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THE TACTILE PERCEPTION EVALUATION OF WOOD SURFACE WITH DIFFERENT ROUGHNESS AND SHAPES: A STUDY USING GALVANIC SKIN RESPONSE

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ABSTRACT

By adopting the methods of PAD subjective emotion measurement and galvanic skin response physiological measurement, this study explores the differences in people's tactile perception evaluation of the surfaces of beech materials with different roughness and shapes. The results show that females prefer beech samples with arc shapes, while males prefer the samples with rectangle shapes; participants' emotional stability under a higher emotional arousal level can to a certain extent be maintained due to the beech materials with arc shapes. The tactile perception of males for beech materials has a greater range of emotional arousal than that of females, but the arousal speed of males' emotions is lower than that of females' emotions. Moreover, a better tactile perception experience can be created for participants when the roughness of beech materials is limited within a certain range of conditions, and a certain sense of "anxiousness" will be brought to participants if the surface of beech materials is too rough.

KEYWORDS: Product design, design evaluation, tactile perception of materials, galvanic skin response signal.

INTRODUCTION

Tactile perception refers to the sensation of human skin, which obtains feedback by touching through human kinesthetic senses (Zelek et al. 2003). Human tactile sensation is of extremely high precision (Skedung et al. 2011). When people use wooden products, the tactile sensation plays a key role in the evaluation of wooden products. Therefore, understanding people's tactile perception evaluation of materials is conducive to product design and development (Okamoto et al. 2013).

At present, the research on the tactile perception evaluation of wood mainly uses the psychological scale to analyze the tactile perception of participants touching materials. Overvliet and Soto-Faraco (2011) verified the consistency of four psychological measurement methods (labeled scaling, magnitude estimation, binary decision, and ranked ordering) in evaluating the naturalness of materials. In the calculation of classification of material naturalness, tactile perception can achieve a 72% accuracy rate, second only to visual perception. Wastiels et al. (2012) related the physical and technical parameters of wood and other indoor decoration materials to the tactile perception experience, and analyzed people's evaluation of tactile warmth perception of materials. The above studies have rich reference value for exploring the tactile perception of wood, but they are all psychological evaluations based on the subjective report. Subjective report evaluation is difficult to evaluate the object in real time without interrupting the evaluation process, and cannot record the dynamic emotional changes of participants (Calvert and Brammer 2012), which makes it difficult for researchers to observe the evaluation process even though the evaluation results can be obtained. Additionally, there may be some deviations in describing the tactile perception of wood only through the method of subjective evaluation (Ding et al. 2017a).

Physiological signals have been proved to reflect people's subjective emotions. The acquisition of physiological data of participants during their evaluations can provide real-time and continuous information support for emotion analysis (Ding et al. 2016). Many physiological measurement methods, including brain imaging, eye tracking, and analyses of heart rate and galvanic skin response, have been proven to have good reliability, applicability, and effectiveness (Yong and Minor 2008). Tang et al. (2019) used the event-related potentials (ERPs) in electroencephalograph (EEG) to reveal the physiological responses of participants when they perceived materials with different friction coefficients. Yamauchi et al. (2018) used the simultaneous measurement of ERPs and electrodermal activity (EDA) signals, combined with Positive and Negative Affect Schedule (PANNAS) subjective questionnaire, to explore the effect of perception on participants' emotions with plants as material media. Jia (2017) proposed a material preference graph based on tactile comfortability by acquiring the physiological index data (including heart rate variability, galvanic skin response, and skin temperature) when elderly people touch indoor materials, and measuring the semantic differences. The above studies show that the method of physiological evaluation is helpful to analyze the evaluation process and details when people perceive materials through tactile sensation.

The galvanic skin response signal is an index of skin conductivity, and this potential difference caused by current flow is known as skin potential. Skin potential varies with visual, auditory, tactile, and algetic stimuli as well as emotional fluctuations, of which the process is called Galvanic Skin Response (GSR) (Critchley 2002). When emotional changes bring about changes of somatic symptoms, the skin electric resistance will change accordingly, thereby forming the galvanic skin response (Benedek and Kaernbach 2010). Electrodermal activity has shown sensitivity to emotional changes (Onghwa and Elisabeth 2008). The galvanic skin response signal can serve as an index of the arousal of brain function and the arousal level.

Because changes in the amplitude of emotional arousal can bring about obvious changes in galvanic skin response, the galvanic skin response signal is regarded as one of the most commonly used physiological signals in the study of emotion recognition (Lang 2000).

In general, the galvanic skin response level in a calm state is defined as the basic level of galvanic skin response. The galvanic skin response signal is mainly composed of a slowly changing tonic activity, namely, Skin Conductance Level (SCL), and a rapidly changing phasic activity, namely, Skin Conductance Response (SCR) (Soni and Rawal 2020). A typical single galvanic skin response signal is usually characterized by four indexes (Shi et al. 2020): *1)* Delay, the duration from the stimulus onset to the occurrence of phase; *2)* Peak amplitude, the amplitude difference between the GSR onset (trough) and the GSR peak; *3)* Recovery time, the time from the peak to the amplitude recovery; *4)* Rise time, the duration from the GSR onset to the GSR peak. To carry out the analysis of skin conductance level, time-domain and frequency-domain analyses are mainly used. In time-domain analysis, GSR is recorded by the device in microsiemens (μS) and calculated as the mean value within a specific event period (Soni and Rawal 2020). In frequency-domain analysis, the power spectral density (PSD) and time-varying spectral analysis of the EDA signal are used to acquire the statistics about the spectral distribution of sympathetic arousal in the skin.

In this study, beech wood was used as an experimental stimulus sample to explore people's tactile perception evaluation of different wood surfaces. Many physical factors affect tactile perception, including but not limited to shape, softness, frictional properties, and surface topography (Ding et al. 2017b). This study focuses on the surface roughness and shape of wood and explores how woods with different shapes and surface roughness affect people's tactile perception evaluation. The content of this study mainly includes the following two aspects: *(1)* the tactile psychological activation level of the friction on the surface characteristics of beech material under different conditions and its emotional classification; *(2)* the tactile physiological arousal response of the surface characteristics of beech material under different conditions based on the galvanic skin response.

MATERIAL AND METHODS

Participants

52 students from the Guangdong University of Technology, 25 males and 27 females, are recruited as participants with a mean age of 22.56 years (SD = 2.83). All participants are healthy and have no history of mental illness. All experiments are carried out at the same time, and each participant only participates in the experiment once.

Experimental materials

The experimental samples for this experiment are prepared with beech wood (*Zelkova schneideriana*). In the material preparation stage, six flat parts and six arc parts are processed respectively. The specification of the flat part is 100 × 100 × 10 mm, and the arc part is a hemisphere with a bottom diameter of 100 mm. All samples are made from the same batch of beech with a moisture content of 13.2% (Fig. 1). To eliminate the influence of wood texture, the wood used for flat parts and arc parts is selected from the beech part with intact appearance and no scar.

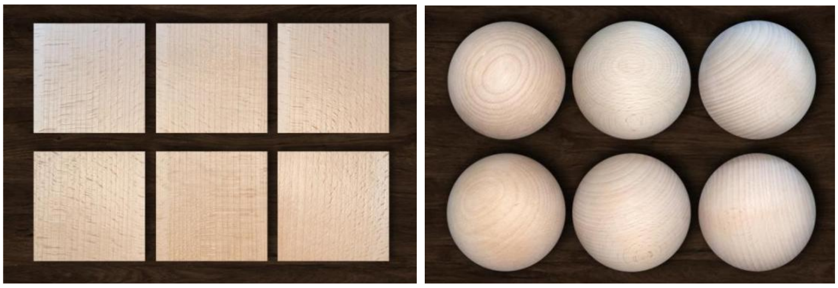

Fig. 1: (a) Flat part samples; (b) arc part samples.

The prepared samples are grouped according to different shapes and grinding degrees, and numbers are marked on the back of the samples. The surfaces of samples are ground manually in the same direction. Sandpapers of 60#, 120#, 240#, 320#, 500# and 800# meshes are used for grinding respectively. Samples are ground with sandpapers in sequence from small to large meshes until all mesh sandpapers required for grinding are used. The time for grinding with one sandpaper is four minutes. A stopwatch is used to count the time in the process of hand grinding. The parts are ground evenly with sandpapers to ensure the basically same speed and pressure during grinding. After grinding, a brush is used to clean away the dust on the surface of parts. All samples were prepared with the same sandpapers, grinding time, and grinding process, so the samples with different shapes ground to the same mesh can be considered to have the same roughness. At last, 12 samples with different shapes and grinding meshes are obtained.

Tactile psychological measurement methods and emotional distance calculation

In this experiment, the Pleasure Arousal Dominance (PAD) emotional scales were used to measure the emotional state of participants when they touch wood samples. To further understand the state of emotions, Mehrabian and Russell developed the PAD emotion model, which divides emotion into three dimensions, namely, “Pleasure”, a feeling of happiness or satisfaction, “Arousal”, a feeling of stimulation caused by surroundings, and “Dominance”, a feeling of being in control of a situation. The PAD emotion model is an emotion measurement method based on psychological response. After that, the Chinese version of abbreviated PAD emotion scales suitable for the Chinese context was summarized by the Institute of Psychology of the Chinese Academy of Sciences (Li et al. 2005), which has been proved to have good structural validity and applicability. There are 12 emotion measurement items in this scale (Zhang et al. 2007). Each dimension in P, A, and D has four items, and each item contains a group of emotional words with opposite meanings. The score ranges from -4 to 4 (Tab. 1).

After the further experimental study, the Institute of Psychology of the Chinese Academy of Sciences obtained the PAD values of 14 basic emotions (Li et al. 2008). With the basic emotional PAD values, the participants’ emotional tendency and the degree of tendency can be evaluated (Tab. 2).

Tab. 1: Dimensions and corresponding words in PAD emotional scale.

Emotional dimension	Emotional words
Pleasure-displeasure (P)	Angry - Activated
	Friendly - Scornful
	Cruel - Joyful
	Excited - Enraged
Arousal-nonarousal (A)	Wide-awake - Sleepy
	Clam - Excited
	Interested - Relaxed
	Relaxed - Hopeful
Dominance-submissiveness (D)	Controlled - Controlling
	Dominant - Submissive
	Guided - Autonomous
	Influential - Influenced

Tab. 2: 14 basic emotion PAD values.

Number	Emotional type	P	A	D
1	Happy	2.77	1.21	1.42
2	Optimistic	2.48	1.05	1.75
3	Relaxed	2.19	-0.66	1.05
4	Curious	1.72	1.71	0.22
5	Docile	1.57	-0.79	0.38
6	Dependent	0.39	-0.81	-1.48
7	Bored	-0.53	-1.25	-0.84
8	Sad	-0.89	0.17	-0.70
9	Panic	-0.93	1.30	-0.64
10	Anxious	-0.95	0.32	-0.63
11	Disdainful	-1.58	0.32	1.02
12	Disgusted	-1.80	0.40	0.67
13	Angry	-1.98	1.10	0.60
14	Hostile	-2.08	1.00	1.12

PAD emotional tendency refers to the degree of closeness between the measured emotional state and 14 basic emotions. The PAD emotional tendency is reflected in the distance relationship of coordinate positions between the measured emotional states and 14 basic emotions. The size of the distance value indicates the degree of the tendency toward the 14 basic emotions. Among them, the basic emotion that has the smallest spatial distance to the measured emotional state is the PAD emotional tendency of the measured emotional state. The coordinate distance of emotional space can be calculated with the algorithm of the following Euclidean distance Eq.1:

$$L_n = \sqrt{(P - p_n)^2 + (A - a_n)^2 + (D - d_n)^2}, n = [1,14], n \in Z \qquad (1)$$

where: L is the coordinate distance between the measured emotional state and the 14 basic emotions in the emotional space; P, A, D are the coordinate values of the measured emotional state e in the emotional space; p_n, a_n, and d_n are the coordinate values of basic emotion.

According to Eq. 1 and Tab. 2, the 14 Euclidean distance values between the measured emotional state and the 14 basic emotions can be calculated and recorded as L_1, L_2,... L_{14}. Among them, the minimum distance is $L_{min} = L_n$, and then the basic emotion in Tab.2 corresponding to n is the PAD emotional tendency of n.

Tactile physiological measurement methods

The acquisition of skin conductance is carried out on an HP laptop with the multi-channel physiological recorder MP160 produced by Biopac company of the United States and the accompanying acquisition software AcqKnowled 5.0. The skin conductance level of participants is measured by the TSD203 finger electrode of the skin conductance monitoring module in the acquisition device. The emotional arousal in this experiment is obtained by measuring the fingertips of participants (Dooren et al. 2012). All participants touch samples with their right hands. To avoid the signal fluctuation caused by the movement of hands during the experiment, the index finger and middle finger of the left hand are connected to acquire galvanic skin response signals. The experiment was carried out in the Physiology Laboratory of the Guangdong University of Technology. The laboratory has a constant and comfortable light, 25°C indoor temperature, and 85% indoor relative humidity. The laboratory environment is quiet and free of noise.

The effective signal frequency ranges of skin conductance mainly concentrate below 0.2 Hz (Cai et al. 2009). The sampling frequency is set to 50 Hz for sampling in this experiment. In this physiological experiment, each participant only touches all six samples with the same shape. To eliminate the influence of the sequence effect on the experiment, the samples are randomly touched by participants according to the roughness.

Experimental process

First, the experimenter leads one participant into the laboratory to get familiar with the environment, explains the experimental process in detail, and instructs the participant to fill in the voluntary form for the experiment and personal information before the experiment; secondly, the participant is connected by measurement electrodes, and rests for 15 min in a seat adjusted to a comfortable state to restore the participant's skin conductance level to a calm state, and then the basic skin conductance level of the participant is measured for five minutes; after that, the participant begins to touch samples one by one and is required to slide the index finger and middle finger of the right hand on the surface of the sample at a slow and uniform speed during the touching process, and a gentle and consistent pressure should be maintained throughout the process. The touch time of each sample is two minutes, and the experimenter records the galvanic skin response signals in real time and marks them manually; after touching, the participant is required to fill in a PAD emotional scale according to the touch feeling, and then rests for one minute; the above steps are repeated until all six samples are touched and the evaluations are completed, and then the participant receives the reward for the experiment (Fig. 2).

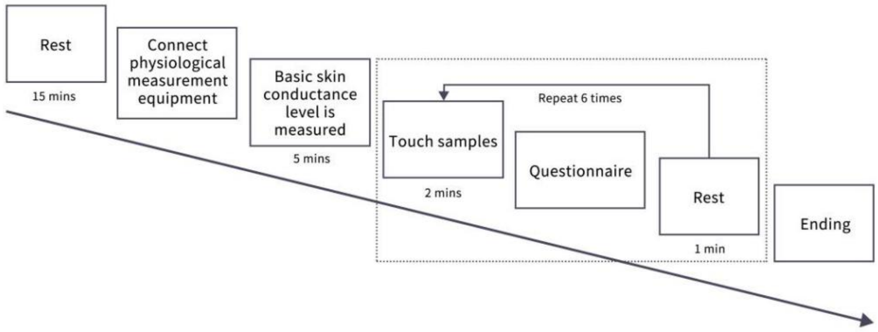

Fig. 2: Experiment process.

Preprocessing and index extraction of GSR signal

By subtracting the galvanic skin response data of the participant in a calm state from that generated when the participant touches samples, the standardized galvanic skin response signals can be obtained, which is used for the study of the relationship between the skin conductance level and the different emotions. The interference in the acquisition process mainly includes baseline drift, other physiological signals, electrode contact noise, electromagnetic interference, and motion artifact. The above interference should be avoided as far as possible during measuring, while some unavoidable interference can only be corrected through proper signal preprocessing (filtering, baseline and useless information removal, and smoothing) after acquisition. In this experiment, the original signals are smoothed by a Butterworth filter with the order set to two and the cut-off frequency set to 0.3 Hz (Cai et al. 2009), so the high-frequency interference can be effectively filtered out.

The following six galvanic skin response indexes are extracted, that is, the mean value of GSR amplitude, the maximum value of GSR amplitude, the number of GSR peaks, the mean value of GSR, the variance of GSR, and the rise time of GSR, as the physiological indexes of galvanic skin response analysis for this experiment. Because each participant touches six samples with different roughness, the data needs to be segmented according to the marks in the experiment. At last, 156 segments of data are obtained for flat parts and arc parts respectively, of which each part has 26 segments for analysis.

Data analysis methods

There are three independent variables in this experiment, which are gender (male and female), shape (flat part A and arc part B), and roughness (60#, 120#, 240#, 320#, 500#, and 800#). The shapes of samples are classified by A and B, and the roughness is represented by numbers 1-6. For example, A1 represents a flat part with 60# roughness. The dependent variables of the experiment fall into the psychological group and the physiological group. The psychological group contains the mean values of each dimension in the PAD scale, while the physiological group contains galvanic skin response signals. The independent variables and dependent variables are analyzed by multi-way ANOVA. The Euclidean distances between PAD and basic emotion values under different variables are calculated.

RESULTS

Psychological evaluation results of tactile perception of materials

The pleasure, arousal and dominance degree of material tactile perception under different independent variables are analyzed by multi-way ANOVA (Tab. 3).

Tab. 3: Basic emotion PAD values.

Variables			Mean	SD	F	*P*
Pleasure	Roughness	1	-0.197	1.250	20.221	< 0.001**
		2	0.024	1.209		
		3	0.567	1.291		
		4	0.923	1.285		
		5	1.284	0.941		
		6	1.740	1.249		
	Gender	Male	0.853	1.420	3.378	0.067
		Female	0.603	1.332		
	Shape	Flat part	0.685	1.385	0.176	0.675
		Arc part	0.763	1.375		
Arousal	Roughness	1	0.678	1.481	3.801	0.002*
		2	-0.014	1.413		
		3	-0.067	1.357		
		4	-0.120	1.082		
		5	-0.375	1.504		
		6	0.428	1.615		
	Gender	Male	0.168	1.402	1.018	0.314
		Female	0.139	1.496		
	Shape	Flat part	0.184	1.494	1.540	0.216
		Arc part	-0.008	1.405		
Dominance	Roughness	1	0.505	1.203	0.140	0.709
		2	0.255	1.203		
		3	0.221	1.267		
		4	0.495	1.312		
		5	0.255	1.394		
		6	0.120	1.422		
	Gender	Male	0.358	1.244	1.142	0.338
		Female	0.262	1.352		
	Shape	Flat part	0.335	1.377	0.440	0.507
		Arc part	0.282	1.222		

Note: *< 0.05, **< 0.001.

According to the mean values of P, A, D of material tactile perception under different factors, the closeness between these values and the basic emotional states is calculated, which can be used to estimate the participant's emotional tendency to the material tactile perception under corresponding conditions (Tab. 4).

Tab. 4: The PAD mean values under different roughness, genders, and shapes.

Variable		P	A	D
Roughness	1	-0.197	0.678	0.505
	2	0.024	-0.014	0.255
	3	0.567	-0.067	0.221

	4	0.923	-0.120	0.495
	5	1.284	-0.38	0.255
	6	1.740	0.428	0.122
Gender	Male	0.853	0.168	0.358
	Female	0.603	0.014	0.262
Shape	Flat part	0.684	0.184	0.335
	Arc part	0.763	-0.008	0.282

The distances between the PAD scores under different roughness, genders, and shapes and the PAD values of basic emotions are calculated separately according to Eq. 1 (Tab. 5).

Tab. 5: Distances between the PAD scores under different roughness, genders, and shapes and the PAD values of basic emotions.

Variable	**Roughness**						**Gender**		**Shape**	
	1	**2**	**3**	**4**	**5**	**6**	**Male**	**Female**	**Flat part**	**Arc part**
Happy	3.15	3.22	2.81	2.46	2.47	1.83	2.43	2.73	2.57	2.61
Optimistic	2.98	3.07	2.69	2.32	2.39	1.89	2.32	2.61	2.44	2.49
Relaxed	2.79	2.4	1.92	1.48	1.24	1.5	1.72	1.9	1.87	1.75
Curious	2.2	2.42	2.12	2.02	2.13	1.29	1.77	2.03	1.85	1.97
Docile	2.3	1.73	1.25	0.94	0.52	1.26	1.2	1.26	1.32	1.13
Dependent	2.55	1.94	1.86	2.16	2	2.43	2.13	1.94	2.09	1.97
Bored	2.37	1.74	1.93	2.27	2.29	2.98	2.32	2.02	2.22	2.11
Sad	1.48	1.33	1.74	2.19	2.44	2.77	2.04	1.78	1.88	1.93
Panic	1.49	1.85	2.2	2.6	2.92	2.91	2.34	2.2	2.19	2.33
Anxious	1.41	1.36	1.78	2.23	2.5	2.8	2.06	1.82	1.9	1.97
Disdainful	1.52	1.81	2.32	2.6	3.04	3.44	2.53	2.33	2.37	2.48
Disgusted	1.64	1.92	2.45	2.78	3.21	3.58	2.68	2.47	2.52	2.62
Angry	1.83	2.32	2.83	3.15	3.6	3.81	2.99	2.82	2.83	2.98
Hostile	2.01	2.49	2.99	3.27	3.74	3.99	3.14	2.98	2.99	3.13

Galvanic skin response signal analysis of the tactile perception of materials

The GSR signals of material tactile perception under different independent variables are analyzed by multi-way ANOVA (Tab. 6).

Tab. 6: Analysis of main effect variances of GSR signals of material tactile perception in different independent variables.

variable			**Amplitude of GSR mean peak**	**Maximum GSR amplitude**	**Number of GSR peaks**	**Variance of GSR**	**Mean value of GSR**	**Rise time of GSR**
Roughness	Mean (SD)	1	0.794 (1.037)	4.948 (3.185)	22.154 (8.472)	0.499 (0.021)	9.188 (6.533)	0.615 (0.997)
		2	0.630 (1.168)	4.694 (3.311)	21.942 (8.180)	0.448 (0.017)	8.720 (6.257)	0.331 (0.455)
		3	0.441 (1.365)	4.368 (2.899)	21.385 (7.832)	0.488 (0.012)	8.300 (7.015)	0.704 (1.118)
		4	0.958 (0.956)	4.923 (3.206)	23.212 (9.878)	0.475 (0.013)	8.259 (6.734)	0.520 (0.951)
		5	0.781 (0.865)	4.688 (3.092)	23.692 (10.442)	0.497 (0.019)	7.907 (6.269)	0.446 (0.628)
		6	0.766	5.340	22.500	0.465	8.612	0.392

			(1.249)	(3.751)	(8.941)	(0.015)	(5.985)	(0.742)
	F		1.427	0.641	0.562	0.762	0.27	1.52
	p		0.215	0.668	0.729	0.578	0.929	0.183
Gender	Mean (SD)	Male	0.972 (1.345)	6.099 (3.461)	26.33 (7.739)	0.048 (0.019)	8.719 (6.091)	0.604 (1.017)
		Female	0.503 (0.807)	3.655 (2.508)	18.91 (8.558)	0.048 (0.014)	7.780 (6.750)	0.406 (0.647)
	F		13.474	0.641	61.905	0.002	0.27	4.394
	p		<0.001**	0.668	<0.001**	0.962	0.604	0.037*
Shape	Mean (SD)	Flat parts	0.472 (1.309)	4.436 (3.104)	20.87 (8.92)	0.047 (0.018)	8.041 (7.468)	0.514 (0.868)
		Arc part	0.984 (0.826)	5.224 (3.332)	24.1 (8.746)	0.049 (0.014)	8.954 (5.186)	0.488 (0.833)
	F		16.818	4.024	10.677	0.546	1.571	0.124
	p		<0.001**	0.046*	0.001**	0.461	0.211	0.725

Note: *< 0.05, **< 0.001.

DISCUSSION

Effect analysis of psychological evaluation of the tactile perception of materials

In light of the results, the pleasure degree of material tactile perception in participants has a significant difference in the variable of roughness. The pleasure score of the sample with No. 1 roughness (60#) is the lowest, while that with No. 6 roughness (800#) is the highest, and the pleasure degree of each sample with different roughness only shows no significant difference with its adjacent samples. An interaction effect is shown between the sample shapes and the genders of participants. The pleasure scores of flat parts in males are significantly greater than those in females, while the pleasure scores of arc parts in females are significantly greater than those in males. The pleasure mainly shows people's positive or negative emotions about stimuli (Zhang et al. 2017, Xue and Dai 2018), reflecting the usability of products and friendly evaluations (Wu et al. 2015). In the variable of roughness, only the pleasure score of the sample with No. 1 roughness (60#) is negative, which indicates that the tactile perception produced by the sample with No. 1 roughness (60#) triggers the negative emotion of participants, resulting in a bad emotional experience. The samples with No. 2/3/4/5/6 roughness can bring participants a more positive emotional experience. In addition, there are no significant differences between the roughness of adjacent samples, which may be because it is difficult for participants to distinguish the nuances due to the relatively close roughness of adjacent samples. Moreover, females prefer the sample with arc shape more than males, and within the female group, the evaluation of the sample with arc shape is more inclined to be positive. This may be because males tend to choose the product with a harder appearance when choosing products, while females show greater interest in the product with a more rounded appearance. The experimental conclusions are also in accord with male's and female's perceptions of product shape preferences.

In the arousal evaluation, participants only show certain differences in different roughness. The arousal score reflects people's neurophysiological arousal level or excitement state (Xue and Dai 2018, Feng 2014). The experimental results show that both the roughest sample (60#) and the smoothest sample (800#) can strongly trigger the nerve arousal state of participants, and only the samples with No. 1 (60#) and No. 6 roughness (800#) have positive arousal scores. Therefore, to achieve a more comfortable roughness, the surface of the wood should neither be too rough nor too smooth.

Through the emotional classification and calculation of the PAD values of tactile perception in participants under different variables, this experiment finds that in addition to the samples with No. 1 (60#) and No. 2 roughness (120#), who are more inclined to arouse the emotions of "anxiousness" and "sadness", other samples with different roughness and shapes are more likely to receive the evaluation of "docility" in the wood tactile perception from participants of different genders. This may be because wood is a material that matches the physiological rhythm of the human body. People can have a positive physiological response to the wooden materials in the environment, and at the same time, people's life expectancy can be greatly prolonged when living in a wood environment for a long time (Liu et al. 2007). The distance between the emotional value of the sample with No. 2 roughness (120#) and the evaluation of "anxiousness" is second only to the distance between that and the "sadness", and the gap is very small, which shows that the wood with low roughness like No. 1 (60#) and No. 2 roughness (120#) can easily bring people a negative experience of emotions such as anxiousness and sadness.

Effect analysis of physiological evaluation of the tactile perception of materials

The above results indicate that the galvanic skin response index mainly shows obvious differences in the variables of gender and shape, and the difference in the variable of roughness is only significant in the GSR variance under different shape conditions. The mean value of GSR amplitude, the maximum value of GSR amplitude, and the number of GSR peaks of participants' physiological responses when they touch arc parts are significantly greater than those when they touch flat parts. The mean value of GSR amplitude, the maximum value of GSR amplitude, the number of GSR peaks, and the rise time of GSR in male participants are significantly greater than those in female participants. As for the GSR variance index, the GSR variance of the arc part with No. 5 roughness (500#) is significantly larger than that of the samples with No. 1 (60#), No. 2 (120#), and No. 6 roughness (800#), and the GSR variance of the flat part with No. 5 roughness (500#) is significantly smaller than that of the sample with No. 1 roughness (60#). Meanwhile, only the GSR variance of the arc part with No. 5 roughness (500#) is significantly larger than that of flat parts.

The mean value of GSR amplitude refers to the variation range of the participant's emotions aroused by the wood sample during the entire touching process, while the maximum value of GSR amplitude represents the maximum value of emotional arousal when the participant touches the sample. Based on the above results, this experiment concludes that touching the arc part can make the participant have a greater emotional arousal amplitude and maximum value, and the emotional arousal amplitude and maximum value in males are greater than those in females. The number of GSR peaks refers to the emotional fluctuations of the participant during the experiment (Han et al. 2018), which shows that in the process of touching wood samples, arc parts are more likely to arouse emotional fluctuations than flat parts, and males are more likely to have emotional fluctuations than females.

The variance represents the dispersion degree of the data, so the larger GSR variance indicates the more unstable emotions aroused when the participant touches the sample (Jessica et al. 2019). When the participant touches the A5 (the arc part with No. 5 roughness) sample, the emotions aroused are more unstable than those aroused when touching the A1, A2, and A6 samples, and the emotions aroused when touching the B1 (the flat part with No. 1 roughness) sample are more unstable than those aroused when touching the B5 sample.

The rise time of GSR refers to the time required to reach the maximum amplitude, which represents the speed at which the participant's emotions are fully aroused when touching the sample. The experimental results show that males need more time to perceive samples before reaching the maximum value of their emotional arousal, which may be because females are usually more sensitive to external stimuli than males and can quickly be affected by them.

CONCLUSION

By combining the psychological questionnaire measurement of PAD emotional scales and the physiological electrical signal measurement of galvanic skin response signals, this study analyzed the results of tactile perception evaluation of beech materials under different variables, and showed the behaviors of people's emotional changes when perceiving the surface of materials. The main conclusions of this study are as follows: *(1)* People of different genders have certain differences in the tactile perception evaluation of beech materials with different shapes and roughness. As for the shape, females prefer beech samples with arc shapes, while males prefer the samples with rectangle shapes. The tactile perception of males for beech materials has a greater range of emotional arousal than that of females, but the arousal speed of males' emotions is obviously lower than that of females' emotions. Meanwhile, compared with males, females may be able to maintain more stable emotions in a higher emotional arousal state when performing the tactile perception of beech materials. *(2)* The roughness of beech materials can bring people a better tactile perception experience within a certain range of conditions. On the contrary, samples that are too rough or too smooth can greatly increase people's emotional arousal, leading to a more negative experience. On the whole, wood can enable people to experience a "docility" tactile perception, but the grinding mesh of wood is better to reach 120# or more. Beech samples that are too rough tend to bring people a certain sense of "anxiousness".

The above conclusions can help designers to adjust the shape and roughness characteristics of wooden products in a specific design, so as to provide data support and objective reference for product differentiation design.

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