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A Factorial Design Experiment in Affective Combination of Visual and Tactile Stimuli in the Context of Keypads

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INTRODUCTION

One of the possible criticisms of affective engineering is that it is often used in a reductionist way. Different elements of a product design are tested separately and it is assumed that recombining the elements will produce a congruent whole. This paper reports an investigation into a method to test this assumption and, more specifically, determine the way in which people combine the effects of visual and tactile stimuli.

The authors have previously used self-report semantic differential questionnaires to investigate the effects of combining visual and tactile stimuli in the context of keypads for electronic equipment. Stimuli were prepared that consisted of a range of surface textures printed in transparent ink onto transparent polyester sheets and placed over a range of smileys, images which are inserted into texts and emails to communicate the intended tone of the message. Respondents were asked to complete semantic differential questionnaires after touching the surface textures; after touching the surface textures printed over the smileys; and after looking at, but not touching, the smileys. A principal components analysis was carried out and the loadings in semantic space for each of the textures, smileys, and smiley and texture combinations were calculated (Henson, Choo, Barnes and Childs, 2006).

Although the approach was a productive one, it perhaps required too much time of the respondents. The number of questionnaires that had to be completed almost certainly went beyond the point at which fatigue bias started. It was also not entirely clear how to interpret the results. The tactile and visual stimuli appeared to be combined by weighted averaging, but the choice of stimuli combinations made it difficult to demonstrate this with a level of certainty.

In the experiment reported here, the results of the first semantic differential experiment were used to identify four visual and three tactile stimuli which scored high, medium and low affective responses, and six words which loaded highly on the principal components. Each smiley was then combined with each texture. Respondents were asked to indicate their responses to the combined stimuli on twenty point semantic differential scales against the six words. Analysis of variance was used to determine whether the scores of the stimuli combinations were independent. The results show no significant interaction between smiley visual and surface touch stimuli, showing that people's combination of effects is first order, perhaps by addition or by weighted averaging.

PREVIOUS WORK

A hypothesis of the research reported in this paper is that people combine their affective responses to different parts of a product using simple algebraic relationships, such as adding or weighted averaging. Such relationships have been demonstrated in a range of judgement tasks such as rating the desirability of dates based on photographs and written descriptions (Anderson 1982).

Experimental psychologists have carried out much research into how people integrate information from different senses. For example, Zampini *et al.* (2003) researched the combination of auditory and tactile stimuli. Although research into the emotional effects of stimulus combination is now beginning to emerge (for example Spence and Zampini (2006)), almost all research has concentrated on human psycho-physical perception rather than affect, and it is difficult to apply outcomes to enhance product design. Of particular relevance to this research, Guest and Spence (2003) showed that combining visual and tactile stimuli does not enhance perception of surface texture. They cite previous work by Jones and O'Neil (1985) that suggests that visual and tactile inputs lead to weighted averaging of the information from the different senses. Although the nature of the averaging that occurs in these studies is not fully characterized, the findings support the starting hypotheses of this work.

In the area of affect, Schifferstein (2004) used self-report questionnaires to investigate which senses dominate consumers' interaction with products. The relative importance of the senses was found to depend heavily on the particular product, for example on whether the product was a vase or a television. Schifferstein's approach depends on the ability of subjects accurately to report their experiences of using products.

The experimental approach used in the research reported in this paper was to develop a factorial design and use a system of scaling pioneered by Anderson (1982). In this approach, a set of stimuli (in the case of this research, images) which evoke high, medium and low responses against some uni-dimensional construct, are combined in all possible ways with other stimuli (in this case, textures), which also elicit high, medium and low responses against the construct. Respondents then rate each of the stimulus combinations against the construct. The results are set out in a matrix (Table I). If the values of each of the stimulus combinations are graphed on the ordinate axis against a regularly spaced abscissa, then the resulting lines between the values for each row are sometimes parallel. This can only happen when i) the response scale is linear, ii) the responses to the different sorts of stimuli are independent, and iii) people combine the effects of the stimuli using a weighted average or a sum.

Table I. Example of factorial design for stimulus interaction experiment

Stimuli 1 / Stimuli 2	H_1	M_1	L_1	
H_2	Response H_1H_2	Response M_1H_2	Response L_1H_2	Average H_2
M_2	Response H_1M_2	Response M_1M_2	Response L_1M_2	Average M_2
L_2	Response H_1L_2	Response M_1L_2	Response L_1L_2	Average L_2
	Average H_1	Average M_1	Average L_1	

Superficially, the approach is similar the kansei method QT1. QT1, however, assumes a model of integration (it assumes that the affect of features are combined according to a weighted sum), rather than testing which model applies in each case.

METHODOLOGY

The results of a previous experiment were used to select the stimuli and create the semantic differential questionnaires used in this study. The tactile stimuli in the previous study were arrays of 20mm × 20mm patches of transparent textures printed on transparent polyester sheet. The textures were made of screen-printed polymer. The textures differed in the size and coverage of dots printed and in the type of polymer used. The visual stimuli were smileys. The smileys were mounted beneath the textures and surrounded by neutral-coloured card. Focus groups were used to develop the adjectives for a semantic differential questionnaire. Sixty three students were asked to indicate their subjective response on a five point semantic scale between two polar opposite adjectives when 1) touching the square patches without the smileys. 2) touching the patches with smileys as a background and 3) looking at, but not touching, the smileys. The results were analysed using principal components analysis (Henson, Choo, Barnes and Childs, 2006).

Table II shows the rotated component matrix, Table III shows the scores for the smileys, and Table IV shows the scores for the surfaces from the first study. The words 'funny' and 'witty' scored highly on component 1, 'smooth' and 'simple' on component 2, and 'practical' and 'smart' on component 3. These six words characterise the components and were selected to be used in the research reported here. Four smileys that scored high, medium and low against component 1 were selected. These were smileys 9, 3, 11 and 2 (highest to lowest). Similarly, three textures that scored high, medium and low on component 1 were chosen. These were 10, 8 and 1, respectively. Textures 2, 4, 5, 7, 9, 11 and 14 were made with a polymer which is no longer manufactured and they could not be selected for this experiment.

For the current study, stimuli were made by mounting a picture of each smiley under each of the three surface textures printed in a 20mm × 20mm square on transparent polyester sheets, i.e. 12 stimuli in all. Each was surrounded by neutral-coloured card measuring approximately 8cm × 8cm.

Table II. Rotated component matrix

Item	Principal Component 1	2	3	Item	Principal Component 1	2	3
Funny	***0.95***	-0.04	0.01	Domestic	0.27	0.78	0.11
Unique	0.60	-0.61	-0.27	Vulgar	0.12	***-0.85***	-0.25
Happy	0.90	0.13	0.33	Artificial	-0.21	-0.53	0.59
Smart	0.39	0.20	***0.75***	Fashionable	0.68	0.14	0.52
Simple	0.21	***0.93***	0.06	Cool	0.75	0.26	0.48
Smooth	0.10	***0.92***	0.09	Witty	***0.94***	0.07	-0.03
Practical	0.19	0.34	***0.81***	Relaxed	0.75	0.51	0.31
Like	0.66	0.53	0.44				

Table III. Scores of smileys

Smiley		Component 1	2	3
1		4.06	0.22	-0.62
2		***-4.06***	***-1.50***	***1.94***
3		***1.96***	***-0.37***	***-0.60***
4		5.01	2.25	-1.80
5		4.00	1.75	-1.33
6		3.95	0.50	-0.92
7		1.90	-0.40	0.01
8		-3.59	-1.00	1.56
9		***5.49***	***2.45***	***-2.72***
10		0.93	0.37	0.16
11		***0.17***	***-0.30***	***0.27***
12		1.08	-1.61	0.46
13		-1.52	-1.30	1.13
14		3.40	-1.71	-0.58
15		3.25	1.81	-1.46

Table IV. Scores of textures

Texture	Component 1	2	3
1	***-0.68***	***-1.52***	***-0.36***
2	2.01	4.37	-2.16
3	0.05	-3.31	-0.43
4	1.46	-0.01	-1.38
5	0.77	-0.38	-1.00
6	0.39	-0.19	-0.79
7	1.38	0.70	-1.28
8	***0.00***	***-2.09***	***-0.25***
9	1.12	0.38	-0.80
10	***0.73***	***-0.35***	***-1.19***
11	2.30	4.46	-2.50
12	-0.39	-2.04	-0.39
13	2.98	4.47	-2.48
14	-0.17	-1.78	-0.46
15	1.88	1.86	-1.59

Semantic differential questionnaires were prepared using the six words from the previous study. The words were presented on a twenty-point scale in random order and in random polarity (Figure 1). A twenty point scale was used because it was used in many experiments reported by experimental psychologists (Anderson 1982). Thirty six students were recruited to complete the questionnaire. There were 15 female and 21 male participants. Twenty of them were aged between 18-20 years, 5 of them between 22-24 years, 4 of them between 25-28 years, and 7 of them above 28 years. The questionnaires were administered in a controlled environment in an affective engineering evaluation room. The protocol introduced the surfaces and smileys as representing combinations of surfaces and functions of keypads for electronic equipment. Each respondent was asked to clean their hands using a disposable wipe. The respondents were presented with each stimulus in a random order, told to lay them flat on the table and to touch with the tip of the second finger in a way that seemed most natural and comfortable.

The data was analysed by tabulating each person's response to the stimuli against each word in the same format as the factorial design (see Table V). The numbers in italics in the table are the scores reported by respondent 15 against the word 'smooth' for each stimulus combination.

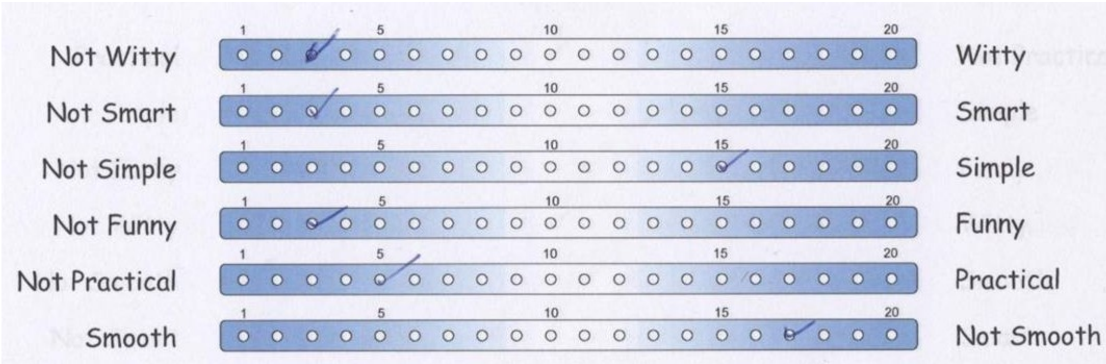

Figure 1. Example of semantic differential questionnaire used in factorial experiment.

If the semantic questionnaire evoked a linear response, and if the interactions between stimuli are independent, and if the interaction is adding or averaging, then there should be no significant interaction between the average scores from each row and column in Table V. The column and row averages were collated and analysed using the multivariate analysis of variance tool in SPSS 12.

Table V. Example of a person's scores for each stimulus combination.

Smiley / Surface	9	3	11	2	Row average
10	*9*	*11*	*7*	*10*	9.25
1	*6*	*9*	*2*	*7*	6
8	*16*	*19*	*14*	*16*	16.25
Column average:	10.33	13	7.67	11	

RESULTS

The average scores for the stimulus combinations against the words 'funny', 'smooth' and 'practical', corresponding to the three principal components in the original study, are shown in Figures 2 to 4. The standard deviations for the scores for 'funny' appeared to be related to the smileys, because each smiley's standard deviations were very similar. The average standard deviation for each smiley is shown in text in Figure 2 for clarity, rather than as error bars. Similarly, in Figure 3, the standard deviations of each surface's scores for 'smooth' were almost the same, and the average σ for each surface is shown. The standard deviations for 'practical' were similar for all stimuli combinations and one average value is shown in Figure 4.

Tests of between subject effects from the multivariate analysis of variance demonstrated that the interaction between the smileys and the surfaces was not significant (p=0.881).

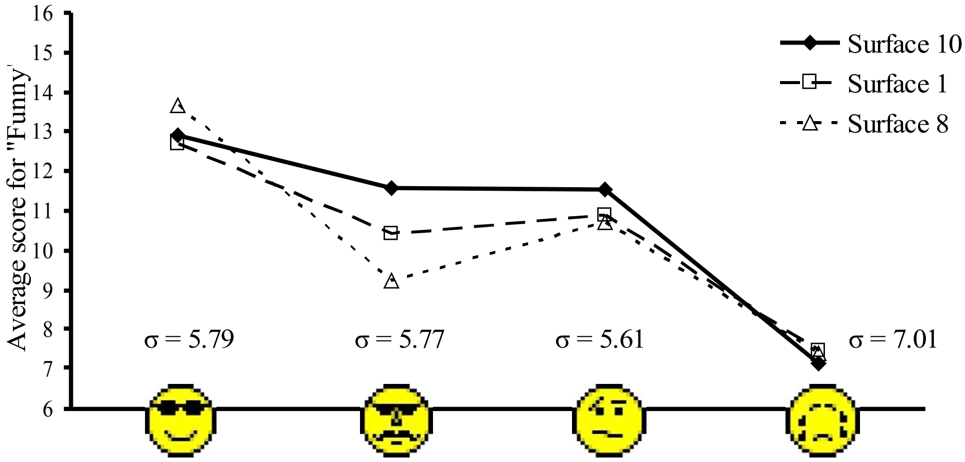

Figure 2. Average scores for each stimulus combination against Funny.

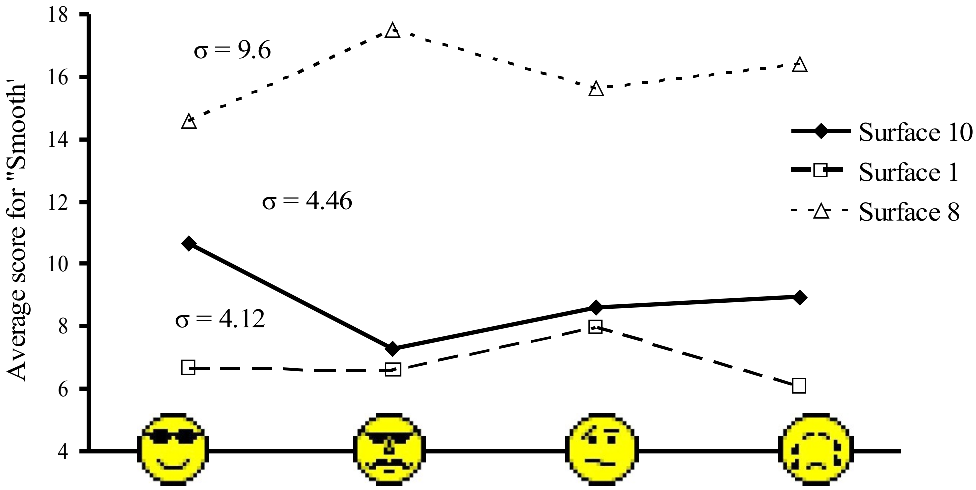

Figure 3. Average scores for each stimulus combination against Smooth.

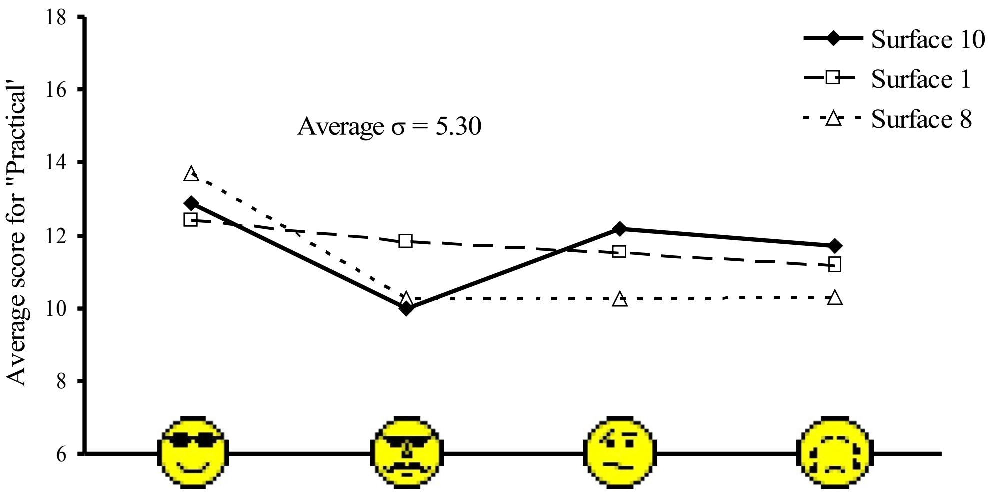

Figure 4. Average scores for each stimulus combination against Practical.

DISCUSSION

The lack of a significant interaction effect between the smileys and the textures supports the hypothesis that the visual and tactile stimuli in this case are combined by weighted averaging or adding. However, the lines connecting the average scores for each surface (Figures 2, 3 and 4) are not obviously parallel to each other. The plots of the scores for ‘funny’ are perhaps the closest to being parallel, but the variance in the data is quite high. It is difficult at this stage to draw further conclusions on the precise nature of the combination.

The variance in the scores for ‘funny’ appeared to vary according to the smiley in the combination, and the variance in the scores for ‘smooth’ according to the surface. This supports the conclusion from the original study that principal component 1 was dominated by the visual effect and component 2 was dominated by the tactile.

An anomaly in the outcomes of this experiment compared to the original experiment is the scores for surface 8 against the word ‘smooth’. In the original study, surface 8 felt quite rough and scored lowly against the word ‘smooth’, but here it scores highly for ‘smooth’. Feeling the surfaces used in this experiment confirms that surface 8 is the smoothest of the three, but it feels much smoother than the surface with the same specification used in the original experiment. Surfaces 10 and 1 felt the same as the original ones. It is difficult to account for this difference other than to speculate that small manufacturing variations might have large effects on the feel of the surface. It is interesting though that the variance in the scores for surface 8 was much higher than for the other two surfaces.

The questionnaire and experimental protocol could be improved to try to elicit more consistent responses. The numbers against the twenty point scale probably confused some respondents as their direction was not changed depending on the word polarity.

On reflection, there are probably better combinations of features other than the use of smileys and surface textures on which to trial this approach, because vision appeared to be dominant in all the cases tested.

CONCLUSIONS

Four smileys, which in a previous semantic differential experiment evoked high, medium and low responses against the first principal component, were covered in all combinations by transparent surface textures that similarly evoke high, medium and low scores. The combined stimuli were then rated by 36 respondents on a 20 point scale against adjectives representative of the principal components. Analysis of the results indicates no interaction between the smileys and the surfaces and that the effect of combining visual and tactile stimuli is probably, in this context and for these stimuli, a weighted average or sum of the effects of the stimuli separately.

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