# Measuring semantic and emotional responses to bio-inspired design

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**Abstract.** This research explores the relation between specific inspirations such as animals postures and the expressiveness of the design solutions provided by the designers. The prediction of semantic and emotional responses underlying animals' postures and attitudes might help designers to define design specifications and imagine design solutions with a high expressivity. To address this issue, an experiment was conducted with designers in watching six sets of animal posture images and corresponding product images. This experiment derived quantitative and qualitative results from the combination of cognitive/physiological methods: a questionnaire, Galvanic Skin Reponse (GSR), and eye tracking system.

**Keywords:** Biomorphism, Animal body posture, PCA analysis, GSR

## 1 Introduction

In the early stage of design, designers employ a large variety of types of inspirational sources from different areas: comparable designs, other types of design, images of art, beings, objects, and phenomena from nature and everyday life (Bouchard et al., 2008). These sources of inspiration are an essential base in design thinking such as definition of context, and triggers for idea generation (Eckert and Stacey, 2000). Indeed this kind of analogy helps them to provide a high expressivity, a high level of creativity, and a high emotional impact into the design solutions (Wang, 1995; Djajadiningrat, Matthews, and Stienstra, 2007).

Remarkably, among the various sectors of influence used by the designers, biologically inspired design proved to be a very efficient and creative way of analogical thinking (Helms, Vattam, and Goel, 2008). Some authors already demonstrated the positive effect of biological examples in idea generation (Wilson and Rosen, 2009). Especially, the use of animal analogies has proved to be very efficient for designers (see Figure 1). In some specific fields of design such as vehicle design animal analogies are prominent in the cognitive processes.

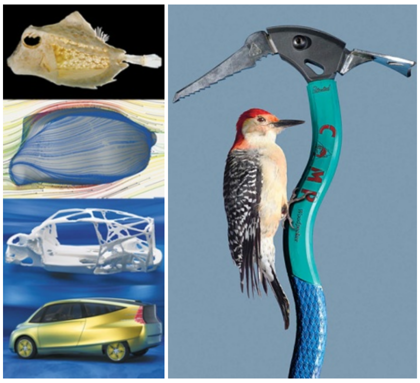


**Fig. 1** Boxfish Mercedes Benz Bionic Car (Left), CAMP Woodpecker Ax (Right)

Up to date, however, there has been no study at the best of our knowledge that investigate the relationship between the semantic and emotion expressed by the inspirational source (e.g., an animal posture) and the emotions that the inspired design elicits in consumers. This is what our explorative study aims at.

This aim necessarily raised a question about assessment methods of semantic and emotional responses. In many cases, the cognitive measurement based on semantic differential approach has been extensively applied in emotional design and Kansei engineering. This cognitive approach has also been employed to assess the emotional responses. In particular, Self Assessment Manikin of Lang (1997) is a pictorial questionnaire in terms of arousal, valence, and dominance. In addition, a lexical emotional feeling, including a list of 50 emotional reaction proposed by the Psychology department of the Geneva University (1988) in Mantelet (2006) enables to evaluate emotional responses in a questionnaire.

Even though the cognitive approach is relatively simple, cheap and quick measurement, questions have been raised about some disadvantages to apply. First, cognitive measurement is not able to assess in real time; and it is hard to catch objectively a subtle emotional state. In addition, the use of emotional scales which often contains a long list of emotion adjectives might cause respondent fatigue. Moreover some of respondents have difficulties in to expressing their feeling because they are not always aware of them and/or certain pressure from social bias (Poels and Dewitte, 2006).

In order to account for the limitation of cognitive measurement of emotional responses, recent studies in Kansei engineering start to triangulate these measures with physiological responses such as Electromyography (EMG), Galvanic Skin Resistance (GSR), heart rate and electroencephalography (EEG) etc. Undoubtedly, unnatural, obstructive and heavy instrument might interfere with respondent's natural way of design and influence on the results; however, applying physiological measurement under careful consideration could deepen our understanding of some respondent' unconscious emotional process (Tran et al., 2003; Gaglbauer et al., 2009).

Hence, for the purpose of measuring semantic and emotional responses in front of bio-inspired design, we intended to apply both cognitive and physiological measurement in our experiment. The use of specific instruments and protocol are described in Part 2. Both qualitative and quantitative results are presented in Parts 3 and 4. Finally, the paper concluded by suggesting future work and by including some considerations regarding the need for deepening on this study.

Original research advances will be provided in the following areas: cognitive/physiological evaluation and prediction of emotions from postural information.

## 2 Design of Protocol Study

### 2.1 Cognitive measurement : Questionnaire

From the work done by Mantelet (2001), we have developed a questionnaire by following five steps: *Definition of the Image stimulus, Definition of the lexical corpus (emotions, semantic adjectives), Definition of the questionnaires (Java algorithms), Data gathering, Data analysis, and interpretation of the results.*

*2.1.1 Definition of the Image stimulus*

As the first step, we gathered six sets of bio-inspired design examples (see Figure 2). The criteria of selecting image stimulus was the name of vehicle such as Beetle from Volkswagen (A2-P2), Audi Shark (A4-P4) and Dodge Viper from Chrysler (A6-P6), and also the similarity of animal body posture selected by designers.

All images stimuli were presented to participants in grey scale with a resolution of 1024x768. Under highly controlled conditions, participants could concentrate on the given images so that we could minimize other possible interruptions, including chromatic effect and experimental environment etc.

*2.1.2 Definition of the lexical corpus (emotions, semantic adjectives)*

The four designers were asked to provide a list of semantic descriptions by manually annotating the set of images. In order to explore the link between the inspirational source and the product, designers were divided in two groups. One group was asked to annotate the six inspirational source images (A1~A6), the other group was asked to provide a set of semantic descriptions to describe the product images (P1~P6). Finally, the semantic descriptions retained are as follows:

- **Semantic descriptions for inspirational source (A1~A6):** *Elegant, Appealing, Soft, Powerful, (Lively), Rapid (Speed), Sharp, Aggressive, Fluid, Light*
- **Semantic descriptions for product (P1~P6):** *Angular, Aggressive, Retro, Appealing, Light, Organic, Sportive, Futuristic, Aerodynamic, Natural*

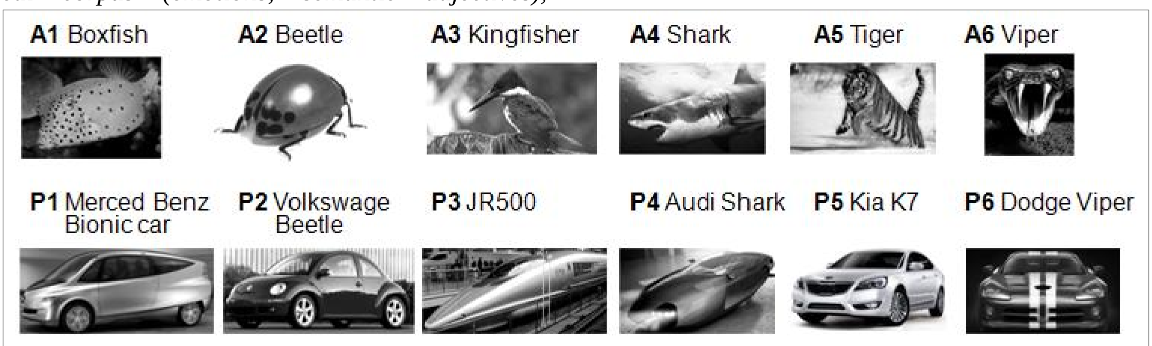



**Fig. 2.** Bio-inspired design examples

Following a similar protocol, the designers were also asked to provide the emotional terms elicited in the same set of images. Since emotional terms which reflect secondary emotion are relatively hard to express in lexical way, a lists of 20 emotional terms extracted by Geneva university (1988) was made available to the designers during the annotation process. The designers were however free to use any emotional terms even if not in the provided in the list.

The retained emotional terms were: a*mused, calm, pleasure, inspired, stimulated, anguished, indifferent, doubtful, astonished,* and *tender*. In addition, the designers were asked to evaluate the images in terms of valence and arousal by using the Self-Assessment Manikin (SAM) scales of Lang (1997).

*2.1.3 Definition of the questionnaire*

The questionnaire consists of three types of slide: *Preparation slide*, *Stimuli slide* and *Rating slide*.

- *The Preparation slide* is a blank page in order for the participants to rest and stabilize their emotional state before watching the next stimuli slide.
- *The Stimuli slide* holds each image stimulus chosen in Figure 2.
- *The Rating slide* consists of three types of questionnaire.
  - The Self-Assessment Manikin (SAM) scales of Lang (1997) in terms of valence and arousal with its pictorial image.
  - The list of 10 emotional terms to be rated on 5-point rating scales (from 1= 'Not at all' to 5 = 'Very much') each.
  - The list of 10 semantic descriptions (either for product or for inspirational source) to be rated on 5-point rating scales (from 1= 'Not at all' to 5 = 'Very much') each.

Following Lang's method (1997), each test began with a preparation slide that lasted for 5 seconds. Then, a stimuli slide was presented for 6 seconds. Finally, the participants were asked to fill in the questionnaire in the rating slide. During the rating slide, a small thumbnail image was displayed for helping the designer's evaluation process. The 11s loops (Preparation slide → Stimuli slide) were the same for each image stimulus. Once rating slide was over, the computerized preparation slide was then activated until all images stimuli to be rated.

Instead of using paper based questionnaire, the questionnaire was integrated in SMI eye tracking system (Figure 3b). This method enables to collect participant's simultaneous responses during task through recording eye movement and facial expression. Most of all, it enables to record automated input time in questionnaire, so that physiological data could synchronize with questionnaire.

## 2.2 Physiological measurement: Galvanic skin response (GSR)

For our exploratory study, a selection of physiological measurements was essential to detect emotional responses of bio-inspired images and identify a correlation between cognitive measurement and physiological measurement. Our criteria to determine the biosensors were non-obstructiveness, easy interpretation of signals and high reliability.

Hence, we intended to apply galvanic skin response (GSR) which could indicate effective correlation to arousal. Significant advantage of GSR is that GSR could provide continuous information and detect very sensitive amount of arousal (Tran et al., 2007; Gaglbauer et al., 2009).

In addition, even though, the results from eye tracking system will not be described in this paper, we expect that a physiological phenomenon gathered by eye tracking system such as fixation number/duration, pupil size, and blink rate/duration could provide supportable results.

In order to employ GSR, the two GSR electrodes were places on two fingers of the left hand. Changes in the skin conductance were collected at 200Hz per second. Using the BIOPAC acquisition unit and the software BSLPro 3.7, we could ampify the collected signal and visualize it (Figure 3).

(a) GSR (b) SMI Eye-tracking & Biopac system

**Fig. 3.** System setup

## 2.3 Data gathering

Six master degree product designers in laboratory CPI have been involved in our exepriment. They were all French students (Five females and one male). Paricipant were divided in two groups: one group was to rate inspirational source (A1~A6), the other was to rate product image(P1~A6).

Generally, the experiment took in average 17,14 minutes (standard deviation was 2,1 minutes) .

### 2.4 Data analysis

The data from the questionnaires were analyzed by Principal Component Analysis (PCA). PCA was employed separately to the data from the rating of the inspirational sources and the data from the rating of the product images. The aim was to explore the way semantic and emotional terms used to rate the correlations between semantic and emotional responses (Mantelet, 2003; Bouchard et al., 2008; Nagamachi et al., 2009).

In order to analyze GSR responses, first, the segment of 11 seconds corresponding to the preparation and stimuli slides were extracted. Next, as large inter-individual differences were expected, we normalized the GSR values [0,1] each using the following formula: Normalized_GSR= (original_GSR - max_GSR) / max_GSR. Finally, the normalized GSR values of six participants were averaged in time.

## 3 Results

### 3.1 Correlation of semantic descriptions

Figure 4 shows the position of the ten semantic descriptions (blue diamond) and the images (red dot) each in the extracted principal component sphere. Given that cumulative contribution of PCA shows the correlations between semantic descriptions, two factors (F1&F2) can explain 86,4% of the data concerning the animal images (Figure 4a). In case of the product image (Figure 4b), the contributions are focused on 74.1% for two factors (F1&F2). Both cases have a common axis which represents '*aggressive – appealing*'.

With regard to the interpretation of axis, we found that there are some differences about inspirational sources (animal) and product image. For example, in case of animal sources (Figure 4a), semantic description *aggressive* was very close to *rapid (speed)*, *powerful* and *lively*. On the other hand, the notion of *aggressive* about product image was closer to *sportive*, *futuristic*, and it was far from *retro*.

In case of product images (Figure 4b), semantic description *appealing* was close to *soft* and *elegant* and far from *sharp*. In case of product image, *appealing* was more linked to *natural*, *organic* and *light* and far from *angular*.

Between the relation of inspirational source and product, we could observe the strong similarities in terms of semantic descriptions between A2-P2, A4-P4 and A6-P6.

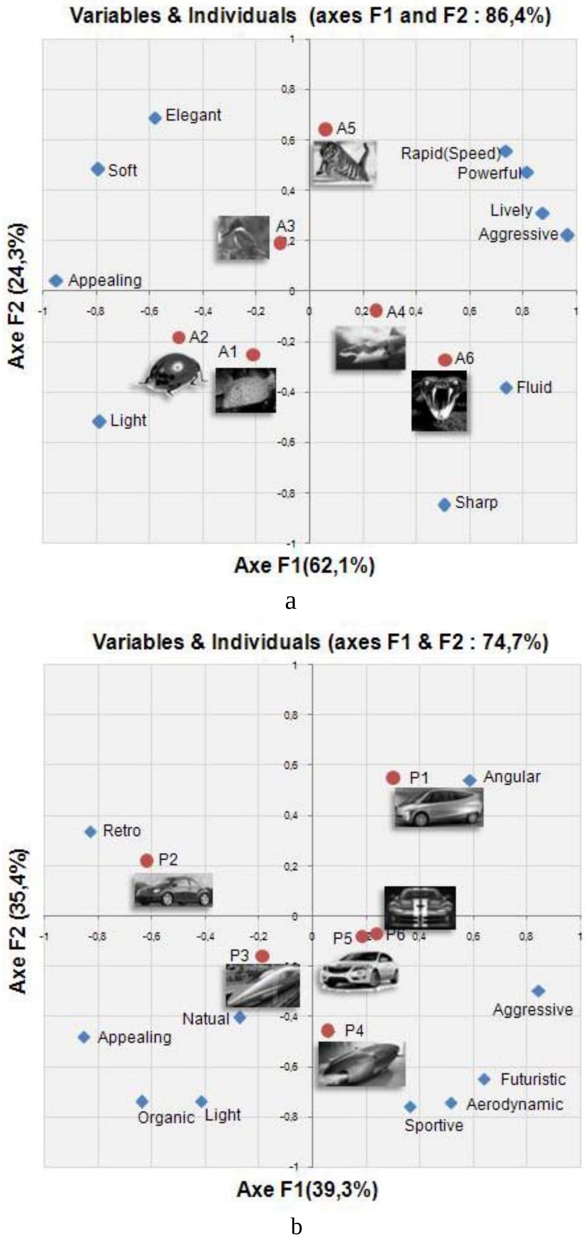



**Fig. 4.** a. PCA of semantic descriptions on animal image; b. PCA of semantic description on product image

### 3.2 Correlation related to emotional terms

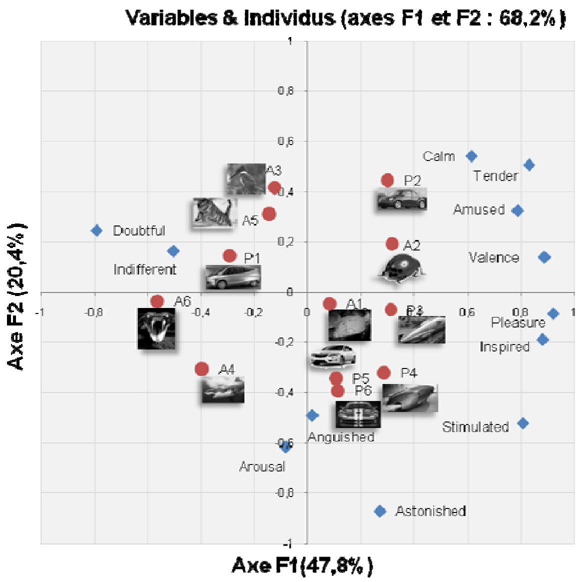
In order to identify the correlation related emotional terms, we also applied PCA analysis of emotional terms on the inspirational source image and product image. As shown in Figure 5a, the contributions were focused on F1 (20.4%) and F2 (47.8%), totally 68.2% for two factors. The principal axes were confirmed *positive-negative* and *high-low arousal*.

The results show that *positive valence* reflects some complementary emotions including: *pleasure*, *amused, inspired,* and *tender*. High arousal related to *anguished* and *astonished*. High arousal ratings were assigned to A4-P4 and P5. Relatively, A3, A5, P2, and P6 received lower ratings.

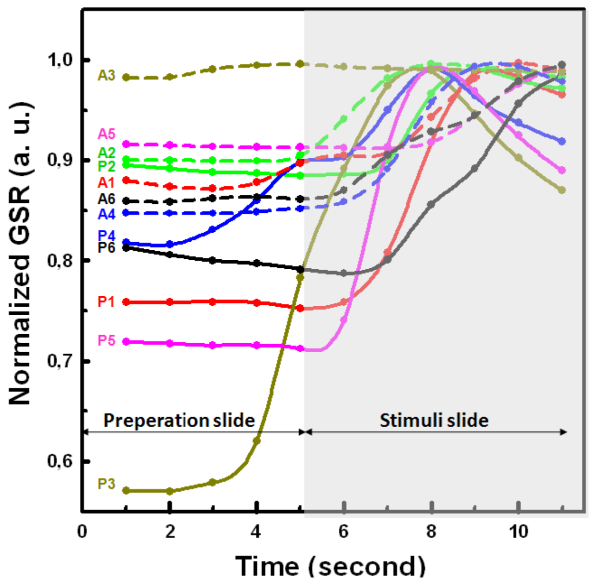
Figure 4(b) shows the normalized average GSR value for 11 seconds i.e., 5 seconds for the preparation slide and 6 seconds for the stimuli slide as indicated respectively by the white and grey region of the image. This graph employed the same color code for the paired images. A dotted line represents animal images (A1~A6) and a continuous line represents the product images (P1~P6).

As GSR sensors measure skin conductivity which usually associated with arousal, we are interested in the peak and troughs of GSR data (Figure 5b). Specifically, we analyze a similar amplitude augmentation tendency between paired-images (animal – product) in watching stimulus slide.

As shown in Figure 5b, the baseline for the animal images (resting state) was always higher than the ones for the product images except for the Volkswagen Beetle (P2). The normalized average GSR of product images started at low level; however GSR data suddenly increased and show a peak in stimuli slide. Most interesting finding is that the GSR data of all the image stimuli arrive at similar peek value (around 1), even though the rising time of GSR data was different. Given the correlation of animal images and corresponding product images, A2-P2, A4-P4, and A6-P6 images have significantly similar tendency of GSR data in time. However, it was hard to explain the correlation of GSR data between A1-P1, A3-P3, and A5-P5.




a




b

**Fig. 5.** a. PCA of emotional terms for animal images and corresponding product images; b. Change of the normalized average GSR for 11 seconds

## 4 Discussion

### 4.1 Various aspects for measuring emotional impact on bio-inspired design

In our specific experiment, we attempted to explore the relation between body posture of animals image and product image, in conjuntion with emotional and semantic responses. A cognitive and physiological method was employed to answer those issuses. Hence, interpretation of results through balancing the data from cognitive approach and physiological approach was a crucial factor.

As mentioned above, some paired images (A2-P2, A4-P4, and A6-P6) have showed a common emotional state in both PCA results and similar amplitude augmentation tendency (Figure 4 and 5). However, the other pairs cannot give any remarkable results. This may be partly explained by the following two points.

First, we assumed that a level of recognition of image might influence on both cognitive and physiological evaluation. In our experiment, as Volkswagen Beetles (P2) and beetles images is very famous biological inspired car through their original name and the advertisement, the experiment also confirmed with high correlation between two images in terms of semantic and emotional responses. In caparison, the pairs of A3-P3 and A5-P5 have little correlation in both PCA results and GSR data, An explanation for this, since the participants were all

French student, they were not relatively aware of P3 (JR500-Japan) and P5 (Kia K7-Korea).

Second, the finding raised some issues about methodological condition. Given that the presenting image size was all unified in screen size (1024*768 resoultion), this led the lack of consideration on a real size of animal and product. Those images can not sufficiently express their own semantic and emotional attibute. We found that tiger image (A5) and viper image (A6) cannot sufficiently convey their attitude and impression from a posture.

## 5 Towards modeling the attitude and posture of animals

Previous behavioral studies have been discovered human body posture and movement as an important affective communication channel. Berthouze et al. (2003) recently reviewed the state of the art on this topic. According to Mehrabian and Friar (1969), changes in a person's affective state in the work done by are reflected not only by changes in facial expressions but also by changes in body posture. They found that bodily configuration and orientation are significantly affected by the communicator's attitude toward her/his interaction partner. Ekman and Friesen (1967) have hypothesized that postural changes due to affective state aid a person's ability to cope with the experienced affective state.

Despite those studies, there has not some studies focused on the attitude and posture of animal and its emotion. Only few studies have been pioneered to explore ‘pleasant’ and ‘threatening (fear)’ animals, plant, fruits, or flowers (Hamm, Esteves, and Öhman, 1999; Tripples et al., 2002; Field and Schorah, 2007).

Meanwhile, this interest led to create models that maps body expression features into emotional states. According to Rudolph Laban (1988), various types of approaches have been taken to measure postures and movement and statistically study this relationship. Wallbot (1998) showed the existence of emotion-specific body-expression patterns that could be partially explained by the emotion dimension of activation. Using motion-capture techniques and an information-theory approach, Berthouze et al. (2003) identified a set of body configuration features that could be used to discriminate between basic emotion categories.

As our next step, we are planning to follow the approach proposed by Berthouze (2003), to perform a more thorough analysis of the shape of the product and of the animal posture to identify particularly expressive postures and attitudes features (e.g. angle between body segments, muscle tension) and body parts that are responsible for these responses.

Finally, those studies would enable to develop computer aide design (CAD) tools. These CAD tools will help designers to generate expressive and user-friendly design solutions for the consumers. We hope new designs will appear on the market in the future, which is oriented towards more pleasurable products in the sense of D. Norman (2002).

## 6 Conclusion

This study aimed to explore the relation which establishes a formal connection between bio-inspired sources and the design solutions produced by the designers in specific fields such as car design. Further study must be needed toward creating computational models to predict emotional/semantic responses to body posture of animals, in order to provide design rules based on analogical reasoning through biomorphism. In short term, we will investigate to refine the results from physiolgocial signal not only through GSR signal, but also eye tracking incuding fixation number and duration, eye-blinking frequency, pupil dilation, etc. during stiluli slide.

In terms of research impact, the results of our approach will benefit several disciplines such as emotional design, marketing, innovation science, psychology and robotics.

In the field of design, as a growing trend is emerging toward the emotional design and pleasurable products, this promises friendlier world of products and services, with more attention paid to the human beings. In addition, this interest is also a manner of increasing the degree of creativity and innovation into the design and engineering design processes.

Moreover the comparison between different ways of measuring emotions about specific stimuli will also be of great interest for the discipline of psychology. Finally, the field of robotics which already integrates some advances in the field of biomimicry (applied to robots behaviors) could benefit of these new results in order to improve the look and user-friendliness of the robots.

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## References


Bouchard C, Mantelet F, Aoussat A, Solves C, Gonzalez J. C, Pearce K, Coleman S, (2009). A European Emotional Investigation In The Field Of Shoes Design. International Journal Of Product Development, Special Issue On Kansei Engineering And Emotional Design, 7(1-2):3-27

Bianchi-Berthouze N, Kleinsmith A, (2003). A categorical approach to affective gesture recognition, Connection Science, 15: 259-269

Coulson M, (2004). Attributing emotion to static body postures: Recognition accuracy, confusions, and viewpoint dependence. Journal of Nonverbal Behavior, 28:117-139.

Djajadiningrat T, Matthews B, Stienstra M, (2007). Easy doesn’t do it: skill and expression in tangible aesthetics, Personal and Ubiquitous Computing 11:657–676

Eckert C, Stacey M, (2000). Sources of inspiration: a language of design, Design studies, 21(5):523-538

Ekman P, Friesen W, (1967). Head and body cues in the judgment of emotion: A reformulation. Perceptual and Motor Skills, 24:711-724

Field AP, Schorah H, (2007). The verbal information pathway to fear and hear rate changes in children. Journal of Child Physiology and Psychiatry, 48(11):1088-1093

Ganglbauer E, Schrammel J, Deutsch S, Tscheligi, M, (2009). Applying Psychophysiological Methods for Measuring User Experience: Possibilities, Challenges and Feasibility. UXEM’09

Geneva Emotion Research Group, (1998) Appendix F. Labels describing affective states in five major languages.http://www.unige.ch/fapse/emotion/resmaterial/resmaterial.html

Globich J, Hamm, AO, Esteves F, and Öhman A, (1999). Fear appears fast: Temporal course of startle reflex potentiation in animal fearful subjects, Psychophysiology, 36:66–75

Helms ME, Vattam SS, Goel AK, (2008). Problem-Driven and Solution-Based Design: Twin Processes of Biologically Inspired Design. In *ACADIA08 Conference*

Jenkins S, Brown R, Rutterford N, (2009). Comparing thermographic, EEG, and subjective measures of affective experience during simulated product interactions. International Journal of Design, 3(2):53-65

Laban R, (1988). The mastery of movement. Princeton,

Lang PJ, Bradley MM, Cuthberth BN, (1997). International affective picture system(IAPS):Technical Manual and Affective ratings. In NIMH Center for the Study of Emotion and Attention.

Mantelet F, (2006). Prise en compte de la perception émotionnelle du consommateur dans le processus de conception de produits. Ph.D Thesis, Arts et Metiers ParisTech, France.

Mehrabian A, Friar J, (1969). Encoding of attitude by a seated communicator via posture and position cues. Journal of Consulting and Clinical Psychology, 33:330-336

Mougenot C, Bouchard C, Aoussat A, Inspiration, Images And Design: A Field Investigation Of Information Retrieval Strategies By Designers, Journal Of Design Research, 7(4):331-351

Nagamachi M, Tachikawa M, Imanishi N, Ishizawa T, Yano S, (2008). A successful statistical procedure on kansei engineering products. Electronic Conference Proceedings.

Picard RW, Vyzas E, Healey J, (2001) Toward machine emotional intelligence: Analysis of affective physiological state. IEEE Transactions Pattern Analysis and Machine Intelligence, 23:1175–1191

Poels K, Dewitte S, (2006). How to capture the heart? Reviewing 20 years of emotion measurement in advertising. In Journal of Advertising Research

Tipples J, Young AW, Quinlan P, Broks P, Ellis AW, (2002). Searching for threat. The quarterly journal of experimental psychology section A, 55(3):1007-1026

Tran TQ, Boring, RL, Dudenhoeffer DD, Hallbert BP, Keller MD, Anderson TM, (2007). Advantages and Disadvantages of Physiological Assessment For Next Generation Control Room Design, Human Factors and Power Plants and HPRCT 13th Annual Meeting, IEEE 8th, 259-263

Van den Broek EL, Westerink JHDM, (2009). Consideration for emotion aware consumer products. Applied Ergonomics, 40:1055-1064

Wallbott HG, (1998). Bodily expression of emotion. European Journal of Social Psychology, 28:879-896

Wang H, (1995). An approach to computer-aided styling, Design Studies, 16(1):50-61

Wilson JO, Rosen D, (2010). The effects of biological examples in idea generation, Design Studies, 31(2):169-186