# CHAPTER 25

# **Measuring Emotion:**
## Development and Application of an Instrument to Measure Emotional Responses to Products

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**Author's Note, 2018 Edition**

This chapter describes the initial version of PrEmo (PrEmo1) that was introduced in 2002. Since its introduction, PrEmo1 was used to measure emotions evoked by a wide variety of products and other designed stimuli, such as wheelchairs (Desmet & Dijkhuis, 2003), automotive design (Desmet, 2003), mobile phones (Desmet et al., 2007), airplane meals, and functional fragrances (Desmet & Schifferstein, 2010), serving both as a means for generating insights for new product conceptualization and as a means for evaluating the emotional impact of new design concepts. In 2013, a fully revised version was launched: PrEmo2, see Figure 1.

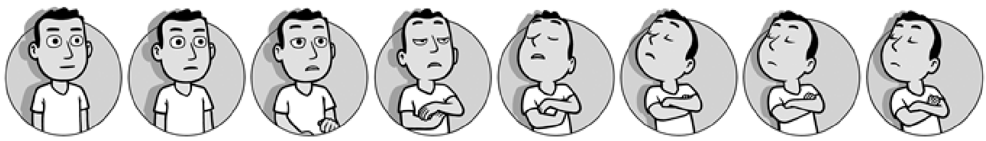

**Figure 1.** Stills from the PrEmo2 "Contempt" animation.

The new version, introduced by Laurans & Desmet (2017), was based on insights gained in ten years of experiences with using PrEmo1. Three main improvements were made. The first is the character design. The PrEmo2 character was designed to be is less 'cute' than the PrEmo1 version. In addition, by adding detail to the facial expressions, the new character gives more reliable information about the expressed emotion. As a consequence, the recognition rate has increased significantly. The second improvement is in the set of emotions. PrEmo2 measures 14 emotions that are categorised in four domains: General well-being emotions (joy, sadness, hope, and fear), expectation-based emotions (satisfaction and dissatisfaction), social context emotions (admiration, contempt, shame, and pride), and material context emotions (attraction, aversion, fascination, and boredom). Whereas the PrEmo1 set was optimised for product appearance, the new set has broader application possibilities. The third improvement is a more extensive validation. The animations were validated in 8 studies across 4 countries (total N = 826), including China, The Netherlands, United Kingdom, and the United States (see Laurans & Desmet, 2017). More information about PrEmo2 can be found on the website of the Delft Institute of Positive Design: https://diopd.org/premo/

## (1) Introduction

Emotions enrich virtually all our waking moments with either a pleasant or unpleasant quality. Cacioppo and his colleagues (2001, p. 173) wrote,

*"emotions guide, enrich and ennoble life; they provide meaning to everyday existence; they render the valuation placed on life and property"*

These words illustrate that our relationship with the physical world is an emotional one. Clearly, the 'fun of use,' i.e. the fun one experiences from owning or using a product, also belongs to the affective rather than rational domain. The difficulty in studying affective concepts as 'enjoyment of use' and 'fun of use' is that they seem to be as intangible as they are appealing. Even more, rather than being an emotion as such, 'having fun' is probably the outcome of a wide range of possible emotional responses. Imagine, for example, the fun one has when watching a movie. This person will experience all kinds of emotions, such as fear, amusement, anger, relief, disappointment, and hope. Instead of one isolated emotion, it is the *combination* of these emotions that contributes to the experience of fun. It is not implausible that the same applies to other instances of fun, whether it is sharing a joke, using a product, or interacting with a computer.

So far, little is known about how people respond emotionally to products and what aspects of design or interaction trigger emotional responses. In order to support the study of these responses, a measurement instrument was developed that is capable to measure combinations of simultaneously experienced emotions: the Product Emotion Measurement Instrument (PrEmo). This chapter discusses the development of PrEmo in the context of existing instruments. In addition, an illustrative cross-culture study is reported, in which emotions evoked by car models have been measured in Japan and in The Netherlands.

## (2) Approaches to Measure Emotions

Before one can measure emotions, one must be able to characterise emotions and distinguish them from other states. Unfortunately, although the concept of emotion appears to be generally understood, it is surprisingly difficult to come up with a solid definition. In the last 100 years, psychologists have offered a variety of definitions, each focussing on different manifestations or components of the emotion. As there seems to be no empirical solution to the debate on which component is sufficient or necessary to define emotions, at present the most favoured solution is to say that emotions are best treated as multifaceted phenomena consisting of the following components: behavioural reactions (e.g. retreating), expressive reactions (e.g. smiling), physiological reactions (e.g. heart pounding), and subjective feelings (e.g. feeling amused). Each instrument that is claimed to measure emotions in fact measures one of these components. As a consequence, both the number of reported instruments and the diversity in approaches to measure emotions is abundant. In this chapter, the basic distinction is made between non-verbal (objective) instruments and verbal (subjective) instruments.

## (2.1) Non-verbal instruments to measure emotions

This category comprises instruments that measure either the expressive or the physiological component of emotion. An expressive reaction (e.g. smiling or frowning) is the facial, vocal, and postural expression that accompanies the emotion. Each emotion is associated with a particular pattern of expression (Ekman, 1994): for example, anger comes with a fixed stare, contracted eyebrows, compressed lips, vigorous and brisk movements and, usually, a raised voice, almost shouting (Ekman & Friesen, 1975). Instruments that measure this component of emotion fall into two major categories: those measuring facial and those measuring vocal expressions. Facial expression instruments are based on theories that link expression features to distinct emotions. Examples of such theories are the Facial Action Coding System (FACS; Ekman & Friesen, 1978), and the Maximally Discriminative Facial Moving Coding System (MAX; Izard, 1979). Generally, visible expressions captured on stills or short video sequences are analysed. An example is the Facial Expression Analysis Tool (FEAT; Kaiser & Wehrle, 2001), which automatically codes videotaped facial actions in terms of FACS. Like the facial expression instruments, vocal instruments are based on theories that link patterns of vocal cues to emotions (e.g. Johnstone & Scherer, 2001). These instruments measure the effects of emotion in multiple vocal cues such as average pitch, pitch changes, intensity colour, speaking rate, voice quality, and articulation.

A physiological reaction (e.g. increases in heart rate) is the change in activity in the autonomic nervous system (ANS) that accompanies emotions. Emotions show a variety of physiological manifestations that can be measured with a diverse array of techniques. Examples are instruments that measure blood pressure responses, skin responses, pupillary responses, brain waves, and heart responses. Researchers in the field of affective computing are most active in developing ANS instruments, such as IBM's emotion mouse (Ark, Dryer, & Lu, 1999) and a variety of wearable sensors designed by the Affective Computing Group at MIT (e.g. Picard, 2000). With these instruments, computers can gather multiple physiological signals while a person is experiencing an emotion, and learn which pattern is most indicative of which emotion.

The major advantage of non-verbal instruments is that, as they are language- independent, they can be used in different cultures. A second advantage is that they are unobtrusive because they do not disturb participants during the measurement. In addition, these instruments are often claimed to be less subjective than self-report instruments because they do not rely on the participants' own assessment of the emotional experience. For the current application however, this class of instruments has several limitations. First, these instruments can only reliably assess a limited set of 'basic' emotions (such as anger, fear, and surprise). Reported studies find a recognition accuracy of around 60-80% for six to eight basic emotions (see Cacioppo et al. 2001).

Moreover, these instruments cannot assess combinations of simultaneously experienced emotions. Given these limitations, it was decided not to use this approach for measuring emotions evoked by products.

## (2.2) Verbal instruments to measure emotions

The limitations of non-verbal instruments as discussed above are overcome by verbal self-report instruments, which typically assess the subjective feeling component of emotions. A subjective feeling (e.g. feeling happy or feeling inspired) is the conscious awareness of the emotional state one is in, i.e. the subjective emotional experience. Subjective feelings can only be measured through self-report. The most often used self-report instruments require respondents to report their emotions with the use of a set of rating scales or verbal protocols.

The two major advantages of the verbal instruments is that rating scales can be assembled to represent any set of emotions, and can be used to measure combinations of emotions. The main disadvantage is that they are difficult to apply between cultures. In emotion research, translating emotion words is known to be difficult because for many emotion words a one-to-one, 'straight' translation is not available. Between-culture comparisons are therefore notoriously problematic. To overcome this problem, a handful of non-verbal self-report instruments have recently been developed that use pictograms instead of words to represent emotional responses. An example is the Self-Assessment Manikin (SAM; Lang, 1985). With SAM, respondents point out the puppets that in their opinion best portray their emotion. Although applicable in between-culture studies, these non-verbal scales also have an important limitation, which is that they do not measure distinct emotions but only generalised emotional states (in terms of underlying dimensions such as pleasantness and arousal). Consequently, a new instrument for measuring the emotions evoked by products was developed. This instrument combines the advantages of existing non-verbal and verbal self-report instruments: it measures distinct emotions and combinations of emotions but does not require the participants to verbalise their emotions.

# (3) Product Emotion Measurement Instrument (PrEmo)

*Does my question annoy him?*
*Is she amused by my story?*

In the face-to-face encounters of everyday life we constantly monitor and interpret the emotions of others (see Ettcoff & Magee, 1992). This interpretation skill was the starting point for the development of PrEmo. PrEmo is a non-verbal self-report instrument that measures 14 emotions that are often elicited by product design. Of these 14 emotions, seven are pleasant (i.e. desire, pleasant surprise, inspiration, amusement, admiration, satisfaction, fascination), and seven are unpleasant (i.e. indignation, contempt, disgust, unpleasant surprise, dissatisfaction, disappointment, and boredom). Instead of relying on the use of words, respondents can report their emotions with the use of expressive cartoon animations. In the instrument, each of the 14 measured emotions is portrayed by an animation by means of dynamic facial, bodily, and vocal expressions. Figure 2 shows the measurement interface.

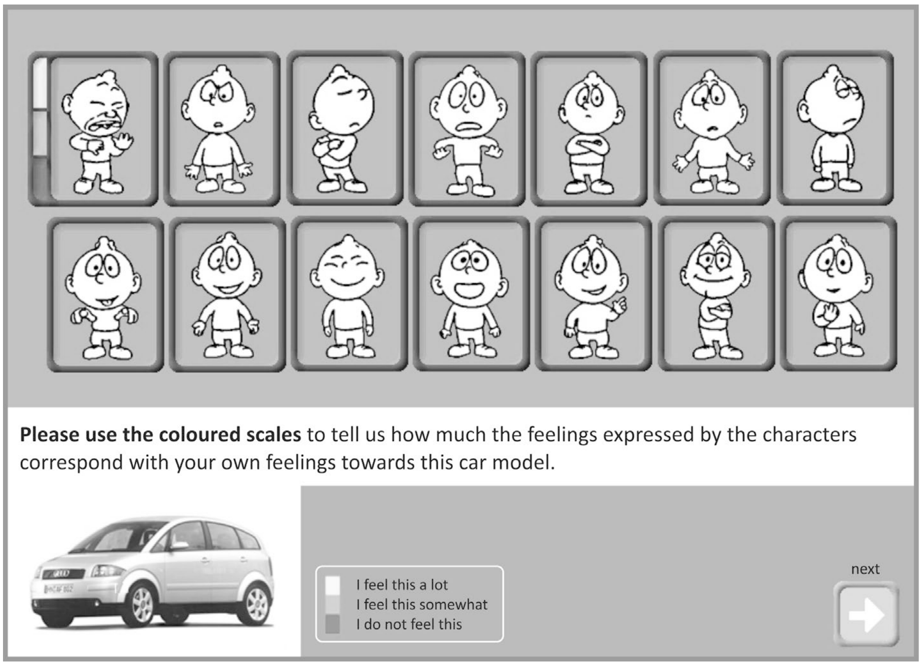


**Figure 2**. *Product Emotion Measurement instrument interface*

The procedure of a PrEmo experiment is self-running. The computer screen displays instructions that guide respondents through the procedure, which includes an explanation of the experiment and an exercise. The program's heart is the measurement interface, which was designed to be simple and intuitive in use. The top section of this interface depicts stills of the 14 animations. Each still is accompanied by a (hidden) three-point scale. These scales represent the following ratings: "I do feel the emotion," "to some extent I feel the emotion," and "I do not feel the emotion expressed by this animation." The rating scales are 'hidden behind' the animation frames. A scale appears on the side of the animation frame only after the animation is activated by clicking on the particular still. The lower section of the interface displays a picture of the stimulus and an operation button. During an experiment, the respondents are first shown a (picture of a) product and subsequently instructed to use the animations to report their emotion(s) evoked by the product. While they view an animation, they must ask themselves the following question: "does this animation express what I feel?" Subsequently, they use the three-point scale to answer this question. Visual feedback of the scorings is provided by the background colour of the animation frame.

## (3.1) Emotions measured by PrEmo

The 14 measured emotions were selected to represent a manageable cross-section of all emotions that can be elicited by consumer products. For this selection, a multistage method was used. First, a set of emotions was assembled that is sufficiently extensive to represent a general overview of the full repertoire of human emotions. This set of 347 emotions was compiled by merging and translating reported lists of emotions. In the first study, participants (N = 20) rated these emotions on the dimensions 'pleasantness' and 'arousal,' which represent the dimensions of the 'Circumplex of Affect' developed by Russell (1980). Both dimensions were rated on a three-point scale: pleasant-neutral-unpleasant, and calm- moderate-excited respectively. In addition, participants marked emotion words with which they were not familiar. On the basis of these ratings, the set emotions was divided in eight categories (see Table 1). Note that one combination, i.e. moderate- neutral is not included. It is left out because it is not considered to be an emotional category in the Circumplex model. Emotions that were ambiguous or marked as unfamiliar were omitted from the set.

Table 1. *Emotion categories*

| *Category* | *Amount of included emotions* | *Category* | *Amount of included emotions* |
|---|---|---|---|
| Excited pleasant | 30 | Calm unpleasant | 34 |
| Average pleasant | 53 | Average unpleasant | 61 |
| Calm pleasant | 24 | Excited unpleasant | 46 |
| Calm neutral | 14 | Excited neutral | 20 |

In order to further reduce the set, the second study was designed to select those emotions that are most often elicited by products. In this study, participants (N = 22) used a rating procedure to indicate which emotions they often, and which they do not often experience in response to product design. They were instructed to do this for each of the eight emotion sets. On the basis of the sum scores, 69 emotions were selected that are evoked regularly by product design (the sum scores of these emotions were significantly higher than the average score). Subsequently, in the third step, the set was further reduced by eliminating those emotions that are approximately similar to others in the set. Participants (N = 40) rated the similarity of the emotions in pairs. With the use of a hierarchical cluster analysis, the set of 69 emotions was reduced to a set of 41 emotions. In a final study, participants (N =23) rated all 41 emotions on a five-point scale (from 'very relevant to product experience' to 'not relevant to product experience'). On the basis of the mean scores, the final set of 14 emotions was selected. Although, evidently, products can elicit more than these 14 emotions, these are the ones that can be considered to occur most frequently. The set of 14 is regarded as a workable balance between comprehensive and surveyable. A detailed report of the selection procedure can be found in Desmet (2002).

## (3.2) Dynamic cartoon animations

The idea to use expressive portrayals of the 14 emotions was based on the assumption that emotional expressions can be recognized reliably. Ekman (1994) found that facial expressions of basic emotions (e.g. fear and joy) are not only recognised reliably, but also univocally across cultures. As the emotions measured by PrEmo are subtler than the basic emotions, more information than merely the facial expression is needed to portray them reliably. Our approach to this problem was to incorporate total body expression, movement, and vocal expression. It was decided to use a cartoon character because these are often particularly efficient in portraying emotions. This efficiency is achieved with abstracting which reduces the emotional expression to its essence. Abstracted portrayals can make the task of recognizing emotional expressions easier because the amount of irrelevant information is reduced (Bernson & Perret 1991). Moreover, with cartoon characters it is possible to amplify (or exaggerate) the expressive cues that differ between emotional expressions (see Calder et al. 1997).

A professional animator designed the character and created the animated expressions. A vocal actor synchronized the vocal expressions. To enable the animator to create clear portrayals, a study with actors was conducted. In this study, four professional actors (two males, two females) were instructed to portray each of the 14 emotions as expressive and precise as they could. These portrayals were recorded on videotape and analysed by the author and the animator. On the basis of this analysis, the animator created the animations. By ways of example, Figure 3 shows the animation sequences of *inspiration* and *disgust*.

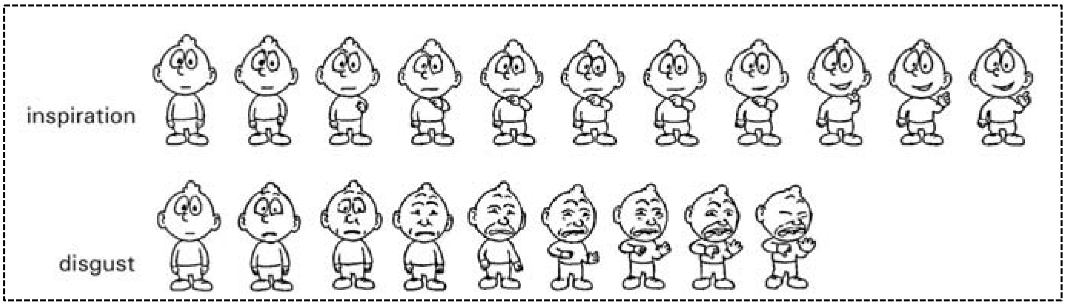


Figure 3. *Two animation sequences*

## (3.3) Validity and reliability

The validity of PrEmo, i.e. the degree to which it accurately measures the emotions it was designed to measure, was assessed in a two-step procedure. The first step was to examine the validity of the animations. An important requirement was that PrEmo should be applicable in different cultures or language areas. Therefore, the study included participants from four different countries (N = 120; 29 Japanese, 29 United State citizens, 33 Finnish, and 29 Dutch participants). Participants were shown three animations and asked which of these three best portrayed a given emotion. Of the three animations shown, one was designed to portray the given emotion, and the other two portrayed other emotions (yet similar in terms of pleasantness and arousal). The animation that was supposed to portray the given emotion was considered valid when it was selected more often than could be expected by chance. A strict significance level (i.e. $p < .001$) was applied because it was important to identify also slightly inaccurate animations. On the basis of the results, it was concluded that in order to be valid, the animations portraying *desire* and *disappointment* needed further development. These two animations were found to be invalid in Japan and therefore adjusted on the basis of a study with four Japanese actors.

The validity of the instrument was examined in a second study (N = 30). In this study, both PrEmo and a verbal scale were used to measure emotions evoked by six chairs. The level of association between the results obtained with PrEmo and those obtained with the verbal scales was analysed. The correlations between emotion scores measured with the two methods were high ($r$ varied from .72 to .99) and all but one (i.e. *amusement*) were significant ($p < .05$). For each emotion a repeated measures MANOVA was performed to examine interaction effects between chair model and instrument (i.e. either verbal scale or PrEmo). None of the analyses found a significant interaction effect between chair and instrument. In agreement with the high correlation, these findings indicate that the participants did not respond differently to each of the chairs as a result of the measurement instrument applied. Based on these results, it was concluded that PrEmo is satisfactory with respect to its convergent validity. Moreover, participants reported in a questionnaire that they preferred using the animations to using words for reporting their emotional responses. The animations were found to be more intuitive in use and, importantly, much more enjoyable.

## (4) Cross-Cultural Application

The application possibilities of PrEmo have been explored with a between-culture study in which emotions evoked by six car models (see Figure 4) were measured both in Japan (n = 32) and in The Netherlands (n = 36). It was decided to use cars because in previous studies we found that car models that vary in appearance can elicit strongly different emotions (see e.g. Desmet, Hekkert, & Jacobs 2000). Participants were matched on gender and age (20-60 years old). In a written introduction, it was explained that the purpose of the experiment was to assess emotional responses to the car designs. After the introduction, participants were shown a thumbnail display that gave an overview of all the models. Subsequently, photos of the six car models were presented in random order. After looking at a photo, participants reported their response with the 14 PrEmo animations.

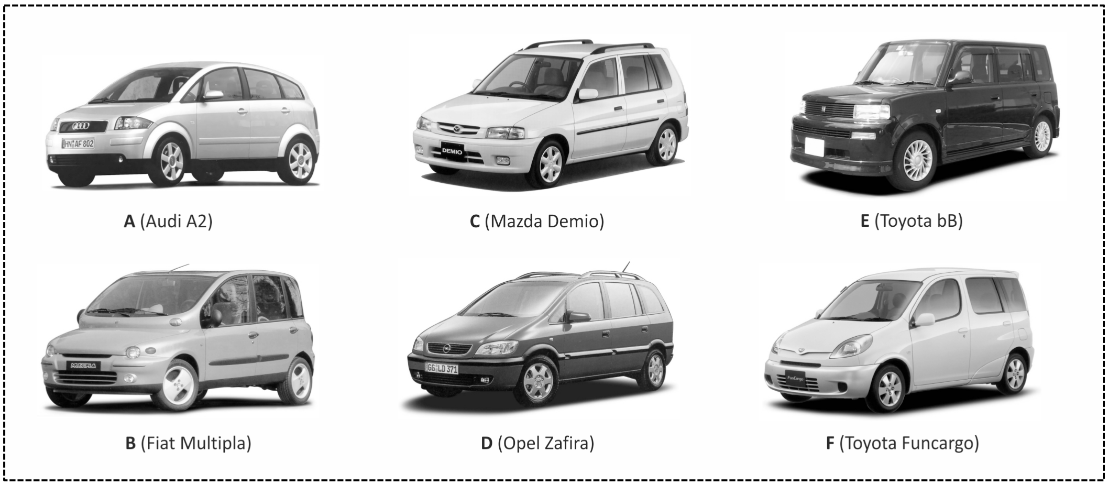


Figure 4. *Stimuli used in the application study*

In order to obtain a graphical representation of the results a correspondence analysis was performed with two factors: Emotion (14 levels) and Car combined with Culture (12 levels). Correspondence analysis is a technique for describing the relationship between nominal variables, while simultaneously describing the relationship between the categories of each variable. It is an exploratory technique, primarily intended to facilitate the interpretation of the data. Figure 5 shows the two-dimensional solution of the analysis, which explains 90.3 % of the total variance: the 'product & emotion space.'

This product & emotion space visualises the associations between the car models and the reported emotional responses. Pleasant emotions are indicated with a triangle and unpleasant with a circle. The results of the Japanese participants are indicated with a 'J,' and those of the Dutch with an 'H.' The distances between the car models reflect the relationships between them (with similar models plotted close to each other). Similarly, the distances between the car models and the emotions reflect the relationship between them. This means that car models that are plotted close to each other evoked similar emotions, whereas those plotted at a distance from each other evoked different emotions. Cars A and D, for example, evoked similar emotions, whereas Cars A and B evoked noticeably different emotions.

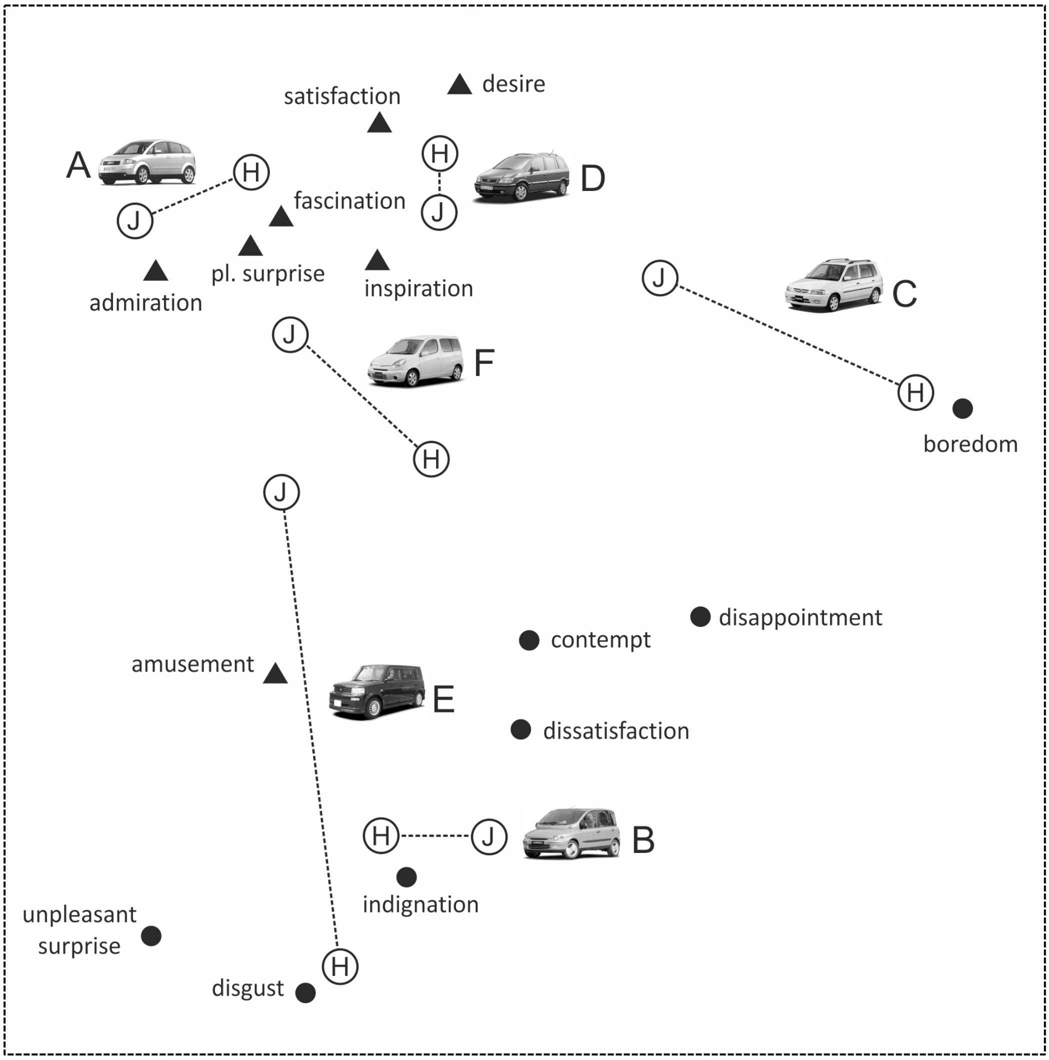


Figure 5. *'Product & emotion space' of Dutch ('H') and Japanese ('J') participants for six car models*

In the product & emotion space some effects catch the eye. Clearly, the degree to which car models differ from each other also varies. The difference between Cars A and D, for example, is smaller than the difference between Cars A and B. Moreover, some car models appear to have elicited mainly pleasant emotions (e.g. Car D), some mainly unpleasant (e.g. Car B), and some both pleasant and unpleasant (e.g. Car F). In addition, two between-culture effects can be observed. First, the degree to which the emotional responses of the cultures differ depends on the car model. The space indicates that cultural differences are greatest for Cars E and C. Cars, A, B, and D, on the other hand, appear to have elicited similar emotions in Japan and in The Netherlands. Secondly, the product & emotion space indicates that the Japanese experienced generally higher ratings on pleasant emotions than the Dutch. The three car models that showed the largest cultural differences elicited more pleasant emotions in Japan than in The Netherlands.

## (4.1) Between-culture differences

The correspondence analysis is an exploratory technique, primarily intended to facilitate the interpretation of the data. Because it is not appropriate to draw conclusions, the observed between-culture effects have been examined in more depth, with an analysis of variance. For each emotion a two-way repeated measures MANOVA was performed with Car (six levels) as within-participants factor, Culture (two levels) as between-participant factor, and the emotion as dependent variable. Some interesting culture effects have been found. For three emotions, cultural differences independent of car model were found. Japanese participants showed higher mean scores on the following emotions: *admiration*, *satisfaction*, and *fascination* ($p < .01$). This may point to a cultural difference in how car models are experienced: apparently Japanese people are generally more admiring of, satisfied, and fascinated by car models than the Dutch. Some Car x Culture interaction effects indicated that there are also cultural differences in responses with respect to the particular car models used in the study. Interaction effects were found for *disgust*, *unpleasant surprise*, *dissatisfaction*, *amusement*, *admiration*, and *satisfaction*. For example, the Dutch participants were not amused by the same car models as the Japanese.

A notable finding was that, contrary to expectations, cultural differences cannot be explained by product-familiarity. For instance, for Car B (Fiat Multipla) no significant cultural differences were found with respect to the emotions it elicited. This was not expected, because the Dutch participants were familiar with this model, and the Japanese were not. These findings confirm the idea that in product development, cultural differences must be recognized, and that these differences are both difficult to predict and to explain. Companies involved in 'global marketing' should be aware of these differences and should perhaps develop various design strategies for different cultures, instead of attempting to market identical products in different countries.

# (5) Discussion

The unique strength of PrEmo is that it combines two qualities: it measures distinct emotions and it can be used cross-culturally because it does not ask respondents to verbalise their emotions. In addition, it can be used to measure mixed emotions, that is, more than one emotion experienced simultaneously, and the operation requires neither expensive equipment nor technical expertise. And, also important, respondents reported that the measurement task with PrEmo is pleasant or even enjoyable. A limitation for the application in human computer interaction is that the 14 measured emotions represent a cross-section of emotions experienced towards static product design. It is not said that this set also represents emotions that are experienced towards dynamic human product interaction. Some emotions may be over-represented, whereas others may be missing. Before PrEmo is applied for the measurement of emotions evoked by interacting with a computer (or any other product) it must be determined if the 14 emotions are adequate and, if not, the set animations should be adjusted.

What is the point of measuring emotions evoked by products or computer programs? More interesting than discovering *which* particular emotions are evoked by a set of stimuli, is to understand *why* those stimuli evoke these particular emotions. This information can be used in the development of new products, to elicit pre-defined emotion profiles. Hence, the interpretation of PrEmo results requires theoretical propositions about how product emotions are related to the product's appearance and interaction, and the characteristics of the person who experiences the emotions. In cognitive emotion psychology, emotions are regarded as outcomes of appraisal processes. According to Frijda (1986), emotions are elicited when a subject appraises a stimulus as important for the gain of some personal concern. A concern can be any goal, standard, attitude, or motive one has in life, e.g., achieving status, feeling safe, or respecting the environment. In following Arnold (1960), Frijda argues that when we appraise a stimulus as beneficial to our concerns, we will experience positive emotions and try to approach this particular stimulus. Likewise, when we appraise a stimulus as conflicting with our concerns, we will experience negative emotions and try to avoid it. As concerns are personal, different subjects have different concerns. As a result, individual subjects will appraise a given product differently. As different types of emotions are evoked by different kinds of appraisals, appraisals can be used to differentiate emotions (e.g., Ortony, Clore, & Collins 1988). For the 14 emotions measured by PrEmo, Desmet (2002) described the specific appraisal patterns underlying each emotion. Understanding these patterns could guide designers in controlling the emotional responses to their designs.

A second application possibility of PrEmo is to use it as a means to communicate emotional responses to products. The emotional aspects of a design can be difficult to discuss because they are often based on intuition. The 'product & emotion space' that results from a PrEmo experiment makes the intangible emotional responses tangible. In various design workshops, the space has proven to be a valuable support to discuss emotional aspects of design in a design team. In addition, designers found it to be effective when used as a means to communicate, argue, and defend their ideas to non-designers who are also involved in the product development (e.g. marketing, engineering, etcetera). The decision to design an instrument that measures both pleasant *and* unpleasant emotions was based on the notion that unpleasant responses are as interesting as the pleasant.

What are the characteristics that make one product more enjoyable or attractive than another? Some of us find riding a roller coaster fun, whereas others would not want to be found dead in one. Some consider the fear experienced when thrown from a bridge with elastic tied to one's ankles to be fun whereas others prefer to play a game of bridge. Whatever the interpersonal differences in what we find to be fun, it would clearly be incorrect to assume that that fun is related only to pleasant emotions. Frijda and Schram (1994) stated that art often elicits paradoxical emotions, that is, positive and negative emotions simultaneously, and that it is precisely these paradoxical emotions that we seek and enjoy. In the words of Frijda (p. 2) "we enjoy watching tragic miseries, and we pay fair amounts of money to suffer threat and suspense." It may be interesting for designers and design researchers to investigate the possibilities of designing such paradoxical emotions. Eventually, these efforts may result in products that are unique, innovative, rich in their interaction, interesting, and fun to use.

## (6) Acknowledgements

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