

# Balancing User Engagement and Sustainable Web Design: A Comparative Study of 2D and 3D Hero Sections Using Kansei Engineering

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**Abstract—** With the increasing usage of digital platforms across the globe, the decisions made by designers in regards to web interfaces affect not only the interaction but also the sustainability of digital systems in the long-term. The primary visual entry point is the hero section which is usually the initial section of the page that the visitor looks at. However, the cost that the environment of the world would bear in case of using heavy 3-dimensional (3D) graphics in place of lighter 2-dimensional (2D) elements is rather unknown. This paper explores trade-off, applied to assess the 2D and 3D hero designs on user engagement and sustainability with the help of Kansei Engineering. A total of one hundred respondents (20-30 years old) rated 20 hero designs in ten themes. They rated clarity, immersion, excitement and professionalism. The PCA was used to identify the important perceptual attributes used to make decisions. Findings indicate that 3D graphics enhanced immersion and excitement with average scores of more than 4.5 out of 5 and 65 percent of the participants preferring 3D graphics. On the contrary, 2D graphics obtained a higher clarity and professionalism score, averages were 3.2 to 3.9 and were more relied upon in a situation where reliability was important. Although 3D components enhance emotional appeal, they significantly increase the computing capabilities, which is why the consideration of experience and smart design are crucial. These results provide guidelines to designers of how they can maximize user interaction and how they can facilitate sustainable web interfaces.

**Keywords—** Sustainable Web Design, Kansei Engineering, User Engagement, 2D and 3D Graphics, Digital Interface Design

## I. INTRODUCTION

The looks of websites create the initial impression, influence how consumers perceive the site, and predetermine the rules of interactions. With the growth of web platforms, design decisions have effects on engagement and on the wider ecological effects [1]. The hero section is one of the interface elements that have appeared as an important means of getting attention and action when it is located above the fold with large and attractive images or calls to action [2]. Conventionally, one would use 2-D graphics since it is straightforward, easy to understand, and portrays professionalism effectively. The more recent developments of 3-D rendering enable web designers to make more emotionally evocative experiences on the web richer [3]. Nonetheless, such advantages are associated with an increased

cost of resources, and the question emerges as to how to reconcile the need to create successfully with the need to be sustainable.

Most of the current studies of 2-D versus 3-D visual methods have concentrated on gaming, virtual reality, or educational applications, and little in any current web-based context, particularly hero section [4][5][6]. The user preference trends are reported in previous studies, but the emotional factors or the psychological factors behind such preferences are not analyzed. With the increasingly complicated nature of web interfaces, it is important to know how the affective and cognitive engagement is influenced by the visual choices [7]. In addition, since immersive technologies are increasingly gaining ground in the field of web design, we need to consider their experiential benefits against sustainable and effective design procedures. This disconnect identifies the necessity of intensive study in the modern web design.

In order to address this gap this paper uses a technique referred to as Kansei Engineering (KE), which is a technique that renders the emotions of users into specific design rules [8]. By integrating KE and Principal Component Analysis (PCA), it is possible to conduct a systematic evaluation of the emotional and cognitive responses of the users to various themes. This was done by 96 study participants aged 20 to 30 who were asked to rate twenty designs of hero (10 2-D and 10 3-D designs) on a five-point scale on the criteria of clarity, immersion, excitement, and professionalism. Such a systematic method allows making a clear comparison of the influence of various visual aspects on user perception in the contemporary web interfaces.

The primary objectives of this study are threefold.

- **Objective 01:** Compare 2 and 3 dimensional hero sections with regards to their effect on user engagement.
- **Objective 02:** Compare KE and PCA responses in analyzing emotional and cognitive responses.
- **Objective 03:** Provide useful design advice with a combination of clarity of 2-D graphic and immersion of 3-D feature of a web design that must be sustainable.

This paper has two fold contributions. First, it is the first expansion of KE in the under-researched field of hero section design, which constitutes a significant gap in the scholarship. Second, it presents empirically supported results, demonstrating the fact that 360 elements enhance immersion and excite, whereas 2-D graphics are better suited to explain and be professional. A moderate solution is created as a hybrid approach. Grounding these results in the principles of sustainable digital interface design, the article provides practical recommendations to designers, developers, and companies that pursue the goal of providing more meaningful interaction, despite assuming responsible and progressive web design principles.

## II. LITERATURE REVIEW

### A. Web Design and User Engagement

User engagement in web design is a multifaceted concept, incorporating visual elements, cognitive functions and emotional engagement [9]. The hero section, the part of the interface section above the fold area that is likely to be viewed first, is an important interface part. The hero section strongly affects first impressions, brand trust, and the likelihood of tapping or clicking a link or button [10]. Other studies have indicated users develop opinions of websites within 1–2 seconds, with choices in visual aspects in the hero section being important choices [11].

### B. 2D Graphics in Digital Interfaces

2D graphics have been used in web design and across the web since the introduction of interfaces due their clarity of information, the speed at which they load, and their professionalism [12]. Research has shown that 2D graphics also improve usability, readability, and trust by reducing cognitive load [13]. In designs such as e-commerce and education, 2D graphics may evoke associations of reliability, and structured professionalism [14]. Compared to more dynamic approaches 2D graphics lack emotional arousal and immersive experiences [15].

### C. 3D Graphics and Immersion

With advances in WebGL, Three.js, and modern rendering [16], creating 3D graphics in web-based interfaces is now possible. Research from various fields, like gaming or virtual realities, indicate immersive environments with 3D elements enhance emotional engagement [17]. In commercial environments, studies have indicated 3D images stimulate users' emotional excitement and interaction times are longer [18]. However, while 3D types of interfaces can stimulate engagement concerns have been raised regarding resource constraints, performance, accessibility of the user experience, and potential distractions [19].

### D. Kansei Engineering and Emotional Design

Kansei Engineering (KE) provides a systematic method for linking design qualities to user feelings. KE has been successfully employed in areas such as product design, automotive interfaces, and consumer electronics, with a basis in defining qualitative affect as an objective design parameter. While it has been shown to be of use to date in product design, KE has only been used minimally in web and interface design. When KE is coupled with statistical analysis such as PCA, it allows for the identification of user feelings on underlying dimensions and could provide evidence-based rationale for design processes [20].

### E. Research Gap

Previous work has shown the advantages of 2D when it comes to clarity, and 3D in terms of immersion, however there is limited empirical research that compares the 2D and 3D for hero sections in web design. Additionally, most studies focus on preference or aesthetics, rather than take a systematic approach to analysis of emotional response, such as using Kansei Engineering. This study attempts to fill the gap in work by investigating participant responses to 2D and 3D hero sections in addition to several themes, using Kansei Engineering and PCA to produce concrete design recommendations.

## III. METHODOLOGY

### A. Research Design

The This study used a quantitative, experimental design based on Kansei Engineering to ascertain emotional and cognitive responses to graphics in 2D versus 3D hero sections. The research was designed to systematically record participant ratings about themes and extract cognitive and affective dimensions across the emotional landscape using Principal Component Analysis (PCA). An overview of the research framework is presented in Fig. 1.

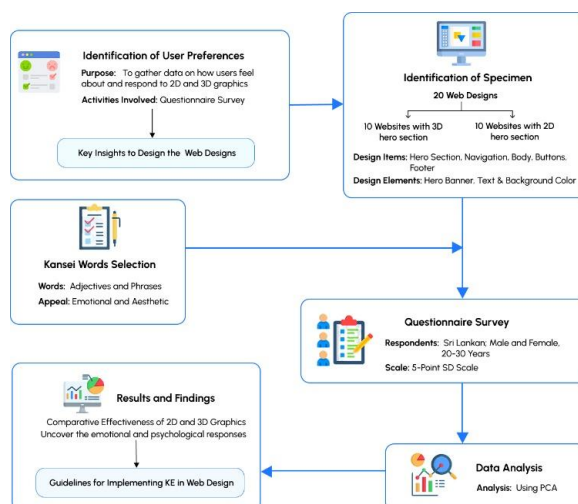


Fig. 1. Methodology implementation flow

### B. Stimuli Development

A composite of 20 hero section prototypes were produced with ten individual themes being depicted in 2D and 3D. The themes include Mobile Phones, E-commerce, Educational Content, Futuristic, Robotics, Wellness, Space Exploration, 3D Modelling, and several others that represented contemporary online contexts within which people are engaged. With all designs controlling overall layout structure and content to restrict for external elements, while being able to compare users' responses to graphics style (2D and 3D) rather than individual design characteristics.

For the 2D designs, there were static images and flat illustrations where clarity and minimalism were highly regarded. For the 3D designs there were rendered models, dynamic light, and dimensions that the authors hoped would enhance the feeling of immersion. All designs were delivered

in desktop/laptop formats to represent the most attended user environments.

### C. Participants

A sample of 100 participants aged 20 - 30 years, were recruited from the university student population and young professionals in Sri Lanka. This age group was selected due to their high level of digital literacy and frequent users of the web which best represents active online consumers. Participation was voluntary and informed consent was provided prior to collecting data. Ethical aspects of the study were considered by allowing for anonymity and confidentiality throughout the study.

### D. Data Collection Procedure

The data were gathered using an online survey platform. Each person viewed all 20-hero section designs in the order randomized to reduce potential order effects. For each hero section design, participants rated the appropriateness of five-point Likert scale (1 = strongly disagree; 5 = strongly agree) statements that were based on Kansei adjectives like clarity, immersion, exciting, and professionalism. After rating the hero section designs, participants were asked to indicate their overall preference between the paired 2D and 3D designs within each theme.

### E. Measures

The study employed both cognitive and affective measures:

- **Cognitive dimensions:** clarity, simplicity, professionalism.
- **Affective dimensions:** immersion, excitement, engagement.

The constructs selected were based on previous KE studies with artefact design and were preliminary tested and validated with a small group of users from various disciplines before this main study.

### F. Data Analysis

The dataset consisted of approximately 8,000+ user ratings, which were interpreted using SPSS (Version 30.0.0.0). Descriptive statistics (means, standard deviations) were calculated for each hero section design first. After the descriptive statistics, exploratory factor analysis using Principal Component Analysis (PCA) was conducted for each theme separately to identify latent factors underlying user ratings. The Varimax rotation was applied to the PCA and retained components that had eigenvalues over 1. The extracted factor components were labelled the affective dimensions (e.g., Immersion/Excitement, Clarity/Professionalism). Further comparisons were made across themes with respect to common patterns. The findings were presented in Radar charts and factor component matrices (see Fig. 2– Fig. 6).

## IV. RESULTS AND FINDINGS

### A. Descriptive Statistics

The descriptive statistics reported similar patterns across the twenty hero section designs. 3D graphic designs received relatively higher mean ratings on the measures of immersion, excitement, and engagement while 2D graphics reported higher scores on clarity, simplicity, and professionalism. For example, within the E-commerce theme, the 2D designs

received higher mean scores on clarity while the 3D designs received higher mean scores for excitement and immersion.

| Descriptive Statistics                               |       |                |            |
|------------------------------------------------------|-------|----------------|------------|
|                                                      | Mean  | Std. Deviation | Analysis N |
| 2D design attractive and modern.                     | 3.434 | .4305          | 100        |
| 2D design calmness and clarity                       | 3.378 | .4509          | 100        |
| 2D design professional and appropriate for the theme | 3.290 | .5143          | 100        |
| 2D design engaging                                   | 3.241 | .4814          | 100        |
| 3D design immersive and futuristic                   | 4.693 | .3352          | 100        |
| 3D design feels excitement and energy                | 4.414 | .3191          | 100        |
| 3D design professional and appropriate for the theme | 4.408 | .4007          | 100        |
| 3D design engaging                                   | 4.499 | .3976          | 100        |

Fig. 2. Descriptive Statistics provides the means, standard deviations and sample size of each attribute in the design set.

### B. KMO and Bartlett's Test

| KMO and Bartlett's Test                          |                    |         |
|--------------------------------------------------|--------------------|---------|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. |                    | .704    |
| Bartlett's Test of Sphericity                    | Approx. Chi-Square | 673.874 |
|                                                  | df                 | 28      |
|                                                  | Sig.               | <.001   |

Fig. 3. KMO and Bartlett's Test

To confirm the data was fit for factor analysis, KMO and the Bartlett's test of Sphericity were analyzed. Because the KMO value was 0.704, this confirms sampling adequacy and Bartlett's test was, further confirming the data was suitable for conducting PCA.

### C. Principal Component Analysis (PCA)

| Component | Total Variance Explained |               |              |                                     |               |              |
|-----------|--------------------------|---------------|--------------|-------------------------------------|---------------|--------------|
|           | Initial Eigenvalues      |               |              | Extraction Sums of Squared Loadings |               |              |
|           | Total                    | % of Variance | Cumulative % | Total                               | % of Variance | Cumulative % |
| 1         | 3.634                    | 45.421        | 45.421       | 3.634                               | 45.421        | 45.421       |
| 2         | 2.883                    | 36.038        | 81.459       | 2.883                               | 36.038        | 81.459       |
| 3         | .492                     | 6.151         | 87.610       |                                     |               |              |
| 4         | .321                     | 4.017         | 91.627       |                                     |               |              |
| 5         | .265                     | 3.315         | 94.942       |                                     |               |              |
| 6         | .183                     | 2.287         | 97.229       |                                     |               |              |
| 7         | .150                     | 1.880         | 99.109       |                                     |               |              |
| 8         | .071                     | .891          | 100.000      |                                     |               |              |

Fig. 4. Total Variance Explained

PCA resulted in two overall components which explained 81.46% of variances. Component One had highly such attributes as cognitive-professional attributes (clarity, professionalism, appropriate) likely drew together the participants responses towards a continuum. In comparison, Component Two reflected more of the affective-emotional attributes (immersion, excitement, engagement).

### D. Rotated Component Matrix

The rotated solution clearly indicated that 2D and 3D attributes were distinctly separated, such that, within Component 1, the 2D characteristics (clarity, professionalism, engagement) were defined separately from Component 2, 3D characteristics (immersion, excitement, futuristic appeal).

| Rotated Component Matrix <sup>a</sup>                |           |      |
|------------------------------------------------------|-----------|------|
|                                                      | Component |      |
|                                                      | 1         | 2    |
| 2D design engaging                                   | .938      |      |
| 2D design calmness and clarity                       | .928      |      |
| 2D design attractive and modern.                     | .910      |      |
| 2D design professional and appropriate for the theme | .903      |      |
| 3D design immersive and futuristic                   |           | .914 |
| 3D design engaging                                   |           | .885 |
| 3D design feels excitement and energy                |           | .874 |
| 3D design professional and appropriate for the theme |           | .803 |

Extraction Method: Principal Component Analysis.  
Rotation Method: Varimax with Kaiser Normalization.  
a. Rotation converged in 3 iterations.

Fig. 5. Rotated Component Matrix

### E. Component Transformation Matrix

| Component Transformation Matrix |       |      |
|---------------------------------|-------|------|
| Component                       | 1     | 2    |
| 1                               | .888  | .459 |
| 2                               | -.459 | .888 |

Extraction Method: Principal Component Analysis.  
Rotation Method: Varimax with Kaiser Normalization.

Fig. 6. Component Transformation Matrix

The transformation matrix illustrated the orthogonality of the rotated factors indicating that it was valid to interpret the two-component solution.

### F. Cross-Theme Comparisons

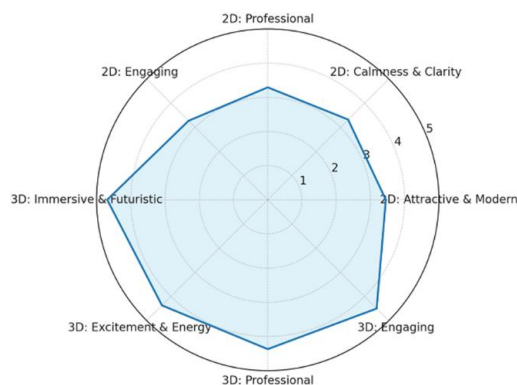


Fig. 7. Average Radar Chart of 2D vs 3D Emotional Scores

When comparing mean ratings across themes (Fig. 7), 3D also outperformed, with respect to emotional engagement, across themes. For the themes - Futuristic Design, Space Exploration, and 3D Modelling - participants reported mean immersion scores greater than 4.7 on average. 2D had the higher mean ratings for the more pragmatic domains like E-commerce, Educational Content, and Wellness, where clarity and professionalism were prioritized.

Most importantly, it found 65% of the participants preferred 3D overall, but almost 30% indicated the conceptual 2D design was more appropriate in professional or trust

sensitive contexts. These findings suggest that both. 2D and 3D offer complementary opportunities in web design. Therefore, it can suggest a "hybrid" approach may be preferable.

### G. Summary of Findings

- 3D-graphics excel at immersion, excitement, and affective/involvement engagement.
- 2D graphics excel at clarity, simplicity, and professional credibility.
- PCA showed a two-component structure of cognitive-professional (2D) versus affective-emotional engagement (3D).
- For thematic content type, there were some variations. A futuristic, tech-based theme tended to favor 3D style graphics. For educational and commercial types of themes, 2D was more advantageous.
- A hybrid design, using 3D for emotional affect and 2D for clarity and trust appeared as a possible pathway forward.

## V. RESULTS AND FINDINGS

### A. Discussion of Key Findings

This paper validates the hypothesis of a significant role of graphic dimensionality in user involvement in web hero sections. In ten thematic contexts, 3D graphics outperformed the 2D graphics in affective engagement, that is; immersion, excitement and arousal whereas 2D graphics outperformed 3D graphics on the cognitive ones, that implies clarity, simplicity and professional credibility. These findings provide evidence of the difference between 2D and 3D visual styles and validate the anticipated correlation between dimensionality and perception of users.

On the PCA outcomes, it showed a strong two-component structure across theme contexts, with:

- **Component 1:** Cognitive professional traits (clarity, professionalism, trustworthiness) were largely motivated by the 2D graphics.
- **Component 2:** Affective-emotional characteristics (immersion, excitement, energy) were largely caused by 3D graphics.

These results are not new as they compare the study with the earlier studies on the subject of visual engagement [12], [16] and carry it over to the under-researched area of web hero design. They also support the application of the Kansei Engineering as a model of mapping emotional reactions to interface objects. In addition to the engagement, the results indicate that dimensional decisions alter the wider aspects of sustainability designs. Although 3D graphics provide more intense experience, they never consume less power than 2D images. The responsibilities of designers in a digital strategy have to be balanced regarding both affective benefits and responsible ones, choosing visual approaches.

### B. Practical Implications

The cultural and historical context-sensitive perspective to the use of hero-sections should be taken by moderation by designers, particularly in the modern digital context where performance and responsible design are more and more central.

3D graphics works better in applications where emotionally charged narration or immersion are needed- e.g. in futuristic platforms, robotics or entertainment locations.

Regular 2D graphics have been proven to be useful where clarity, usability, and trust are important e.g. e-commerce site, learning or health care site.

The hybrid approach may bring advantages of both: apply 3D to provide an introductory experience and retain 2D to make it easy sure and to have a structured information flow. This fair balance increases the involvement and encourages considerate design that appreciates experience and efficiency that are sustainable web practices.

### C. Limitations

In as much as the study is insightful, it has certain limitations:

- **Participants sample demographics:** All the participants were predominantly young adults aged 20-30, which might restrict the applicability of the study to other cultures and populations.
- **Device on which designs were analyzed:** It was tested in desktop and laptop settings only; mobile and tablet interfaces, which have other performance and screen size constraints, may contribute to differences in perceptions of 2D vs. 3D trade-offs.
- **Limitations of self-reporting:** The information was obtained based on Likert-scale assessments, which is not possible to include unconscious and behavioral elements of engagement..

### D. Future Research

Future studies should build on this work by:

- It needs to add more significance and strengthen the study globally by engaging diverse age ranges and cross-cultural samples.
- Testing across mobile and multi-device environments that may influence the 2D-3D trade-off, loading times, and sizes of screens.
- Implement behavioral data (e.g. click-through-rate, dwell time, eye-tracking) with self-report data within their analysis.
- Investigating adaptive interfaces that engage AI for adjusting from 2D and 3D elements based on user context and their emotional state.

### E. Conclusion

This research indicates that 2D graphics alone, as well as 3D graphics alone, do not dictate best engagement in web hero sections. In lieu of this, a middle ground between making it too immersive with 3D and making it too clear and business-centered with 2D is better. Using Kansei Engineering and PCA, this study contributes to the emotional design theory, as well as the actual interface development.

Notably, the results are a call to designers to consider visual dimensionality as an engagement but also in greater sustainability of web interfaces. Careful, contextual design choices, propagated by this work, are helpful in user-directed, careful digital practices.

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