Appealing avatars from 3D body scans: Perceptual effects of stylization

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Appealing Female Avatars from 3D Body Scans: Perceptual Effects of Stylization

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Abstract: Advances in 3D scanning technology allow us to create realistic virtual avatars from full body 3D scan data. However, negative reactions to some realistic computer generated humans suggest that this approach might not always provide the most appealing results. Using styles derived from existing popular character designs, we present a novel automatic stylization technique for body shape and colour information based on a statistical 3D model of human bodies. We investigate whether such stylized body shapes result in increased perceived appeal with two different experiments: One focuses on body shape alone, the other investigates the additional role of surface colour and lighting. Our results consistently show that the most appealing avatar is a partially stylized one. Importantly, avatars with high stylization or no stylization at all were rated to have the least appeal. The inclusion of colour information and improvements to render quality had no significant effect on the overall perceived appeal of the avatars, and we observe that the body shape primarily drives the change in appeal ratings. For body scans with colour information, we found that a partially stylized avatar was most effective, increasing average appeal ratings by approximately 34%.

1 INTRODUCTION

Virtual avatars are frequently used in games, virtual worlds and for online communications. How an avatar is perceived by others is considered extremely important but creating a highly detailed and realistic avatar does not necessarily produce appealing results (Boberg et al., 2008). *Appeal*, one of the twelve principles of animation (Johnston and Thomas, 1981) is commonly used to describe well designed, interesting and engaging characters. In the same way animated movie and game characters require appeal in order for people to engage with them, virtual avatars also require appeal in order to engage others.

In this paper, we explore different ways in which we can increase the appeal of 3D body scans via stylization. In particular, we explore which styles make the virtual avatars most appealing, and what is the optimal amount of stylization for the most successful ones. We also examine the role of other factors in the appeal of the final stylized avatar, namely the realism of the renders and the appearance of the original subject. For this, we acquire 3D body scans of real people using a state-of-the-art capturing system and automatically create virtual avatars with different styles and degrees of stylization. We render these avatars with and without colour information and also improve the render quality to simulate varying levels of realism. We then study, in multiple experiments, which factors affect the perceived appeal of these avatars.

2 BACKGROUND

Human-like virtual characters are becoming more and more present in our lives. Since virtual environments often try to replicate the real world, a natural design choice for these virtual characters is to make them as real as possible. This is becoming easier thanks to the improvements of 3D capturing systems in terms of speed, accuracy, quality and price. However, not all virtual characters are designed with reality in mind. Highly stylized avatars, such as the ones used by the game consoles Xbox and Wii, seem to suggest that people find the stylized look very appealing. The stylized approach to avatar creation has traditionally required the user to manually define and

personalize their avatar; creating a true resemblance of that person is hard to achieve. Game studios are already attempting to cut out the manual work associated with this process by capturing gamers' features and applying them to in-game characters. For example *NBA 2K15* (Take-Two Interactive, 2014) attempts to capture the player's face while *Kinect Sports Rivals* (Microsoft, 2014) captures the entire body. Extracting information about the player is currently achieved using peripherals such as Microsoft's *Kinect 2* and Sony's PS4 camera.

Despite the availability of both high quality, realistic body scans and increasingly convincing avatars from consumer peripherals, highly stylized characters are still extremely popular and can be seen in many animated movies, games and even web-based support services. Animation companies such as *Disney*, *Blue Sky* and *Pixar* tend to aim for a highly stylized look when designing characters. Attempts to increase realism in stylized characters have often led to negative reactions from viewers (Melina, 2011; Chaminade et al., 2007). Examples of this include films such as *Polar Express* (Zemeckis, 2004), *Mars Needs Moms* (Wells, 2011), and *The Adventures of Tintin* (Spielberg, 2011).

Furthermore, negative reactions to the almost, but not quite, photo-realistic characters seen in some film and game productions (Chaminade et al., 2007) and the human-like robots that inspired the "Uncanny Valley" hypothesis (Mori et al., 2012) suggest that stylizing (therefore decreasing realism), rather than attempting to improve realism, could actually produce more appealing results. For example, (Inkpen and Sedlins, 2011) conducted a survey into peoples' comfort when communicating with avatars and found that although respondents were comfortable interacting with both realistic and cartoon looking avatars, some avatars rated highly realistic were also felt to be eerie or creepy. It is therefore possible that, even if one created a photo-real digital replica of a human, a stylized version could still be more appealing.

Experiments performed by (Seyama and Nagayama, 2007), where they morphed between artificial and real faces, suggest that stylization should be done consistently in order to avoid viewer discomfort as abnormal features (e.g. cartoon eyes applied to a human head) produced the lowest pleasantness scores in their experiments. These conclusions match similar findings by (MacDorman et al., 2009) who found that a mismatch between the size and texture of the eyes and face was especially prone to making a character look eerie. Interestingly, again for faces, results by (McDonnell et al., 2012) suggest that both highly realistic and highly abstract render styles were both considered appealing but render styles inbetween the two were considered unappealing. Recently (Zell et al., 2015) found that while face shape was important for portraying realism, it was the material – specifically the albedo map – that played the key role in influencing the perceived appeal of CG characters and a stylized smooth looking skin texture (obtained via blurring) was perceived as being more appealing than a realistic skin texture.

To go beyond previous work on face appeal and investigate the perceptual effects of stylization on full-bodied avatars, we conducted two separate experiments. The aim of the first experiment was to investigate the effects of stylization when applied to a realistic average female body shape containing no colour information. This allowed us to focus purely on body shape. In the second experiment we stylized 3D body scans of real people. The aim here was to assess the effect of the subjects appearance (both in terms of body shape and colour information) and render quality on perceived appeal and realism. Overall the aim of these experiments is to better understand how to create appealing female avatars from 3D body scans.

3 STYLIZATION OF 3D BODY SCANS

3.1 3D Body Scanning

To represent realistic human body shape and appearance we first captured detailed 3D body scan and colour information from 2 female actors (see Fig. 3) in an A-pose using a full body 3D scanning system (3dMD USA, 2014).

The system (see Fig. 1) is composed of 22 stereo units, each including a pair of black and white cameras observing a projected speckle light pattern, and one 5 megapixel colour camera that captures the body appearance 2 ms after the speckle image, synchronized with white flash units. The system provides very good coverage of the entire human body and can resolve the 3D locations of a point on the body to approximately 1 mm.

Raw scans contain noise, occasional holes and are difficult to manipulate. Consequently we registered a common 3D body template to the scans in order to obtain a coherent mesh topology for each. For this we used a statistical 3D body model that compactly parametrises body deformations automatically in terms of shape changes due to subjects' identity and body pose (Hirshberg et al., 2012). The model is

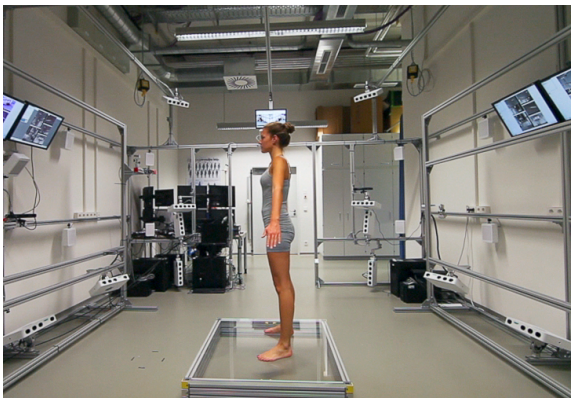

Figure 1: Taking a full body scan in the 3D scanning system.

based on approximately 2100 body scans of women from the US and EU CAESAR dataset (Robinette et al., 2002).

Through this process we obtained 3D geometry that resembles the original 3D scans but also shares a common layout. We call these meshes *registrations*. Since registrations share mesh topology, their vertex positions fully describe the body geometry. Therefore, morphing between two or more bodies can be performed as a weighted sum of the corresponding vertex positions across registrations.

Once registered, we extracted both albedo and pre-lit colour maps (Bogo et al., 2014) from each scan (using the UV texture coordinate layout defined in the template). The albedo maps were illuminated using simple point lights within 3ds Max 2014 (Autodesk, USA). The pre-lit colour maps (Fig. 5 right), provided a more realistic look and, unlike the albedo maps (Fig. 5 left), required no CG lighting due to the lighting information already being embedded within the maps.

3.2 Shape Stylization

For our initial experiment, five female style templates were created in the digital sculpting application Zbrush (Pixologic, USA) (Fig. 2). The two most appealing styles were then used again for our second experiment.

The style templates were created by a trained 3D artist and were modelled to match the body proportions of existing stylized designs (see Tab. 1). The style templates used the same topology as the registrations, therefore direct morphing between registrations and style templates was made possible by simply interpolating vertex positions. While creating the styles is a time-consuming manual task that requires a skilled artist, it is worth noting that thanks to the shared topology, this only needs to be done once and can then be reused for all future scans.

Table 1: Female style template references

Style Name	Description
Marvel	Typical female Marvel superheroine (Marvel Entertainment, USA)
Disney	"Rapunzel" from the animated movie "Tangled" (Disney, 2010)
Sony	"Sam Sparks" from the animated movie "Cloudy with a Chance of Meatballs" (Sony, 2009)
Pixar	"Princess Merida" from the animated movie "Brave" (Pixar, 2012)
Barbie	"Barbie" doll (Mattel, USA)

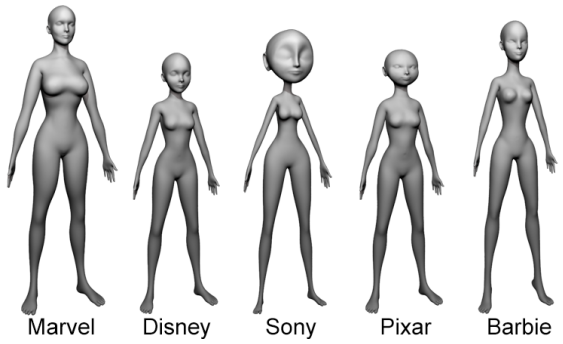

Figure 2: Style templates created from character reference.

3.3 Body Shape Generation

For experiment 1 we used an average female body shape M (Fig. 3 top left). This shape was computed by averaging the $n \approx 2100$ original registrations O_i (as described in section 3.1): $M = \frac{1}{n}\sum_{i=1}^{n} O_i$.

In experiment 2, rather than stylize the average female body shape, we stylized registrations F obtained from 3D body scans of real people. In order to maintain the characteristic body features (even when fully stylized) we augmented the resulting morph between registration F_i and template S_j with data derived from the registration: Half of the Euclidean difference between the mean body shape M and the registration F_i was added back to the current body style template S_j (right term of Eq. 1). See Fig. 3 for an illustration of the process.

We obtain the final stylized avatar shape $N_{i,j|\alpha}$ used for one trial (with identity i, style j and stylization level $\alpha \in [0\ldots1]$) by linear interpolation between the original registration F_i and the current style template S_j, augmented by the individual body characteristics:

$$N_{i,j|\alpha} = (1-\alpha)F_i + \alpha\left(S_j + \frac{1}{2}(F_i - M)\right) \quad (1)$$

This helped to maintain the more subtle characteristics of the original body shape while keeping the overall proportions of the stylized models.

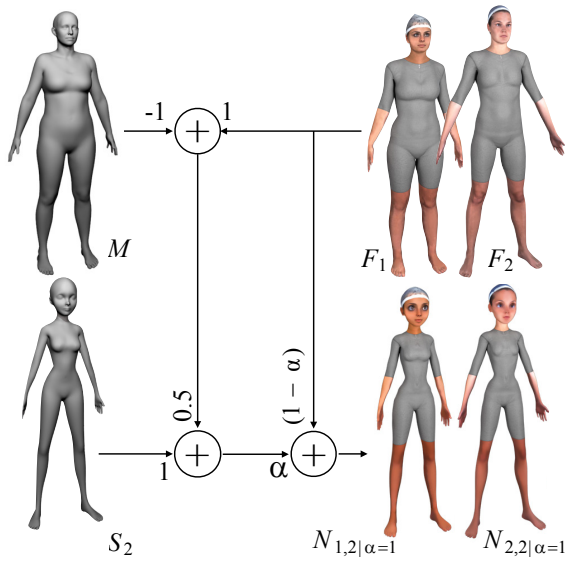

Figure 3: Stylization process for style S_2 (Disney)

Eq. 1 was implemented using the *Morpher* modifier in 3ds Max, morphing the scans from their original state to the 100% stylized model (see Fig. 3 bottom for examples). Two intermediate states were also generated at 33% and 66% stylization.

3.4 Stylization of Albedo and Pre-lit Colour Maps

For experiment 2, we used the albedo and pre-lit colour maps extracted from our scans. These required some manual clean-up work as they contained visual marker information (recorded for a different purpose) and had some missing data (Fig. 4). This was achieved using basic retouching tools and techniques in Photoshop (Adobe, USA). Note that normally this step would not be necessary as subjects are scanned without markers.


Figure 4: Original albedo map (left), cleaned up and grey body suit added (centre), stylized result (right).

As all actors wore swimwear during scanning, a grey body suit template was placed over each map (Fig. 4 centre) to avoid participants becoming distracted by the clothing. Due to the shared topology, and thus the shared UV texture layout, this only needed to be done once for all characters. To match the realism of the pre-lit colour maps, a realistic version of the suit was rendered using area lights and global illumination in the V-Ray 2.0 renderer (Chaos Group, Bulgaria).

The albedo and pre-lit colour maps were also stylized in order to recreate a similar look to most of the style references. A typical feature film animation look is often represented through heavily saturated colours and soft surface details. To achieve this, our colour stylization technique was implemented as a Photoshop action and involved Photoshop's edge-preserving Surface Blur filter and increasing the colour Vibrancy (increasing the saturation of less saturated colours), controlled by masking regions (Fig. 4 right).

Both the albedo and pre-lit colour maps had a resolution of 1024×1024 pixels. Parameter α in Eq. 1 was used to linearly blend between the normal and stylized versions of these maps.


Figure 5: Avatar using CG lit albedo map (left), and pre-lit colour map with embedded lighting (right).

4 EXPERIMENT 1

We ran a 15 minute experiment with 18 Participants (10 female, average age = 26.5 yr, SD = 7.5). The experiment was conducted in accordance with the Declaration of Helsinki. All participants signed informed consent and were financially compensated.

4.1 Experimental Design

For our first experiment we asked participants for their judgements of appeal on a 7-pt Likert scale when observing an average female body shape, as well as that shape being morphed into 5 different style templates (Fig. 6) at 3 levels of stylization (33, 66, 100%). This resulted in a total of 16 avatars (15 for the stylized body and 1 for the average body shape). Stimuli were presented in a random order. The avatar featured no colour information and was rendered in real-time within the Unity 4 game engine (Unity Technologies, Denmark).

Participants were instructed to answer quickly and simply provide their first impression. Participants

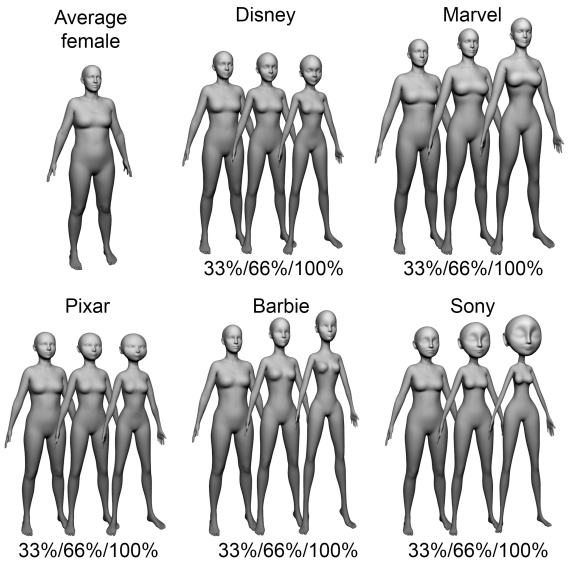

Figure 6: Styles used in Experiment 1

were also given an in-depth definition of appeal before they began:

High appeal: "you find the person extremely appealing. This may include finding the person extremely engaging, likeable and/or generally pleasing to the eye."

Average appeal: "you neither find the person appealing nor unappealing. They are acceptable but essentially you are indifferent, finding them neither engaging nor disengaging, likeable nor unlikeable."

Low appeal: "you find the person extremely unappealing. This may include finding the person extremely disengaging, unlikeable and/or repellent."

4.2 Experiment 1 Results

A partially stylized avatar was often rated as more appealing than the average female (where the amount of stylization for optimal appeal depends on the style, see Fig. 7 and Tab. 2).

Table 2: Mean appeal ratings by stylization level and style (standard deviations in parentheses)

Style	33% stylized	66% stylized	100% stylized
Marvel	4.94 (1.211)	5.00 (1.085)	4.17 (1.724)
Disney	4.72 (1.127)	4.83 (1.425)	3.67 (1.847)
Barbie	4.39 (1.195)	4.00 (1.572)	2.33 (1.138)
Pixar	4.39 (1.092)	3.44 (1.504)	2.17 (1.043)
Sony	2.22 (1.003)	1.56 (0.784)	1.28 (0.461)

We ran a repeated measures ANOVA on the rating of appeal of avatars in a within subject factors design with two factors: Style (5 levels: Marvel, Disney, Sony, Pixar, Barbie) and Percent Stylized (3 levels: 33, 66, 100%).

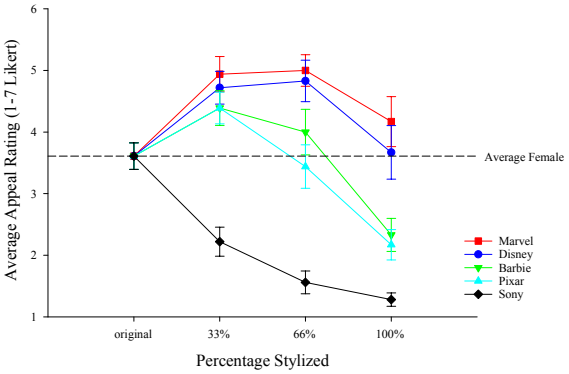

Figure 7: Appeal ratings on a 7-pt Likert scale by style and stylization level (n=18). Ratings for the average female have been included in this graph as a reference. Error bars represent one standard error of the mean in all figures.

There was a significant effect of Percent Stylized on appeal ratings, F(2,34) = 18.33, $p < 0.001$, η_p^2 = 0.519. 100% stylized had significantly lower appeal ratings than both 33% and 66% while both 33% and 66% stylized avatars were found to be more appealing than the original body scan (as revealed by post-hoc comparisons using Bonferroni adjustments, $(p < 0.001)$).

There was also a significant effect of Style on appeal ratings, F(4,68) = 63.03, $p < 0.001$, η_p^2 = 0.788. The five styles did not have the same effect on appeal ratings across percent stylized (as revealed by post-hoc comparisons using Bonferroni adjustments). Most notably the Sony style had a significantly lower rating of appeal than all of the styles ($p < 0.001$) and was always rated as less appealing than the original body scan. The appeal ratings of the Marvel and Disney styles did not significantly differ from each other (p = 1.00) and appeal ratings of the Barbie and Pixar styles also did not significantly differ from each other (p = 0.907). All other comparisons between styles resulted in significantly different appeal ratings ($p < 0.05$).

These main effects were conditioned upon a significant interaction between style and percent stylized, F(8,136) = 3.02 p = 0.004, $\eta_p^2 = 0.151$. We therefore tested for an effect of percent stylized for each individual style. The effects of percent stylized were significant for all styles $(p < 0.05)$ except for the Marvel style (p = 0.12). Not surprisingly, there was a simple effect of style found when testing at each percent stylized, driven by the low ratings of appeal for Sony $(p < 0.05)$. In addition, at 100% stylized the Marvel and Disney appeal ratings were significantly

greater than both Barbie and Pixar appeal ratings (as revealed by post-hoc comparisons using Bonferroni adjustments, ($ps < 0.05$)).

These results show that for all styles except Sony, a partially stylized avatar leads to the greatest appeal ratings and depending on that style either 33% or 66% leads to optimal appeal. Excluding the Sony style, an improvement upon the original appeal ratings for the average female of approximately 29% could be achieved by stylizing the body shape.

5 EXPERIMENT 2

Both the Marvel and Disney styles provided the most significant improvements for appeal ratings in experiment 1 and were therefore used to stylize the body scans of real people in our second experiment.

5.1 Visual Stimuli

For experiment 2, 14 images were rendered in 3ds Max at 500×1000 pixels using our CG lit albedo maps, 7 rendered images per character: three percentages at two styles each, plus the original body scans (Fig. 8). Another 14 images were rendered in 3ds Max using our pre-lit colour maps at the same resolution (Fig. 9).

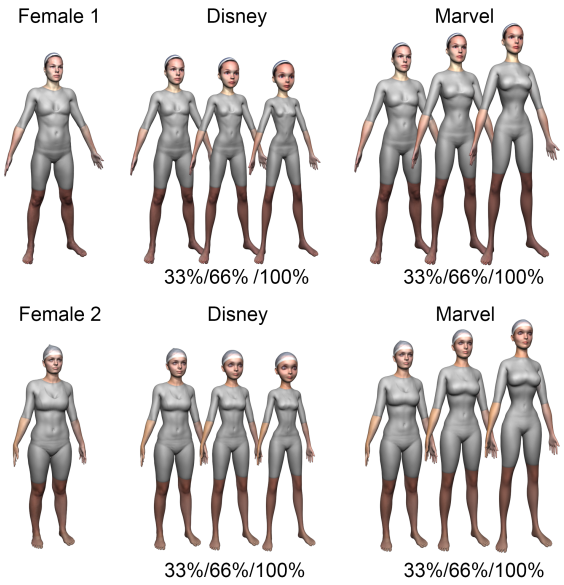

Figure 8: Styles featuring albedo maps and CG lighting

5.2 Experimental Design

There were 61 Participants (35 female) with an average age of 28.08 yr (SD = 7.6) and none of the participants had been involved in experiment 1. The experiment was conducted in accordance with the Declaration of Helsinki. All participants signed informed consent and were compensated. There was no time limit assigned to the sessions but participants were instructed to answer quickly and provide their first impression. The experiment lasted approximately one hour.

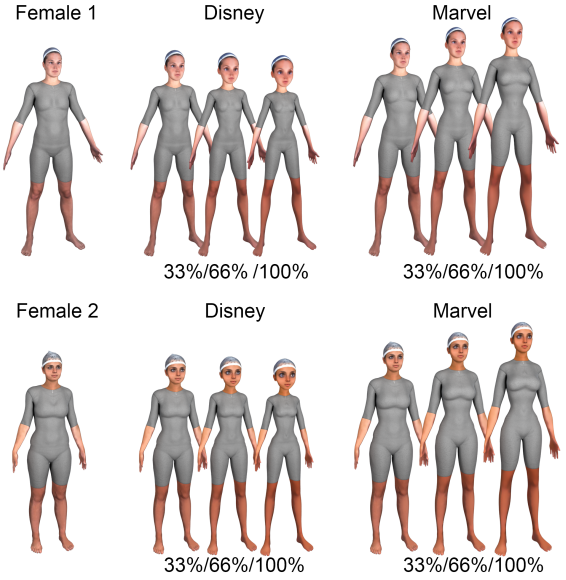

Figure 9: Styles featuring pre-lit colour maps

There were two tasks in this experiment. First, subjects provided appeal ratings as in Experiment 1. Second, participants were asked were asked to dynamically create the most appealing and repelling characters.

5.2.1 Task 1: Likert Scale Ratings

Experiment 2 was a repeated measures design and involved rating avatars on a 5-pt Likert scale and had three within subject factors: Actor Identity (2 levels: F_1, F_2), Style (2 levels: Marvel, Disney) and Percent Stylized (3 levels: 33, 66, 100%) and one between subject factor of Render Quality (2 levels: albedo maps with CG lighting (42 participants), pre-lit colour maps without CG lighting (19 participants)).

In addition to appeal, we asked our participants six further questions (Tab. 3) to see whether our stylization technique had a significant effect on other character traits[1].

[1]Our questions were inspired by existing research, e.g. *appeal* (McDonnell et al., 2012; McDonnell, 2012) and *sympathy* (Hodgins et al., 2010), *neuroticism* inspired by the Big Five personality traits (Johnson et al., 1993).

This resulted in a total of 7 questions being asked for 14 avatars (2 actors $\times$ 2 styles $\times$ 3 stylization levels) + 2 original body scans. We additionally asked the participants who saw the avatars with prelit colour maps to rate realism. The avatars were presented in a random order. Questions were asked for each avatar in the same order as in Table 3.

Table 3: Avatar questionnaire

1	Do you feel as if you can sympathise with this person?
2	Are you repelled by this person?
3	Would you accept help from this person?
4	Do you find this person engaging?
5	How appealing do you find this person?
6	How charming do you find this person?
7	Does this person come across as being neurotic?

5.2.2 Task 2: Interactive Creation of Appealing Characters

In a second task, 37 participants were asked to specify the exact level of stylization they found to be most appealing/repelling by interactively adjusting a slider in real-time within the Unity 4 game engine.

In addition to the stylized result controlled by the slider, the participants were also shown the original 3D body scan next to the avatar they were manipulating, giving them a non-stylized reference. Albedo maps and CG lighting were used for this task. The dependent variable was the chosen percentage of stylization and the fixed factor was the style (Marvel and Disney) and the actor identity (F_1 and F_2). Each trial always began with the slider value set to 0% (i.e. showing the original body shape). This resulted in four trials (two styles for each of the two actor identities). They were presented in random order. The instructions were as follows:

"Make this character as *appealing* as possible.", and "Make this character as *repelling* as possible."

For this task participants were instructed to take their time and be as accurate as possible. Participants were also instructed to adjust the slider once more after deciding on a level of stylization to verify their decision before submitting a rating.

5.3 Experiment 2 Results

For the most part responses to our questions show a similar pattern across percent stylized: an increase in rating at 33% and a decrease in rating at 100% (as can be seen in Fig. 10). We decided to analyze only appeal and realism ratings because appeal seems to be representative of the majority of the questions in Table 3. Indeed the mean Appeal rating did not significantly differ from all other questions ($p < 0.05$) (with the exceptions only being neurotic and repelling which were inverted in scale). Realism appears to be the only question that demonstrates a unique pattern across percent stylized so we analyzed separately realism ratings in the following section.

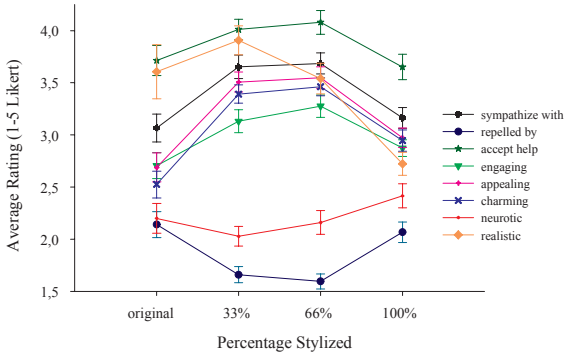

Figure 10: Ratings on a 5-pt Likert scale by stylization level for all questions, collapsed across all styles, identities and render quality (n=61, n=19 for realism). Note: Repelling and Neurotic ask for negative traits and therefore have inverted values compared to all other questions asking for positive traits

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5.3.1 Appeal Ratings Results

Average appeal rating for the original body scans was 2.69. The average appeal ratings for style templates was 3.49 for Marvel and 3.19 for Disney (see Fig. 11 and Tab. 4).

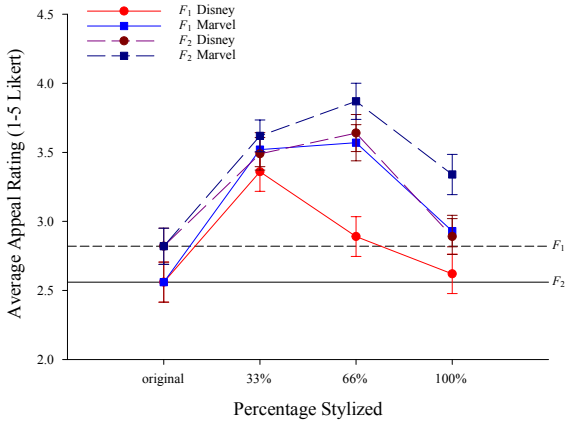

Figure 11: Appeal ratings on a 5-pt Likert Scale by style, actor identity and stylization level, collapsed across both render styles (n=61).

We ran a repeated measures ANOVA on the rating of appeal of characters with three within subject

Table 4: Appeal ratings per actor, style and stylization level (standard deviations in parentheses).

	Actor F_1		Actor F_2	
Level	Marvel	Disney	Marvel	Disney
original	2.56 (1.13)	2.56 (1.13)	2.82 (1.02)	2.82 (1.02)
33%	3.52 (0.96)	3.36 (1.11)	3.62 (0.90)	3.49 (0.92)
66%	3.57 (1.02)	2.89 (1.13)	3.87 (1.02)	3.64 (1.05)
100%	2.93 (0.89)	2.62 (1.11)	3.34 (1.14)	2.89 (1.02)

factors: Actor Identity (2 levels, F_1, F_2), Style (2 levels: Marvel, Disney) and Percent Stylized (3 levels: 33, 66, 100%) and one between subject factor of render quality (2 levels: albedo maps with CG lighting, pre-lit colour maps without CG lighting).

Surprisingly, we found no significant effect of render style on appeal ratings (albedo maps with CG lighting versus pre-lit colour maps without CG lighting stimuli), $F(1,59) = 1.03, p = 0.315, \eta_p^2 = 0.017$.

Similar to Experiment 1, we found a significant effect of percent stylized on appeal ratings, $F(2,118) = 19.63, p < 0.001, \eta_p^2 = 0.250$. In relative terms, our method achieves approximately 34% improvement in appeal ratings for the original body scans by stylizing at 33% or 66% towards Marvel or Disney styles.

33% and 66% do not significantly differ from each other on appeal ratings (p = 1.0), while 100% stylized is significantly lower rated on appeal than both 33% and 66% ($p < 0.001$, as revealed through post-hoc comparisons using Bonferroni adjustments)

We also found a significant effect of style on appeal ratings, $F(1,59) = 16.24, p < 0.001, \eta_p^2 = 0.216$. Marvel is significantly higher rated on appeal than Disney (as revealed through post-hoc comparisons using Bonferroni adjustments, $p < 0.001$). Finally, we found a significant effect of actor identity, $F(1,59) = 8.66, p < 0.005, \eta_p^2 = 0.128$. A stylized female F_1 is significantly lower rated on appeal than a stylized female F_2 (as revealed through post-hoc comparisons using Bonferroni adjustments, $p < 0.001$).

These effects suggest that all factors (style, actor identity and percent stylized) influence the ratings of appeal. These main effects were conditioned upon a significant interaction between Actor Identity, Style and Percent Stylized, $F(2,118) = 3.45, p = 0.035, \eta_p^2 = 0.055$ and a significant interaction between Actor Identity and Percent Stylized $F(2,118) = 5.34, p < 0.01, \eta_p^2 = 0.083$. The Disney F_1 at 66% seems to drive the interaction between Actor Identity, Style and Percent Stylized. This one data point deviates from the typical pattern of improved appeal at 33%, greater improvement at 66% and then a decrease in appeal at 100% stylized, as revealed through post-hoc comparisons using Bonferroni adjustments, $p < 0.001$.

5.3.2 Realism Ratings Results

As a reminder, we only asked realism ratings for the avatars with pre-lit colour maps. Realism ratings for the original body scans was on average 3.61. Average realism for the stylized avatar at 33% was 3.91, at 66% was 3.54, and at 100% was 2.72 (see Fig. 12 and Tab. 5). Interestingly at 33% stylized there was no decrease in ratings of realism as compared to the original scan, at 66% only the Female F_1 Disney style received a decreased realism rating and for 100% almost all stylized body scans received a significantly lower realism rating.

We ran a repeated measures ANOVA on the rating of realism of avatars with three within subject factors: Actor Identity (2 levels, F_1, F_2), Style (2 Levels: Marvel, Disney) and Percent Stylized (3 levels: 33, 66, 100). Since we had not asked for realism ratings with the albedo colour map with CG lighting there is no between subject factor for ratings of realism.

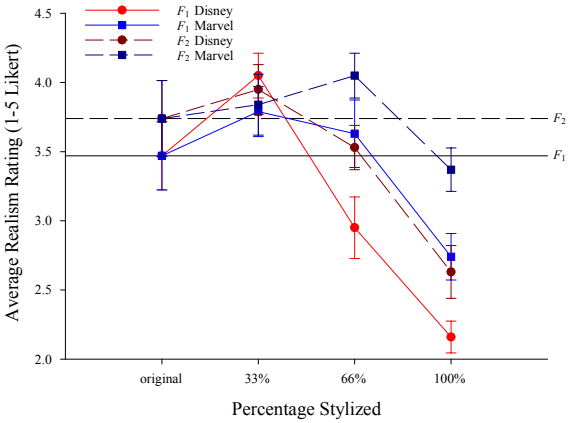

Figure 12: Realism ratings on a 5-pt Likert scale by style, actor identity and stylization level (n=19).

Table 5: Realism ratings per actor identity, style and stylization level (standard deviations in parentheses).

	Actor F_1		Actor F_2	
Level	Marvel	Disney	Marvel	Disney
original	3.47 (1.07)	3.47 (1.07)	3.74 (1.09)	3.74 (1.09)
33%	3.79 (0.79)	4.05 (0.71)	3.84 (0.96)	3.95 (0.78)
66%	3.63 (1.07)	2.95 (0.97)	4.05 (0.71)	3.53 (0.70)
100%	2.74 (0.73)	2.16 (0.50)	3.37 (0.68)	2.63 (0.83)

We found a significant effect of Percent Stylized, $F(2,36) = 35.042, p < 0.001, \eta_p^2 = 0.661$. There was a significant difference between 33, 66 and 100% stylized in realism (as revealed through post-hoc comparisons using Bonferroni adjustments, $p < 0.05$). This was seen as a decline in realism ratings as stylization percentage increased.

We found a significant effect of style, F(1,18) = 18.841, $p < 0.000$, $\eta_p^2 = 0.511$. Marvel is rated to have a significantly higher realism rating compared to Disney (as revealed through post-hoc comparisons using Bonferroni adjustments, $p < 0.001$). Similarly, we also found a significant effect of actor identity, F(1,18) = 29.439,$p < 0.001$, $\eta_p^2 = 0.621$. Consistent with appeal ratings, a stylized female F_1 is rated significantly lower for realism than a stylized female F_2 (as revealed through post-hoc comparisons using Bonferroni adjustments, $p < 0.001$).

These main effects were conditioned upon a significant interaction between style and percent stylized F(2,36) = 11.378,$p < 0.001$, $\eta_p^2 = 0.387$ and a significant interaction between actor identity and percent stylized F(2, 36) = 6.610, $p < 0.005$, $\eta_p^2 = 0.269$. This can be summarized by the styles not changing realism ratings at 33% stylized, but as stylization increases the styles and the actors are being perceived with a variety of different ratings of realism. High levels of Marvel stylization result in decreased realism ratings for F_1 but not so for F_2, where the Marvel stylization seems to have the same influence on realism ratings across the actors. These results are consistent with our appeal ratings and may shed some light on why 100% stylization is seen as less appealing, because it is also seen as less realistic.

5.3.3 Interactive Creation of Characters Results

When asked to interactively create the most appealing character using sliders it was extremely rare that participants chose either the original body scan (3%) or the fully stylized avatar (5% of the trials). The average stylization amount chosen was 40.9% across actors and styles for an appealing character (see Fig. 13 and Tab. 6).

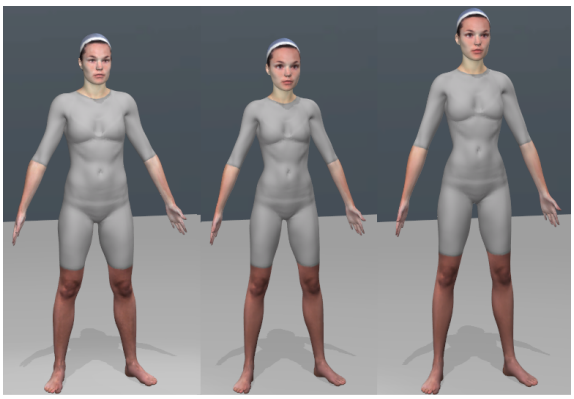

Figure 13: Original body scan of female F_1 (left), 38% Disney (center), 51% Marvel (right). Real-time images captured from within the Unity 4 game engine.

Table 6: Average stylization level in the method of adjustment task for most appealing character per actor and style (standard deviations in parentheses).

Style	F_1	F_2
Marvel	50.77% (26.3)	45.56% (24.90)
Disney	37.65% (23.3)	29.71% (22.02)

Due to this amodal distribution for the repelling characters we decided to present the histograms for the percent stylized chosen (see Fig. 14). When participants were asked to create the most repelling avatar they chose the 100% stylized version for 58% of the total trials and the original scan for 24% of the total trials. This further confirms that the most appealing avatar is a partially, and specifically not a fully, stylized one. These results are also consistent with the repelling ratings from task 1. However, the degree to which the original body scans and 100% stylized body scans were rated as repelling was only just above 2 on the 5-pt Likert scale (see Fig. 10). Important therefore to note is that original body scans and 100% stylized avatars were not seen as extremely repelling, but rather more repelling as compared to partially stylized avatars.

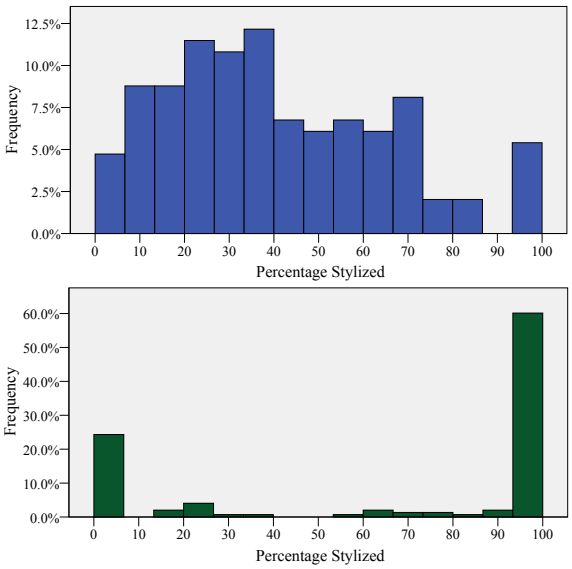

Figure 14: Frequency of stylization level chosen interactively for maximum appealing (top) and repelling characters (bottom), collapsed across actor identity and style (n=37).

6 DISCUSSION

In general, appeal ratings for the average female body shape were highest when some level of stylization was applied (usually 33% but in some cases 66%). However, not all styles affect the resulting

appeal score in a similar manner. In experiment 1, the Disney and Marvel stylizations were found to be consistently more appealing than the average female body shape. Styles with exaggerated body shapes tended to be rated lower than styles with more human-like body shapes, with the Barbie and Pixar styles producing lower appeal ratings than the Disney and Marvel styles. The Sony style (featuring the most exaggerated body shape) was rated as being consistently less appealing than the average female body shape, regardless of the level of stylization applied. This seems to suggest a preference for human likeness when observing avatars and a dislike for extremely exaggerated proportions.

In our second experiment involving the stylization of body scans with colour information, we again found that moderate levels of stylization are effective at increasing appeal since 33% and 66% levels both produced higher appeal ratings than the original body scans. However, 100% stylized avatars in most cases were rated no differently than the original body scans. We also found that efforts to make the avatars appear more realistic (through improvements in render quality) had no significant impact on appeal ratings. Considering our results, it could be that in contradiction to (Zell et al., 2015), body shape is playing a larger role in the influence of perceived appeal than the inclusion (and modification) of surface colour, however further testing is needed to better understand this.

Realism ratings were consistent with appeal ratings and may provide some insight as to why higher levels of stylization are less desirable than partial stylization, as the highest level of stylization was rated lowest in realism. Interesting, 33% stylized body scans were not seen as less realistic as compared to the original body scans. This could be due to the stylization of the texture drawing attention away from imperfections in the surface colour. The fact that there is not an immediate decrease in realism with stylization also is a result that further supports the use of stylization to create more appealing avatars. Additionally, a partially stylized avatar may not suffer from the Uncanny Valley effect. We hope to further investigate the perception of realism in more depth to better understand the role realism plays in the appeal of our avatars and specifically further investigate why our original body scans receive similar realism ratings as the 33% stylized avatars.

A limitation of our findings is the small number of templates and body registrations presented in this paper. We hope to extend this work by investigating a larger variance in body shape of actors (i.e. male participants, a wider range of BMI and different age groups). Most importantly we would like to increase the number of style templates that we use to stylize our avatars to be suitable for a greater variance in the shape of humans.

7 SUMMARY

The stylization technique presented in this paper allows for the semi-automatic creation of more appealing personalized avatars from 3D body scans for use in games, virtual environments and online communications.

For stylizing 3D body scans, the main steps are the automatic registration of a statistical 3D body model to the body scan data, followed by the stylization through feature-preserving morphing with colour filtering and blending. Our technique can be automatically applied to any human body scan after registration of the scan to our 3D body template. The only manual process involved is the sculpting of the style templates. However, once created, these can be applied to an infinite number of body scans and based on the individual templates, can be applied at the optimal level of stylization required to maximize the appeal of these body scans. The rest of the process is fully automated. Based on the results presented in this paper, the proposed system can increase appeal ratings by approximately 34% depending on the actor.

We conducted multiple experiments in which participants were asked to rate the appeal of different avatars. Our results demonstrate that some stylization (approximately 37%) is perceived as most appealing on average for our female actors. This suggests that 3D body scans can be made to look more appealing with some type/level of stylization. Finally, when we asked our participants to interactively create the most appealing and repelling avatars from 3D body scans, we found again that a partially stylized avatar is the most appealing at approximately 41%. In contrast, when considering the percent of stylization people used to create repelling avatars, we found that 82% of the chosen avatars were made to be either 100% stylized or the original body scans themselves and that a highly stylized avatar was most often chosen as the most repelling avatar.

Our results show that partially stylized female 3D body scans are perceived as most appealing as compared to the original and fully stylized body scans.

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