5 mm of skin indentation. Increasing the force more than threefold to 100 g produces only an extra 0.6 mm of indentation (Vega-Bermudez & Johnson, 1999). The data illustrated in Figure 1 show that the same is true of conformance. The relevant mechanical stimulus for the mechanoreceptors that are responsible for tactile perception is local tissue distortion (Phillips & Johnson, 1981b), not pressure per se, because they are embedded within an aqueous medium, which is incompressible. The distortion and the accurate representation of spatial form depend on the degree to which the skin conforms to the object being sensed. The finding that the skin is so conformant (that most of the conformation occurs at forces less than 40 g) accounts for the fact that neural responses to spatial patterns scanned over the skin are affected minimally by changes in contact force (K. O. Johnson & Lamb, 1981; Phillips, Johansson, & John-

son, 1992). This, in turn, accounts for the fact that tactile spatial pattern recognition (Loomis, 1985) and roughness judgments (Lederman, 1974) are affected minimally, if at all, by changes in contact force.

Conclusion

There is a substantial relationship between skin conformance and tactile spatial acuity in the fingertips of younger subjects. However, the general decline in spatial acuity with aging is the result of something other than a change in skin conformance. This suggests that neural factors play the major role in this decline. A secondary finding is that the skin ridges of the fingertip make the skin more conformant in the direction orthogonal to the skin ridges. Therefore, stimuli that vary in the dimension orthogonal to the ridges (e.g., gratings with bars oriented parallel to the ridges) are discriminated more readily than stimuli that vary in the dimension parallel to the ridges (e.g., gratings with bars oriented orthogonal to the ridges).

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