Quantifying assessment of touch-feel perception: an investigation using stylus base equipment and self-touch (human fingertip)

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ملخص البحث

يهدف البحث إلى قياس خشونة السطوح لمجموعة من المواد بإستخدتم جهاز (Taly-surf®) ومقارنتها مع ردود فعل الناس من خلال حاسة اللمس (وهي أحد الحواس الخمسة). ومن ثم معرفة ما إذا كان هنالك علاقة ما بين حاسة اللمس والنتائج المعملية التي تم التوصل إليها عن طريق جهاز قياس خشونة السطوح. بالإضافة إلى تحديد ما إذا كانت الاختبارات النفسية البسيطة (من خلال حاسة اللمس) يمكن أن توفر علاقة دقيقة بين الخصائص الفيزيائية المقاسة والنتائج التي تم الحصول عليها عن طريق اللمس لمجموعة من المواد المختلفة. في التجربة الأولى ، تم قياس خشونة السطوح لمجموعة من المواد من أجل تحديد مستوى المعايير الإحصائية. بينما في التجربة الثانية ، تم الحصول على النتائج من خلال عشرون مشاركاً (عشرة رجال و عشرة نساء وكان أصغر مشارك يتراوح عمرة ١٥ سنة وأكبر المشاركين يصل عمرة إلى ٥٥ سنة).

Abstract

This paper demonstrates two experiments that investigated based on self-touch (human fingertip) and stylus base equipment. The aim of the experiment was to investigate the tactile perception of a variety of materials, with the intention of revealing how well human perception related to the physical property data. Besides, to establish whether simple psychophysical tests could provide an accurate correlation between the measured physical properties and the tactile perception of a set of different materials. This investigation focuses on the direct measurement of the surface roughness generated when a fingertip and stylus are stroked on test specimens. In the first experiment, the surface profile was quantitatively analyzed in order to determine the statistical standard parameters as (average roughness, Ra, root mean square, Rq, ten point height, Rz, total profile depth, Rt, skewness, Rsk, and kurtosis, Rku) by using Form Taly-surf® (from Taylor Hobson, Inc.). In the second experiment, twenty healthy participants were acquired in order to gain the relevant results time-effectively and use the conclusions for huger studies later on. Ten men and ten women took part, the youngest participant being 15 years old and the oldest participant being 55 years old. In the work reported here, the measured roughness has a strong correlation with rough-smooth, cold-warm and like-dislike. The data presented here confirm that women gave more concordant sensorial judgments than men, while men had more consistent preference by touch.

Keywords: Self-touch; Stylus; Tactile Perception; Physical Properties; Psychophysical

1. Introduction

Touch (as one of the most intimate forms of human communication) is the first of our senses to develop and it provides us with our most fundamental means of contact with the external world. Indeed, there is a major trend for product development to move towards customer-oriented affective design, which takes account of customers' emotional feelings and preferences. Many consumer products, which are held in the hand for use, are generally designed with careful attention to their function and visual appearance and increasingly some ergonomic aspects [1]. This interest is driven by many of the tasks that can undertake, such as the development of a sense of touch in robotics, haptic perception for virtual reality and remote sensing, as well as the desire to improve the tactile aesthetics in consumer products such as phones, touch-pads, papers and fabrics [2]. The perception haptic (i.e., touch with hands) one of the basic human-touch senses essential for people's everyday life, is not as simple as some many think [3]. When we touch the surface of an object, we encode information that allows us to make perceptual decisions about that object. Object information can be based on both geometric (e.g. shape, size, orientation and curvature) and materials properties (e.g. temperature, compliance, texture and weight) [4]. Human make a judgment about each of these feelings with regards to characteristics of how the surface is felt and whether they liked this feel or not. This subjective judgment has been recognized as one key factor to win or lose customers in the future for industries such as auto-motives, textiles and telecommunications, where personal taste on touch-feel perception will be a main purchase criterion, as well as heightened product quality beliefs [5]. Within the consumer behavior literature, touch has been shown to enhance positive feeling in the context of interpersonal touch [6], to improve confidence in product judgment when the environment allows physical inspection [7], as well as to enhance product evaluation when softness and texture vary, especially for high quality products [8]. Touch plays an integral role within consumer behavior and sensory engagement [9].

What is more, touch-feel perception is generally concerned with five modes of perception, that is smooth-rough, slippery-grippy, cold-warm, soft-hard and like-disliked. Roughness is related to the height differences on the surface of the material; compliance to the material's elasticity; coldness to the material's heat capacity and thermal conductivity; and slipperiness to the friction between the material and the skin [10]. Improving products on behalf of their emotional and subjective qualities is known as affective engineering (or Kansei engineering) developed originally by Nagamachi over 30 years ago in Japan [11]. Surprisingly, there is no commercial instrument available which can mimic a fingertip to sense the above mentioned properties, despite the importance of touch in our everyday social interactions from birth through to adulthood and old age. So, in this paper, the study is based on two experiment methods to measure the surface:

a) ***Stylus base equipment.*** We choose products where the texture is a key product characteristic and consequently will play a vital role in determining overall product quality and so does to the consumer's decision-making process.
b) ***Self-touch (human fingertip)*.** Our aim is to contribute to the literature on touch within consumer behavior by showing how additional sensory inputs can influence haptic perceptions.

1.2. Skin Structure

The human being is very developed "sophisticated" creatures in both mental and the body physiology. Sense of feeling is one of the different senses that our body used it as way to communicates with the external environment. It is very sophisticated property, which is haptic sense, is complex. Unlike vision, touch involves a direct physical interaction, so that human actions cause and change what is perceived. It is the fundamental role of touch to sense the results of these contact interactions in order to guide manipulation and body motion [11].

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. [2]. The skin is the human body's its largest organ, covering 1.6 m2 of surface area and accounting for approximately 16% of an adult weight [12, 13, 14]. As the largest organ in human body, skin serves as the major sensory organ for touch-feel perception. The structure of human skin tissue and the image of human finger (skin) are shown in Figure 1. The structure of skin tissue shows two main layers of skin, the upper epidermal barrier layer (about 0.1 - 0.2 mm in depth) and the lower dermis barrier which is much thicker. The epidermal barrier layers relatively thin and securely attached to the underlying dermis by a specialized basement membrane zone. The dermis is well vascularized and also contains receptors for touch (mechanoreceptor), temperature (thermoreceptor) and pain (nocireceptor) [15]. Stratum corneum is the outmost layer of epidermis, which acts as a barrier to protect our body from harsh environmental factors. Stratum corneum is constituted with a stacking of keratinized cells (coenocytes) and is presented in the form of a pavement of penta or hexagonal cells from 26 to 45 µm diameters. Its thickness consists of 10 to 30 layers of flat cells from 0.3 to 0.7 thicknesses. It is stiffest layer of the skin, whose Young's modulus can reach 0.5 to 1.0 GPa [16]. The micro structure of the skin surface, determined by the epidermis resembles a pattern with a net-like structure. This structure consists of polygonal forms, most often triangles, with a global configuration of furrows and ridges. Also, a microstructure of ridge patterns occurs on the skin of fingertips, palms and soles [17].

It is worth mentioning that the structure of the skin and skin appendages are influenced by sex hormone metabolism. In particular, there are conspicuous physiological differences between male and female skin, e.g., men in general have thicker skin, higher production rate of sebum and sweat than women as reviewed by Paolo U. Giacomoni [18]. The authors in the investigation suggest that those physiological differences may be associated with the gender difference in tactile perception.

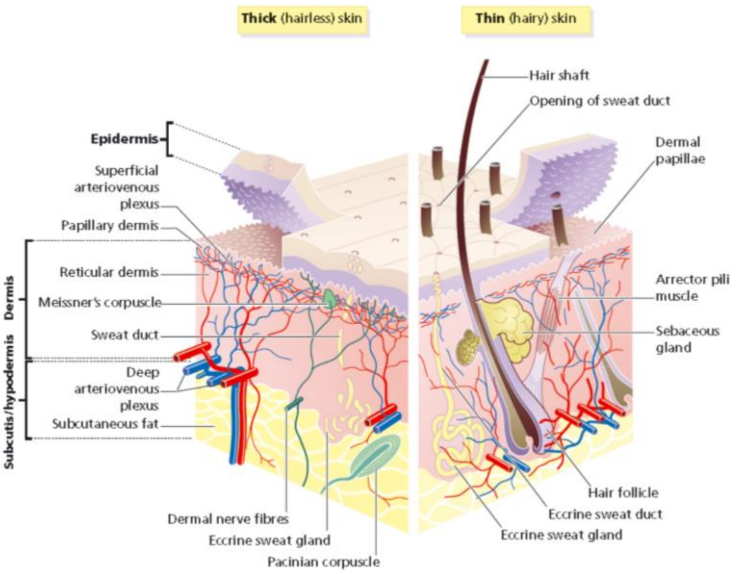


Figure 1: (a) structure of human skin, adapted from [11] and (b) image of human finger

1.3. Process View of Touch-feel Perception

The process of touch-feel perception is structured into three levels: biophysical interaction level, neuron sensory level and perception evaluation level [11]. Figure 2 shows the process of the touch-feel perception (e.g., finger touch).

- ***At biophysical interaction level***, as human touches the candidate surface by finger, his/her complicated motion leads to the physical interfacial interaction between the skin epidermis layer (about 0.1 – 0.2 mm in depth) and surface. Not only the surface properties such as texture and strength affect this interaction, but also the variation of skin conditions due to a series of skin physiological mechanism, e.g., blood circulation, sebum/sweat lubrication. Physically, the interfacial could lead to the changes of strain/stress or thermal state at the dermis layer.
- ***At neural sensory level***, those changes are sensed as tactile stimuli by numerous mechanoreceptors or thermoreceptor. Meanwhile other visual stimuli in associated with surface color or reflectivity may also be sensed. The tactile stimuli transfer through nervous system and reach the brain. The sensory receptors for touch and proprioception are complex in structure, but the basic organization is that of a neuron that has an ending, endings responsible for mechanic-electric transduction. Once the mechanical stimulus is transduced into an electrical impulse, the neuron transmits this information very quickly to the spinal cord and then to the brain. Information arising from the mechanoreceptors of the body and face goes to specific regions within the brain that interpret the signals in terms of tactile perceptions. The cortical regions devoted to this function have many independent representations of the body surface.

- ***At perceptual evaluation level,*** as the tactile stimuli reached the brain, where psychophysical judgments are made and combined and also later compared to memory of previous experience to create affective judgment. These judgments are finally expressed upon the understanding of complicated semantic context at the evaluation stage.

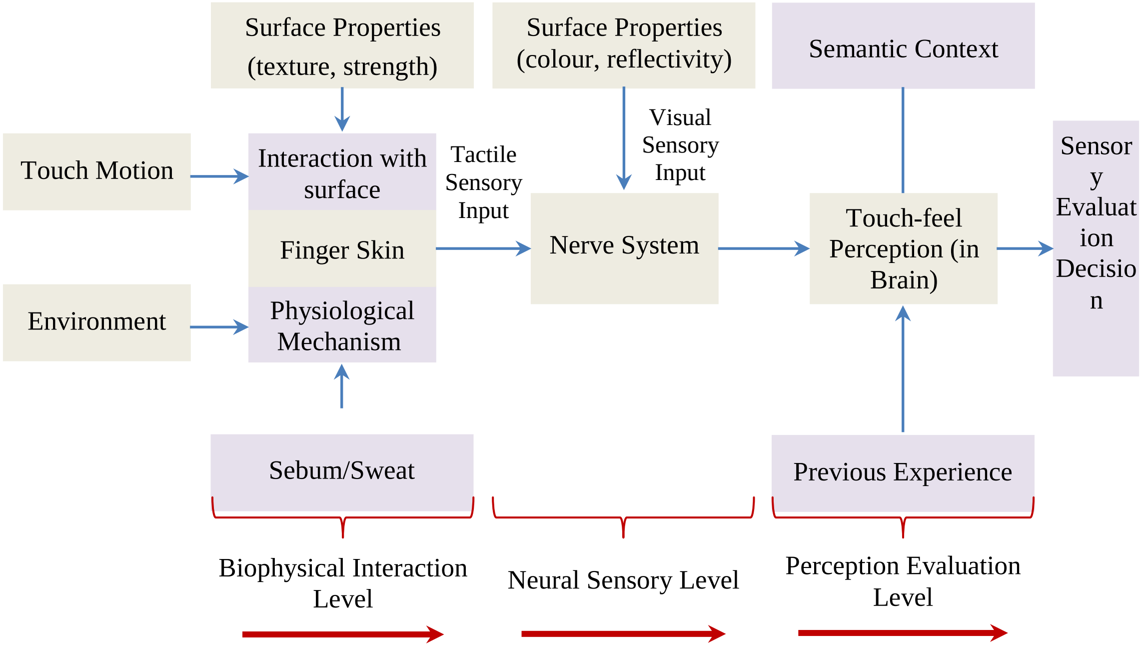


Figure 2: The process of tactile perception by finger touch, adapted from [11]

2. Experiment Procedure

2.1. Materials

A range of different materials were used as the stimuli in this study. Nine polymers (Lyondellbasell, Basell, German) with different topographies and identical dimensions of length of 10 × 10 × 2 mm were chosen for this experiment as shown in Table 1. The density, tensile stress and flexural modulus of all the material samples were obtained using (Lyondellbasell, Basell, German) database. The pattern polymer surfaces are made of five types of materials as listed in Table 1 and the entire pattern surfaces are heat embossed with four different pattern types: Yukon, Stripple 005, N111 and N127. The materials were either typical of automotive interior or of household items, so that the haptic familiarity to the participants has to be assumed.

Table 1: List of materials being used in the investigation (Lyondellbasell, Basell, German)

Sample No.	Material Name	Density (g/cm^3)	Tensile Stress (MPa)	Flexural Modulus (MPa)
S1	Softell TKG 300N	1.09	36	2500
S2	Softell TKG 259N (*Yukon*)	1.05	31	1700
S3	Softell TKG 259N (*Stripple 005*)			
S4	Hostacom EYC 136N (*Yukon*)	1.00	22.5	2000
S5	Hostacom EYC 136N (*Stripple 005*)			
S6	Softell TKS 209N (*N111*)	0.91	8	85
S7	Softell TKS 209N (*N127*)			
S8	Hostacom ERC 342N (*N111*)	0.97	21	1600
S9	Hostacom ERC 342N (*N127*)			

2.2. Participants

As the study is the first of its kind in the region of Saudi Arabia (no such data available to compare in this region at this stage of investigation) and only nine materials had to be evaluated, the minimum recommended number of twenty healthy participants was acquired in order to gain the relevant results time-effectively and use the conclusions for huger studies later on. Ten men and ten women took part (from academic and community settings), the youngest participant being 15 years old and the oldest participant being 55 years old. No bias was given for or against anyone as a result of their gender, ethnicity or nationality. All participants were familiar with polymer, as is either doing research on plastics or being sensible for products made of plastics. A small gift was given to each participant after the evaluation session as a compensation for their time and effort.

2.3. Procedure

The aim of the experiment was to investigate the tactile perception of a variety of materials with intention of revealing how well human perception related to the physical property data. The participants had read the information sheet prior to taking part in the experiment. Upon agreeing to take part in the study, all participants were free to withdraw at any point. Participants were then compensated for their time and effort. Prior to each testing session, the participants washed their hands and then dried these sites using a cotton towel before being seated at the station. The time between washing and the first test was approximately 5 minutes. Testing took place in an air-conditioned room, with an ambient temperature of 20±1oC and a relative humidity of greater than 40±5% RH. Participants were seated at a table comfortably opposite the investigator and they were then presented with the nine materials samples one at a time, in a random order. Participants were instructed to assess five parameters (smooth-rough, slippery-grippy, cold-warm, soft-hard and like-dislike) by moving the index finger of their preferred hand over the nine materials using reciprocating motion (forwards and backwards), starting on the left side and ending at the right. No time limit was enforced for each assessment, and participants could stroke or press the polymer surface as many times as they wished. Judgments were typically made within tens of seconds for each attribute. This procedure was repeated for all of the participants. The data presented in this part of experiment, were obtained from 20 people, three measurements for each sample, at different time and dates over one month period. It is important to note that respondents were only asked how each specific touch would make them feel, and not what the motivation of the toucher might be.

Figure 3 shows image of a right hand fingertip's participant pressed against sample in a reciprocating motion (forwards and backwards) and image of different polymer samples. The test material was mounted on the sample holder and the stroking movement load around 0.5 N and the velocity of finger slide was approximately the same for all participants touching the nine materials 6 cm/s (they were supervised to use the same pressure for each sample).

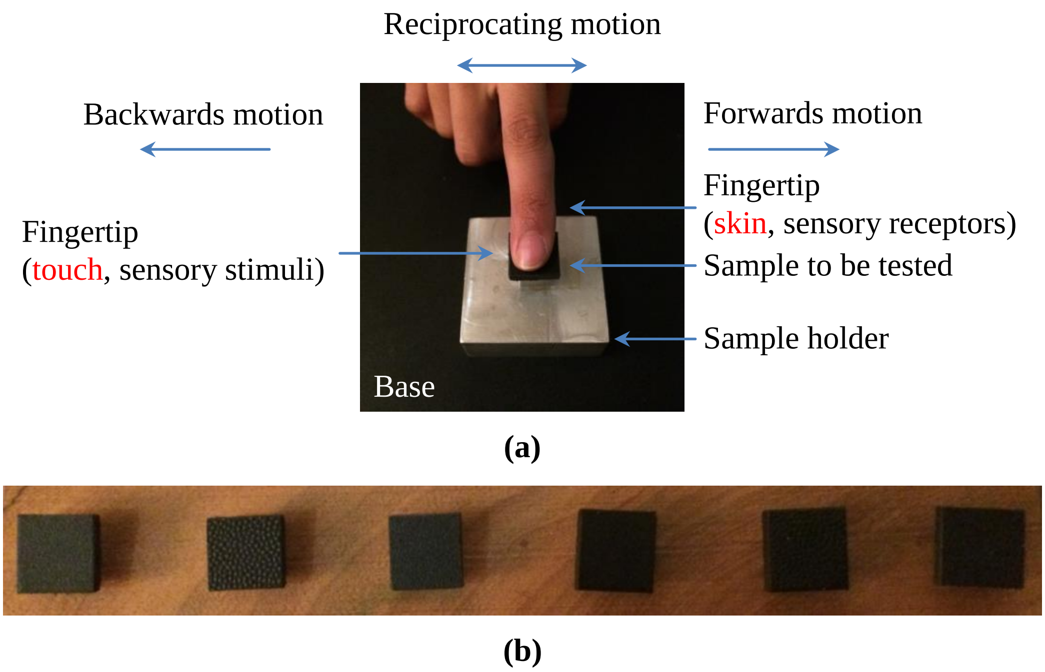


Figure 3: (a) image of a right hand fingertip's participant (youngest participant, 15 years old) pressed against sample in a reciprocating motion (forwards and backwards) and (b) image of different polymer samples

Figure 4: shows responses scales developed and used to rate five parameters (smooth-rough, slippery-grippy, cold-warm, soft-hard and like-dislike), always in the order listed using visual analogue type scales printed on the paper sheets. These attributes have been established as salient dimensions of tactile perception [18, 19, 20, 21]. All values were noted down by the healthy participants during the experiment.

- **First:** Smooth-Rough

Smooth - Rough								
Smooth	Strongly Agree	Agree	Partially Agree	Neutral	Partially Agree	Agree	Strongly Agree	**Rough**
	( )	( )	( )	( )	( )	( )	( )	

- **Second:** Slippery-Grippy

Slippery - Grippy								
Slippery	Strongly Agree	Agree	Partially Agree	Neutral	Partially Agree	Agree	Strongly Agree	**Grippy**
	( )	( )	( )	( )	( )	( )	( )	

- **Third:** Cold-Warm

Cold - Warm								
Cold	Strongly Agree	Agree	Partially Agree	Neutral	Partially Agree	Agree	Strongly Agree	**Warm**
	( )	( )	( )	( )	( )	( )	( )	

- **Forth:** Soft-Hard

Soft - Hard								
Soft	Strongly Agree	Agree	Partially Agree	Neutral	Partially Agree	Agree	Strongly Agree	**Hard**
	( )	( )	( )	( )	( )	( )	( )	

- **Fifth:** Like-Dislike

Like - Dislike								
Like	Strongly Agree	Agree	Partially Agree	Neutral	Partially Agree	Agree	Strongly Agree	**Dislike**
	( )	( )	( )	( )	( )	( )	( )	

(a)

Word Category Scale						
Strongly Agree	Agree	Partially Agree	Neutral	Partially Agree	Agree	Strongly Agree
1	2	3	4	5	6	7

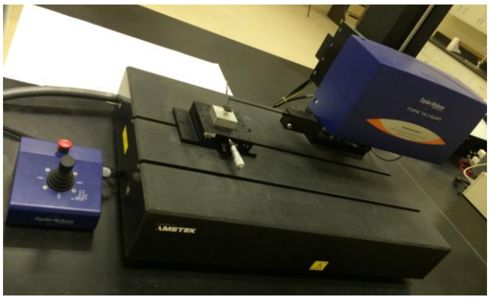
(b)

Figure 4: (a) Response scales to rate five parameters using a side-to-side motion and (b) developed evaluation scale

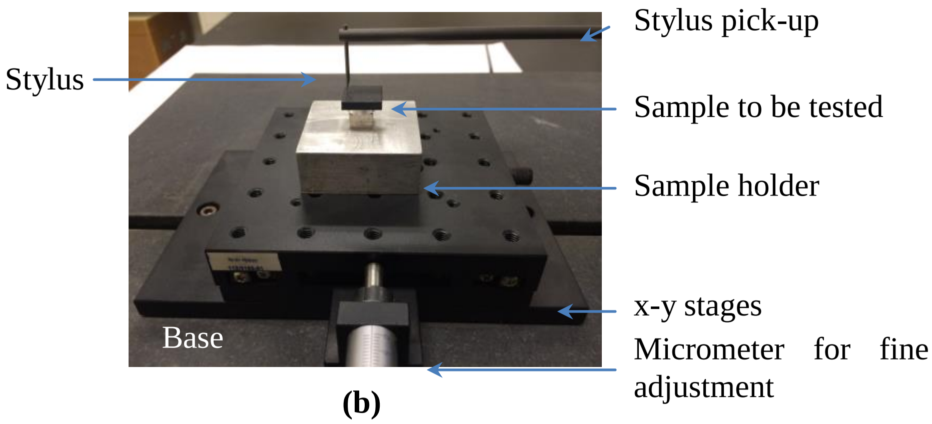
3. Experiment No.1: Stylus Base Equipment

The surface profile was quantitatively analyzed in order to determine the statistical standard parameters as (average roughness, R_a, root mean square, R_q, ten point height, R_z, total profile depth, R_t, skewness, R_{sk}, kurtosis, R_{ku}) by using Taly-surf® (from Taylor Hobson, Inc. delivers 0.8 nm resolution over 12.5 mm seamless measuring range, include 0.125 µm horizontal data spacing, a nominal 2 µm stylus was used with a normal load of 0.7 mN and selectable traverse speed down to 5 mm s^{-1}), and conforms to British Standards, see Figure 5. Surface roughness errors were calculated from the standard deviation of the absolute values of height deviation (absolute values). The traces were auto-levelled to a linear least-squares straight line and then filtered with a standard 0.8 mm cut-off. The surface parameters were selected according to the recommendations in the literature and also under consideration of the data processing facilities available [24, 25, 26, 27, 28]. Every test condition was repeated at least three times at different "*new*" locations on the sample surface in order to ensure reproducibility of the results over three days. The new location was ±200 µm from the previous one. This approach should avoid any alteration of the counter-body surface, e.g., due to wear, which might occur during the test and affect the measurements in the following tests.

All experiments were performed with typical "ball-on-flat" arrangement applying a linear sliding contact at constant velocity over a specific distance. Tests were performed by using single scan mode (forwards motion). Profiler at scan length of 10 mm, which is close to the size of human fingertip.



(a)



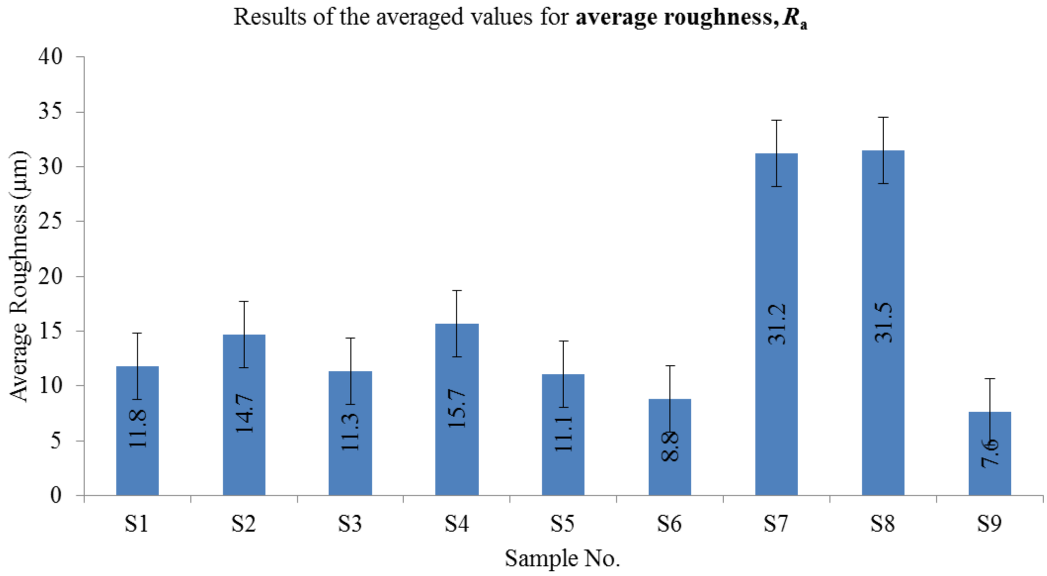
(b)

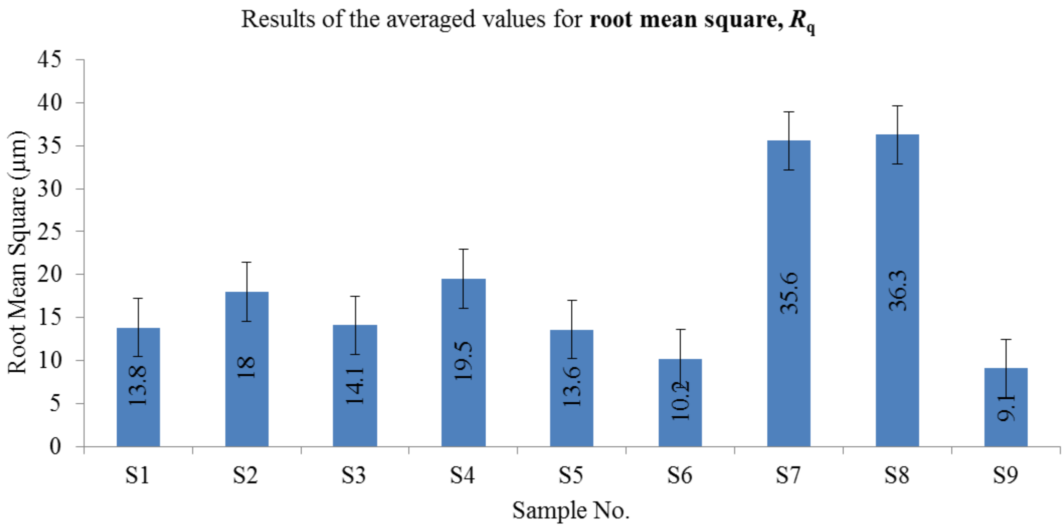
Figure 5: (a) image of Taly-surf® (from Taylor Hobson) and (b) *x-y* stages for mounting the sample holder and specimen.

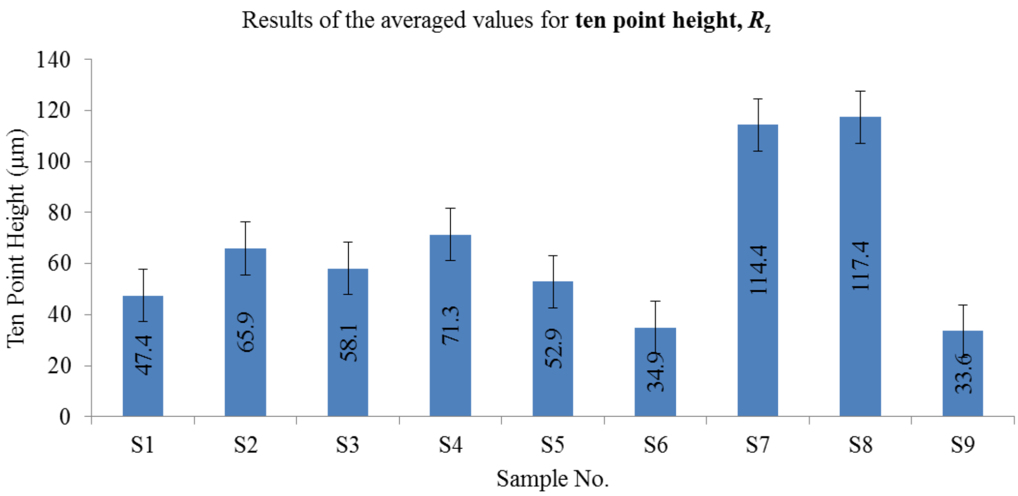
Table 2 and Figure 6 show the results of the averaged values for nine soft-touch polymer surfaces using Taly-surf test-rig. As can be seen, materials No. S9, S6 and S5 are showed the smoothest surfaces topography, as expected, correlates strongly with the physical and mechanical properties of a mixed set of samples listed in Table 1. The topography features of the patterns have an order of *N127* < *N111* < *Stripple 005* < *Yukon* in low roughness R_a. The roughness distribution parameters of skewness (R_{sk}) and kurtosis (R_{ku}) characterize, respectively, the degree of asymmetric spread of the surface heights around its mean and the relative peakedness or flatness of a distribution compared to normal distribution. Using the limited data from these preliminary experiments on nine polymer samples, it appears that skewness larger than -0.07 and a kurtosis larger than 1.9 results in lower coefficient of friction. Lower values in skewness and kurtosis result in higher coefficient of friction. The majority of polymer films have positive skewness values, but if the surface has some deep valleys or uncoated sites, its skewness will tend to become negative value and the kurtosis is low (less than 3.0) [29]. The pattern type of *N111* is observed with bumpy grains while *Stripple 005* pattern has dimples with similar grain size. Due to the material strength differences, the grain size of the patterns is slight difference among them. The *N127* and *Yukon* are observed with "*skin-like*" patter and glossy spherical bumps, respectively. Their visible surface are usually embossed with a grain pattern to improve the appearance and hide surface defect such as sink marks and flow lines that occur as a result of building process and part design.

Table 2: Results of the averaged values for nine samples using Taly-surf test-rig.

Sample No.	R_a (μm)	R_q (μm)	R_z (μm)	R_t (μm)	R_{sk} (μm)	R_{ku} (μm)
S1	11.8	13.8	47.4	50.9	-0.39	1.9
S2	14.7	18.0	65.9	78.4	-0.63	2.8
S3	11.3	14.1	58.1	75.4	-0.57	3.1
S4	15.7	19.5	71.3	88.2	-0.99	3.3
S5	11.1	13.6	52.9	64.8	-0.44	2.8
S6	8.8	10.2	34.9	39.5	-0.15	1.9
S7	31.2	35.6	114.4	126.4	-0.45	1.9
S8	31.5	36.3	117.4	134.3	-0.29	1.9
S9	7.6	9.1	33.6	41.0	-0.07	2.2


Results of the averaged values for **average roughness, R_a**
Average Roughness (µm)
40
35
30
25
20
15
10
5
0
11.8
14.7
11.3
15.7
11.1
8.8
31.2
31.5
7.6
S1
S2
S3
S4
S5
S6
S7
S8
S9
Sample No.


Results of the averaged values for **root mean square, R_q**
Root Mean Square (µm)
45
40
35
30
25
20
15
10
5
0
13.8
18
14.1
19.5
13.6
10.2
35.6
36.3
9.1
S1
S2
S3
S4
S5
S6
S7
S8
S9
Sample No.


Results of the averaged values for **ten point height, R_z**
Ten Point Height (µm)
140
120
100
80
60
40
20
0
47.4
65.9
58.1
71.3
52.9
34.9
114.4
117.4
33.6
S1
S2
S3
S4
S5
S6
S7
S8
S9
Sample No.

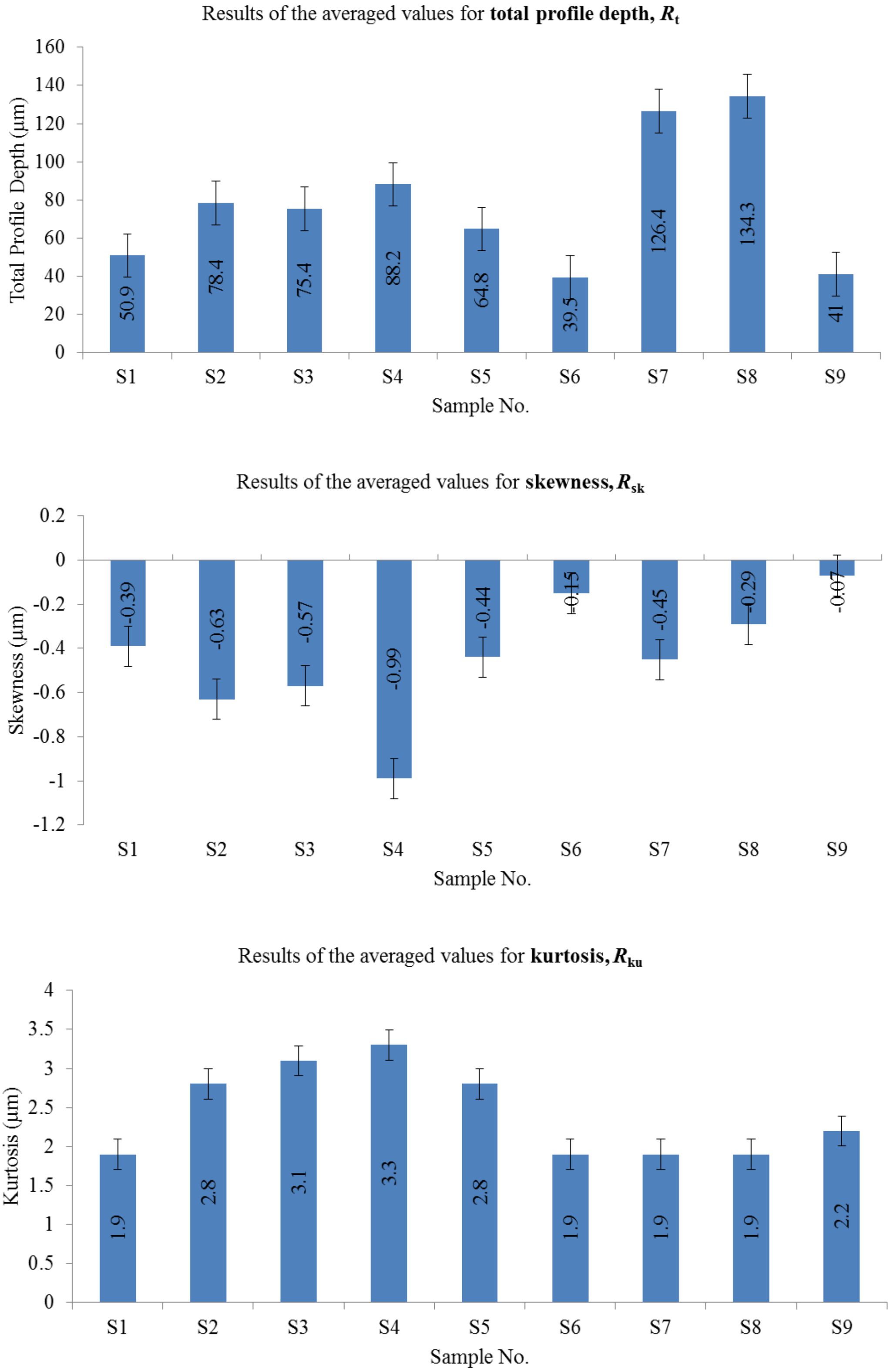


Figure 6: Results of the averaged values for nine samples using Taly-surf test-rig (average roughness, R_a, root mean square, R_q, ten point height, R_z, total profile depth, R_t, skewness, R_{sk}, kurtosis, R_{ku})

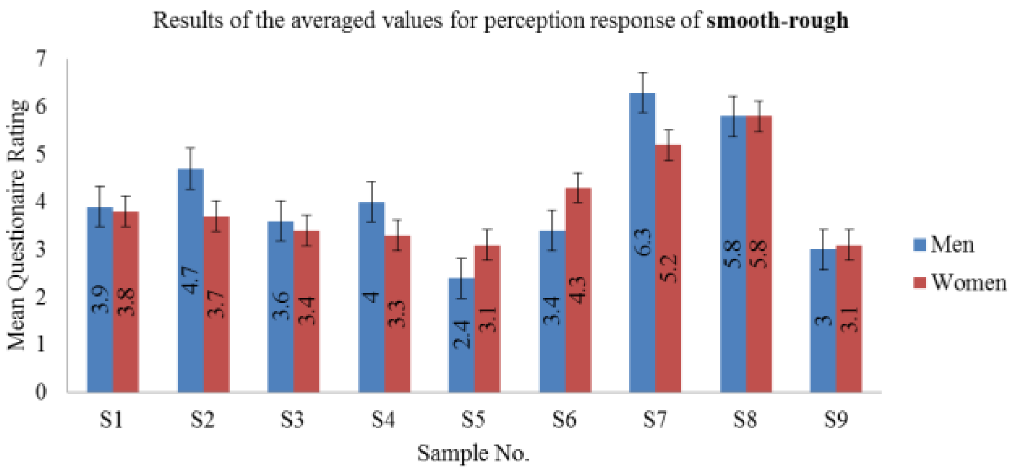
4. Experiment No.2: Self-touch (human fingertip)

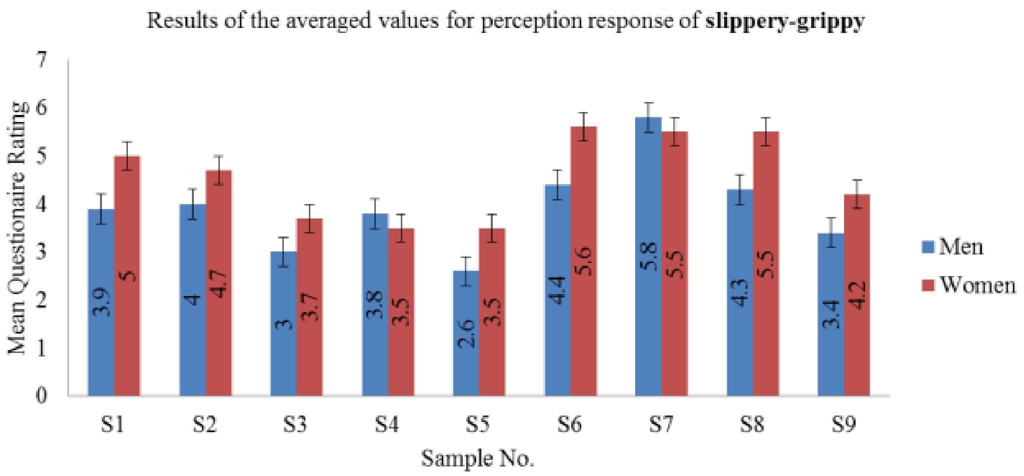
The same nine samples were then used for touch-feel judgment. Healthy participants were given an assessment form for each of the nine materials with five linear scales representing each of the range of tactile perceptions of (smooth-rough, slippery-grippy, cold-warm, soft-hard and like-dislike) as shown in Figure 4. Participants were asked to place a mark on each scale at a position where they felt their perceptions fell in relation to the subjective extremes. The actual position of each of the response were then measured and expressed as a numerical value from 0.00 to 7.00 to enable statistical analysis to be carried out. Questionnaire ratings (0.00 = not at all; 7.00 strongly agree). Table 3 summarize the results for averaged perception response for each one. Figure 7 shows the results of the averaged values for perception response for men and women for comparison.

Comparing the evaluation results between participants (men and women), as shown in Table 3, women show higher perceptual concordance than men in the modes of smooth-rough, cold-warm and like-dislike. These findings suggest that women have more accurate and consistent decision in sensorial level, some evidential findings of neuroimaging scientist also suggest similar gender differences in motor programmes for exploration in mainpulospatial tasks such as tactile discrimination with active touch [18]. In contrast, men only effectively discern the difference in slippery-grippy and soft-hard. The participants could effectively discern the difference among polymers in the modes of smooth-rough, slippery-grippy and soft-hard. However, there are no concordant judgments in the modes cold-warm and like-dislike. This might suggest that the potential link exist between the perceptual modes of cold-warm and like-dislike in emotion. In general, material No. S9 and S5 are agreely perceived as the smoothest pattern for both gender, and material No. S8 (for women) and S7 (for men) are agreely perceived as the roughest one. Moreover, material No. S6 (for women) and S7 (for men) is the grippiest one. There were strong correlations between physical and mechanical properties of the polymers and perceived qualities, these relationships were clearly linear as expected.

Table 3: Results of the averaged values for perception response of (smooth-rough, slippery-grippy, cold-warm, soft-hard and like-dislike)

Sample No.	smooth rough (Average)		slippery grippy (Average)		cold warm (Average)		Soft Hard (Average)		Like Dislike (Average)	
	Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
S1	3.9	3.8	3.9	5	3.6	4.1	5.8	5.9	3.8	3.5
S2	4.7	3.7	4	4.7	4.3	4.4	5	5.2	1.1	3.3
S3	3.6	3.4	3	3.7	4.6	4	4.8	5.2	3.6	3
S4	4	3.3	3.8	3.5	3.5	3.5	5.3	5.4	3.5	2.9
S5	2.4	3.1	2.6	3.5	3.9	3.9	5.6	5.3	4.2	3.3
S6	3.4	4.3	4.4	5.6	4.1	4.2	3.8	4.3	3.3	4.4
S7	6.3	5.2	5.8	5.5	4.5	4.4	4.9	4.6	4.7	4.7
S8	5.8	5.8	4.3	5.5	4	4.3	6.5	6.3	5.1	4.5
S9	3	3.1	3.4	4.2	3.9	3.8	5.7	5.8	5.2	3.8





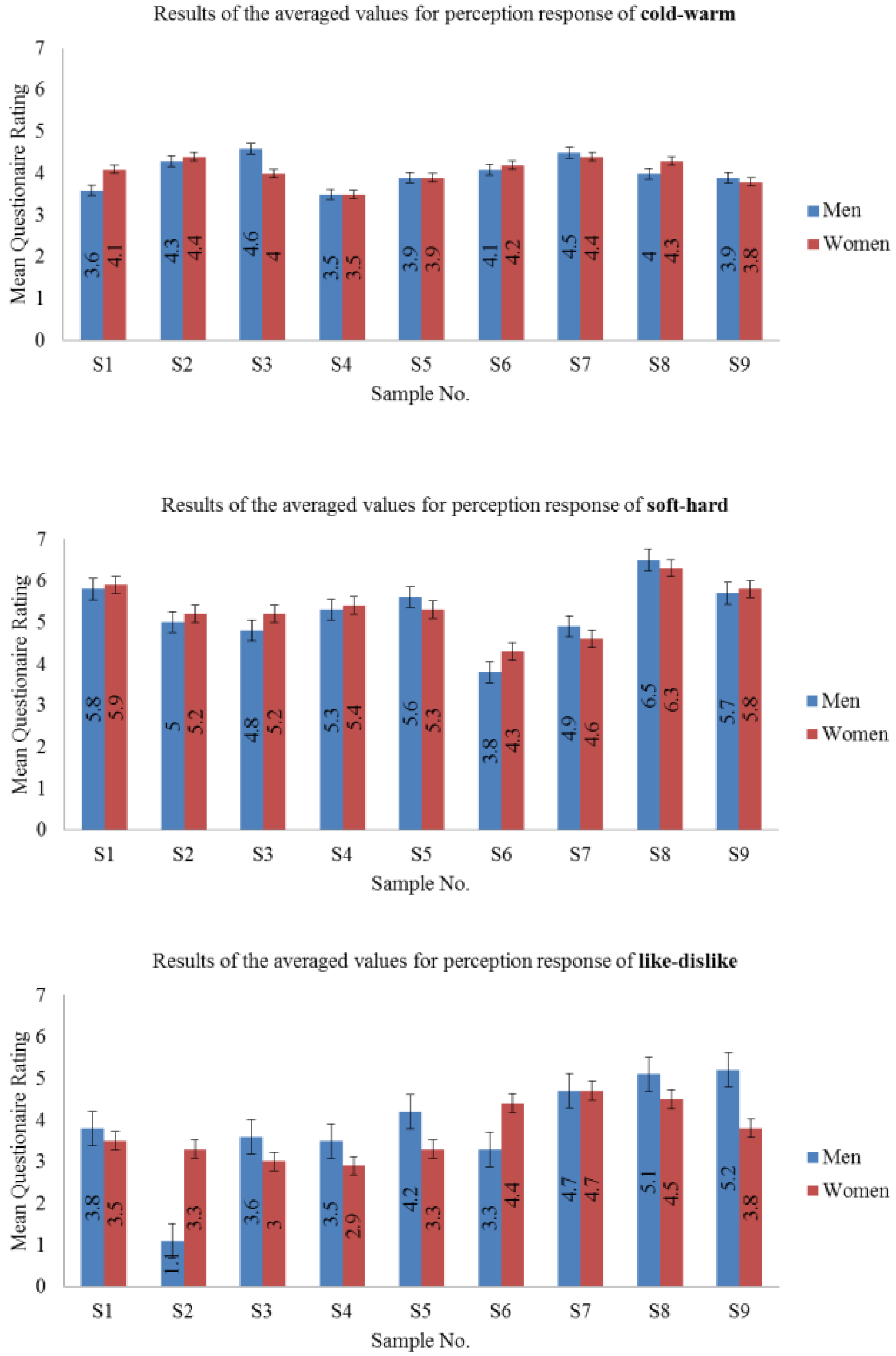


Figure 7: Questionnaire results of the averaged values for perception response of (smooth-rough, slippery-grippy, cold-warm, soft-hard and like-dislike) for men and women

5. Correlations

Correlation analysis has been carried out for perceived and measured data, although it must be treated with care because there is an arbitrary numerical scale associated with the perception tests. As shown in Figure 8, perceived roughness was highly correlated with all topography parameters, especially, R_a. The parameter R_a was notably correlated with perceived smooth-rough. For the perception mode of smooth-rough and average roughness R_a measured by the Taly-surf (from Taylor Hobson, Inc.), the correlation reached as high as 95%. The averaged spacing values of these specimens have similar trend to the roughness R_a, so it has a similar correlation with the perceived rankings. Statistically, sample No. S9 was evaluated as preferable sample by both men and women as well as by the Taly-surf® (from Taylor Hobson, Inc.).

Figure 8: Results of the averaged values between men, women and average roughness

6. Conclusions

Touch is the first of our senses to develop and it provides us with our most fundamental means of contact with the external world. In the first experiment, the surface profile was quantitatively analyzed in order to determine the statistical standard parameters as (average roughness, R_a, root mean square, R_q, ten point height, R_z, total profile depth, R_t, skewness, R_{sk}, kurtosis, R_{ku}) by using Form Taly-surf® (from Taylor Hobson, Inc.). In the second experiment, Subjective tactile evaluations on the selected touch-feel polymer surfaces are carried out in order to build up the psychophysical database in term of five major tactile modes (smooth-rough, slippery-grippy, cold-warm, soft-hard and like-dislike).

It appears that, within the bounds of these experiments, this paper examined whether the physical properties of the materials can be useful predictors of psychophysical properties of materials. Roughness actually appears to be the dominant factor in touch perception, meaning that roughness is the primary sensation when people are exploring materials by touch. The data presented here confirm that women gave more concordant sensorial judgments than men, whereas men had more consistent preference by touch.

The authors believe that even the most advanced devices will not be able to deliver something that can approximate to realistic touch if we do not know in the first instance what needs to be communicated and how to communicate it. To this point, it seems to us that our knowledge about tactile perception is still at a relatively early stage of development that does not allow for highly-complex forms of long-distance realistic interpersonal tactile communication to be fully effective (and emotionally fulfilling). Additionally, more complex multi-modal effects may have a significant impact of the perception of materials and are worthy of further investigation.

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