

Using 3D Printing Technology to Embody Kandinsky's Motifs in Fashion Designs for Women

Assist. Prof. Dr/ Olfat Shawki Mohamed Mansour

Assistant professor, Apparel Department, Faculty of Applied Arts, Helwan University.

Abstract

Technological innovation is an important factor for innovative projects because coupled with creativity can provide differentiated aesthetic innovations. Fashion design is a sector that is always attentive to innovations, which may enable a different design on a final product with, higher quality, sustainability and many other factors that can add value to creation. 3D printing technology is used in fashion to engage creatively and exciting potential values inspiring, extending fashion designers' range of work and provides new aesthetic perspectives.

The most important advantages offered by 3D printing are cost reduction, time reduction, accuracy, sustainability and the separation of product design from manufacturing capabilities. Like any other technology, 3D printing has a series of disadvantages and limitations, the printed 3D garments are fairly strong and water-resistant and they cannot be treated like many popular materials we use daily such as cotton and silk.

The research aims to use woven fabrics and 3D printings in combination to embody Kandinsky's motifs and provides new aesthetic perspectives in fashion designs for women. It is also aims to draw attention to the diverse use of 3D printing technology in fashion design.

Keywords:

3D printing technology, Fashion Design, Kandinsky

المخلص

يُعد الابتكار التكنولوجي عامل هام للمشروعات التي تعتمد عليه، حيث أنه يوفر إلى جانب الابتكار الإمكانيات الجمالية المختلفة. تصميم الأزياء أحد القطاعات التي تتطلع دائماً للابتكارية التي قد تؤدي إلى منتج نهائي على قدر كبير من الجودة، الاستدامة، والعديد من العوامل الأخرى التي تُعد قيمة مضافة للتصميم. تُستخدم تكنولوجيا الطباعة ثلاثية الأبعاد في الموضة لتحقيق القيم الابتكارية مما يزيد من نطاق عمل مصممي الأزياء ويوفر جماليات جديدة للتصميم.

أهم المزايا التي تقدمها الطباعة ثلاثية الأبعاد هي خفض التكاليف والوقت، الدقة، الاستدامة، وفصل عملية التصميم عن التصنيع. لكنها مثل أي تكنولوجيا أخرى لديها بعض العيوب فالملابس المنتجة تكون صلبة إلى حد ما ومقاومة للماء، ولا يمكن التعامل معها مثل الخامات التقليدية كالقطن والحريير.

ويهدف البحث إلى استخدام الأقمشة المنسوجة والمطبوعات ثلاثية الأبعاد لتجسيم مفردات "كاندينسكي" في تصميمات ملابس للسيدات من منظور جمالي جديد. ويهدف أيضاً إلى لفت الانتباه إلى الاستخدام المتنوع لتكنولوجيا الطباعة ثلاثية الأبعاد في تصميم الأزياء.

الكلمات المفتاحية

الطباعة ثلاثية الأبعاد، تصميم الأزياء، "كاندينسكي".

1 Introduction

Since three-dimensional (3D) printing was first introduced it has been widely used in many manufacturing industries from medicine to transportation, and has even slowly become popular among fans of Computer Aided Design (CAD) that can now own and use a 3D printer at their homes. 3D printing is a way of manufacture where material is laid down layer by layer to create 3D objects. These objects are created from a digital file containing three-dimensional data extruded by printer. [1] a computerized file using a 3D CAD program such as 3D Max, Alias, Catia, Solid work, and Rhino etc. They should be saved in the "STL" file format. [2]

Recently, apparel industry has shown the adoption of this technology for different products such as shoes, garments, and fashion accessories [3] like gadget cases, jewellery, shoes and eyewear [2]. With the help of 3D printing technology, designers can create unique and complicated shapes of their own design without any limitations [4].

The 3D printing technology consists of three main phases - the modeling, the printing and the finishing of the product. In the modeling phase, in order to obtain the printing model, the machine uses virtual blueprints of the object and processes them in a series of thin cross-sections that are being used successively. The virtual model is identical to the physical one. In the printing phase, the 3D printer reads the design (consisting of cross-sections) and deposits the layers of material, in order to build the product. The final phase consists of the finishing of the product. [5]

The materials used for printing with the 3D printing technology are, e.g., ABS (Acrylonitrile butadiene styrene), PLA (polylactic acid) and several others with diverse physical and chemical properties. Especially in combination with textile materials, soft printing materials can be ideal for adding design features or changing mechanical properties in defined areas of the original fabric. Nevertheless, rigid materials are also used for clothing design regularly due to the new opportunities offered to textile designers [3].

The number of fashion products manufactured using 3D printers has also been increasing in the recent years. Designs manufactured using 3D printers are now commonly available in the collections of designers and brands which participate world's leading fashion weeks such as Paris, London, New York, and Milano fashion week. Pioneered by famous designers such as Iris van Herpen, Janne Kyttanen, Danit Peleg, Michael Smith, and Francis Bitonti. [6]. Van Herpen was the first designer to send 3D-printed couture down the runway, beginning in 2010 [7] at the Amsterdam Fashion Week, with her Crystallization collection, which included a printed piece in 3D, Image 1. In January 2011, she introduced 3D printing on the runways of Paris Haute Couture Week, Image 2. In her 2013 collection, Voltage, Iris Van Herpen presented the first flexible printed dress, in collaboration with the MIT Media Lab, where a different texture was developed, incorporating a hard material and soft one, able to assign softness and elasticity, Image 3. In March 2014, Iris Van Herpen, Biopiracy collection, 3D printing gained even more flexibility and movement with addition of new materials and the first printed dress in a flexible material was shown. In September 2014, she presented her collection, Magnetic Motion, containing a printed 3D piece in a transparent material with crystalline formations, Image 4. [8]



Image 1: 3D Crystallization Collection's 3D piece, 2010.



Image 2: Escapism Collection's 3D printed clothes, on/in Paris Haute Couture Week 2011.



Image 3: Voltage Collection Look, by Iris Van Herpen, 2013.



Image 4: Biopiracy Collection's 3D printed dress. Magnetic Motion Collection's 3D printed dress.

The most important advantages offered by 3D printing are: Additive manufacturing offers the possibility of creating, in a short timeframe, complex 3D objects, with fine details, from different materials, waste reduction, print small movable parts of the final object, reduces the necessary amount of human interaction and requires a low level of expertise for the operator. [5]

Additionally, the 3D printing medium offers many benefits attractive to small apparel designers including reduced lead times- the time between developing the design and its manufacture- as well as reduced material cost. Design prototypes may be made much more cheaply and quickly by cutting labor time and material costs, which in turn, allows small business designers who often cannot meet the large minimum orders required by manufacturers to produce their own designs. [9]

Like any other technology, 3D printing has a series of disadvantages and limitations that currently obstruct a large-scale expansion of this technology. The main disadvantages and limitations of 3D printing are: At the actual price of the device and materials, the 3D printing is the best solution when one needs to print a small number of complex objects, but it becomes expensive to print a large number of simple objects, when compared to traditional manufacturing techniques. Due to the material costs (especially regarding the moulds), the additive manufacturing is not always the best technical choice, most of the moulds' materials being degradable over time and sensible at outdoor exposure. [5]

Due to the drapability stretchability and comfortability requirement of a garment, the filament material used for 3D garment printing needs to be more flexible and absorbent. However the

filaments for 3D printing are far from the above mentioned property requirement. The printed 3D garments are fairly strong and water-resistant and they cannot be treated like many popular materials used daily such as cotton and silk. Textiles printed with these filaments cannot be machine washed, ironed or pressed. [1] 3D product would not be safe to manufacture in mass production, it is mostly for couture and runways, though a few have filtered into ready-to-wear. [7]

Kandinsky's motifs were used in this research as an inspiration source of designs.

Wassily Kandinsky was a great Russian painter who became pioneer of abstract art during the second decade of the twentieth century. Kandinsky, an experimental artist, approached abstraction tentatively and visually, by gradually and progressively concealing forms drawn from nature. He achieved abstraction not decisively, based on theory, but tentatively, based on vision. [10]

Kandinsky is painting music. That is to say, he has broken down the barrier between music and painting, and has isolated the pure emotion. Presumably the lines and colours have the same effect as harmony and rhythm in music have on the truly musical. [11]

His painting gradually elevates the onlooker, through pleasurable realization of aesthetic refinement, to harmony containing order, which proves satisfying to the soul's need for perfect peace. The ideal of his art was conceived even before the utter illusion of the density of matter had been proved by science, and before the reality of frequencies and invisible forces had opened the imagination of man to unlimited expectations. The profound truth of Kandinsky's theories at once impressed those who were equally capable of feeling aesthetic enjoyment through his paintings and of realizing the importance of Kandinsky's mission at its advent. [12]

2 Materials and Methods

The process of 3D printing starts with the design file that needs to be comparable with the software built in the 3D printer for manufacture. The software gives directions to the components to be printed with what needs to be completed.

3D printers were used to print Kandinsky's motifs called Tronxy P310 and Cube X. The material was used called PLA (Polylactic Acid).

Due to the small area available for printing of the most widely used commercial printers, it is almost impossible to print a whole design in one setting. Therefore, the design printing needs to be done in parts, and then assembled together where needed. These parts will be created through segmentation of the design. So, motifs were printed separately.

There are many possibilities for the assembly of the parts such as bonding with adhesive and melting together. In this study, bond by adhesive technique was used to assemble motifs where needed.

To achieve the flexibility and absorbance properties of woven fabrics, Satin fabric is used as a base surface and 3D printer prints (Kandinsky's motifs) the output on this surface. Motifs were fastened to the dress with Nylon thread through holes along the perimeter of them. Sometimes Direct drawing on canvas technique was used to add more details to the design. The dress form used in this study is a mini body.

The inspiration source of the designs was Kandinsky's motifs, which were retrieved from his four paintings (Composition, 1910, Contrasting Sounds, Red oval, Transverse Lines), Fig. 1. 2018 fashion lines used to create 10 dresses which correspond to Kandinsky's motifs lines.



Composition, 1910



Contrasting Sounds



Red oval



Transverse Lines

Figure 1

Kandinsky's paintings [13]

To evaluate the creative designs and be sure that the research objectives were achieved, the researcher designed and constructed a questionnaire includes 10 items as follows:

- 1- Woven fabrics and 3D printings work well together;
- 2- 3D printing is suitable to embody Kandinsky's motifs;
- 3- 3D printing adds aesthetic perspectives to the design;
- 4- Kandinsky's Motifs lines correspond to the design lines;
- 5- The design confirms the aesthetic values of Kandinsky's motifs;
- 6- The design keeps up with fashion lines;
- 7- There is harmony between the design colours;
- 8- The design achieves balance among its parts;
- 9- The design achieves balance among its parts;
- and 10- Unity is accomplished among the design parts.

Each item was assessed on a 5-degree (5= strongly agree, 1= strongly disagree).

The researcher asked eleven professors and assistant professors in the field of fashion design and apparel production technology, to evaluate the designs through a questionnaire, each referee viewed the designs and was instructed to read the items of the questionnaire and place a degree for each item through a personal interview.

3 Results and Discussion

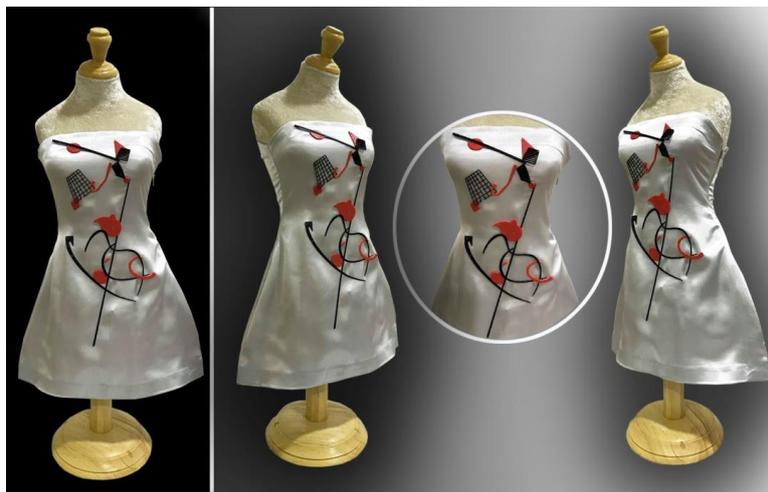
3.1 Presentation of the designs

Each design was presented in an appropriate layout, which consist of the design in different positions (front-left side-right side) and a zoom in 3D printing details, as follows:



Design 1

Design 1: The design was inspired by Kandinsky's motifs. The asymmetrical balance was achieved through emphasizing the 3D Kandinsky's motifs on a small area (corsage), versus the big plain area of the dress. The contrast between warm and cool colors used to draw attention to this part of the dress. The design achieved transition rhythm through moving the eye between different parts of the design. There is harmony between the design lines and colors. Unity is accomplished among the design parts. Overall, all of the parts of the dress work well together, so that a well proportioned look was resulted.



Design 2

Design 2: 3D Kandinsky's motifs added aesthetic values to the design through the movement of the curved lines and different directions of straight lines. Rhythm was achieved through the smooth flow of lines, colors and shapes. Asymmetrical balance added chic look and lots of drama to the dress. Color, size and detail created a sense of harmony. Unity created an integrated image in which all the motifs were working together to support the dress as a whole.



Design 3

Design 3: Asymmetrical balance was achieved in current design through the movement and spontaneity of shapes and lines. Deliberate placement of motifs was used to create opposition by abrupt transition between shape and space. Rhythm was achieved through the movement of curved lines. There is harmony between the design shapes and colors. 3D Kandinsky's motifs succeeded in creating unity between parts of the design. Overall, all of the parts of the dress work well together.



Design 4

Design 4: Emphasis was achieved in the design through the bright yellow rhombus in the background of the motifs. The pleasing arrangement of combination of Kandinsky's motifs led to achieve harmony among the design parts. Visual interest was enhanced by introducing dissimilar elements and spatial arrangements. Unity created an integrated image in which all the motifs were working together to support the dress as a whole.



Design 5

Design 5: Variety was achieved in the design through the way of combining the Kandinsky's motifs in involved ways to achieve intricate and complex relationships. Rhythm was achieved through the careful placement of repeated motifs which invites the viewer's eye to jump glide smoothly from one to the next motif. There is harmony through a way of combining the motifs to accent their similarities and bind the design parts into a whole. It was achieved through the use of repetition and simplicity.



Design 6

Design 6: 3D Kandinsky's motifs added aesthetic values to the design through the movement of the curved lines. Rhythm added a feeling of organized movement as the arrangement of the design motifs makes the eye move easily over the dress areas. Good proportion added a pleasing relationship between the sizes of various design motifs in a dress and between the dress itself and the design motifs. Unity gave an overall impression, a feeling of belongingness to the composition that attracts and holds the attention of the viewer and gave a balanced look to the design.



Design 7

Design 7: Direct drawing on the canvas technique added aesthetic perspectives to the design and enhanced the overall look. Asymmetrical balance was achieved through placement of motifs in a way that will allow motifs of varying visual weight to balance one another around a fulcrum point. Motifs combined proportions seem to belong with each other and the dress on whole. Shapes and spaces- created by motifs- harmonized by soft curved and straight angular motifs in accordance with the major forms of the dress.



Design 8

Design 8: Direct drawing on the canvas technique added more features to the design. The pleasing arrangement of the design motifs moved the eye well over the dress. It directed the flow of eye movement. Rhythm was achieved through the curved lines. The asymmetrical balance was achieved through emphasizing the 3D Kandinsky's motifs on a small area (corsage), versus the big plain area of the dress. Unity in the design referred to the visual linking of various motifs of the design.



Design 9

Design 9: 3D Kandinsky's motifs added aesthetic values to the design through the contrast between shapes and spaces. Rhythm was achieved through the smooth flow of lines, colors and shapes. A graceful placement of 3D Kandinsky's motifs provided the design with asymmetrical balance. Good proportion added a pleasing relationship between the sizes of various design motifs in a dress and between the dress itself and the design motifs. Motifs supported each other and all work together toward the final look. Variety of motifs added interest and energy to the design.



Design 10

Design 10: Evocative interrelation between color and form was used to create an aesthetic experience that engaged the sight and emotions of the viewer. Asymmetrical balance was achieved through placement of motifs in a way that allowed motifs of varying visual weight to balance one another on both sides of a fulcrum line. It added chic look and lots of drama to the dress. Variety of motifs added interest and energy to the design. Unity gave an overall impression, a feeling of belongingness to the composition that attracts and holds the attention of the viewer and gave a balanced look to the design.

3.2 Data Preparation and Data Analysis

The data was analyzed using the Statistical Package for the Social Sciences (IBM SPSS Statistics 25). To ensure validity and consistency of the results, the data was screened and leaned at a holistic level incorporating the entire data set.

3.2.1 Reliability and validity

To assess internal consistency for the 5-factor, 10-item model, the Cronbach α score was calculated using the whole sample, construct validity was assessed by computing scale scores for each item by calculating the mean score of the items for each respondent. Inter correlations between the scale scores for the 10-item and the 'overall grade' were computed to determine the discriminate validity. Strengths were defined artificially as those positively worded items which $\geq 75\%$ of respondents endorse by answering 'agree/strongly agree', or 'most of the time /always' (or when $\geq 75\%$ of respondents disagreed with negatively worded items). Areas with the potential for improvement were identified as items which $\leq 50\%$ of respondents answered positively. The average positive percentage of each dimension and item with 95% confidence interval was calculated

3.2.1.1 Reliability Test

The Cronbach's α reliability coefficients for the 10 questions were = 0.819, The Cronbach α score indicated an acceptable level of internal consistency (>0.70). Cronbach's alpha score was good provide the following rules of thumb regarding levels of internal consistency: >0.9 , excellent; >0.8 , good; >0.7 , acceptable; >0.6 , questionable; >0.5 , poor and <0.5 , unacceptable.

Table 1 displayed the inter-correlations of the 10 questions, and the total scale is significantly different

Table 1 Correlation with the total scale and inter-correlations of the 10 questions

No	Items	Pearson Correlation	Sig
1	Woven fabrics and 3D printings work well together.	.528**	0.000
2	3D printing is suitable to embody Kandinsky's motifs.	.510**	0.000
3	3D printing adds aesthetic perspectives to the design.	.670**	0.000
4	Kandinsky's Motifs lines correspond to the design lines.	.659**	0.000
5	The design confirms the aesthetic values of Kandinsky's motifs.	.720**	0.000
6	The design keeps up with fashion lines.	.576**	0.000
	There is harmony between the design colors.	.599**	0.000
8	The design achieves balance among its parts.	.551**	0.000
9	Rhythm is achieved in the design through repeating its shapes and colors.	.641**	0.000
10	Unity is accomplished among the design parts.	.736**	0.000

** Correlation is significant at the 0.01 level (2- tailed)

In the above table, correlation analysis indicates that positively correlated appears that all the variables show strong positive relationships with one another. A positive correlation coefficient (r-value) indicates a strong or positive relationship among the variables. None of the variables showed a negative/reverse relationship. All variables indicated strong inter-item correlation. The variables with the highest positive r-value (strongest positive relationship) were found

3.2.2 Analyzing the quantitative data

3.2.2.1 Results of the descriptive statistics

After gathering the data, we have entered them in SPSS (Statistical Package for the Social Sciences) version 25. These entered data have been analyzed by some of SPSS tools.

As the first analysis, we have described the basic features of the data with the descriptive statistics to provide simple summaries about respondents.

After the quantitative data collection process had been completed, data analysis began.

3.2.2.2 Descriptive Statistics

This section contains the descriptive statistics and analyses using ANOVA Analysis. The first section of the questionnaire will provide an overview of the respondents' interaction with 10 designs.

Table 2 Means and percentage of mean and responses

Items	strongly disagree	2	3	4	strongly agree	Mean	%
1	0%	0%	1.8%	22.7%	75.5%	4.74	95%
2	0%	2.7%	9.1%	15.5%	72.7%	4.58	92%
3	0%	4.5%	13.6%	21.8%	60.0%	4.37	87%
4	0%	4.5%	16.4%	30.9%	48.2%	4.23	85%
5	0%	3.6%	20.9%	33.6%	41.8%	4.14	83%
6	0%	2.7%	8.2%	44.5%	44.5%	4.31	86%
7	0%	2.7%	6.4%	15.5%	75.5%	4.64	93%
8	0%	1.8%	2.7%	26.4%	69.1%	4.63	93%
9	0%	1.8%	5.5%	17.3%	75.5%	4.66	93%
10	0%	1.8%	5.5%	28.2%	64.5%	4.55	91%
Overall						4.48	90%

As table 2 of 10 Items, were positive with an overall mean score of 4.48 (% of mean = 90%).

The majority of respondents agreed to with 10 designs

- The item with the highest level of satisfaction (75.5% 'strongly agree') was 'Woven fabrics and 3D printings work well together'. This also had the highest mean score (M = 4.74 and 95%).
- The second highest rated item (76% 'strongly agree'; M = 4.66) was 'Rhythm is achieved in the design through repeating its shapes and colors'. This also had the highest mean score (M = 4.66 and 93%).
- The third highest rated item (76% 'strongly agree'; M = 4.64) was 'There is harmony between the design colors'. This also had the highest mean score (M = 4.64 and 93%).

- The fourth highest rated item (73% ‘strongly agree’; $M = 4.58$) was ‘3D printing is suitable to embody Kandinsky's motifs’. This also had the highest mean score ($M = 4.58$ and 92%).
 - The fifth highest rated item (69.1% ‘strongly agree’; $M = 4.63$) was ‘The design achieves balance among its parts’. This also had the highest mean score ($M = 4.63$ and 93%).
 - The sixth highest rated item (64.5% ‘strongly agree’; $M = 4.55$) was ‘Unity is accomplished among the design parts’. This also had the highest mean score ($M = 4.55$ and 91%).
 - The seventh highest rated item (60% ‘strongly agree’; $M = 4.37$) was ‘3D printing adds aesthetic perspectives to the design’. This also had the highest mean score ($M = 4.37$ and 87%).
 - The eighth highest rated item (48.2% ‘strongly agree’; $M = 4.23$) was ‘Kandinsky's Motifs lines correspond to the design lines’. This also had the highest mean score ($M = 4.23$ and 85%).
 - The ninth highest rated item (45% ‘strongly agree’; $M = 4.31$) was ‘The design keeps up with fashion lines. This also had the highest mean score ($M = 4.31$ and 86%).
- The tenth highest rated item (42% ‘strongly agree’; $M = 4.14$) was ‘The design confirms the aesthetic values of Kandinsky's motifs’. This also had the highest mean score ($M = 4.14$ and 83%). as show in chart 1.

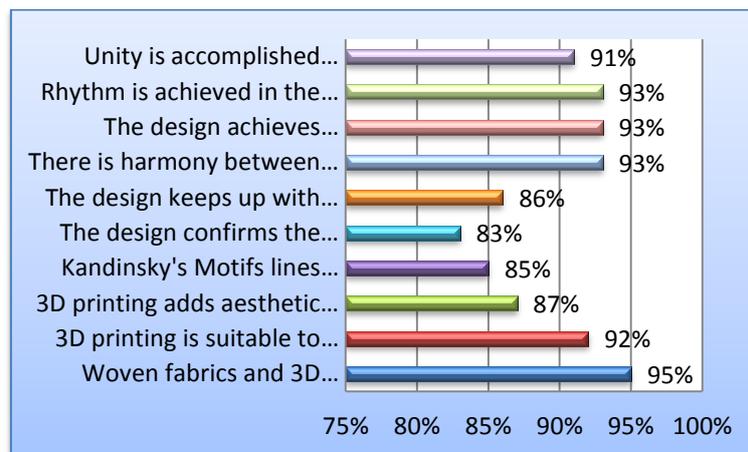


Chart 1 percentage of mean and responses

Using one-way ANOVA, the F statistic test whether the designs are all equal, that there are differences among the means of the 10 designs. A significant F value indicates that there are differences in the means, but it does not tell us where those differences are, by using LSD TEST we can find which designs are differences

ANOVAs were used to determine if statistically significant differences existed among 10 designs for 11 referees. There were statistically significant differences based on sum of all questions between 10 designs for 11 doctors

Table 3 Analysis of variance (ANOVA)

design	N	Mean	Std. Deviation	rank	F	Sig.
Design 1	11	48.00	1.844	2	5.916	.000
Design 2	11	47.00	3.847	3		
Design 3	11	44.27	4.519	6		
Design 4	11	41.55	6.056	9		
Design 5	11	39.45	4.967	10		
Design 6	11	48.27	1.009	1		
Design 7	11	44.18	2.822	7		
Design 8	11	43.55	3.934	8		
Design 9	11	45.45	3.174	5		
Design 10	11	46.73	3.952	4		
Total	110	44.85	4.594			

Table3 shows the descriptive statistics of all design of all referees.

For "Design 6" has the highest mean of 48.27 (=96.5%). Subsequently, it followed by Design 1 and Design 2. However, Design 5 has the lowest mean which 39.45 (=78.9%) as show in chart 2.

As shown in Table 3 the ANOVA, Table 3, F= 5.916; p= 0.000

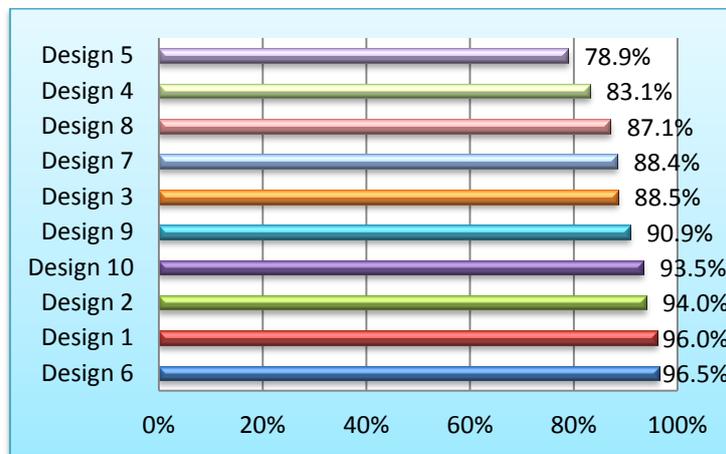


Chart 2 percentages of mean and responses

The differences according to referees regarding the reading frequency of and the importance assign to various design. It was found that there is a statistical significance by using woven fabrics and 3D printings in combination to embody Kandinsky's motifs and provides new aesthetic perspectives in fashion designs for women.

4 Conclusions

- In this research, the diverse use of 3D printing technology in fashion design was presented.
- 3D Kandinsky's motifs added aesthetic values to the designs through the movement of the curved lines and different directions of straight lines. Rhythm was achieved through the smooth flow of lines, colors and shapes. Asymmetrical balance added chic look and lots of drama to the designs. Color, size and detail created a sense of harmony. Unity created an integrated image in which all the motifs were working together to support the design as a whole.
- According to the evaluation of designs and the referees' opinions, "Design 6" has the highest mean of 48.27 (=96.5%). Subsequently, it followed by Design 1 and Design 2. However, Design 5 has the lowest mean which 39.45 (=78.9%).
- By using Statistical analysis of referees' opinions, it was found that there are differences of statistical significances which confirms that the research aim "using woven fabrics and 3D printings in combination to embody Kandinsky's motifs and provides new aesthetic perspectives in fashion designs for women" is achieved.

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