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An Affective Engineering Study of Vibrational Cues and Affect When Touching Car Interiors

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Keywords: affective engineering, kansei engineering, touch.

Category: Research paper

INTRODUCTION

Within the field of psychology, and psychophysics in particular, the understanding of texture and the perception of it has been an exciting research field since Katz's The World of Touch in 1925 (Kreuger, 1989). The World of Touch underpins the view that movement and the resulting vibrations are almost certainly needed in texture discrimination. Bensmaia and Hollins (2003) concluded in a recent study concerning roughness and the speed of lateral finger movement that there was a relationship between frequency and spatial periods on the surfaces tested within the context of roughness. In contrast, Lederman (1982) found that vibration has no service in the perception of roughness which leaves no real conclusive evidence as to the importance of vibration as a whole. Although much work has been undertaken in the perception of texture, little has been undertaken in the application of textures in product design such as this study presents.

An affective engineering study is reported in this paper in which relationships between tactile vibrational cues and affect were examined in the context of car interiors. The motivation behind the research was to generate hypotheses to test in future experiments concerning how touching surface textures evokes particular emotional responses. A variety of textures for mould decoration on otherwise identical black plastic tiles were chosen as stimuli. Any variation in the affective response of participants is therefore due to the surface textures of the tiles. The context was car interiors and the demographic was males aged 18 to 26. Focus groups were used to generate and reduce adjectives using the triad method and stimuli were chosen using semantic mapping. The semantic differential method was used to generate a semantic space for the tiles, which was compared with the frequency components of the vibrations when touched. The profiles of the frequency spectra might be responsible for the emotional responses of participants when touching surface textures.

METHODOLOGY

Two focus groups were held to generate adjectives. All participants were unaware of the precise purpose of the focus groups, other than that they would be asked to talk about their attitudes and feelings about the interiors of cars, and that it would be audio recorded. Thirteen male undergraduate students took part in the focus groups.

The first activity in each session was used as an icebreaking exercise to encourage conversation and interaction within the group who were not familiar with each other. They were asked to talk about cars that they liked and disliked.

In the first focus group, adjectives were generated by using the triad method on pictures of cars (Thomson and McEwan, 1988). Six images of car exteriors and 6 images of interiors were mounted on A3 boards and randomly ordered. The images of the car exteriors were shown to the group, three images at a time. The participants were asked the similarities and differences between the three images and their answers were audio recorded. The group was then shown the images of car interiors in the same way. The two sets of images were arranged in a random order again, but this time with both interiors and exteriors within each triad. Once again, the pictures were shown to the group in triads and they were asked the similarities and differences. Finally, the participants were shown the all 12 images again, one at a time, and asked to choose one adjective that best described their feelings.

The triad method was used for the second focus group study and the stimuli used were 18 parts of car interiors, such as steering wheels, which were prearranged into triads comprising of all aspects of the interior. Participants were encouraged to feel each stimulus and, again, find similarities and differences between them.

After the focus group studies were completed, adjectives were collected from the session recordings. Using adjective reduction guidelines (Barnes et al, 2007), unsuitable words were rejected and the most popular and strongest words were retained. Emotive words were grouped by similar meaning words using an affinity diagram. Twelve words were selected: quality, masculine, engineered, warm, cheap, exciting, comfortable, sophisticated, relaxed, unique, sporty and fashionable. The opposite polarity of each word was indicated using 'not'.

The stimuli for this study were samples of mould decorations purchased from Standex (Standex). As supplied by Standex, the samples consisted of sheets of black plastic moulded with a number of different surface textures (Figure 1). For this experiment, the sheets were sawn into tiles, each with a different surface texture. From the 50 available tiles, 28 were selected by the authors. This was carried out in a subjective manner with touch being the sole discriminator. Many of the tiles provided had the same ‘pattern’ design but different grades of roughness, so it was decided that that for this study, all pattern types with a variety of roughnesses be used.

The tiles were placed inside a black box, which had a front entrance with a small window through which the participants could feel a section of each surface. The boxes were black to match the colour of the tiles; none of which could be seen. This ensured that the results yielded were based wholly on the tactual qualities of the tiles.

To reduce the number of stimuli, three semantic mapping exercises were carried out against axes reading cheap-expensive, relaxing-exciting, each with two participants who had not taken part in the focus groups. The participants who were asked in pairs to determine where on the map they would best place the tiles, numbered 1 to 28 with regards exclusively to the way the tile felt when touched. Each tile had a correspondingly numbered marker to be placed on the map. The participants were permitted to revisit their initial decisions and revise them if required and tile markers could be placed on top of each other. The students were asked during the study to keep the theme of car interiors in the forefront of their minds throughout the decision making process. A photograph was taken of each of the completed maps and they were compared. Tiles that were similarly placed on each of the three maps and a range of tiles from each of the maps’ quadrants were selected. This resulted in eleven tiles (Table I).

Semantic differential questionnaires were prepared using the adjectives selected from the focus group sessions. The words were presented in a random order and with random polarity. Fifty seven male participants aged between 18 and 16 were recruited in small groups to rate their subjective response to the eleven tiles on the questionnaire. This activity took place in a controlled environment in a special purpose affective evaluation room. Each group was read the same introduction sheet, explaining the purpose of the study and what they were required to do. Incentives were given as a token of appreciation. They were asked to fill out a practise sheet with tiles not part of the experiment in order to familiarise themselves which the style of questionnaire. The participants were asked to complete the questionnaire in silence so not to disturb or influence the opinions of other participants. The data from the semantic differential questionnaires was transcribed twice to spreadsheets, compared and corrected. Missing responses were replaced with average values. The data was analysed using principal components analysis in SPSS 14. Varimax rotation was used and components with an eigenvalue greater than 1 were retained. The positions of the tiles in semantic space were calculated.

Figure 1. Standex mould decorations.

Table I. Stimuli used in semantic differential study

Tile	Standex no.
1	MT 9022
2	MT 9015
3	MT 9097
4	MT 9081
5	K9000G
6	MT 9124
7	MT 9002
8	MT 9112
9	MT 9049
10	MT 9080
11	MT 9030

The tiles were mounted on a Kistler piezo-electric force measurement platform that could respond to frequencies in sliding friction force up to at least 1kHz. Vibration measurements of the 11 tiles were obtained by the principal author pulling the left-hand index finger in a continual motion across each tile from right to left at a speed of between 5 and 10 mms^{-1}. The data was captured from the Kistler measurement apparatus on LabView recording 1000 times per second. Each data set lasted for approximately 7 seconds. MatLab was used to apply a fast fourier transform to the vibration data to give a graphical representation of the frequency spectra of the tactile vibrations. The autocorrelation plots and the frequency spectra were then compared with the positions of the tiles in semantic space.

RESULTS

At first, the principal components analysis was unable to generate a positive definite correlation matrix. This was resolved by removing the averages for the word 'fashionable' from the analysis, because it correlated highly with the word 'sophisticated'. Subsequent analysis identified three components (Table II). Component 1 accounted for 49.2% of the variance; component 2, 25.8%; and component 3, 14.0%. The words that loading most highly on component 1 were 'exciting' and 'unique'; on component 2, 'quality' and 'sophisticated'; and on component 3, 'warm'. The semantic space is illustrated in Figures 2 to 4.

The frequency spectra of the vibrations that occur when a finger is moved across the surface of each texture are shown in Figures 5 to 15. The ordinate axis on each graph is relative amplitude.

Table II. Rotated component matrix

	Component		
	1	2	3
Quality	-0.165	***0.929***	-0.094
Masculine	0.476	-0.491	0.691
Engineered	0.743	-0.153	-0.104
Warm	-0.207	0.001	***0.952***
Cheap	-0.210	-0.787	-0.095
Exciting	***0.870***	0.332	0.293
Comfortable	-0.828	0.524	0.079
Sophisticated	-0.111	***0.901***	-0.180
Relaxed	-0.811	0.557	-0.033
Unique	***0.947***	0.145	-0.025
Sporty	-0.544	0.675	-0.420

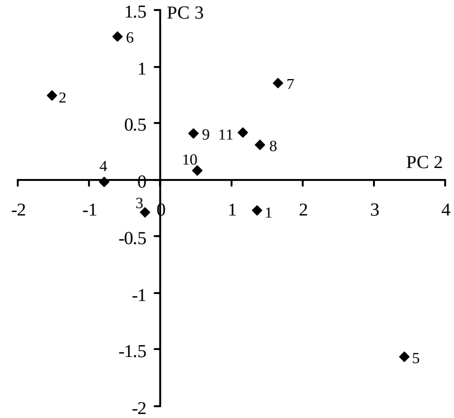

Figure 3. Stimulus loadings in components 2 and 3.

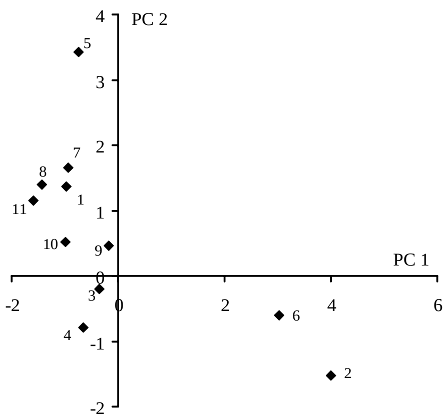

Figure 2. Stimulus loadings in components 1 and 2.

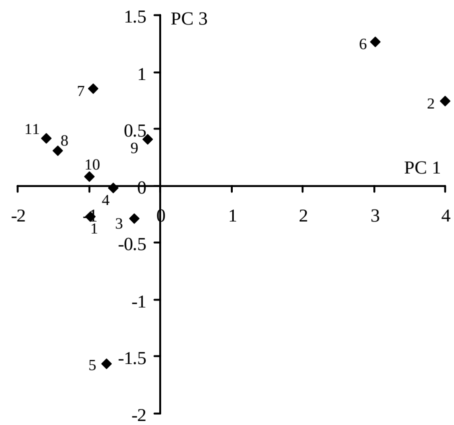

Figure 4. Stimulus loadings in components 1 and 3.

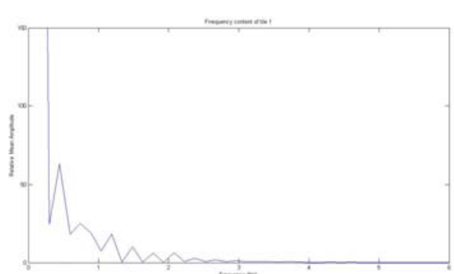

Figure 5. Spectrum of tile 1.

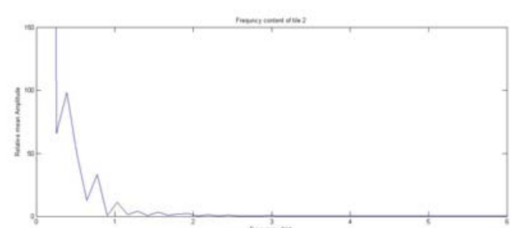

Figure 6. Spectrum of tile 2.

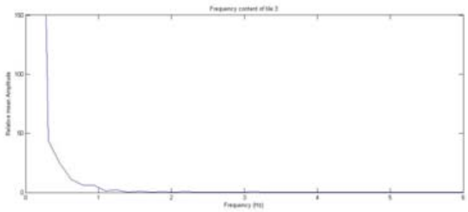

Figure 7. Spectrum of tile 3.

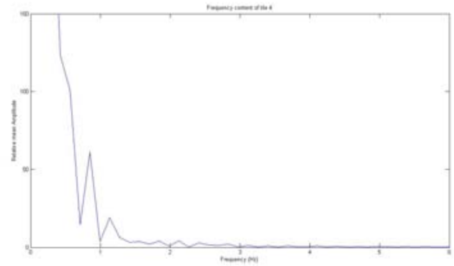

Figure 8. Spectrum of tile 4.

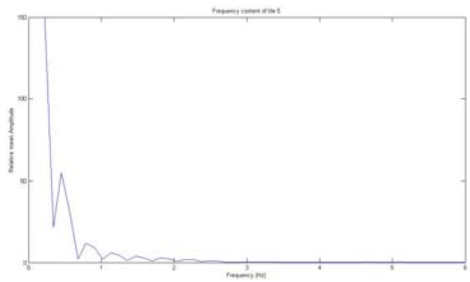

Figure 9. Spectrum of tile 5.

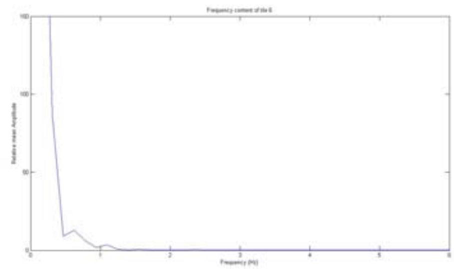

Figure 10. Spectrum of tile 6.

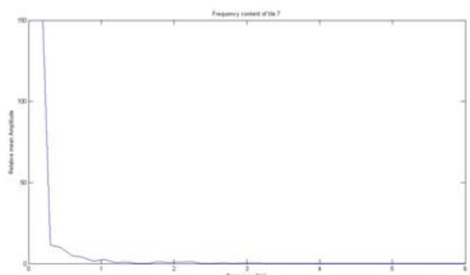

Figure 11. Spectrum of tile 7.

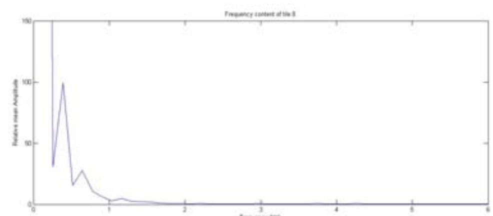

Figure 12. Spectrum of tile 8.

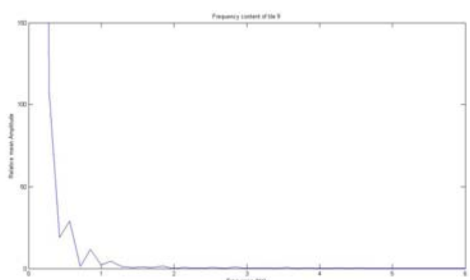

Figure 13. Spectrum of tile 9.

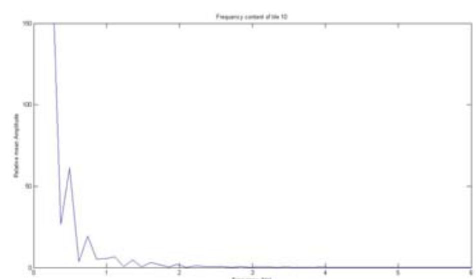

Figure 14. Spectrum of tile 10.

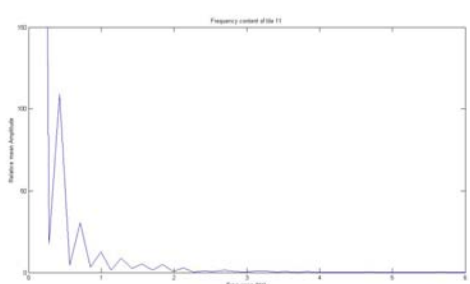

Figure 15. Spectrum of tile 11.

DISCUSSION

The plots of the frequency spectra (Figures 5 to 15) for each surface differ from each other in a number of ways. They can be characterised by:

- The number and distinctiveness of frequency peaks.
- The extent to which frequency peaks exist above 1.8Hz.
- The steepness and radii of the curves that results if a line is drawn connecting each frequency peak.
- The frequency of the maximum peak.
- The range and relative amplitude of low frequency (>0.5Hz) components.

Consideration of the relationships between the positions of the stimuli in the semantic map and their frequency spectra is notable for how surfaces with similar spectra elicit different responses, and for how surfaces with different spectra can elicit similar responses.

Against component 1, which is characterised by feelings of uniqueness and excitement, surfaces 2 and 11 appear at opposite ends of the response scale, but have very similar spectra. On the other hand, surface 6 is close to surface 2 in component 1, but they have very different spectra. Surfaces 2 and 6 are only similar in the range of low frequency components, but surface 11 is also similar in this respect. Surfaces 1, 4, 5 and 11 evoke a low response against component 1, and are very similar in the distinctiveness of their frequency peaks and the presence of frequency peaks above 1.8Hz, but if this might indicate a relationship then the position of surface 2, which also shares these attributes, is anomalous.

Against component 2, surfaces 5 and 2 appear at opposite ends of the response scale, but have very similar spectra. These two surfaces differ in that surface 2 has a more pronounced frequency peak close to 0.7Hz, and so does surface 4, which is close to surface 2 in semantic space. It is difficult to conclude a relationship between the height of the peak at about 0.7Hz and feelings of quality and sophistication for those surfaces close together and in the mid-range of component 2, because it is unlikely that the variance of the responses will allow discrimination of the positions of the stimuli in semantic space (although the authors have yet to perform this analysis). The importance of the height of the 0.7Hz peak remains an issue for further testing. Almost all the surfaces tested demonstrate a peak at between 0.6Hz and 0.8Hz and it remains to be determined how this arises from the interaction of the finger and the material from which the surfaces are made.

Component 3 is particularly interesting because of its association with feelings of warmth. All the tiles were made of the same material and so the effect of thermal conductivity, even when taking into account the difference in finger to surface contact area because of different profiles, is likely to be very small. The response might be accounted for by the other connotations of the word ‘warm’ associated with comfort and safety, or psycho-physical perception of warmth may depend to some extent on the profile of the surface.

Surfaces 6 and 7 evoked high responses against component 3. They are similar by not having distinctive peaks of high relative amplitude. Surface 5, which evoked low feelings of warmth, does not share these properties. On the other hand, surface 2 does not share these properties either, but is close to surfaces 6 and 7 in semantic space against component 3. Nevertheless, the hypothesis that the presence of distinctive peaks does not elicit feelings of warmth can be tested in further research.

Other properties of the surface profiles, such as roughness and autocorrelation, remain to be measured.

CONCLUSIONS

An affective engineering study is reported in which relationships between the frequency spectra of tactile vibration and affect were examined in the context of car interiors. A semantic space was generated for surface textures on otherwise identical black plastic tiles. Vibration measurements were taken when a finger was moved across each of the surfaces, from which frequency spectra were calculated. The frequency spectra were compared with the tiles' positions in semantic space. There were no clear relationships between the frequency spectra and the tiles' positions in semantic space. The comparisons suggest the following research questions which could be tested in future work.

1. Whether there is a relationship between relative amplitude of a frequency peak at between 0.6Hz and 0.8Hz and feelings of quality and sophistication.
2. Whether surfaces with few distinctive frequency peaks of high relative amplitude feel warmer than surfaces with more distinctive, higher amplitude peaks.

ACKNOWLEDGEMENTS

This work was funded by the UK's EPSRC (EP/D060079/1) and the EC (NEST 043157). The views expressed here are the authors' and not those of the EC.

REFERENCES

Barnes, C.J., Delin, J., Lillford, S. P., Sharoff, S. (2007). Linguistic Support for Concept Selection Decisions. Artificial Intelligence for Engineering Design, Analysis and Manufacturing, 21(2), pp.123-135.

Bensmaia, S. J. and Hollins, M. (2003). The vibrations of texture. Somatosensory & Motor Research, 20(1), pp.33-43.

Kreuger, L. E. (1989). The world of touch by David Katz. Edited and translated by L. E. Kreuger. Hillsdale: Lawrence Erlbaum Associates, Publishers.

Standex Engraving Group. http://www.standexengraving.com/ Accessed 4 April 2007.

Taylor, M. M., Lederman S. J. (1975). Tactile roughness of grooved surfaces: a model and the effect of friction. Perception and psychophysics, 64, pp489-494.

Thomas, D. M. H., McEwan J. A. (1988). An application of the repertory grid method to investigate consumer perceptions of foods. Appetite, 10, pp181-193.