ICIC Express Letters
Part B: Applications
Volume **14**, Number **4**, April **2023**

ICIC International ©2023 ISSN 2185-2766
pp. 443–448

EMOTIONAL FACTORS OF TACTILE PERCEPTION ON THE SURFACE MATERIALS FOR STEERING WHEELS

Jihong Hwang[1] and Wonil Hwang[2,*]

[1]Department of Mechanical System Design Engineering
Seoul National University of Science and Technology
232 Gongneung-Ro, Nowon-Gu, Seoul 01811, Korea
hwangjh@seoultech.ac.kr

[2]Department of Industrial and Information Systems Engineering
Soongsil University
369 Sangdo-Ro, Dongjak-Gu, Seoul 06978, Korea
[*]Corresponding author: wonil@ssu.ac.kr

Received September 2022; accepted December 2022

Abstract. *The experience of users in tactile contact with car interior plays an important role in determining users' satisfaction. Accordingly, the surface design of in-vehicle materials considering users' tactile perception has been of great interest to automotive manufacturers. Consequently, many studies have been made to investigate the relation between the characteristics of surface and the tactile perception by human. However, few studies have been made to find the emotional factors of tactile perception on steering wheels. In this sense, this study sought to experimentally find the emotional factors of tactile perception on the surface materials for steering wheels. The experiment was conducted with 12 participants, 9 types of leather-based surface materials for steering wheels, and 24 emotional expressions. Through the factor analysis, three tactile emotional factors – Factor 1 (bumpy/rough/slippery/smooth/dry), Factor 2 (yielding/soft) and Factor 3 (elastic) were derived. It is expected that the derived tactile emotional factors can be utilized to control car users' perception on the surfaces of steering wheels.*
Keywords: Emotional factors, Tactile perception, Steering wheel, In-vehicle materials

1. **Introduction.** The experience of users in tactile contact with car interior plays an important role in determining users' satisfaction. Accordingly, the surface design of in-vehicle materials considering users' tactile perception has been of great interest to automotive manufacturers. Consequently, many studies have been made to investigate the relation between the characteristics of surface and the tactile perception by human [1-6]. They have mainly focused on extracting emotional factors in the tactile perception on various materials. Among them, Yun et al. [7] examined affective feelings on the surface materials for 30 different car interiors and specified the design features that have correlation with the feelings. Giboreau et al. [8] determined 14 adjectives that can represent the tactile perception of velvet-type fabrics using the multi-dimensional scaling (MDS) method, and claimed that the touch gesture in evaluating the tactile perception should be differed depending on the adjectives. Kim et al. [9] assessed the tactile perception for four representative leathers employed for car interior using 7 adjective pairs – 'cold-warm', 'dry-wet', 'flat-rugged', 'slippery-sticky', 'soft-hard', 'in-elastic-elastic' and 'thin-thick'. Based on the assessment result, they concluded that the touch perception could be influenced by visual interaction as well.

When narrowing down the scope to steering wheels, there were studies on vibration perceived through a steering wheel [10,11], grip force affected by road condition [12], and visual perception varied with steering wheel design [13]. However, it is noted that

DOI: 10.24507/icicelb.14.04.443

few studies have been made to find the emotional factors of tactile perception on steering wheels. In addition, 4 adjective pairs – 'hard-soft', 'rough-smooth', 'warm-cold' and 'sticky-slippery' have been commonly used as the emotional dimensions of tactile perception for various surface textures and materials. However, it is not evidenced whether these emotional factors are valid for the tactile perception that users experience via their palms in contact with the surfaces of steering wheels.

In this sense, this study sought to experimentally find the emotional factors of tactile perception on the surface materials for steering wheels. Leather-based materials that are commonly used for steering wheels were employed for the experiment. The experiment was designed to evaluate tactile perception on these materials, and the result was statistically analyzed to extract the emotional factors. It is expected that the derived tactile emotional factors can be utilized effectively for controlling car users' tactile perception on the surfaces of steering wheels.

2. Methods.

To derive the tactile emotional factors for leather-based surface materials for steering wheels, an experiment was performed for 12 participants. The participants were asked to freely touch each of 9 steering wheel samples as shown in Figure 1 and then answer the questionnaire. Thus, 12 participants randomly selected in this study produced 108 data points for each of emotional expressions by experiencing 9 steering wheel samples through the within-subject design.

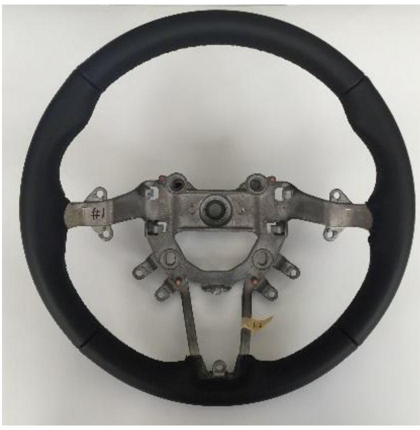

Figure 1. Steering wheel sample

2.1. Preparation of material samples.

Before carrying out the experiment, 9 steering wheel samples were prepared using different leather-based materials. The leather-based materials were fabricated by applying additional processes on leather which is used for various parts of steering wheels as a base material. These samples were chosen by in-vehicle material design experts since they were considered as a cross-sectional representation of leather-based materials. Each of these sample materials has the same base material of leather, but is differed in terms of color, moisture, embossing type (i.e., grain shape, grain size and shape of groove edges) and pattern as shown in Figure 2. Table 1 shows the result of the surface profilometry measurement for four roughness parameters (R_a, R_z, R_q and R_{tm}) and the result of the frictional test (static and dynamic friction coefficients) for the samples. In the table, it is seen that the samples have a wide range of surface roughness (R_a: 2.07-12.42 μm) and coefficient of friction (static: 0.56-1.27). The steering wheel samples used for the experiment were fabricated by encapsulating steering wheel frames with foam and the leather-based sample materials as shown in Figure 2. The steering wheel samples share the same base structure in common, but the encapsulating leather-based material was differed.

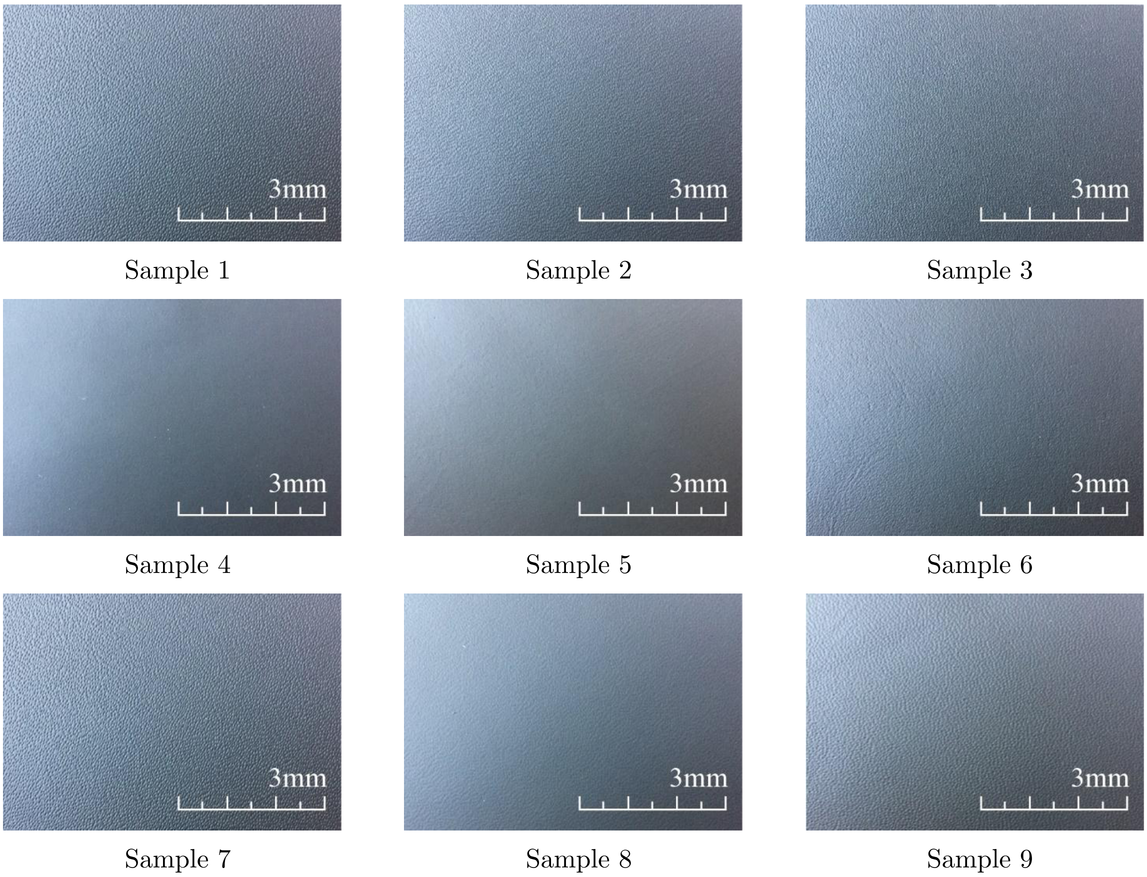

Figure 2. Pictures of material samples

Table 1. Characteristics of material samples

	Surface roughness [µm]				Coefficient of friction	
No	R_a	R_z	R_q	R_{tm}	Static	Dynamic
1	12.39	93.80	15.82	81.03	1.20	0.70
2	10.26	79.40	13.04	68.63	1.27	0.74
3	10.86	88.10	13.72	75.25	1.25	0.76
4	2.07	19.80	2.64	16.22	0.61	0.27
5	2.37	26.20	3.09	20.35	0.56	0.27
6	6.64	57.10	8.52	45.44	0.59	0.24
7	12.42	85.60	15.92	74.32	0.61	0.24
8	4.40	42.60	5.90	35.61	0.58	0.24
9	8.05	61.70	10.13	50.73	0.61	0.27

2.2. **Participants.** Twelve participants consisting of 6 businessmen, 4 graduate students and 2 undergraduate students, participated in the experiment. The numbers of males and females were the same, and the age was 29.3 years on average with a standard deviation of 6.0 years. The participants did not have any difficulties in sensing the material surfaces with their bare hands.

2.3. **Procedure of experiment.** According to the within-subject experimental design, each of 12 participants responded to the same questionnaire for all the samples. The questionnaire included 24 emotional expressions (see the first column of Table 2) to measure the agreeability of emotion invoked by the surfaces of the samples. The emotional expressions were carefully selected among those employed in the previous studies through

Table 2. Factor loadings for three emotional factors

Emotional expressions	Factor 1	Factor 2	Factor 3	Communality estimates
Grainy	**0.854**	−0.211	−0.213	0.819
Embossed	**0.750**	0.205	−0.037	0.606
Bumpy	**0.742**	0.027	−0.148	0.573
Rough	**0.845**	−0.301	−0.231	0.858
Prickly	**0.802**	−0.265	−0.280	0.793
Sandyish	**0.799**	−0.243	−0.304	0.789
Slippery	**−0.682**	0.158	0.275	0.566
Oily	**−0.717**	0.305	0.118	0.622
Slick	**−0.754**	0.139	0.321	0.691
Fine	**−0.601**	0.123	0.472	0.599
Smooth	**−0.766**	0.265	0.270	0.730
Sleek	**−0.796**	0.250	0.243	0.755
Crispy	**0.662**	−0.167	−0.225	0.516
Dry	**0.619**	−0.390	0.142	0.555
Parched	0.451	−0.548	0.219	0.553
Yielding	−0.048	**0.768**	0.195	0.631
Malleable	−0.070	**0.732**	0.096	0.550
Cushiony	−0.178	**0.742**	0.317	0.683
Soft	−0.243	**0.737**	0.347	0.722
Tender	−0.212	0.560	0.375	0.498
Flexible	−0.176	0.495	0.504	0.530
Elastic	−0.245	0.178	**0.822**	0.767
Firm	−0.315	0.340	**0.712**	0.653
Stretchable	−0.301	0.235	**0.699**	0.704
Variance explained by each factor	11.626	2.714	1.419	15.759

Notes. Factor loadings in bold type were considered to be significant.

brainstorming and consulting with experts. The agreeability of 24 emotional expressions was measured in a 7-point scale (1: strongly disagree, 2: disagree, 3: somewhat disagree, 4: neither agree nor disagree, 5: somewhat agree, 6: agree, 7: strongly agree). Every participant was given enough time to sense the surfaces of the samples with his/her palm and answer the questionnaire.

3. Results.

Factor analysis was performed to derive tactile emotional factors from 24 emotional expressions. Their validation was performed by examining their internal consistency represented by Cronbach's alpha coefficient.

3.1. Tactile emotional factors.

Factor analysis was carried out to derive tactile emotional factors in touching the surface materials for steering wheels using a principal component method with varimax rotation. Three emotional factors were derived as shown in Table 2 and denoted by 'Factor 1', 'Factor 2' and 'Factor 3', respectively. These three factors comprise 65.7% of the total sample variance. This indicates that these factors are suitable, with parsimony, for representing 24 tactile emotional expressions. Three experts, whose research areas included tactile emotions, reviewed the emotional expressions grouped by the factor analysis, and extracted common features as tactile emotional factors for three groups of emotional expressions while referring to prior research. Factor 1 represents bumpy-, rough-, slippery-, smooth- and dry-related emotional expressions which include grainy, embossed, bumpy, rough, prickly, sandyish, crispy, dry, slippery, oily, slick, fine, smooth and sleek. Factor 2 represents yielding- and soft-related emotional expressions which include yielding, malleable, cushiony and soft. Factor 3 represents elastic-related emotional expressions which include elastic, firm and stretchable. In this case, the threshold for retaining the emotional expressions in a pool was set to 0.6 for each of the factors.

3.2. **Internal consistency of each factor.** Examination of internal consistency was conducted to validate the reliability of those driven as above as tactile emotional factors for the surface materials for steering wheels. It is commonly accepted that Cronbach's alpha coefficient represents internal consistency well, which tells how reliably the items (or variables) on a test measure the same construct [14]. A commonly accepted rule of thumb related to this is that the internal consistency is considered acceptable, good and excellent when Cronbach's alpha coefficient is greater than 0.7, 0.8 and 0.9, respectively. The Cronbach's alpha coefficient values for the three tactile emotional factors are shown in Table 3. The Cronbach's alpha coefficient value for the emotional expressions included in Factor 1 is found to be 0.956, showing excellent internal consistency. The Cronbach's alpha coefficient values for the emotional expressions included in Factor 2 and Factor 3 are 0.856 and 0.875, respectively, showing good internal consistency for both cases. This indicates that the emotional expressions listed in Table 3 could be employed to measure the three tactile emotional factors reliably.

Table 3. Cronbach's alpha coefficient of each factor

Factors	Emotional expressions	Cronbach's alpha coefficients
1	Grainy Embossed Bumpy Rough Prickly Sandyish Slippery Oily Slick Fine Smooth Sleek Crispy Dry	0.956
2	Yielding Malleable Cushiony Soft	0.856
3	Elastic Firm Stretchable	0.875

4. **Conclusions and Discussion.** In this study three tactile emotional factors were driven for the leather-based surface materials for steering wheels, based on the experiment that was conducted with 12 participants, 9 types of materials and 24 emotional expressions. The derived factors are Factor 1 (bumpy/rough/slippery/smooth/dry), Factor 2 (yielding/soft) and Factor 3 (elastic). It was found that the emotional expressions

that belong to each of these factors have good or excellent consistency. This indicates that the tactile emotions that belong to Factor 1 such as ‘bumpy’, ‘rough’, ‘slippery’, ‘smooth’ and ‘dry’ are closely related with each other when automobile users sense the surfaces of steering wheels. Likewise, the tactile emotions of ‘yielding’ and ‘soft’ that belong to Factor 2 are closely related with each other, but not with the tactile emotion of ‘elastic’ that belongs to Factor 3. Thus, these emotional expressions could be employed to reliably measure the three tactile emotional factors for the surfaces of steering wheels. For further study, it is needed to investigate the relation between these emotional factors and the physical characteristics of the surface materials for steering wheels, which would provide a way to control the emotions invoked by touch by changing the physical characteristics of the surface materials.

Acknowledgment. This study was supported by the Research Program funded by the SeoulTech (Seoul National University of Science and Technology).

REFERENCES

[1] X. Chen, F. Shao, C. Barnes, T. Childs and B. Henson, Exploring relationships between touch perception and surface physical properties, *International Journal of Design*, vol.3, no.2, pp.67-76, 2009.
[2] S. Guest, A. Mehrabyan, G. Essick, N. Phillips, A. Hopkinson and F. McGlone, Physics and tactile perception of fluid-covered surfaces, *Journal of Texture Studies*, vol.43, pp.77-93, 2012.
[3] N. Kawasegi, M. Fujii, T. Shimizu, N. Sekiguchi, J. Sumioka and Y. Doi, Physical properties and tactile sensory perception of microtextured molded plastics, *Precision Engineering*, vol.38, pp.292-299, 2014.
[4] M. Karlsson and A. V. Velasco, Designing for the tactile sense: Investigating the relation between surface properties, perceptions and preferences, *CoDesign: International Journal of CoCreation in Design and the Arts*, vol.3, sup.1, pp.123-133, 2007.
[5] C. Bertheaux, R. Toscano, R. Fortunier, J.-C. Roux, D. Charier and C. Borg, Emotion measurements through the touch of materials surfaces, *Frontiers in Human Neuroscience*, vol.13, 455, 2020.
[6] W. Kim, A study on the subjective feeling affecting tactile satisfaction of leather in automobile: A structural equation modeling approach, *International Journal of Industrial Ergonomics*, vol.84, 103167, 2021.
[7] M. H. Yun, H. You, W. Geum and D. Kong, Affective evaluation of vehicle interior craftsmanship: Systematic checklists for touch/feel quality of surface-covering material, *Proc. of Human Factors and Ergonomics Society 48th Annual Meeting*, pp.971-975, 2004.
[8] A. Giboreau, A. S. Navarro, P. Faye and J. Dumortier, Sensory evaluation of automotive fabrics: The contribution of categorization tasks and non-verbal information to set-up a descriptive method of tactile properties, *Food Quality and Preference*, vol.12, pp.311-322, 2001.
[9] W. J. Kim, G. W. Shin, J. H. Lee, Y. S. Lee and M. H. Yun, Identifying the visual interference by design and tactile properties of leathers using automobile interior, *Proc. of 2016 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, pp.272-275, 2016.
[10] M. S. Shayaa, J. A. Giacomin, E. Dormegnie and L. Richard, Human perception of sinusoidal rotational steering wheel vibration, *Proc. of the 36th UK Group Conference on Human Response to Vibration*, pp.12-14, 2001.
[11] S. M. Yusoff, *Clustering Classification and Human Perception of Automotive Steering Wheel Transient Vibrations*, Ph.D. Thesis, Brunel University London, UK, 2017.
[12] M. Eksioglu and K. Kızılaslan, Steering-wheel grip force characteristics of drivers as a function of gender, speed, and road condition, *International Journal of Industrial Ergonomics*, vol.38, pp.354-361, 2008.
[13] Y. M. Chang and C. W. Chen, Kansei assessment of the constituent elements and the overall interrelations in car steering wheel design, *International Journal of Industrial Ergonomics*, vol.56, pp.97-105, 2016.
[14] C. Duncan, *Basic Statistics for Social Research*, Routledge, London, 1997.
[15] W. Tang, R. Liu, Y. Shi, C. Hu, S. Bai and H. Zhu, From finger friction to brain activation: Tactile perception of the roughness of gratings, *Journal of Advanced Research*, vol.21, pp.129-139, https://doi-org-ssl.libproxy.seoultech.ac.kr:8443/10.1016/j.jare.2019.11.001, 2020.