Chapter 38
Understanding the Dynamics of Emotions During the Design Process

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Abstract Research on emotion and design literature has relied primarily on the product generated by the designers and the emotional experience felt by the users while using the product. A limited number of studies have addressed the dynamics of the designer's emotions during the design process. This exploratory study attempts to understand the emotional experience of designers during the design process with supporting empirical evidence. Twenty-five designers were asked to carry out a design task for a limited period of time. The data was analyzed using the FBS ontology framework, linkography, and PANAS ratings to establish the dynamics of the emotions during the design process based on the video and audio recordings of the task. This study demonstrates mostly positive affect throughout the design process with associated high entropy scores and high outcomes, where the affective states varied between different time intervals and at different phases of the design process.

38.1 Introduction

Present theories of emotions are a conglomerate of supporting pieces of evidence of several features and phenomena that constitutes an emotional episode [1]. These episodes activate or stimulate human behavior resulting in a complex act of decision making. Given the importance of emotions on high-level cognitive functions such as creativity, design, decision making, and reasoning [2, 3], scant attention has been paid to understand personal emotional experiences that a designer feels during the design process. Previous studies have demonstrated the importance of the product

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generated by the designers and the emotional experience felt by the users while using the product [4–6]. The design process is a complex phenomenon where designers often deal with wicked and ill-defined problems [7, 8], which generate a complex set of emotions to deal with the goal at hand. Different stages of design in the creative design process have also been explored and established [9]. Several tacit experiential decision making is applied at every stage of the design process, and designers keep jumping from one stage to another and several stages [10]. The emergence of an idea and insight during the creative design process is considered to be a highly emotional step that happens involuntarily [11]. Much has to be learned about designers and their design cognition from an emotional point of view. This gap can help us to understand and address the varieties of ways a designer faces an emotional experience and the challenges faced during the design process. Csikszentmihalyi et., al. believed that the designer's emotional experience would influence their decision making in the design process [12]. Some researchers have found the correlation of positive emotions with creativity during the design process [13]. Ho and Siu [14] proposed a conceptual model to understand emotions during the design process through two key concepts—*emotionalize design and emotional design.* The former describes the emotional experience of the designers during the design process, and the latter is about eliciting emotions on a specific set of users through a product. Remarkably few studies have tried to investigate and propose frameworks to understand the designer's emotions during the design process [15, 16].

38.2 Measuring the Design Process and Emotions

Protocol analysis (*concurrent and retrospective*) has been widely used to measure the cognitive process of the designers based on the verbal utterances by the designers [10, 17–20]. Diversity in coding schemes has been developed and used over these years [21, 22]. A widely accepted method, linkography, is used to measure the design process through protocol analysis. Linkography describes a design process by discerning the number of moves and the links produced between these moves [23]. Gero [24] proposed the FBS ontology of design to carry out the protocol analysis based on the goal of designing and transforming a set of functions (F) into a set of design descriptions (D). See Fig. 38.1.

The design starts with a set of requirements, and a designer then transforms the requirements into the Function (F), which is referred to as the teleology of design. A set of expected behavior (Be) tries to fulfill the function, and an abstract structure (S), which is referred to as the artifact's elements and their relationship, is generated. The derived behavior (Bs) from this structure is compared with the expected behavior to analyze the design. Once the structure is finalized, it is then documented (D). The syntactic design process explains the transformation of a design issue based on its previous preceding issue through Markov's chain [25]. Entropy scores represent creativity in the design process through the number of linked segments and the distribution of those links using Shannon's information theory model. A high number

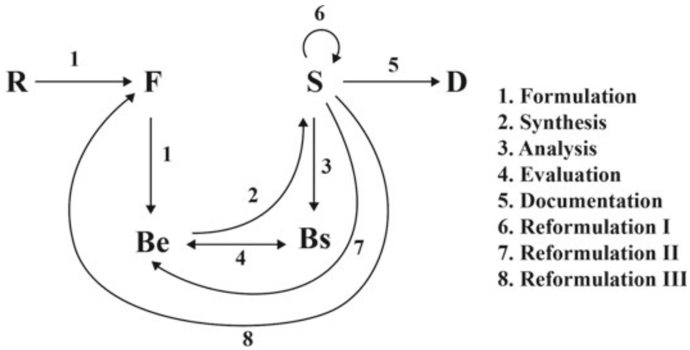

Fig. 38.1 FBS framework with the eight FBS processes [25]

of forelinks are associated with the divergent thinking process, and a high number of backlink explains the convergent thinking process. Horizon links are associated with incubation or cohesiveness during the design process [25].

Emotions are largely our feelings associated with physiological changes in the body. Since emotions are multidimensional, it becomes challenging to measure emotions on multiple factors. However, previous works have demonstrated methodologies to measure emotions on several dimensions [26]. Mauss and Robinson [27] did an extensive review on the measurement of emotions some of which are (a) self-report measures where participants report their moment to moment experiences, e.g., PANAS, mDES, SAM, etc. (b) physiological aspects of emotion measurement rely on physiological changes, e.g., autonomic nervous system responses from the subjects, eye blink rates, etc., and (c) behavioral elements rely on the facial expressions change, body expressions, and gestures [28].

38.3 Aims and Objective of the Study

This exploratory study aims to understand designers' emotional experience during the design process with supporting empirical evidence. This research took an inductive approach to investigate the variation and patterns of the designer's affect(s) during the eight syntactic FBS processes in the act of designing.

38.4 Method

38.4.1 Participants

Participants were twenty-five postgraduate students from the design discipline at IIT Kanpur (Mean age = 24.68 years, SD = 1.43). Participants had diverse backgrounds ranging from mechanical engineering, electrical engineering, civil engineering, computer science, electrical engineering, architecture, and fashion design. These participants were enrolled in a design practice course offered at the institute. They received a sum of Rs 200 as compensation.

38.4.2 Material

The Design Task To design a low-cost and efficient phototherapy unit for neonates who have neonatal jaundice that can be used in rural India. This problem was chosen as the students already had done their fieldwork in this area one week before sitting for this experiment as a part of the coursework.

Assessment of the design process Two Akaso V50 pro native cameras were fixed on the tripod to capture the ongoing ideation process. One camera captured the zoomed view, and the other master camera captured the overall scene. An android phone was used to capture the verbal utterances of the group members. Linkoder (www.linkoder.com) [29] software was used to analyze the design moves and the links between these moves based on utterances produced during the ideation process. Linkoder helps to produce several outputs, e.g., entropy scores, the ratio of forelinks, backlinks, horizonlinks, FBS issue distribution ratio, eight-design process syntactic distribution ratio, and link ratio.

Assessment of the affective states The psychology literature presents a distinction as well as an overlap with respect to emotions and affective states. The term 'affect' is a broader umbrella concept that encompasses moods and emotions [30]. We will be using the term 'affective state' and emotions interchangeably throughout this paper. Positive and negative affect schedule scale inspired by Peilloux et al. [31] was chosen for the study. Four positive affects (*interested, curious; inspired, stimulated; determined, decided; satisfied, blooming*) and four negative affects (*anxious, nervous; sad depressed; hesitant, doubtful; stressed, overwhelmed*) on a 5-point Likert scale ranging from 1 = not at all to 5 = definitively were used to capture the affective profiles of the designers. These eight affective profiles were alternately mixed and presented to the participant.

38.4.3 Procedure

Twenty-five participants were randomly divided into a group of 5 and were called to solve a design task mentioned in Sect. 38.4.2. These five groups participated alternately on the weekend (*three groups on Saturday and two groups on Sunday*) and were asked to think aloud while solving the tasks. This was a group design task where participants interacted and brainstormed together to come up with a solution. They were video and audiotaped throughout the entire session. Informed consent was taken from the participants prior to the task. The total time to finish the task was 30 min for each group. Preeceding with a short break, each participant was asked to rate their affective state retrospectively for the design process through video stimulated recall. Each participant was given a separate laptop to watch the video and rate their emotional profile (on PANAS) on a 30 page printed booklet. These participants were placed separately in 5 different rooms in the presence of five different volunteers. Each volunteer probed each participant every 60 s to rate on the parameters mentioned above. The video was paused, and participants then rated. Participants had the freedom to fast forward the video at their convenience. The 60 s interval was chosen for two reasons; first, this paper aims to find the emotional profile retrospectively for a long interval and not mood that happens in order of seconds and minutes, which can only be reported on that very moment it is happening, and the past research have used similar time interval to achieve good success [32]. The total administration time to complete the task and retrospective ratings together was approximately 75–90 min.

38.5 Analysis

38.5.1 Affective States During the Design Process

Combined mean scores of the positive and negative affects of each participant were calculated, providing us with thirty positive and thirty negative *time-affect* samples. To compute a single affect score, affect balance score was calculated by subtracting the mean negative ratings from the mean positive scores [33]. A total group affect balance mean was also computed (see Table 38.1).

38.5.2 Dynamics of the Design Process

Process refers to the transition or transformation of one design state to another. Protocols were segmented and coded twice using the Delphi method with two weeks of separation, as suggested by Gero and McNeill [20]. Five Linkographs of each session were produced through the Linkoder software (see an excerpt here, Fig. 38.2).

Table 38.1 Groupwise affect, linkography, entropy, and the design outcome scores

Group	Mean_affect balance score	Total segments	Total links	Link ratio	Forelink entropy	Backlink entropy	Horizonlink entropy	Total entropy	Mean outcome score (novelty and creativity)
1	9.42	270	654	2.42	0.4332	0.4985	0.142	1.073	9.66
2	9.27	236	405	1.72	0.3803	0.3828	0.087	0.850	6.66
3	8.05	239	483	2.02	0.3832	0.4246	0.101	0.909	7.33
4	8.78	202	461	2.28	0.4213	0.4289	0.092	0.942	8.33
5	7.82	272	511	1.88	0.3617	0.4133	0.102	0.877	6.33

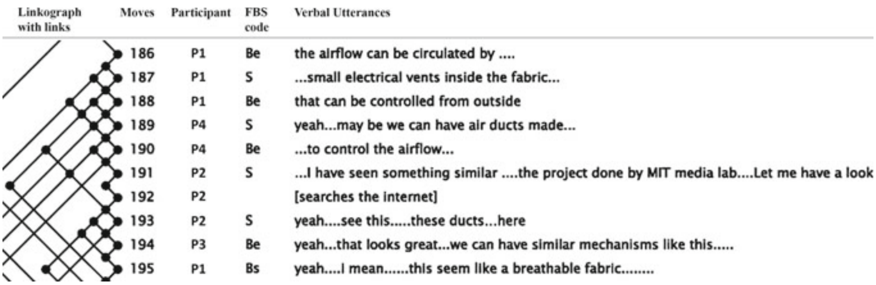

Fig. 38.2 Design activity excerpt details of Group 2, where column one is the visual Linkograph with the links, column two is the number of moves, column three is the participant number, column four is the FBS code assigned to verbal utterances in column five. In this heavily linked segment, participants were brainstorming to figure out the design prototype. The design process sequence was very rapid, where participants were jumping between the behavioral and structural aspects of the design prototype. Move 192 is blank as it fell under the 'other' category

Three independent experts in the domain of product and mechanical engineering design rated the final output on the criteria of novelty and creativity using a 5-point Likert scale (from 1 = 'less novel; uncreative' to 5 = 'very novel; very creative'). Overall summary of the quantitative results is produced for each group in Tables 38.1, 38.2, and 38.3. Also, for the purpose of this study, early phases of the design process are referred to as *the conceptual design phase* and the later phase as the *embodiment design phase*, as proposed by Howard et al. [9]. Based on the time-affect sample, 30 time-based linkograph statistics (*Entropy scores and FBS processes*) for each group were computed. Afterward, 3-axis graphs were plotted for the FBS processes, and affect, over a 30 min timeline, combined for all the groups. This cumulative mean computation was done to visualize the overall affect change during the design process and not just on individual groups.

Table 38.2 Groupwise distribution of the FBS issues

Group	Mean_affect_balance score	*R*%	*F*%	Be%	Bs%	*S*%	*D*%
1	9.42	14.2	8.5	17.7	12.3	34.2	13.1
2	9.27	10.3	3.6	24.7	18.8	34.1	8.5
3	8.05	3.4	5.6	22	15.1	40.1	13.8
4	8.78	10.7	4.1	17.7	13.7	31.5	22.3
5	7.82	5.2	1.5	25.4	20.9	32.8	14.2
	Mean	8.76	4.66	21.5	16.16	34.54	14.38

Table 38.3 Groupwise distribution of the eight FBS syntactic processes

Group	Mean_affect balance score	Formulation %	Synthesis %	Analysis %	Evaluation %	Docmentation %	Reform ulation1%	Reform ulation 2%	Reformulation 3%
1	9.42	3.3	20.7	17.3	8.3	11.6	25.6	9.9	3.3
2	9.27	2.9	25.7	23.8	7.6	7.6	13.3	18.1	1
3	8.05	1.5	20.3	16.5	11.3	12	17.3	17.3	3.8
4	8.78	2.5	16.5	12.7	6.3	19	27.8	13.9	1.3
5	7.82	0	21.1	21.8	15	11.3	18	12.8	0
	Mean	2.04	20.86	18.42	9.7	12.3	20.4	14.4	1.88

38.6 Results

The overall design process for every group was associated with positive affects and high arousal. In the first half of the design process, i.e., *conceptual design phase*—(1 to 12 min), participants reported having positive affects. They were interested/curious; inspired/stimulated during this phase, as reported in PANAS. Toward the second half of the process, i.e., *the embodiment design phase,* participants reported being anxious/nervous, hesitant/doubtful (12–25 min), and more determinant/decided; satisfied/blooming at the end (25–30 min). These results are based on the mean affect balance score for all the groups. However, we are losing important data by ignoring the negative ratings. Studies have reported the occurrence of both the affects parallelly [34, 35]. So, we present a separate graph to illustrate the occurrence of positive and negative affect parallelly based on the ratings (see Fig. 38.4). It can be inferred from the graph that the beginning part of the design process (1–7 min and 8–12 min) was associated with positive affects and high arousal. The process at the end (12–25 min) was associated with negative affects and high arousal. Though the affect balance score is overall positive (above the *X*-axis), we still can observe several peaks and lows signifying the affect size variability.

As visible in Table 38.2, the majority of the cognitive efforts were dedicated to discerning the structural issues (34.54%), followed by expected behavior issues (21.5%). The groups majorly worked on understanding the elements and their relationships of the artifact.

High entropy scores (1.073), high link ratio (2.42), and high mean outcome scores (9.66) were associated with a high affect mean balance score of 9.42 for group 1 (see Table 38.1). High forelink (43.47) and backlink entropy (49.85) show that this group generated many ideas and then later built upon them. The second group to score higher on the mean outcome score (8.33) was group 4 with an affective balance score of 8.78 and an entropy score of 0.942. Interestingly, the lowest-scoring group no 5 with a mean outcome score of 6.66 and a total lowest entropy score of 0.850 scored high on the affect balance score (9.27). In general, high entropy scores were associated with positive affects.

We present the following observations related to eight FBS processes and the associated affective state based on Fig. 38.3 and Table 38.3. Student's cognitive efforts were majorly expended upon the syntactic processes of synthesis (20.86%), where students were engaged in deriving the structure to fulfill the expected behaviors. During reformulation I, student's were indulged in modifying the proposed structure space by introducing new components and elements in their design (20.4%) followed by the analysis process (18.42%) where students derived the actual behavior (Bs) from the proposed structure (S) (Fig. 38.4).

(1) Formulation ($R \rightarrow F \rightarrow$ Be) and the associated affective state(s)—A sharp peak of formulation happens at (2–5 min), and multiple peaks can be observed between (15–26 min). The participants were majorly reading and discussing the design requirements and assigning a function (purpose) to the artifact that was to be designed during this process. The affect balance score shows peak during

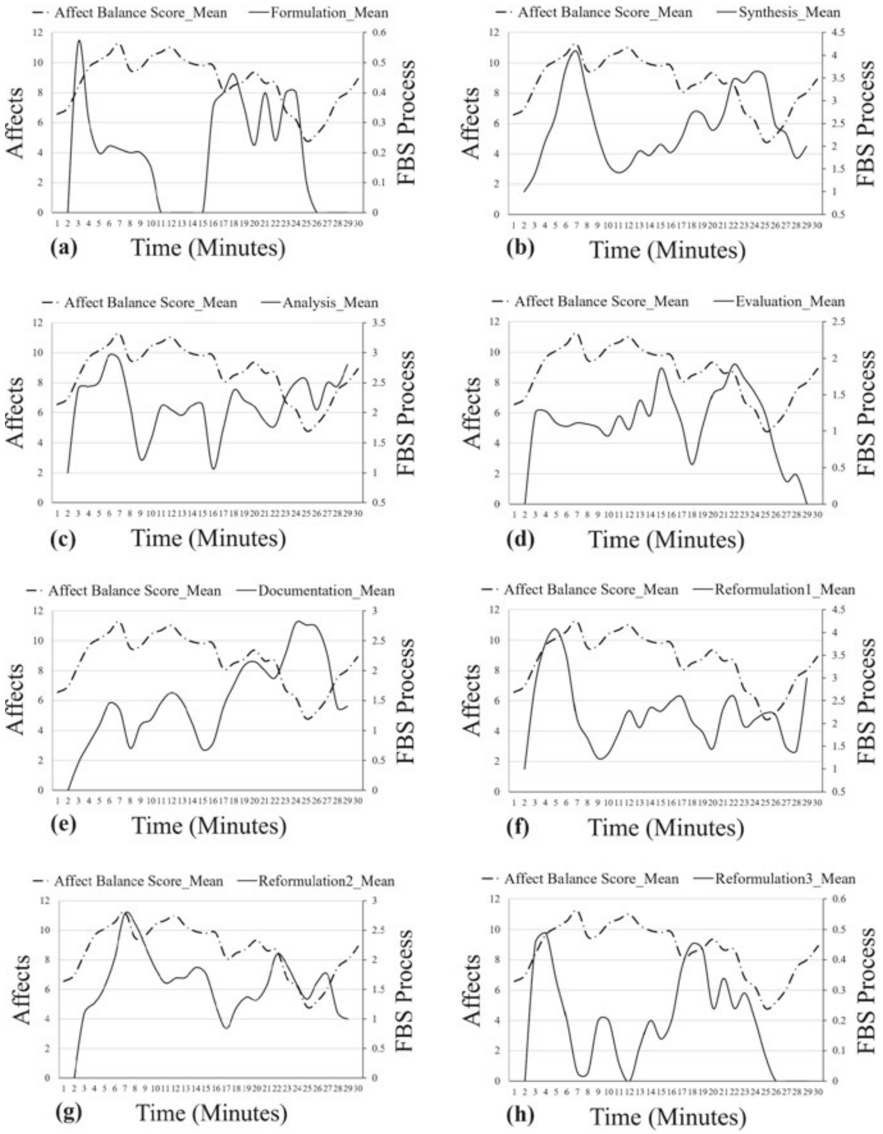

Fig. 38.3 Mean of the eight FBS syntactic processes and associated mean affect balance score combined for all the five groups

the beginning, where participants reported to be more excited and curious (2–5 min). However, formulation peaks between (15–26 min) were associated with low positive affects (16–25 min). Rather than discussing the artifact and relationship (*S*) at this point in time, designers were still trying to either define the

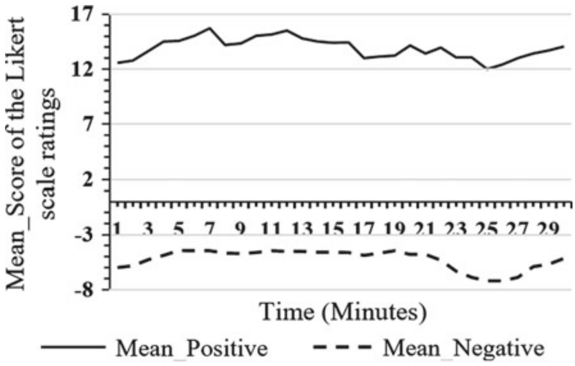

Fig. 38.4 Mean positive and negative affect balance score combined for all the five groups

artifacts' purpose or discuss the expected behavior (Be), where they reported being nervous and anxious.

(2) Synthesis (Be → S) and the associated affective state(s)—The synthesis process showed a peak at (2–7 min) and was associated with the positive affect (2–7 min) and at (11–25 min). However, the synthesis process declined from (7–11 min) and again after the 25th minute. The affect mean score was high during this period (11–22 min). This indicates the designers' expending the majority of their cognitive efforts in proposing a structure (S) by transforming a set of expected behavior (Be) and reported being inspired and stimulated.

(3) Analysis (S → Bs) and the associated affective state(s)—Multiple peaks can be seen at (2–6 min), (9–11 min), (16–18 min), and from (22–29 min). This indicates that the designer's expended most of their cognitive efforts in deriving behavior from the structure at different intervals. The affect balance score declined at (23–25 min) and grew back again (25–30 min).

(4) Evaluation (Bs ↔ Be) and the associated affective state(s)—Evaluation process (2–15 min) was majorly associated with positive affect. Also, the graph drops sharply (22–29 min) with which the mean affect balance score also drops (22–25) and increases at (25–29 min). Designers reported being stressed and overwhelmed before the end, and as they sorted and adjusted their concept they reported being satisfied and blooming.

(5) Documentation ($S \rightarrow D$) and the associated affective state(s)—the graph shows a growth in the documentation process from (2–26 min). This makes sense as the documentation requires partial description of designs through doodles, sketches, and specifications that usually happened once the structure was finalized by the groups. However, in the end, groups reported being stressed and overwhelmed (24–29) for a few minutes.

(6) Reformulation I ($S \rightarrow S'$) and the associated affective state(s)—During Reformulation I, a very short peak in the graph (2–5 min) can be seen during which the mean affect scores also shows a growth for this timeline.

(7) Reformulation II (S → Be′) and the associated affective state(s)—the graph shows a progression from timeline (2–8 min) which was mainly associated with

positive affects. During this process, designers reframed the behavior space, which leads to modifying the structure space.

(8) Reformulation III (S → F′) and the associated affective state(s)—Function state space change or reformulation is seen in the beginning (2–5 min) and from (12–18 min). Reformulation III has also been associated with positive affects. However, the affect size decreases at the end for reformulation III (18–26 min).

38.7 Discussion

This exploratory study investigated the dynamics of emotions during the design process using the FBS ontology and linkography. We observed that high affect balance scores were associated with high entropy scores of the individuals. Also, positive affects dominated the conceptual phase of the design process, and negative affects were more dominant in the embodiment stages of the design process. However, the syntactic processes differ in their emotional profiles during the early and the later phases of the design process. This is an interesting finding, as it sheds light on the designer's cognitive efforts distributed to the same FBS processes at different time frames resulting in different affective profiles. During the initial phase, designers were interested, curious, and inspired to solve a new task in the beginning, and as time progressed, they got anxious and nervous regarding the deadline. The later stages also demanded designers to converge to a single concept, which was associated with negative affect profiles (stress, nervousness, hesitant, and doubtful). The intensities of these negative affects were moderate as compared to the high activated positive affects. In conclusion, this study was an attempt to understand the designer's emotional experience in with supporting empirical pieces of evidence. However, the affective ratings taken were retrospective, and one can argue regarding the memory loss to recall the specific emotional experiences during the subjective ratings. Despite this fact, this study is the first of its kind to capture emotions using linkography and FBS ontology of design with empirical evidence. Another limitation of the study is the limited design experience of the designers. Studies have shown a difference between the expert and novice designer's design process approach. Studying emotions during the design process is of great importance for understanding the creator's cognitive and behavioral aspects. Several design support systems could be developed to help designers self-regulate their emotions to avoid fixation and improve their design process. For example, Blom [36] proposed a system *(video game)* that adapts to the individuals' emotional state based on facial expression change. Several such systems could be designed and developed.

Extending this research, we have conducted a behavioral experiment with 85 samples using the ML algorithm to capture facial action units in real time while solving multiple creativity tasks. We are still in the process of data analysis. We also wish to do emotional profiling based on the creative stage using time-series analysis.

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