Perception of Strength and Power of Realistic Male Characters

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Figure 1: *Weak and strong characters computed from our first experiment (from left to right) in an A-Pose (used in Experiment 1), in a standing low-power pose, and in a standing high-power pose (both used in Experiment 2).*

Abstract

We investigated the influence of body shape and pose on the perception of physical strength and social power for male virtual characters. In the first experiment, participants judged the physical strength of varying body shapes, derived from a statistical 3D body model. Based on these ratings, we determined three body shapes (*weak*, *average*, and *strong*) and animated them with a set of power poses for the second experiment. Participants rated how strong or powerful they perceived virtual characters of varying body shapes that were displayed in different poses. Our results show that perception of physical strength was mainly driven by the shape of the body. However, the social attribute of power was influenced by an interaction between pose and shape. Specifically, the effect of pose on power ratings was greater for weak body shapes. These results demonstrate that a character with a weak shape can be perceived as more powerful when in a high-power pose.

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1 Introduction

Perception of virtual characters (both static and in motion) is a very important multi-disciplinary (e.g., computer graphics, social psychology, neuroscience) research area. For computer graphics applications and animations, it is important to consider how observers perceive human characters. As a designer of human characters, it is important to understand how changes in appearance and motion influence the desired perceived attributes of the character [McDonnell 2012; McDonnell et al. 2009; Hoyet et al. 2010; Kiiski et al. 2013]. Our motivation is to gain a greater understanding of the perception of human characters with regard to perceptual attributes when both shape and motion are altered in a systematic way. We are specifically interested in the perception of two attributes: *strength* and *power*. Their meanings are related to each other but focus either on a physical or a social component.

Previous research has demonstrated that multiple aspects of a person can be judged from viewing either just the person's body shape or just their motion, without an associated shape. For example, a real world study shows that tall women are rated as more intelligent and ambitious than short ones [Chu and Geary 2005]. A point-light display, which represents a moving person only through white dots that are connected to the major joints of the body, contains enough information for observers to recognize the gender of a recorded walker [Kozlowski and Cutting 1977], to identify own motion or that of a friend [Cutting and Kozlowski 1977], and to estimate personality traits like vulnerability [Gunns et al. 2002]. Previous research has also investigated how people assess potential fighting ability [Sell et al. 2009]. Here, participants from various cultures judged the physical strength from viewing pictures of men's bodies and faces. Their results suggest that strength judgments were largely determined by upper body strength, and were independent of height, weight, and age.

A separate area of research investigated the relationship between perceived power and body pose. Open postures have been known

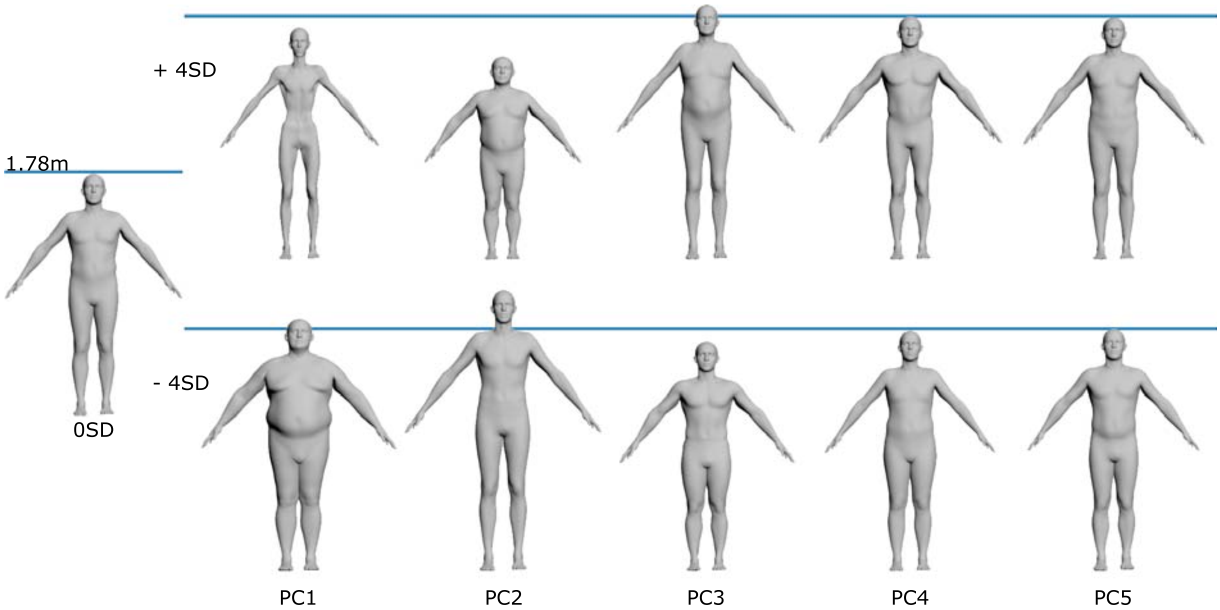

Figure 2: *The first five PCs of the statistical 3D body model in the space of body shape deformation, from left to right: average male shape with all PC values set to 0; first 5 PCs with PC value set to +4 SD (top) and -4 SD (bottom).*

to reflect high social power, as has already been observed in human and non-human primate movements [Darwin 2009; Carney et al. 2005]. Interestingly recent research suggests that one's body pose does not only reflect social status with regard to power, but can also influence how powerful humans believe themselves to be. Carney et al. [2010] show that people who are posing in expansive, open postures (Fig. 1 right) have increased feelings of power, as well as an increased risk-taking behavior and testosterone level. In contrast, contractive and closed postures (Fig. 1 middle) result in the opposite: people feel less powerful. Behaviour changes when people perform power poses and, as a result, their performance in a subsequent job interview increases [Cuddy et al. 2015].

Previous interpretations [Carney et al. 2010] have suggested that people feel more powerful when performing these poses because of physiological changes (i.e., testosterone and cortisol levels). Another possibility could be that while performing a specific pose, people imagine how they look to others and have the impression that they appear more powerful. However, an open question remains whether seeing a person of any shape in a high-power pose also leads to thinking of this person as more powerful. Therefore, the following questions were investigated in this study: Are bodies placed in different poses perceived as more powerful? If so, how does this relate to the shape of one's body, and the related factor of perceived strength?

We investigated the relative contributions of shape and pose on the perception of *physical strength* and *social power* of male bodies. This study consists of two experiments where the second builds upon the first. In the first experiment, we investigated how participants perceived physical strength of various body shapes in the same pose. Results allowed the identification of an example for a weak and a strong body shape. In the second experiment those identified shapes (*weak*, *average*, and *strong*) were animated with high-power and low-power poses from [Cuddy et al. 2012] and subsequently rated in terms of the perceived physical strength and social power.

2 Experiment 1: Identification of strong and weak body shapes

The goal of this experiment was to determine the shape of bodies that people perceive to be physically strong or weak. Participants were asked to perform two tasks: First they had to conduct a *rating task* in which they were asked to report how strong or weak a selection of realistic body shapes appeared. Next they were asked to interactively adjust 3D body shapes using on-screen sliders to show maximal strength or weakness. This *method of adjustment* task was done, in addition to the rating task, to allow participants to continuously adjust body shapes and provide a more precise estimate of a weak and a strong body shape rather than being constrained to the fixed intervals of the first task.

We originally ran these tasks with two motivations: The rating task allowed us to compute a regression between rated strength and the parameters of the statistical body model we used. The goal of this equation is to be able to take any given body, compute it's body model parameters, and then estimate how strong it might be perceived. The method of adjustment task on the other hand should give us examples of what the average person perceives as very strong and weak.

2.1 Method

2.1.1 Participants

We recruited 17 participants (9 male) from the local community. Average age was 31.41 years ($SD = 9.23$). The participants were financially compensated for their time. Informed consent was given according to the declaration of Helsinki.

2.1.2 Visual Stimuli

The experiment was developed with the game engine Unity 3D v4 [Unity 2014] and presented on a Dell U2412M monitor which was oriented in portrait mode so that it was 1200px wide and 1920px high. Participants viewed the stimuli from a distance of approximately 60 cm.

To generate different realistic body shapes we used a statistical 3D model [Hirshberg et al. 2012; Anguelov et al. 2005]. The model is based on approximately 1700 body scans of men from the US and EU CAESAR dataset [Robinette et al. 2002] in an upright pose. A template mesh was automatically aligned to all scans, putting them in correspondence. For each scan, shape is then represented by 3×3 matrices describing the triangle deformations from the template. To construct a model of body shape, the aligned meshes were normalized to the same pose. The mean deformations were computed and subtracted from all meshes. Principal component analysis (PCA) was then applied to construct a low-dimensional subspace of deformations. Body shapes were then approximated as a linear combination of basis shapes (principal components) plus the mean. For this experiment only the first five principal components (PC) of the model were used as a reduced PC space because of the combinatorial explosion, explaining 57.76% of the variance in male body shapes from our sample, see Fig. 2. Note that each change of a PC leads to changes in different parts of the body shape, but can not be explained by specific semantic attributes. For the rating task we created various different bodies: For all five PCs three standard deviation (SD) values (*PC values*) were used: -2, 0, +2 SD. In addition, for the first three PCs two more PC-values ($\pm$ 4 SD) were used to cover a wider range of realistic body shapes. Body shapes of all possible SD combinations were generated, producing a total of 341 ($3^5 + 5^3$, removing duplicates) body shapes (for the rating task). All bodies were rendered in a plain grey color in order to focus attention on the shape of bodies. In the method of adjustment task all participants had the opportunity to adjust all five PCs between the values $\pm$ 4 SD.

The PC space was combined in a morphable mesh in Autodesk 3ds Max 2014 [Autodesk 2014] and then exported in FBX format to the experimental Unity program which generated the 341 body shapes. The characters were placed on a tiled floor to improve the perspective visual focus, and were rotated 45° to their left, as shown in Fig. 3. The camera was placed at a distance of 4m and a height of 1.6m, rotated 10° downwards. Body shapes were shown in random order.

2.1.3 Experimental Design & Procedure

Participants read instructions and a definition of strength displayed on-screen. Definition for strength was provided either in English or German, and repeated after every 70 trials as a reminder.

(1) Very weak:
A person appears to lack in bodily strength and has little ability.

(4) Average strength:
The person appears to have average strength and ability.

(7) Very strong:
A person appears to be able to exert great physical power and ability.

Participants had the opportunity to ask questions before and during the experiment. For each trial the body shape was shown on-screen and the following question was asked: "How strong is this person?". First, participants rated the displayed body shapes by clicking on an on-screen button of a 7-point Likert scale, ranging from *very weak* (1) to *very strong* (7) (Fig. 3 left). Upon response the character disappeared for one second before the next trial started.

The *rating task* started with a familiarization phase, to acquaint participants with the range of body shapes. Seventeen body shapes were displayed, these included the average body shape (all PC values set to 0) and the extreme body shapes (each PC value set to $\pm$ 2 SD on isolation; PC1, 2, 3 were also set to $\pm$ 4 SD). Afterwards there were 341 experimental trials as described earlier where many possible body shapes were sampled from possible male body shapes based on varying the individual PCs by $\pm$ 2 and $\pm$ 4 SD from the average body. All trials of the familiarization phase were shown again in the experimental trials.

In the *method of adjustment* task there were two tasks to be completed by the participants: 1) adjust the body to appear as strong as possible, and 2) adjust the body to appear as weak as possible. The participants had five on-screen sliders, associated with each of the first 5 PCs, with which they could interactively change the body shape of the character (see Fig. 3 right). Each trial started with the average body shape and participants had as much time as they needed to adjust the body shape with the sliders.

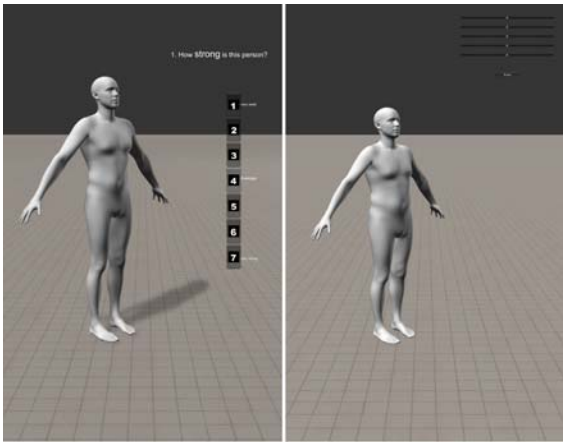

Figure 3: *Rating task (left) and method of adjustment task (right) with the sliders in the top right corner.*

2.2 Results of Experiment 1

Due to a technical error each participant rated only 331 different body shapes instead of the intended 341. Because of the randomized order of the trials each of the 341 body shapes was rated by at least 13 participants. We then regressed ratings of strength onto each PC, including higher order terms, and interactions among terms. To simplify the equation, the interaction effects were included only if they had a significant impact on the result. We scaled the independent variable (PCs 1-5) such that 1 unit change corresponds to 2 SDs.

With the following equation it is possible to calculate an estimate of the perceived strength of a given body from the values for the first five principal components in PC body space:

$$\text{Strength} = 4.42 - 0.28P_1 - 0.33P_2 - 0.42P_3 + 0.18P_4 - 0.17P_5 - 0.34P_1^2 + 0.18P_1P_2 - 0.04P_2P_3 - 0.09P_3P_4 + 0.04P_1^2P_2 + 0.03P_1^2P_3 - 0.04P_1P_2P_3 - 0.06P_1P_2P_5$$

where $P_{1...5}$ are the principal components 1–5 divided by 2.

The selection of the weakest and strongest body shape can be done through either strength ratings (Task 1) or the method of adjustment task (Task 2).

For task 1, the average scores were calculated, and then the two body shapes that received the lowest or the highest rating on average for all body shapes were chosen. The weak mesh (Fig. 4 left) was

	PC1	PC2	PC3	PC4	PC5	Strength ratings based on regression
Weak body shape	$M = 3.01$, $SD = 2.65$	$M = 1.99$, $SD = 2.93$	$M = 2.14$, $SD = 2.61$	$M = -2.04$, $SD = 2.98$	$M = 1.07$, $SD = 3.56$	2.56 points
Strong body shape	$M = -.51$, $SD = 1.28$	$M = -3.38$, $SD = 1.58$	$M = -1.10$, $SD = 2.06$	$M = 2.96$, $SD = 1.86$	$M = -1.39$, $SD = 2.94$	5.78 points

Table 1: *Descriptive statistics for each PC value of the weak and strong body shape on a scale from ± 4 SD as determined through the method of adjustment. See Fig. 5 for pictures of weak and strong character.*

rated with an average of 1.47 points and the strong mesh (Fig. 4 right) was rated with an average of 6.0 points. These results lead to an unnatural appearance for the weak character. We suggest that this outcome is based on the fixed intervals of ± 2 SD, which were chosen for the rating task. Smaller intervals might have resulted in natural characters but this would have also lead to a combinatorial explosion.

The method of adjustment task resulted in a weak character consistent with the rating task, but one that appeared more healthy and natural. The adjustments for strong and weak characters were averaged over all participants. The values for each PC, and the predicted strength rating based on the equation are presented in Table 1. For each PC, values range between ± 4 SD. The combinations of the PC values result in a weak and a strong body shape, shown in Fig. 5. We found no effect of the participant's gender on these results.

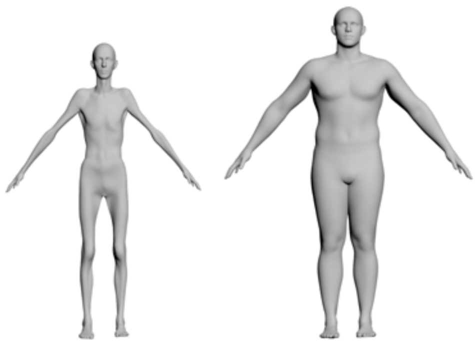

Figure 4: *Weak and strong characters, resulting from the strength ratings from Experiment 1. PC values for weak character: PCs 1 - 5:* 4, 0, 4, 0, 0*. PC values for strong character: PCs 1-5:* -2, -4, -4, 0, 0.

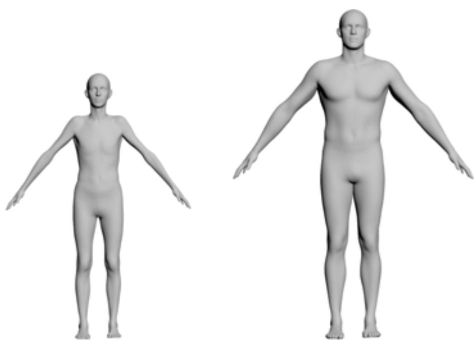

Figure 5: *Weak and strong characters, resulting from the method of adjustment task from Experiment 1. See Table 1 for PC values.*

A repeated measures analysis of variance (ANOVA) was performed with shape (weak, strong) and PC space (1-5) as within-subjects factors to test whether the shape of these bodies significantly differed from each other. As hypothesized, the strong body was significantly different from the weak body, $F(1, 16) = 15.306, p = .001$, see Fig. 6. Across the PC space, participants adjusted body shapes differently depending on whether their task was to create a weak or strong body. This demonstrates that people were able to discriminate strength based on body shape.

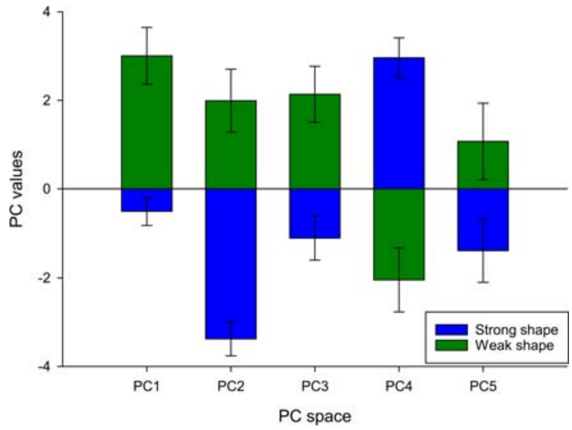

Figure 6: *PC values for each shape (strong and weak), averaged over all participants. Error bars indicate one standard error of the mean.*

We also analysed the variability in ratings as a function of weak vs. strong and PC. We conducted this analysis in order to determine whether, across participants, ratings of weak characters were more or less consistent than ratings of strong characters. Was there a common definition of weak and strong? Variability was calculated by taking the absolute difference between ratings and average rating on each PC. A repeated measures ANOVA was conducted with shape (weak, strong) and PC space (1-5) with all factors as within-subjects. There was a main effect of shape, $F(1, 16) = 43.94, p < .001, \eta_p^2 = .73$, such that there was more variability when rating weak characters, suggesting that there may be a wider definition of what defines weakness, see Fig. 7. There was also a main effect of PC, $F(4, 64) = 5.70, p = .001, \eta_p^2 = .263$, which shows that variability increased with PC, and the variability in ratings was significantly different for the first 4 PCs, but not the fifth, $F(1, 16) = 3.950, p = .064$, suggesting that the fifth PC was not relevant to our task of generating a strong or weak character.

We used the strong and weak body shapes constructed from the *method of adjustment* task to create the characters used in the second experiment. Additionally, we used the average body shape (all PC values set to 0) from the 3D body shape model as a neutral condition.

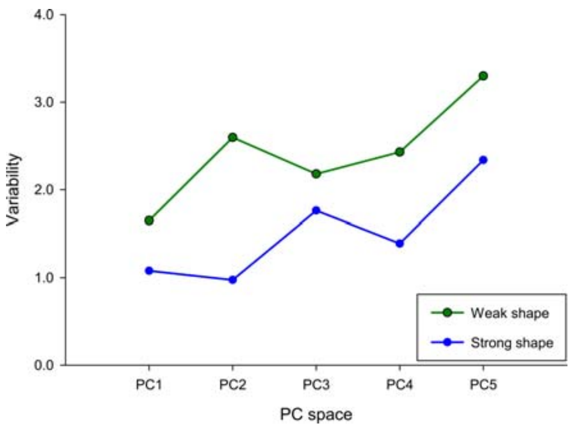

Figure 7: *PC value variability for each shape, averaged over all participants.*

3 Experiment 2: Influence of shape and pose on strength and power ratings

The goal of Experiment 2 was to determine whether perceived strength and power of an actor is determined more by the shape of the body or by the pose in which the body is displayed.

We hypothesized that ratings of strength would be positively correlated with strong body shapes and that ratings of power would be correlated with powerful poses.The more interesting question here motivated by previous research [Cuddy et al. 2015] is the question of how powerful poses interact with body shapes. Can powerful poses make a weak body shape appear more powerful and, if so, to what degree? If there is a dependency between powerful poses and body shape this will be revealed as a significant interaction.

3.1 Method

3.1.1 Participants

The data of three participants (1 Male) was excluded because they used only three points on the Likert scale (1, 4, or 7). In the end strength ratings were obtained from 16 participants (7 male) with an average age of 28.94 years ($SD = 8.67$). Power ratings were obtained from 20 participants (8 male) with an average age of 27.55 years ($SD = 5.48$). None of the participants took part in Experiment 1.

Strength was defined as in the first experiment. Power was defined as following:

(1) Very low power:
You find the person extremely powerless. This may include that the person is in an inferior position and does not have the ability to control or influence others.

(4) Average power:
You neither find the person powerful nor powerless. They are acceptable but essentially you are indifferent, finding them neither dominant nor inferior.

(7) Very high power:
You find the person extremely powerful. This may include finding the person dominant and thinking the person has the ability to control or influence others.

3.1.2 Recording of Pose Animations

The technical setup was the same as in Experiment 1. Animations were created using the inertial motion capture system MVN BIOMECH from Xsens [Xsens 2014].

We chose two high-power, two low-power, and two neutral pose animations. For each category there was one sitting and one standing posture, see Fig. 8. The power poses were motivated by [Cuddy et al. 2012] and one high-power pose was adjusted according to [Cuddy 2012]. Each pose animation started in a neutral stance, then the actor moved into a high-power or low-power pose.

A male actor performed each pose multiple times with a real-time motion display. Small retargeting problems were corrected on the fly by asking the actor to adjust his limb positions. This way no time-consuming post-processing was necessary. The best pose animation of each recorded motion was used for stimuli generation. Frame rate for recording was 120 frames per second, playback was at 60 frames per second.

3.1.3 Visual Stimuli

The recorded pose animations were edited into small motion segments with a length of approximately 7.6 seconds. The neutral pose in the beginning of the animation was shown for at least 0.83 seconds and the power pose in the end was shown for at least 4.17 seconds. To represent these motions on the three characters, we used the auto-rigging online service Mixamo [Mixamo 2014] to calculate skinning weights and place animation structures (bones) into the different body shapes. This assured that all bodies were rigged with the same procedure and quality.

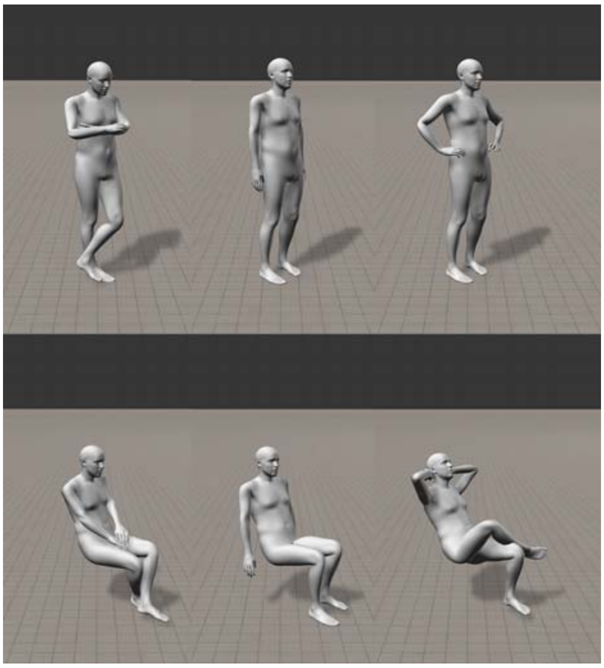

Figure 8: *From left to right: Average shaped character in low-power, neutral and high-power poses (top: standing posture, bottom: sitting posture).*

3.1.4 Experimental Design & Procedure

The experimental procedure was the same as in Experiment 1 (section 2.1.3). However, participants in Experiment 2 additionally rated characters based on their social power. Based on this factor participants saw one definition in the beginning of the experiment (for definitions see section 2.1.3 and 3.1.1).

The three body shapes (*weak*, *average* and *strong*) calculated from the first experiment were animated each with six animation segments. These 18 trials were shown once as a practice block and two additional blocks, trials were randomized within the block, resulting in 36 trials. A full set of stimuli was used as a practice block so that participants experienced the full range of possible shapes. Before the experiment, participants were told that the characters could be sitting or standing.

During each trial the animated character was shown and afterwards one of the following questions appeared: "How strong is this person?" or "How powerful is this person?". Seven buttons (representing the Likert scale) appeared on screen for response. After each response the character disappeared for one second before the next trial started.

As in the first experiment, the rating task was followed by a *method of adjustment* task. For participants who were asked to rate strength the task was identical to the first experiment. Participants who rated power were asked to first generate a body that looked as powerful as possible, and second as powerless as possible. The method of adjustment task was repeated in the second experiment to confirm that participants in the current experiment rated the strength of bodies consistently with participants in Experiment 1, and to investigate if the shape of very strong and very powerful bodies were similar.

3.2 Results of Experiment 2

3.2.1 Physical attribute: Strength

Results of the method of adjustment tasks in Experiment 1 and 2 were consistent, $F(1, 31) = .004, p = .950, \eta_p^2 = .00$, showing that participants of both groups had the same understanding of weak and strong body shapes.

A repeated measures ANOVA was performed with posture (sitting, standing), power pose (low-power, neutral, high-power), shape (weak, average, strong), and block (first, second) with all factors as within-subjects.

As hypothesized, the ANOVA revealed that shape had a main effect on perception of strength on male virtual characters, $F(2, 30) = 61.83, p < .001, \eta_p^2 = .81$. The direction of the effect confirmed findings from Experiment 1 where strong shapes ($M = 5.19, SE = .14$) were rated as being stronger than neutral ($M = 4.31, SE = .15$) and weak body shapes ($M = 2.37, SE = .25$), see Fig. 9. All other main effects were non-significant.

However, there was a significant interaction between posture and block, $F(1, 15) = 5.98, p = .027, \eta_p^2 = .29$. Planned-comparisions revealed that there was a trend towards significance, that sitting postures ($M = 3.90, SE = .139$) were rated as less strong than standing postures ($M = 4.05, SE = .121$) but only in the first block, $F(1, 15) = 3.55, p = .08$.

There was also a trend towards significant interaction between posture and power pose, $F(2, 30) = 3.27, p = .052, \eta_p^2 = .18$. For the low-power pose, the sitting posture was rated significantly weaker than the standing posture ($F(1, 15) = 5.27, p = .037$). In addition, there was a significant effect of power pose for the sitting posture ($F(2, 30) = 3.60, p = .040$), showing that the sitting low-power pose ($M = 3.53, SD = .18$) was rated less strong than the sitting neutral ($M = 4.02, SD = .22$) and high-power ($M = 4.23, SD = .19$) poses.

There is no significant interaction between power pose and shape, $F(4, 60) = 1.31, p = .278$, see Fig. 9, and also the other effects of posture and power pose and two-, three- and four-way interactions between posture, power pose, shape and block were all non-significant (all $ps > .05$).

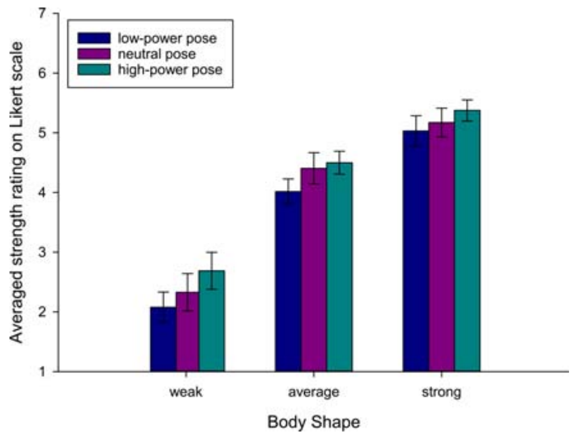

Figure 9: *Strength ratings for each shape in each power pose, averaged over all participants. Error bars indicate one standard error of the mean.*

3.2.2 Social attribute: Power

The same repeated measures ANOVA as in the strength ratings was conducted with power ratings as the dependent measure. The ANOVA revealed that power was rated differently depending on shape ($F(2, 38) = 49.26, p < .001, \eta_p^2 = .72$), power pose ($F(2, 38) = 40.30, p < .001, \eta_p^2 = .68$) and posture ($F(1, 19) = 14.56, p = .001, \eta_p^2 = .43$) of the character. These findings reveal that on average a weak shape ($M = 3.40, SE = .15$) is rated significantly less powerful than a strong shape ($M = 4.77, SE = .11$), a character in a low-power pose ($M = 3.41, SE = .16$) as significantly less powerful than a character in a high-power pose ($M = 5.05, SE = .16$), and a character in a sitting posture ($M = 3.94, SE = .10$) is rated less powerful than when in a standing posture ($M = 4.33, SE = .11$). These results suggest that the social power rating is a complicated construct that is influenced by the shape of one's body, its power pose, and also whether it is standing or sitting.

In addition, there was a significant interaction between posture and power pose, $F(2, 38) = 8.70, p = .001, \eta_p^2 = .31$, see Fig. 10. Similar to strength ratings, characters in the low-power pose were rated as more powerful when standing ($M = 3.93, SE = .25$) compared to sitting ($M = 2.89, SE = .15$), ($F(1, 19) = 17.20, p = .001, \eta_p^2 = .46$). The effect of power pose was significant for both sitting ($F(1.51, 28.62) = 52.95, p = .000, \eta_p^2 = .74$) and standing postures ($F(1.37, 26.03) = 10.01, p = .002, \eta_p^2 = .35$). These results suggest that how powerful a character is perceived is influenced by whether they are standing or sitting, but only when the power pose is a weak or neutral one.

There was also a significant interaction between posture and block ($F(1, 19) = 4.52, p = .047, \eta_p^2 = .19$). The effect of posture was larger in the first block than in the second but sitting was rated as less powerful for both the first ($F(1, 19) = 23.46, p < .001, \eta_p^2 =$

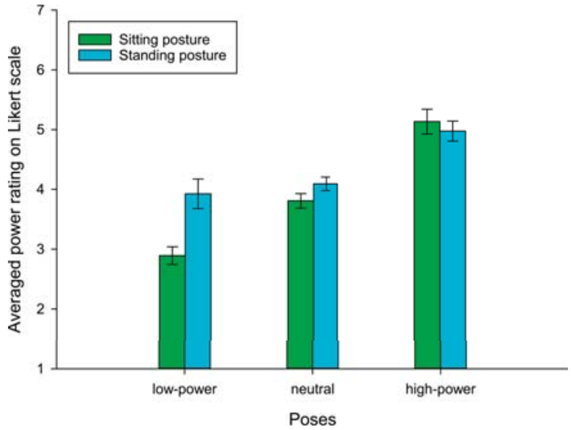

Figure 10: *Power ratings for each power pose in a sitting and standing posture, averaged over all participants. Error bars indicate one standard error of the mean.*

.55) and second blocks ($F(1, 19) = 5.67, p = .028, \eta_p^2 = .23$). Perhaps people applied a heuristic that standing was more powerful than sitting, however this effect diminished over time.

As predicted, there is also a trending interaction between pose and shape ($F(4, 76) = 2.43, p = .055, \eta_p^2 = .11$) see Fig. 11. The effect of power pose was greater for weak body shapes ($\eta_p^2 = .67$) than neutral ($\eta_p^2 = .60$) and stronger shapes ($\eta_p^2 = .63$). Also, the low-power pose has a bigger effect of shape ($\eta_p^2 = .80$) than neutral poses ($\eta_p^2 = .60$) and high-power poses ($\eta_p^2 = .55$). However, it is important to note that there was an effect of power pose for all shapes ($p < .001$) and an effect of shape for all power poses ($p < .001$). These findings suggest that shape and power pose are important factors for perceiving the power of a male character. Also a weak body that lacks of physical strength can be perceived as more powerful when performing power poses. It even goes to such lengths that weak and average body shapes when in powerful poses are sometimes perceived as equally or more powerful than the strong shape. This is indicated by the reference line in Fig. 11.

In the method of adjustment task the generated body shapes

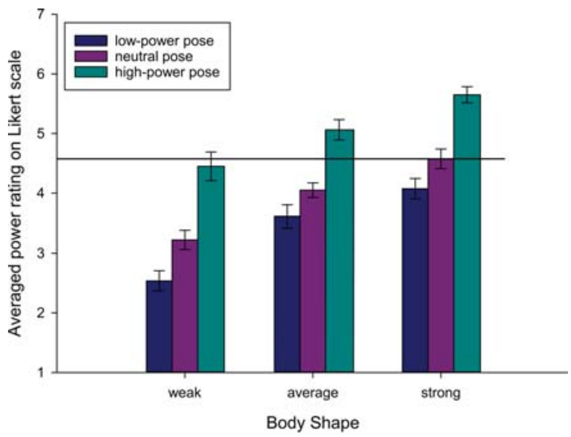

Figure 11: *Power ratings for each shape in each power pose, averaged over all participants. Reference line indicates power rating of a strong shaped body in a neutral pose. Error bars indicate one standard error of the mean.*

for strength and power were consistent, $F(1, 34) = .60, p = .443, \eta_p^2 = .02$, even though their assigned tasks were different. These findings show that participants had a similar understanding of the appearance of very weak and powerless characters, as well as very strong and powerful characters. However, a lack of significant difference could be due to large variability in ratings. When viewing the generated body shapes there are no visible differences for the strong and powerful character – but there are visible differences for the weak and powerless characters (see Fig. 12). Specifically, the powerless character seems to be a bit shorter and thicker than the weak one.

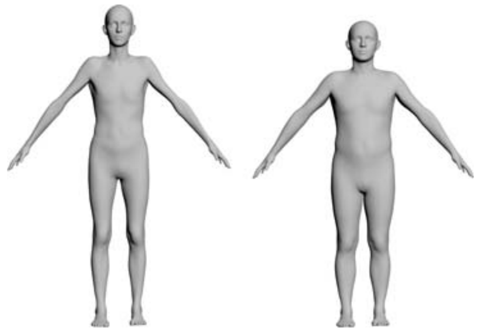

Figure 12: *Weak and powerless characters, resulting from the method of adjustment tasks.*

4 Discussion & Summary

The goal of the current experiments was to determine how different body shapes and poses influence observers' perception of physical strength and social power on male virtual characters. Our results show that perceived strength can be judged from the shape of the body. Also when humans see characters with pose animations, their perception of strength depends mainly on the body shape. This suggests that a physical trait like strength depends mostly on the physical body shape and not on body language or other social components.

Our results indicate that perception of power is influenced by one's body shape and the pose it assumes. Our findings suggest that physically weak characters can be perceived as more powerful when placed in specific poses. Also poses can influence the perception of a strong character to be perceived as less powerful. This is useful for character design because it shows that for designing *strong* virtual characters designers have to focus exclusively on the body shape. For powerful or powerless characters on the other hand it is also important to consider the poses the character performs.

Our results show that power poses may not only influence how the performing person feels after posing powerfully as found by Cuddy et al. [2012], they also make male characters *appear* more powerful to others. Accordingly, it would be possible that people do not have to perform the power poses prior to a job interview to subsequently feel more powerful. It might even be sufficient to only look at a picture of oneself in a high-power pose. This would simplify the realization of Cuddy et al.'s [2012] procedure, but further research is needed to back up this assumption.

Our findings are also interesting for computer graphics applications and animation and the effort to create appealing virtual humans that vary enough from each other to create large crowds in virtual environments [McDonnell 2012; McDonnell et al. 2009]. Others have also looked at the influence of shape and motion on perception of bodies, specifically emotion perception [McDonnell et al. 2009] and task performance perception [Hoyet et al. 2010]. This perceptual research approach to evaluating virtual humans presented in our paper and related research [McDonnell 2012; McDonnell et al. 2009; Hoyet et al. 2010; Kiiski et al. 2013] could help animators to convey convincing animated virtual characters with the attributes, expression, motion motivated by the perception of the audience.

Virtual reality studies have demonstrated that self-avatars with different ages [Hershfield et al. 2011], shapes [Piryankova et al. 2014], and races [Kilteni et al. 2013] alter participants' perception and attitudes. Future work could investigate if self-perception of strength and power can also be influenced by a modified self-avatar. Using a setup with a virtual mirror, participants could see themselves in different body shapes and in different power poses.

In sum we used a human 3D body model to generate realistic male body shapes to investigate how a body shape should appear to be perceived as physically strong or weak. Moreover, we animated the shapes with high-power and low-power poses to find out whether the shape or the poses matter more for our perception of strength and power. We found that ratings of the physical attribute *strength* are mainly based on the body shape of the character. Ratings of the social attribute *power* are also influenced by the pose animation of the character. This suggests that physical and social attributes are perceived differently by observers, and by taking this into account, we might be able to control how a character is perceived by others. Most noteable, if a male weak body is seen in a high-power pose he is perceived to be just as powerful as a strong male body in a neutral pose.

One could speculate a popular message from these results:

If you have a weak body shape and want to be perceived as if you had a strong and powerful body shape you should just stand up and use high-power poses when interacting with others!

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