

How to Enhance Realistic Avatars

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Aim

This supplement describes an approach that can be used to create an “enhanced” avatar based on a) a *realistic*, current avatar (R) and b) an *idealised*, desired future avatar (I) of a user. The aim of the approach is to create avatars that reflect “enhancements” of the realistic avatar along a realistic trajectory. The realistic avatar is used as a starting point, and the idealised avatar as a “goal”.

We used the approach to create two enhanced avatars. The first enhanced avatar (E1) represents the player after one month assuming they led a healthy lifestyle and completed regular exercise according to their exercise goals. Similarly, the second enhanced avatar (E6) represents the player after 6 months on the same trajectory. The images below are examples of realistic, enhanced and idealised avatars:



Exercise Goals

Body shape changes depend on the exercise programme performed, which in turn is typically created based on exercise goals. Therefore we elicited each participant's exercise goals through a questionnaire and when talking to them during the design of their idealistic avatar. The following questionnaire was used:

1. What are your short term exercise goals? Check all that apply.

- Increase Strength
- Lose Weight
- Increase Balance
- Increase Flexibility
- Other: _____

2. What are your long term exercise goals? Check all that apply.

- Increase Strength
- Lose Weight
- Increase Balance
- Increase Flexibility
- Other: _____

3. What forms of exercise do you currently do? Check all that apply.

- Aerobic
- Strength
- Balance
- Flexibility
- Other: _____

4. If you do not currently exercise why not? Check all that apply.

- Lack of motivation
- Lack of time
- Cost
- Other: _____

5. How important is gaining muscle mass to you? Mark only one box.

1 2 3 4 5 6 7

Not Important at all Very Important

6. How important is body toning to you, i.e. leanness of the body, noticeable muscle definition and shape, but not significant muscle size? Mark only one box.

1 2 3 4 5 6 7

Not Important at all Very Important

7. How important is losing weight to you? Mark only one box.

1 2 3 4 5 6 7

Not Important at all Very Important

8. How close are you to your end exercise goal, in terms of your view of your physical attributes? Mark only one box.

1 2 3 4 5 6 7

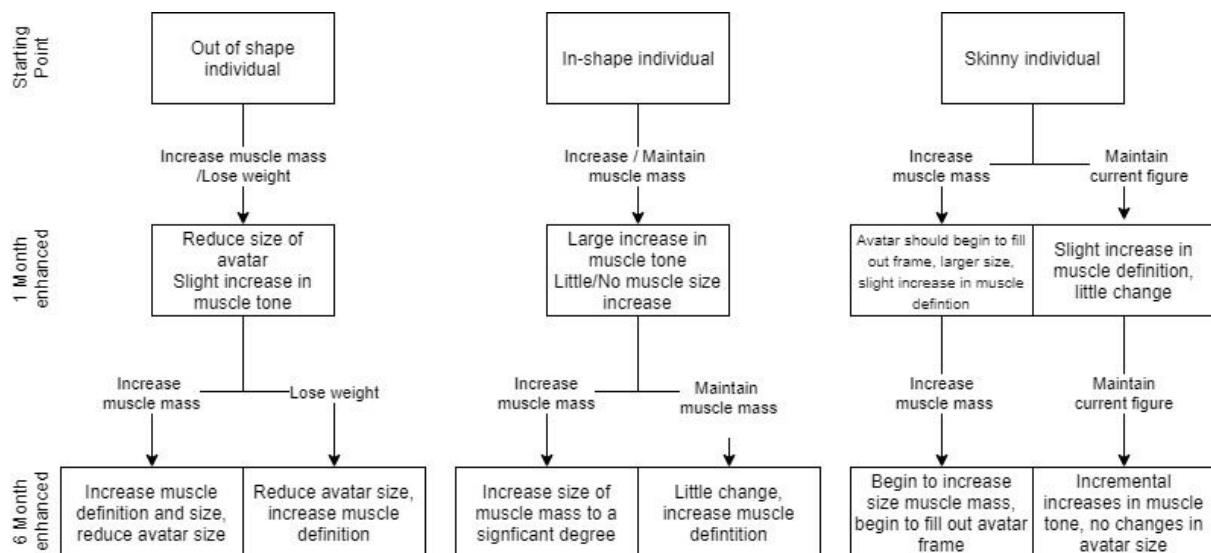
Not close at all Very close

Any further comments on your exercise goals?

Additionally, we measured a participant's body height, body weight, and body composition (percentages of muscle and body fat, using a scale with body analyser). We also calculated the participant's BMI. Based on these measurements, the idealised avatar, and the questionnaire results (especially questions 5, 6 and 7), we determined whether a participant wanted to lose weight, and whether she wanted to gain muscle or maintain her current muscle mass. If the participant wanted to gain muscle mass, we determined where the muscle mass should primarily be gained, mainly by consulting the idealised avatar, i.e. in the upper body, the lower body, or a combination of both. If the exercise goals were unclear or ambiguous, we discussed and confirmed them directly with the participant.

General Body Changes

In order to keep the adaptations realistic and consistent across participants, they were guided by a simple decision tree. The tree considers the current general body shape of a participant based on their BMI as a starting point, and then their exercise goals in broad categories, as described above. The decision tree determines roughly which changes need to be applied to a participant's avatar to reflect the effects of 1 month and 6 months of healthy diet and exercise according to the exercise goals:



For example, in month 1 (avatar E1), an underweight (“skinny”) or healthy weight (“in-shape”) participant would mainly develop increased muscle tone, and an overweight participant would mainly lose body fat. By month 6 (avatar E6), visible changes would diverge more depending on the exercise goals, with muscles becoming more defined or increasing in mass.

Weight Loss

In order to determine how much body weight could change for participants with weight loss goals, we considered the following studies:

- Williamson et al. [134] observed a weight loss per week through diet of 0.6 kg for men and 0.5 kg for women.
- Rosenkilde et al. [102] observed a weight loss per week through exercise of about 0.3 kg, depending on intensity of exercise.
- Stiegler & Cunliffe [117] provide an overview of studies combining diet and exercise, with an approximate body weight loss per week of 1%.

Based on these studies, we assumed that weight loss would occur through both diet and exercise and calculated that participants with weight loss goals would be able to lose about 1% of their initial body weight per week, up to a safe maximum of 0.7 kg per week, down to their minimum healthy weight as recommended by the UK National Health Service (NHS) (<https://www.nhs.uk/live-well/healthy-weight/height-weight-chart/>).

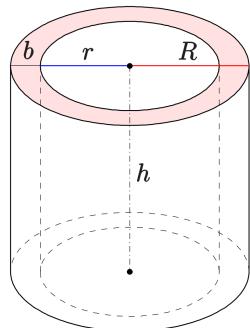
Muscle Gain

In order to estimate how much participants with muscle gain goals could increase their musculature, we considered studies about muscle growth [78,109,111,116], which typically measure changes in a muscle’s cross-sectional area (CSA). From the related works we estimate that resistance training can increase muscle size by about 6% per month, with similar changes for both men and women in the first two months for untrained individuals. After two months of training, and for trained individuals right from the start, women have a reduced muscle growth of an estimated 3% per month due to hormonal differences. These numbers give an indication of how much muscles can be enlarged in the enhanced avatars, but in order to achieve a realistic outcome, two factors need to be considered:

Muscle Gain vs. Fat Loss: Muscles are covered by fat, therefore for individuals with weight loss goals, muscle growth is less (or even not at all) visible as long as a participant is overweight or obese (see NHS healthy weight chart in link above). Muscles become visible with increased definition when a participant is closer to a “healthy” weight or underweight. For participants with weight loss goals, muscle gain is often visually compensated for by loss of fat around the muscle. Therefore, we increased the muscle size of an avatar only markedly when the projected body weight was close to a “healthy” weight.

Muscle Diameter: It may not be immediately obvious how a growth in muscle mass relates to a growth in a muscle’s thickness, i.e. the “bulge” of the muscle in the avatar model. Assuming a simple cylindrical model of the muscle with a constant length, as shown below, a 6% growth in muscle mass corresponds approximately to a 6% increase in its diameter d or

thickness. Similarly, a 3% increase in muscle mass corresponds approximately to a 3% increase in its diameter.

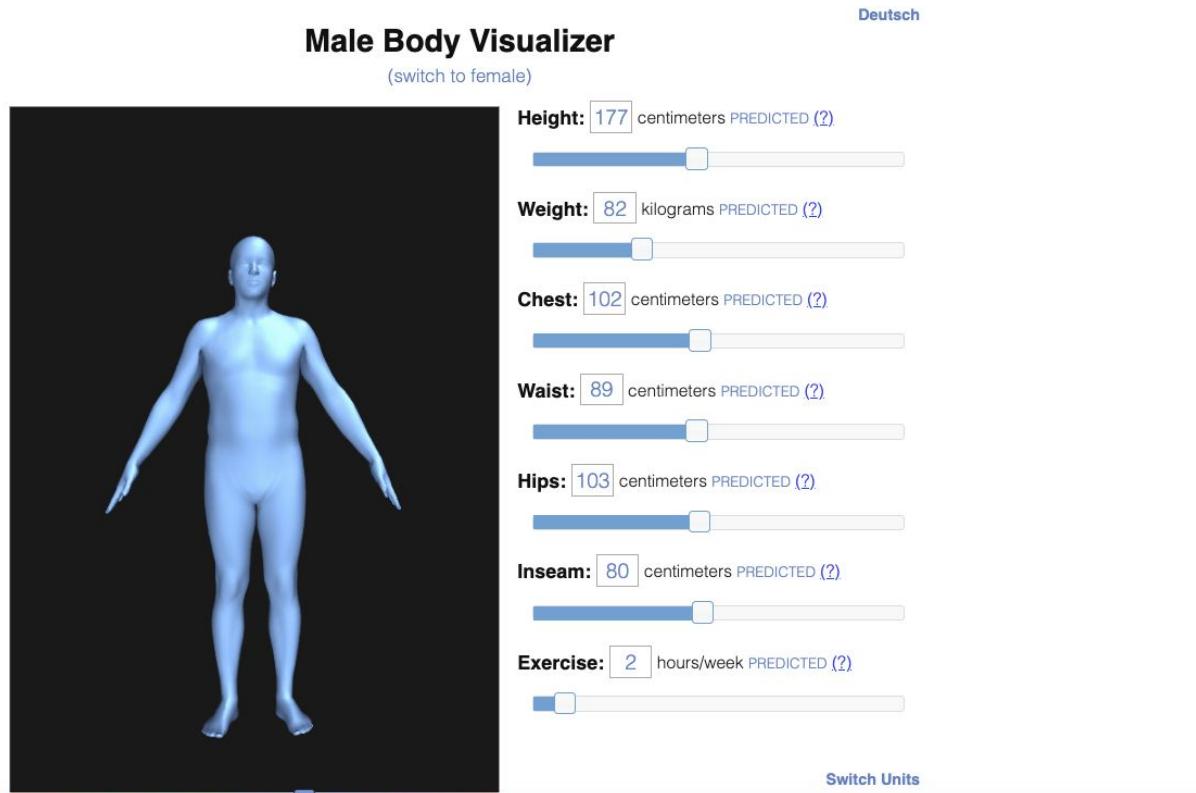


$$V = \pi r^2 h \quad d = 2r$$

Image (CC) by Wikipedia user Ag2gaeh

Overall Body Shape

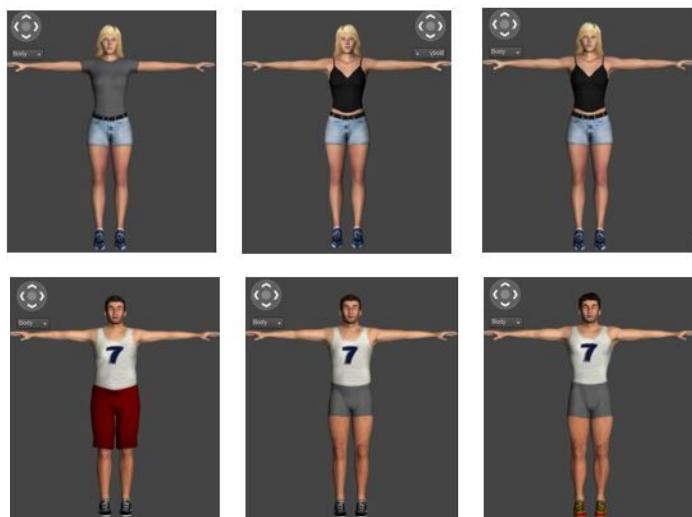
We used a participant's realistic avatar as a basis for her enhanced avatars. We retained the key facial features of the realistic avatar in order to maintain realism and a high level of similarity identification. After calculating expected weight loss, as described above, we visualised how much the overall body shape of the participant would typically change. In order to enhance the avatar in a realistic manner, we used a body visualiser (<http://bodyvisualizer.com/>) to illustrate the overall projected body shape of the participant, based on the participant's body height and predicted body weight, as shown below:



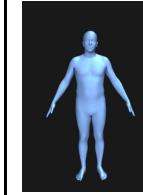
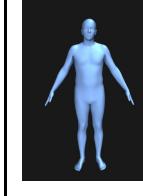
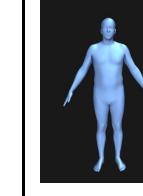
Besides gender, height and weight, the body visualiser allowed us to adjust other body measurements such as chest, waist and hip circumference and inseam length. These body measurements are automatically estimated with default values, and we adjusted them only if there was a mismatch with the general body shape of the realistic avatar. For example, we adjusted the inseam so the length of the legs matched that of the participant. The body visualiser also has a setting for exercise hours per week. We adjusted this setting first of all to visually match the physique of the realistic avatar, considering also how many hours per week the participant reported as their typical exercise routine. The setting allowed us to get a first impression of the expected changes in muscle definition for enhanced avatars. For the 1-month enhanced avatar (E1) we generally increased this setting by 3 hours per week, and then again by 3 hours per week for the 6-month enhanced avatar, to get a first idea of how the body could change during that time. Note that the setting does not add much muscle, but mainly increases the definition of the musculature, so muscle still needs to be added manually for participants with muscle gain goals. For reference, we have added tables illustrating typical changes in body shape at the end of this document.

Enhanced Avatar Modelling

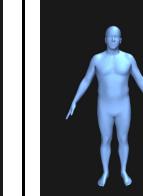
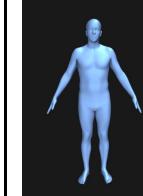
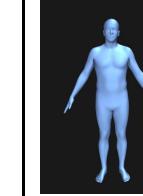
Finally, we duplicated the realistic avatar as a basis for the enhanced avatars and edited it using the Autodesk Character Generator software. As a first step, we changed the avatar to match the overall body shape generated by the body visualiser, as described above. We also dressed the avatar in the clothes of the idealised avatar, to illustrate the fact that the avatar was “enhanced”. Then, we considered the participant’s exercise goals, as described above, and their ideal body shape as shown in the idealistic avatar, to identify the detailed changes related to muscle definition and growth. For example, we considered whether a participant wanted to grow muscle mass mainly in the upper body, the lower body, a combination of both, or specific muscles such as shoulders or biceps in particular. We then calculated realistic changes in muscle mass for the affected muscles, as described above, and changed the diameter/thickness of the muscles accordingly. For example, the top row of images below shows the avatar progression of a low-BMI female avatar with a goal of increased muscle definition, from realistic to 1-month enhanced and 6-month enhanced. The bottom row shows a high-BMI male avatar with weight loss and muscle gain goals.



Male body shape visualization with 0 hours exercise per week

Height					
176.78 cm					
182.88 cm					
Weight	63.50 kg	69.85 kg	76.20 kg	82.55 kg	88.90 kg

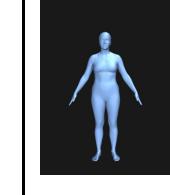
Male body shape visualization with 6 hours of exercise per week

Height					
176.78 cm					
182.88 cm					
Weight	63.50 kg	69.85 kg	76.20 kg	82.55 kg	88.90 kg

Female body shape visualization with 0 hours exercise per week

Height					
167.64 cm					
170.68 cm					
Weight	53.97 kg	57.15 kg	60.32 kg	63.50 kg	66.67 kg

Female body shape visualization with 6 hours exercise per week

Height					
167.64 cm					
170.68 cm					
Weight	53.97 kg	57.15 kg	60.32 kg	63.50 kg	66.67 kg