# Adult2Child: Dynamic Scaling Laws to Create Child-Like Motion

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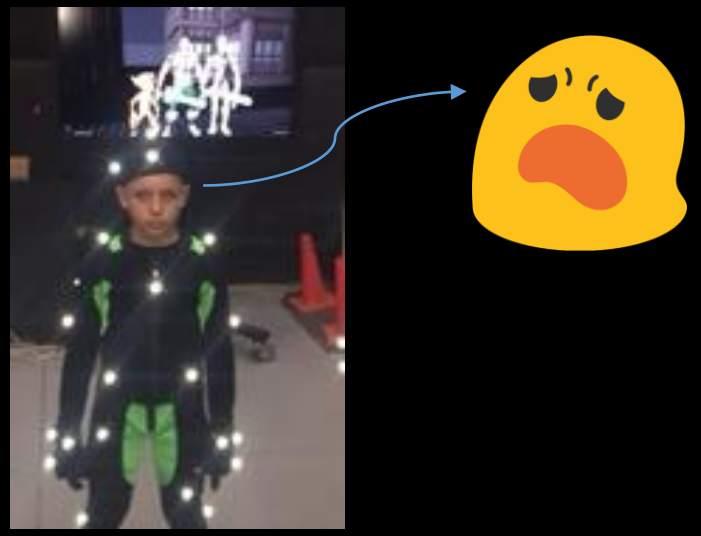
# Motivation

- There is a demand for creating child motion for variety of applications such as games, movies, avatars in online education.

8 years old Clemetine from game “Walking dead”

# Challenge

- However, motion capturing children is difficult.
  - Lack of patience
  - Easily distracted
  - Hard to follow instructions



Fast Motion Studios

- Given the difficulties of motion capturing children, can we just use adult motion capture data instead of child data?

Adult

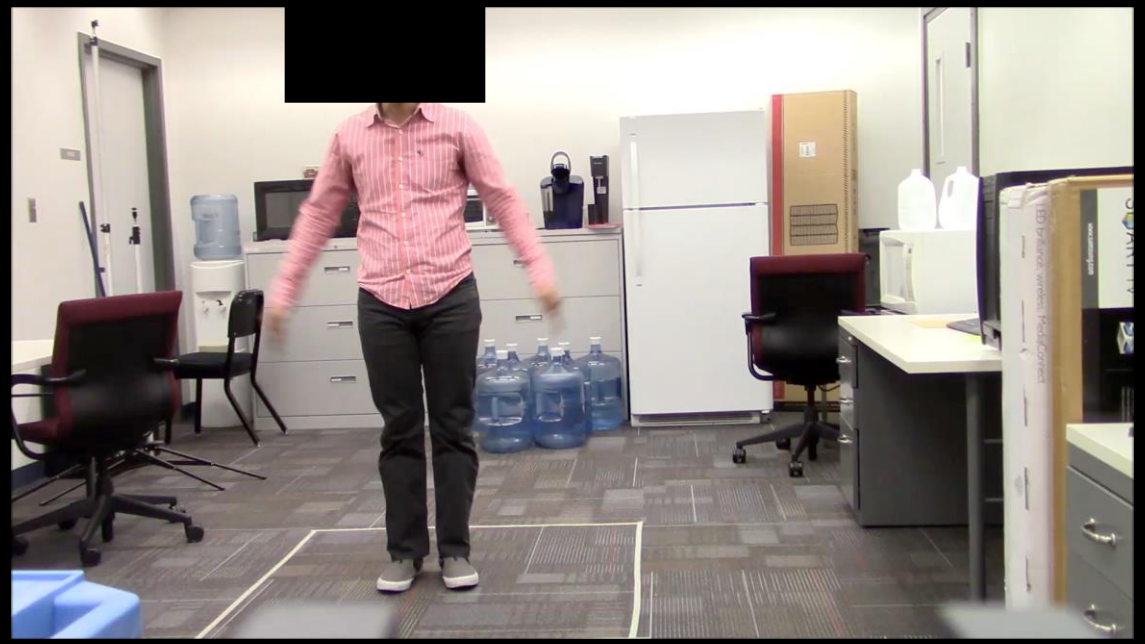
Actor 921

Child

Actor 290

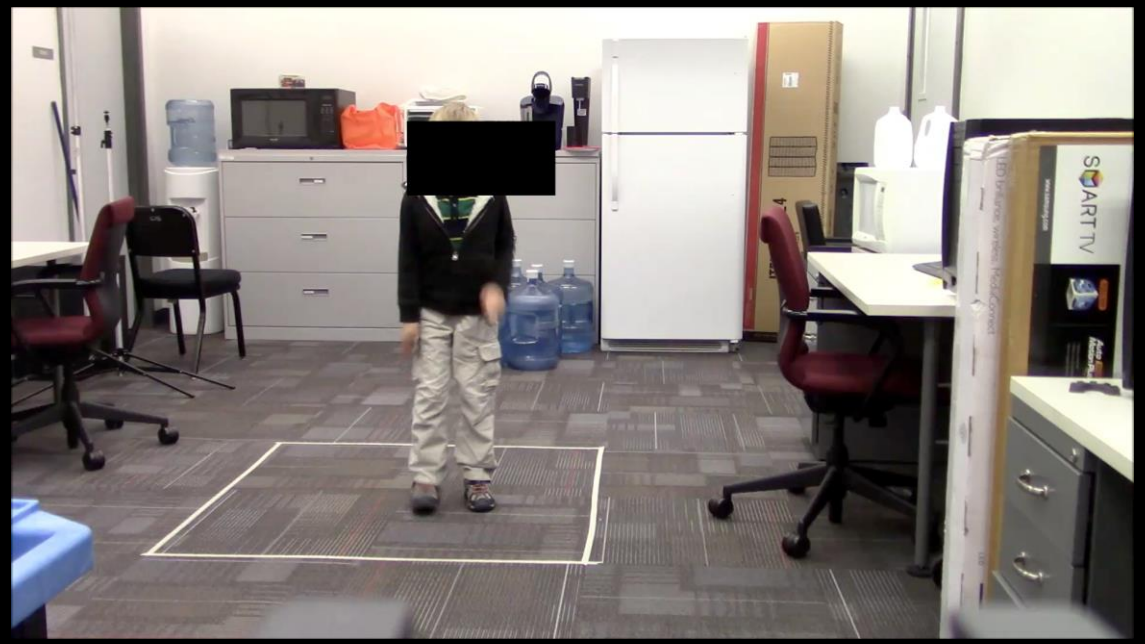
Not really. Jain et al. [ 2016]  showed that viewers could identify if a motion came from a child actor or an adult actor, even without appearance or height information.

Adult



Actor 921

Child



Actor 290

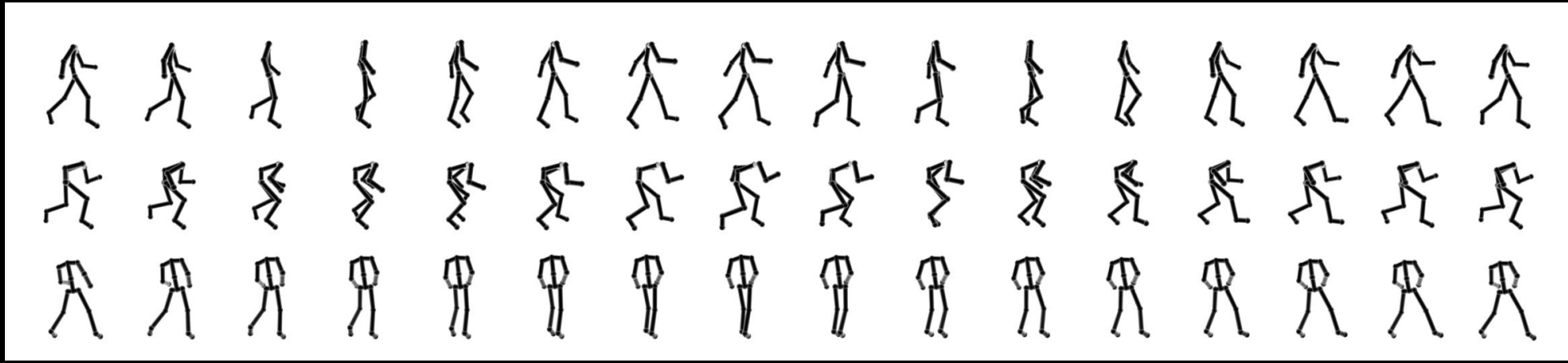
Our work: can we algorithmically modify adult motion data in such a way that it appears child like to a viewer.

# Background Literature

- The difference in the motion characteristics of child motion and adult motion have been studied in the context of walking and jumping actions. [Thomas et al.1980; Horita et al. 1991].
  - Children usually move faster than adult

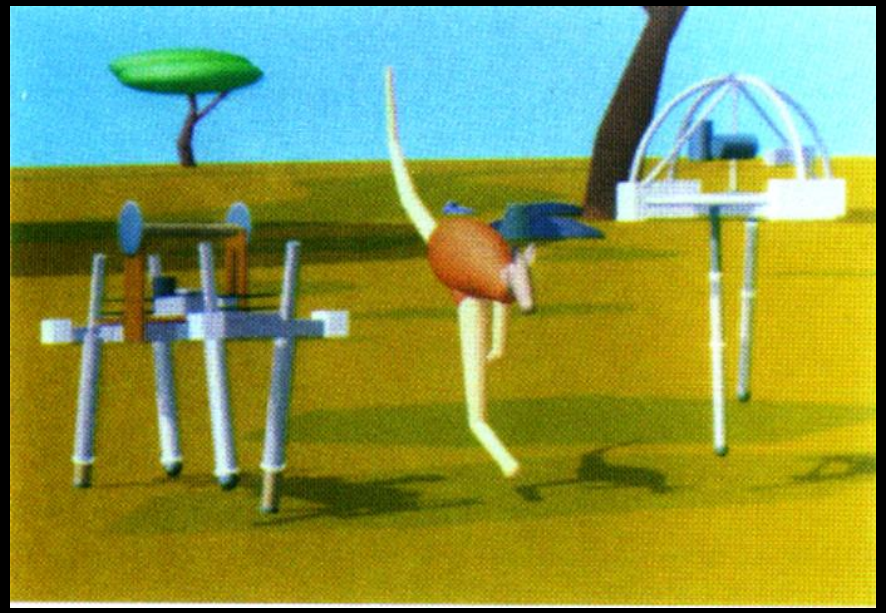
# Background Literature

- Motion stylization has been used to change a character's gait [Hsu et al. 2005] , conveyed emotion [Xia et al. 2015] and so on .
- These approaches either require long training sequences [Hsu et al. 2005] or large training samples [Xia et al. 2015].



# Background Literature

- Dynamic scaling laws transfer motion from one character to its scaled version [Raibert & Hodgins, 1991; Hodgins & Pollard, 1997].



Raibert & Hodgins, 1991

Hodgins & Pollard, 1997

# Background Literature

- Studies have shown that a point light display can convey information regarding
  - Motion [Pavlova et al, 2001]
  - Actor’s identity[Cutting &Kozlowski, 1977; Beardworth & Buckner 1981; Loula et al]
  - Gender[Barclay et al, 1987]
  - Emotions [Atkinson et al, 2004].

# Key Idea

- How effective if dynamic scaling laws be used to transform adult motion to appear more child-like?

https://www.steelcityjump.com/summercamp.php

http://www.iswmenswear.com

# Contribution

- The application of dynamic scaling laws to create child-like motion from adult motion capture data.
- The perception study conducted to evaluate how viewers perceive dynamically scaled adult motion.

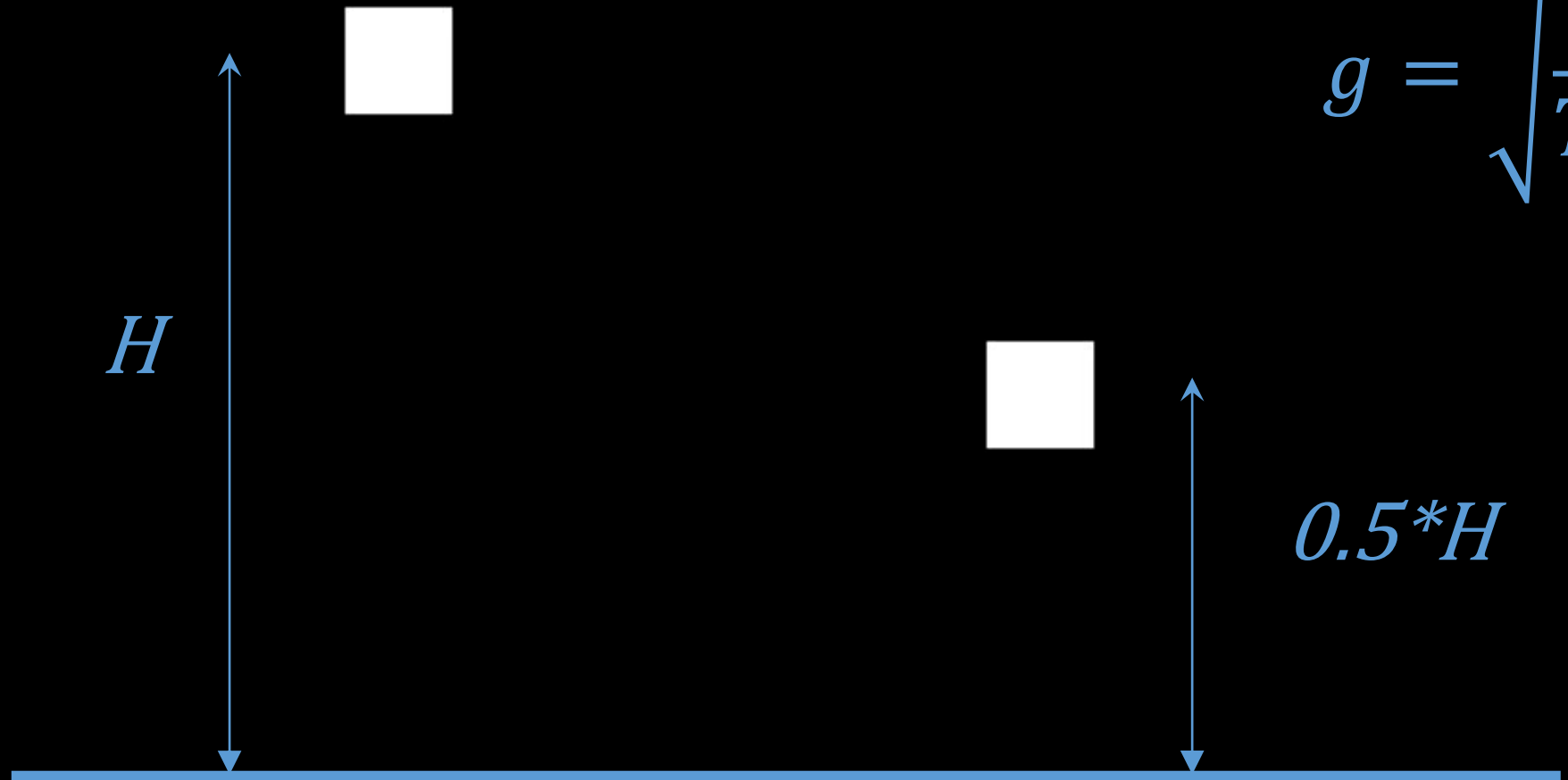
# Dynamic Scaling Laws

When the body of a character is scaled by a factor L, its new motion can be found using the table below.

| Quantity | Units | Geom. Scaling | Mass Scaling |
|---|---|---|---|
| **basic variables** | | | |
| length | $L$ | $L$ | – |
| time | $T$ | $L^{1/2}$ | – |
| **Motion variables** | | | |
| displacement | $L$ | $L$ | – |
| velocity | $LT^{-1}$ | $L^{1/2}$ | – |
| acceleration | $LT^{-2}$ | 1 | – |
| angular displacement | – | 1 | – |
| angular velocity | $T^{-1}$ | $L^{-1/2}$ | – |
| angular acceleration | $T^{-2}$ | $L^{-1}$ | – |

# This procedure preserves the gravity in a jump

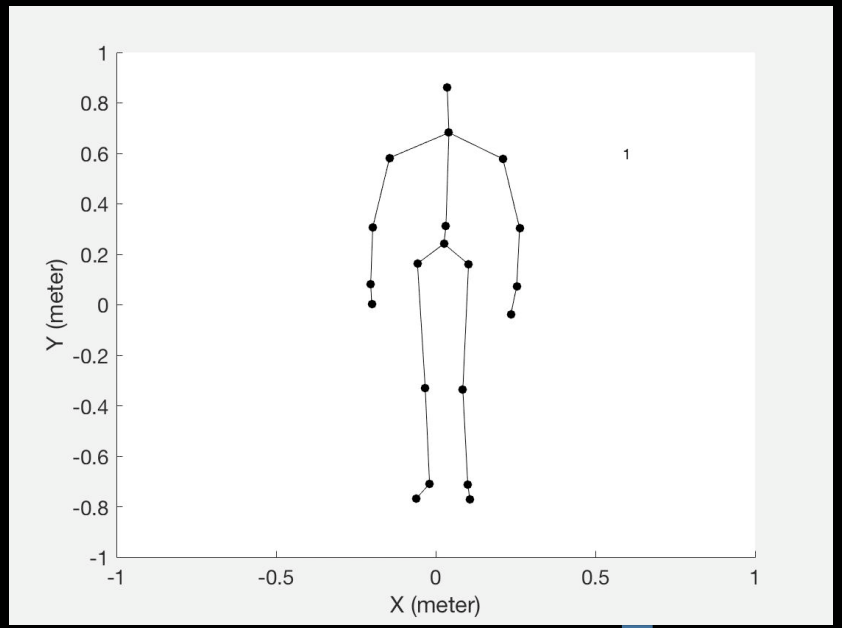
$$g = \sqrt{\frac{H}{T^2}}$$

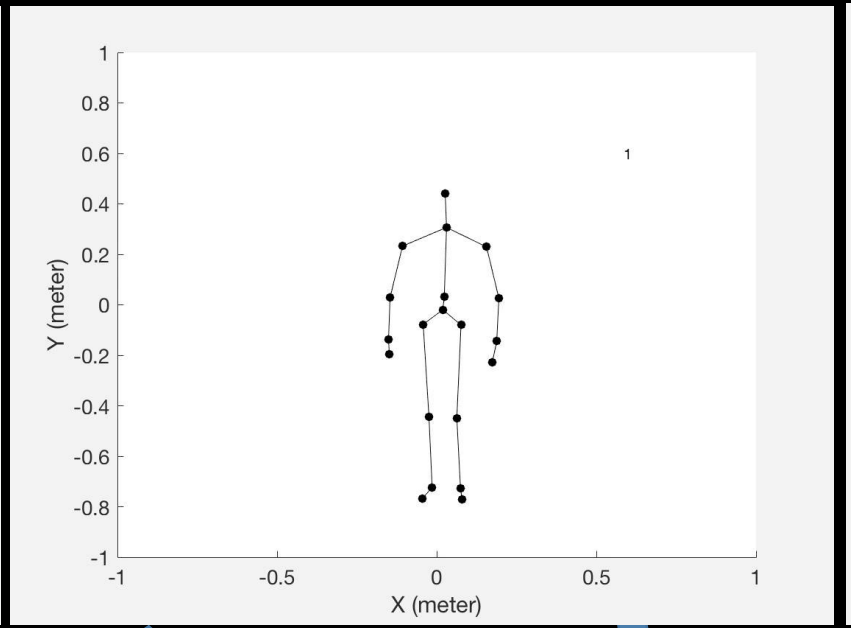


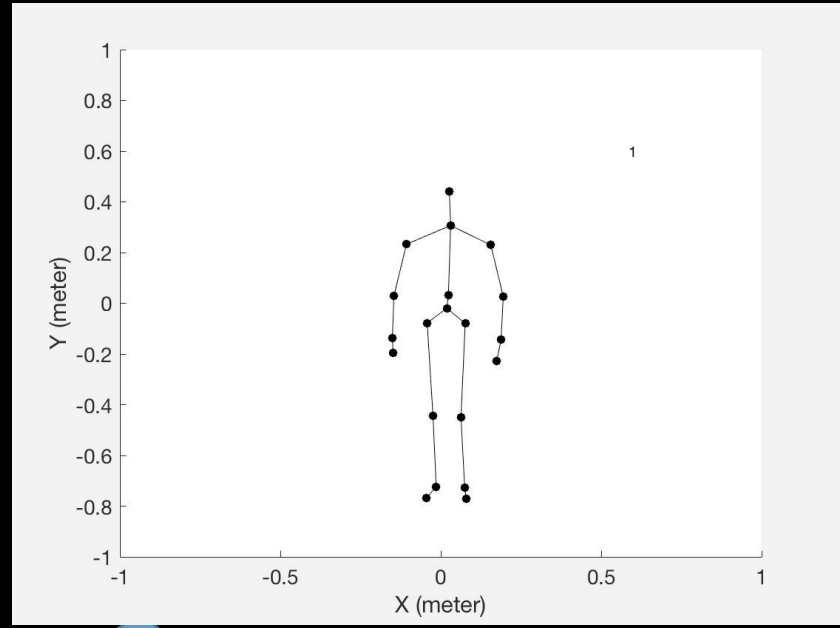
# Run Fast (showing dynamic scaling procedure)

Height of character, limb length, displacement scaled by L

Faster by $\sqrt{L}$




Actor 921

Length scaled

Length and time scaled

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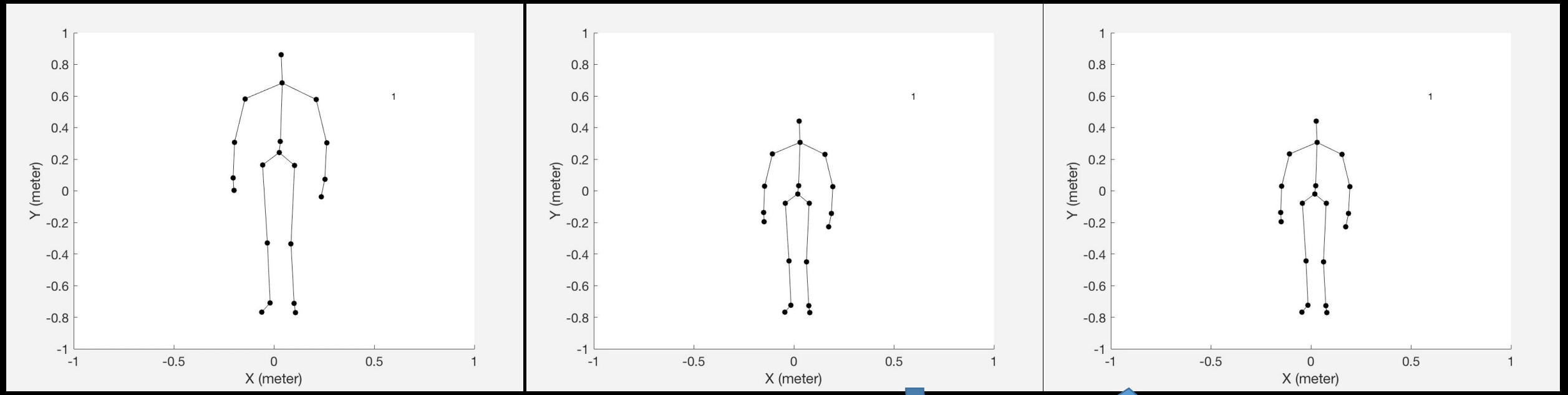



Actor 921

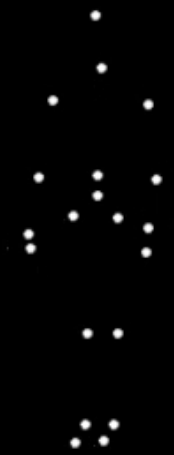
Length scaled

Length and time scaled

# Evaluation

- Actor Type: Adult, Child, Dynamically Scaled (DS) adult.
- Four actors per actor type.
- Action: Walk, Wave, Fly Like a Bird, Jump High, Run Fast, Jumping Jacks.
- 3*4*6=72 videos in total
- Order of videos randomized
- 24 participants: 11 male, 13 female

**Online Experiment**



Does this motion belong to a Child or an Adult?

- Child
- Adult

What is the action being performed?

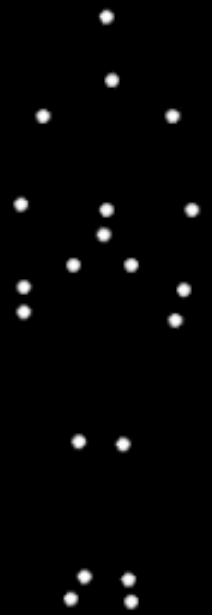
Indicate your confidence level in the answer on a scale of 1 (Really not confident) to 7 (Really confident). ● 1 ● 2 ● 3 ● 4 ● 5 ● 6 ● 7

# Run fast

Adult

Our result (Dynamic Scaling Procedure)

Child



Actor 921

Dynamically scaled actor 921

Actor 290

# Analyze the Data

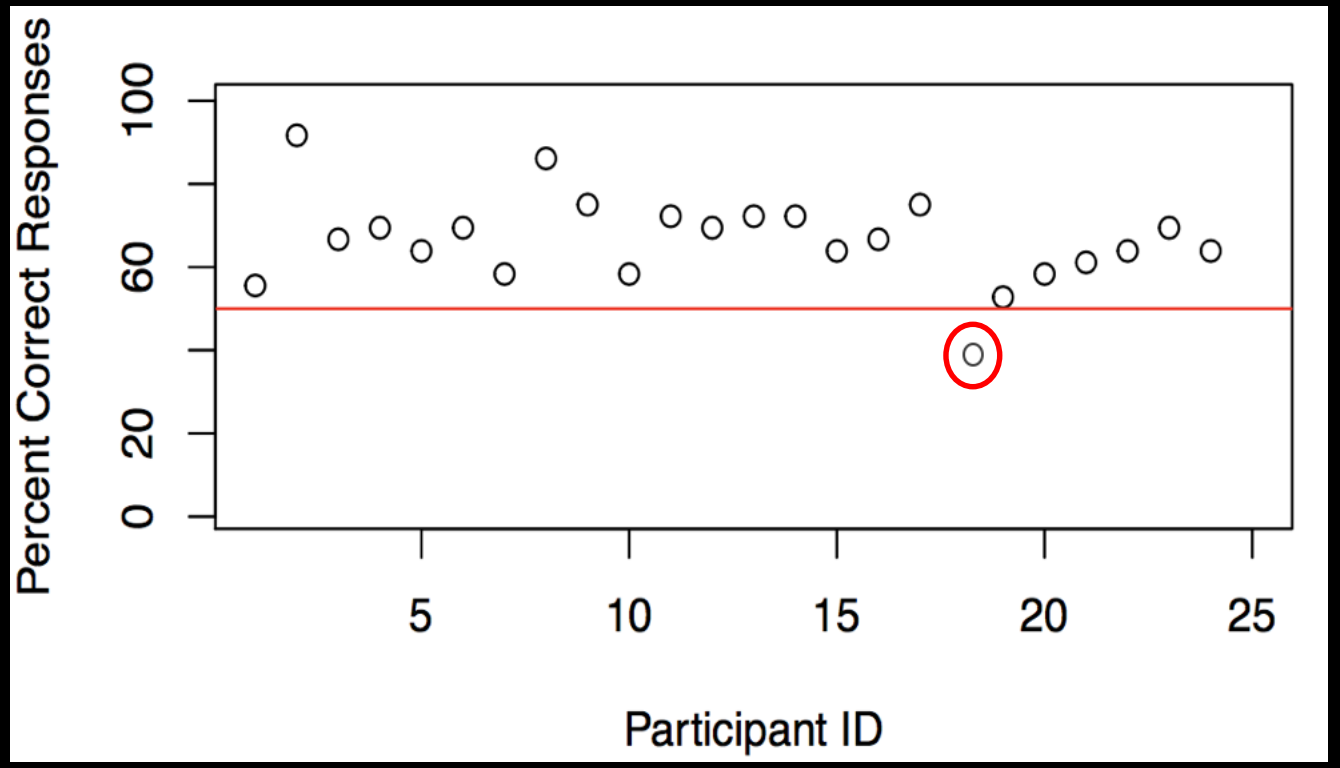
- Are participants able to identify Child and Adult videos correctly?
- Do participants attribute Dynamically Scaled(DS) videos to a Child actor?

# Analyze the Data

- Are participants able to identify Child and Adult videos correctly?
  - Only consider the Child videos and Adult videos and seen by the participant.
  - For each video, match the response(Child/Adult) with the actual Actor Type.
  - If it matches, it is a correct response.
  - For each participant, compute the percentage of correct responses.

# Analyze the Data

- Are participants able to identify Child and Adult videos correctly?




Removed from subsequence analysis

# Analyze the Data

- Are participants able to identify Child and Adult videos correctly?
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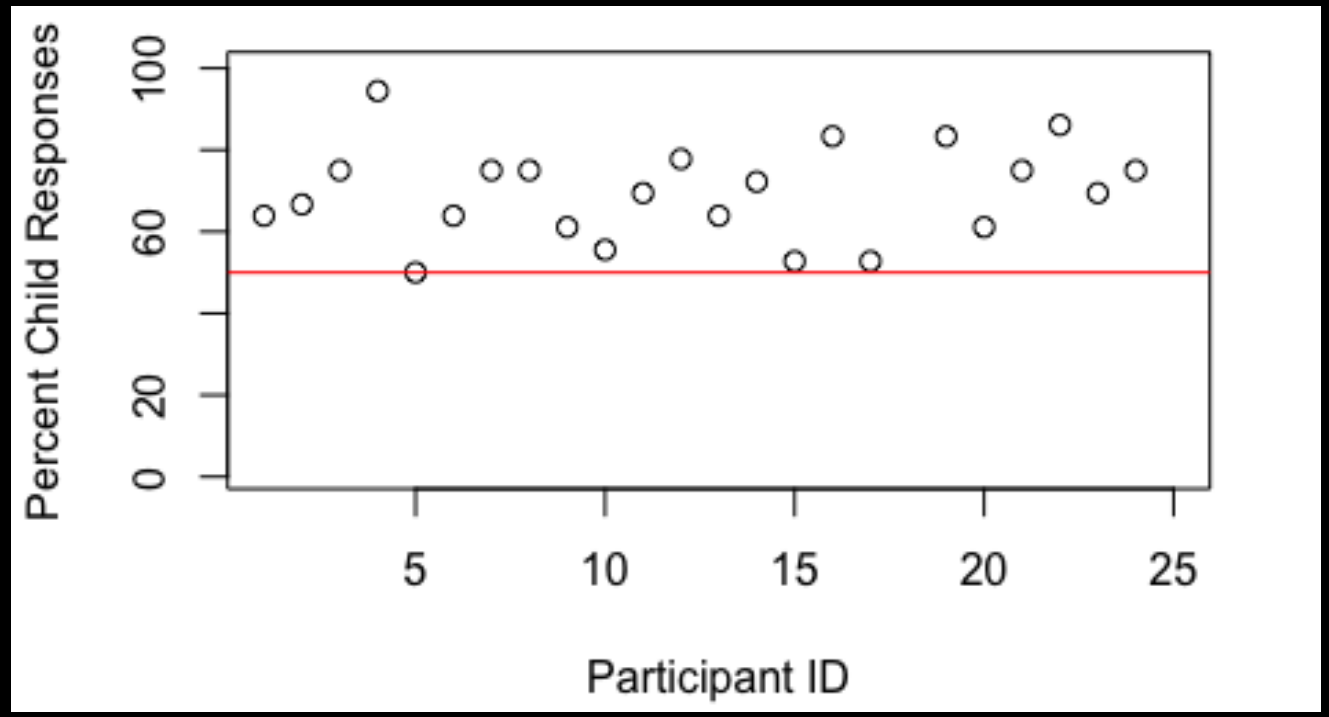
# Analyze the Data

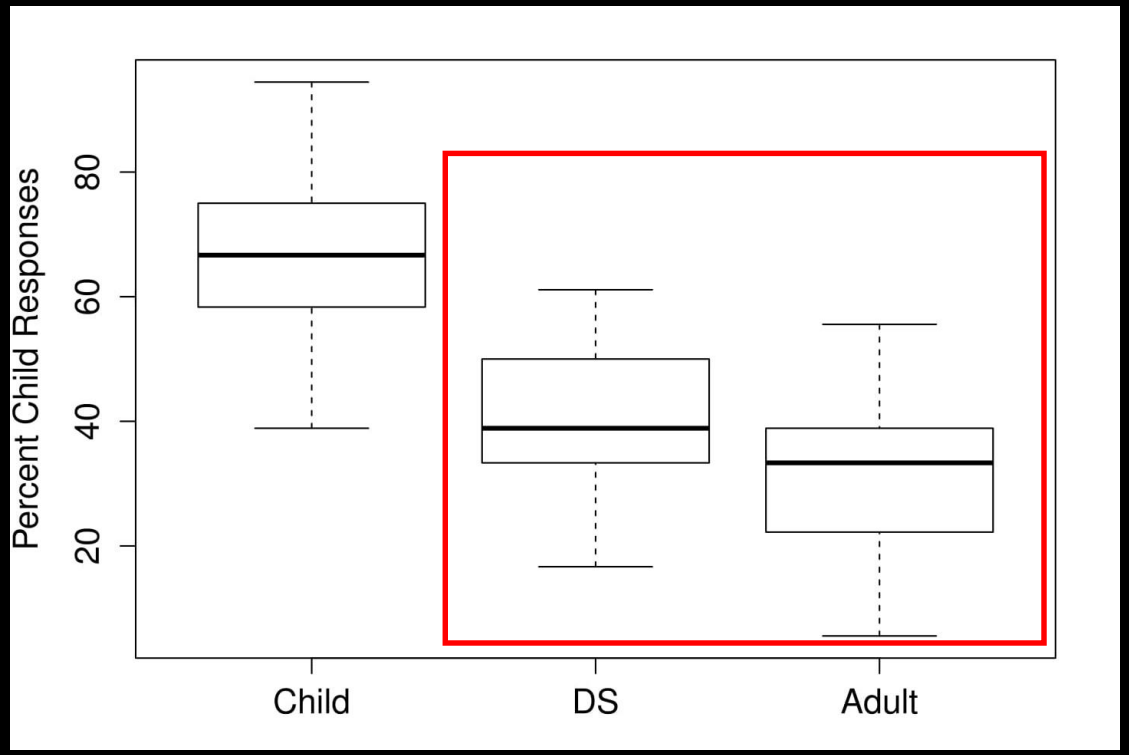
- Do participants attribute Dynamically Scaled (DS) videos to a Child actor?
  - Considering Child, Adult, Dynamically Scaled (DS) videos.
  - For each video, match the response (Child/Adult) with Child.
  - If matches, then the participant attributed the video to a child actor.
  - For each participant, compute the percentage of child responses for each actor type.
  - For each participant, compute the percentage of child responses for each action .

# Analyze the Data

- Do participants attribute Dynamically Scaled(DS) videos to a Child actor?

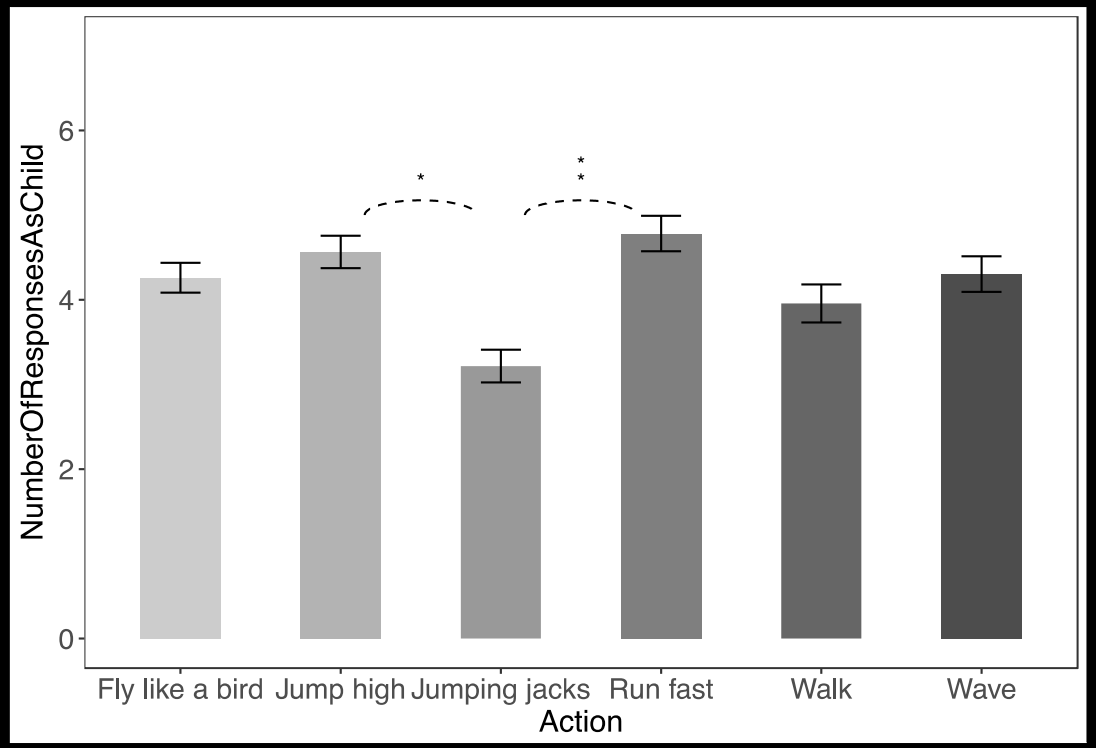


# Results




- Our results were more likely to be identified as child motion compared to adult motion.
- Two way ANOVA followed by Tukey HSD
- Significant main effect of actor type ($p<0.05$).

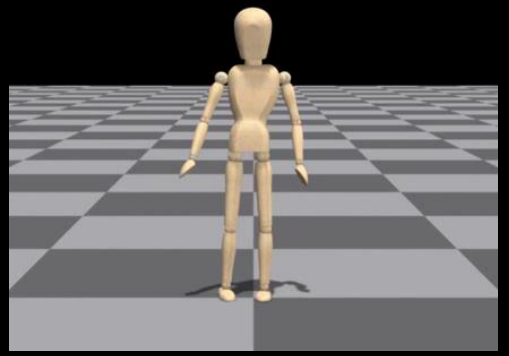
# Results



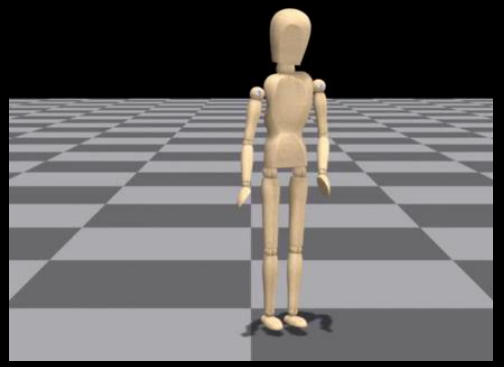

- Two way ANOVA followed by Tukey HSD.
- significant main effect of action ($p<0.05$).
- Viewers were generally more likely to attribute “Jump High” and “Run Fast” to a child actor.

# Discussion

Child
jump high

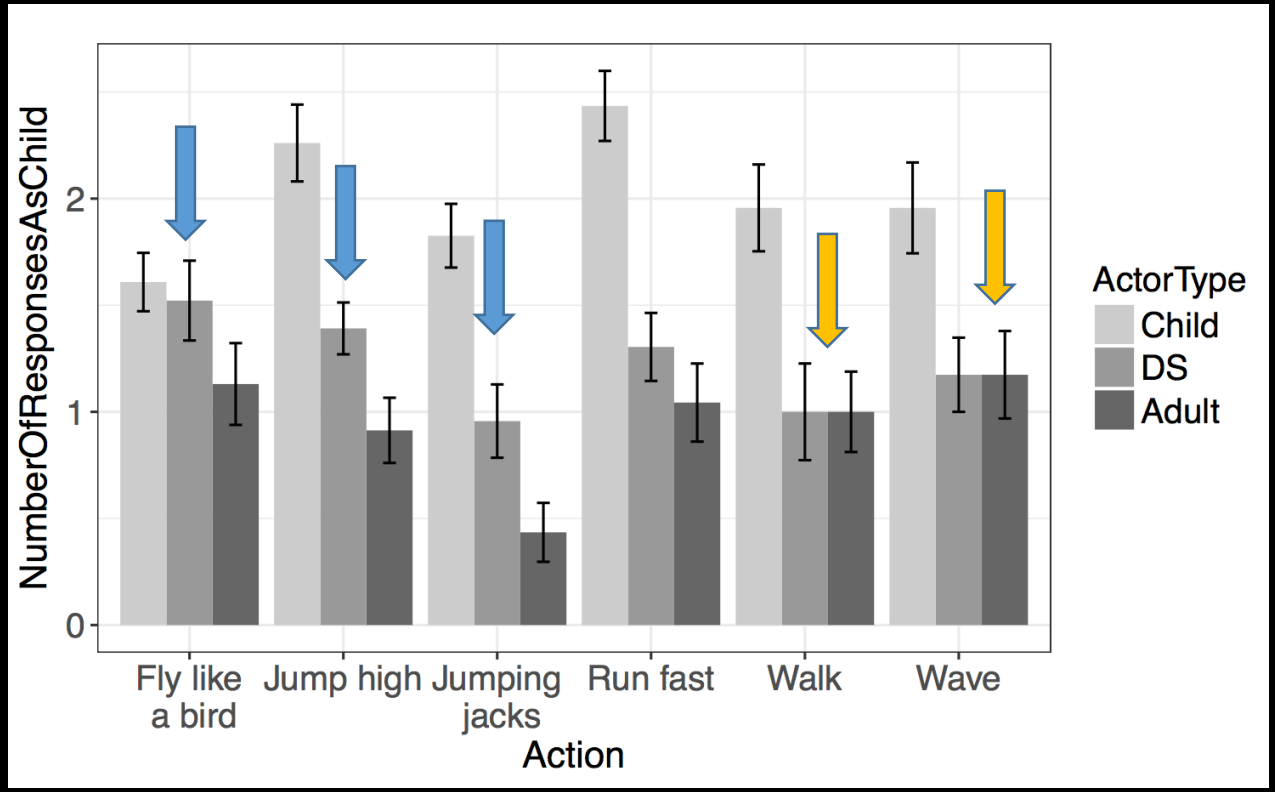


Child
run fast



- Viewers have no difficulties saying the motion came from a child.
- In contrast, for more coordinated action viewers sometimes think that the child motion capture data came from an adult.

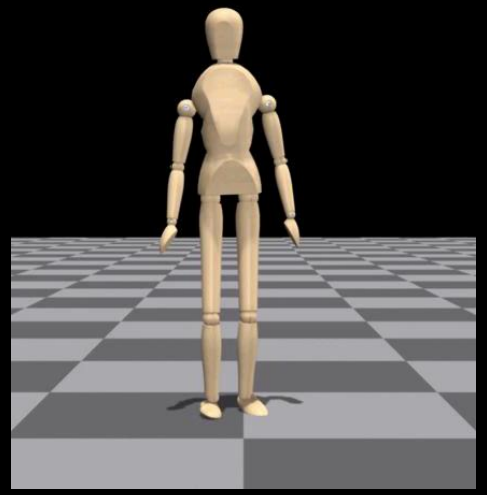
# Results



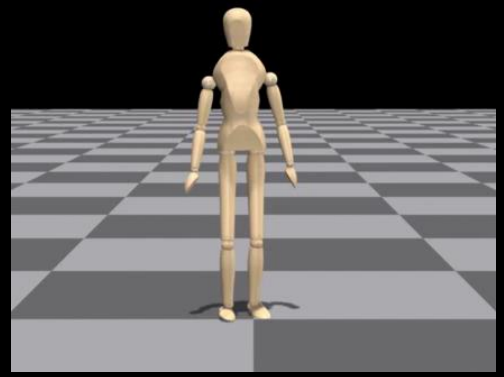

- For faster motion such as “Jump high”, “Jumping Jacks” and “Fly like a bird”, viewers are more generally attribute DS motion as performed by a child.
- For slower motion like “Walk” and “Wave”, DS motion is more likely to be identified as belonging to an adult.

# Discussion

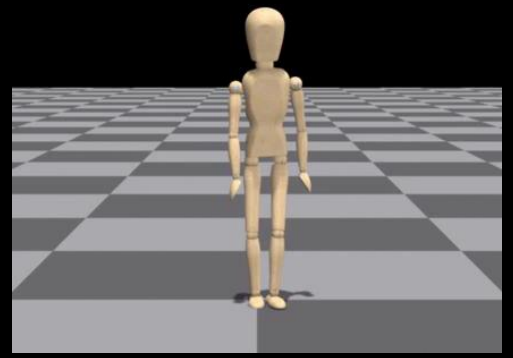
Adult



Our result



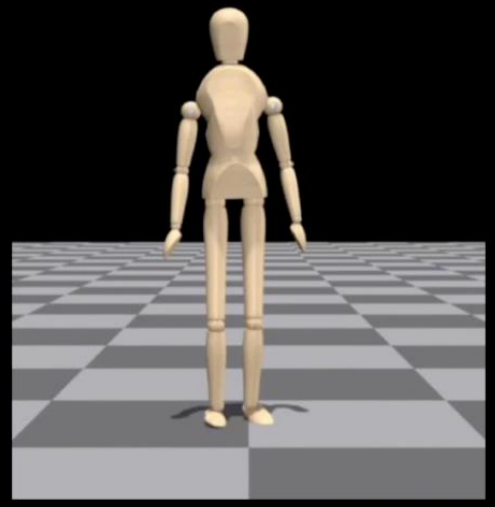
Child



- The coordination level of dynamic scaled motion seems similar to that of adults, but the speed is faster than adult motion.
- Viewers may perceive faster actions as belonging to children.

# Discussion

Adult



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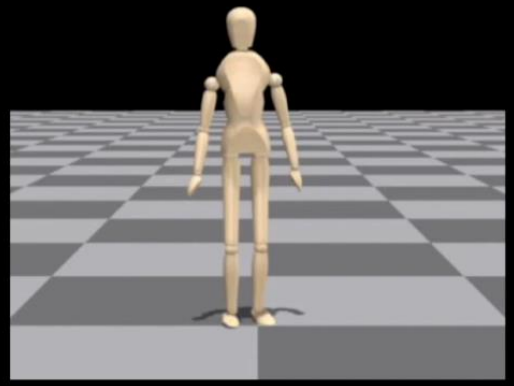
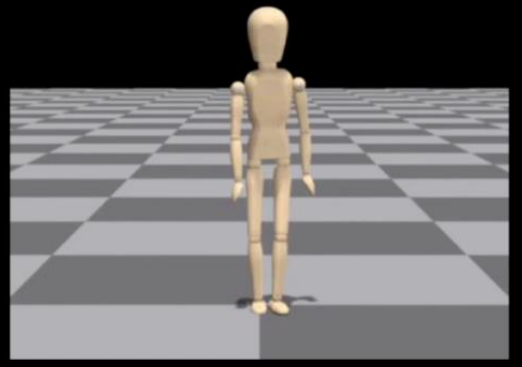


Child



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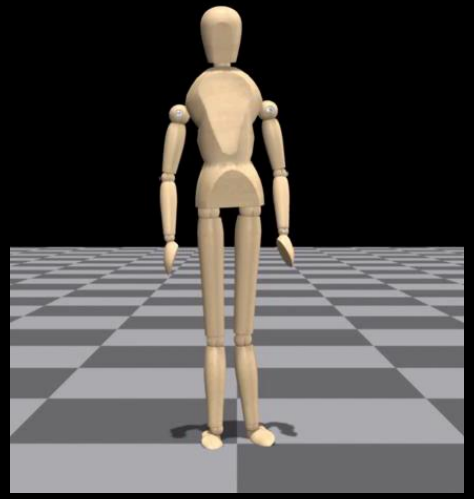

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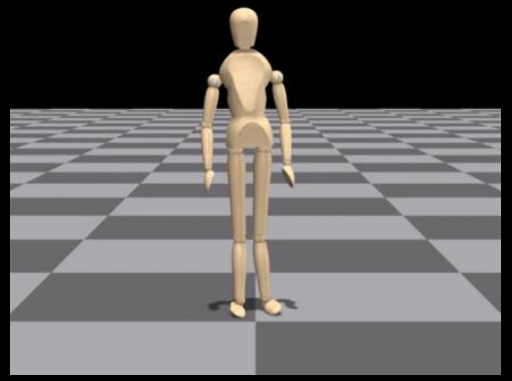
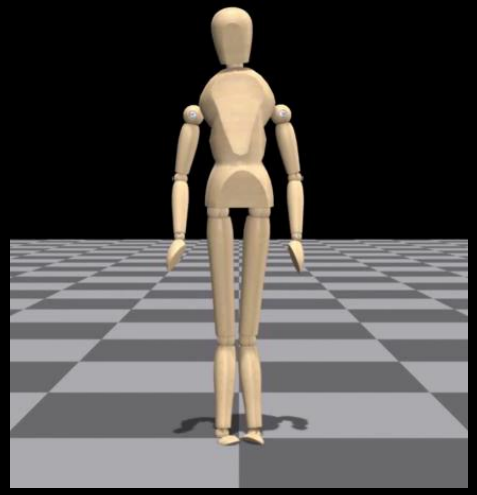


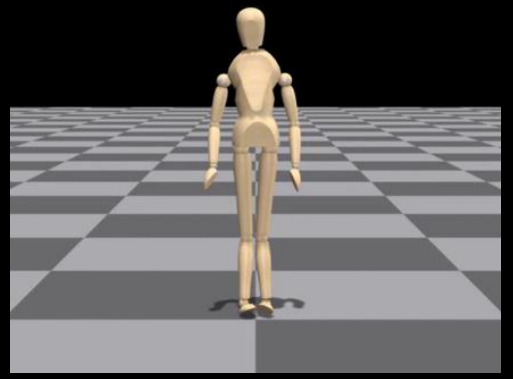
- For slower motion such as walk and wave, the visual difference between DS actor and adult actor is not that noticeable.

# Discussion

Adult



Our result



- For slower motion such as walk and wave, the visual difference between DS actor and adult actor is not that noticeable.

# Conclusion

- Viewers judged dynamically scaled adult motion as belonging to a child significantly more often than the original adult motion, although less than the original child motion.
- The dynamic scaling procedure is simple to implement and achieves some success in convincing viewers.
- This method is a good first step to create child like motion.

# Future work

- Investigate other algorithms that could retarget the motion to child characters with different limb ratios and mass distributions.
- Explore other algorithms that could further stylized the motion with respect to coordination and consistency to be more child like.

**Thank you**

# Why DS  actor doesn’t match child actor

- Dynamic scaled actor is generated from scaling adult actor to an average height of age 5 to 9 old child using dynamic scaling laws. This procedure is not able to create motion that match the motion of a real child actor.
- The child motion that we use in the paper is for validation and evaluation.

# How to put mocap data on wooden figures how I did it in Maya

- Translate joint angle to joint position. Use the average length of the limb as its limb length
- Convert csv file to bvh file
- Import csv file into Maya
- Export the motion as MotionExport file
- Import the animation for

# How to translate joint position to rotation

**ALGORITHM 1:** Joint Angle Computation

**Input:** Joint position in local coordinate ${}^{x}_{l}u^{j}_{i}, {}^{y}_{l}u^{j}_{i}, {}^{z}_{l}u^{j}_{i}$

**Output:** Joint rotation in local coordinate $({}^{Rx}_{l}u^{j}_{i}, {}^{Ry}_{l}u^{j}_{i}, {}^{Rz}_{l}u^{j}_{i})$

**for** *each frame i* **do**
  **for** *each branch in the tree structure* **do**
    **for** *each joint j from root to leaf* **do**
      ${}^{Ry}_{l}u^{j}_{i} = 0$
      **if** *joint=root node* **then**
        ${}^{Rz}_{l}u^{j}_{i} = \arctan({}^{z}_{l}u^{j}_{i}, {}^{y}_{l}u^{j}_{i})$
        ${}^{Rx}_{l}u^{j}_{=} \arctan({}^{y}_{l}u^{j}_{i}, \sqrt{{}^{y}_{l}u^{j2}_{i} + {}^{z}_{l}u^{j2}_{i}})$
        $R = rotZ({}^{Rz}_{l}u^{j}_{i})) * rotX(-{}^{Rx}_{l}u^{j}_{i}))$
      **else**
        $({}^{x}_{p}u^{j}_{i}, {}^{y}_{p}u^{j}_{i}, {}^{z}_{p}u^{j}_{i}) = [({}^{x}_{l}u^{j}_{i}, {}^{y}_{l}u^{j}_{i}, {}^{z}_{l}u^{j}_{i})] * R$
        ${}^{Rz}_{l}u^{j} = \arctan({}^{z}_{p}u^{j}_{i}, {}^{y}_{p}u^{j}_{i})$
        ${}^{Rx}_{l}u^{j} = \arctan({}^{y}_{p}u^{j}_{i}, \sqrt{{}^{y}_{p}u^{j2}_{i} + {}^{z}_{p}u^{j2}_{i}})$
        $R = R * rotZ({}^{Rz}_{l}u^{j}_{i})) * rotX(-{}^{Rx}_{l}u^{j}_{i}))$
      **end**
    **end**
  **end**
**end**

# Complete dynamic scaling laws

| Quantity | Units | Geom. Scaling | Mass Scaling |
|---|---|---|---|
| **Basic variables** | | | |
| length | $L$ | $L$ | – |
| time | $T$ | $L^{1/2}$ | – |
| force | $F$ | $L^3$ | $M$ |
| torque | $FL$ | $L^4$ | $IL^{-1}$ |
| **Motion variables** | | | |
| displacement | $L$ | $L$ | – |
| velocity | $LT^{-1}$ | $L^{1/2}$ | – |
| acceleration | $LT^{-2}$ | 1 | – |
| angular displacement | – | 1 | – |
| angular velocity | $T^{-1}$ | $L^{-1/2}$ | – |
| angular acceleration | $T^{-2}$ | $L^{-1}$ | – |
| **Mechanical parameters** | | | |
| mass | $FL^{-1}T^2$ | $L^3$ | $M$ |
| stiffness | $FL^{-1}$ | $L^2$ | $ML^{-1}$ |
| damping | $FL^{-1}T$ | $L^{5/2}$ | $ML^{-1/2}$ |
| moment of inertia | $FLT^2$ | $L^5$ | $I$ |
| torsional stiffness | $FL$ | $L^4$ | $IL^{-1}$ |
| torsional damping | $FLT$ | $L^{9/2}$ | $IL^{-1/2}$ |

# Jump High

Adult

Our result (Dynamic Scaling Procedure)

Child

Actor 921

Dynamically scaled actor 921

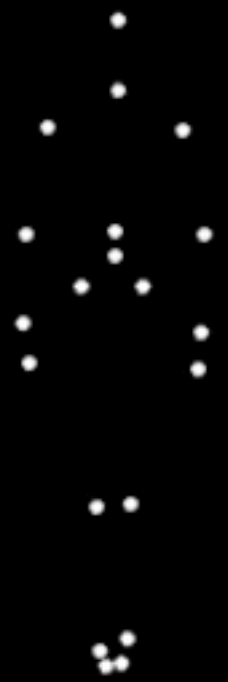
Actor 290

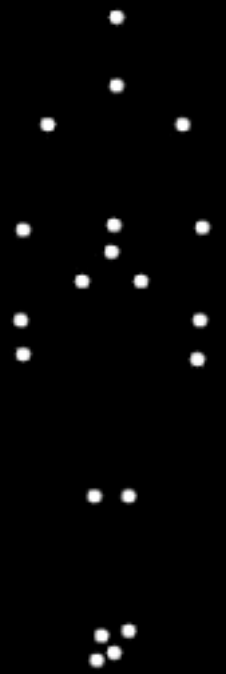
# Wave

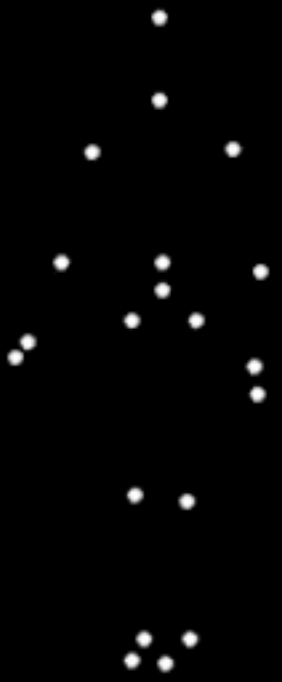
Adult

Our result (Dynamic Scaling Procedure)

Child







Actor 921

Dynamically scaled actor 921

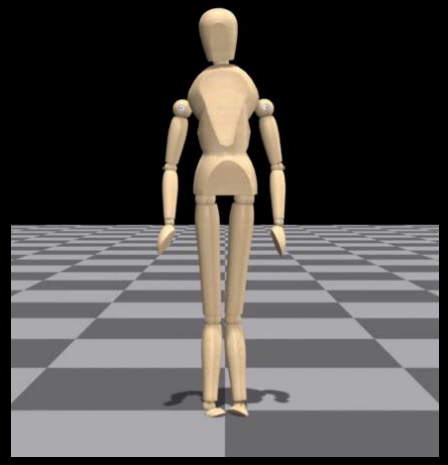
Actor 290

# Wave

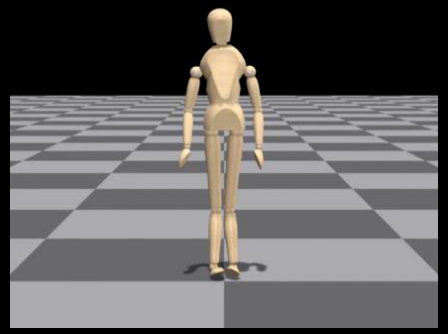
Adult

Our result

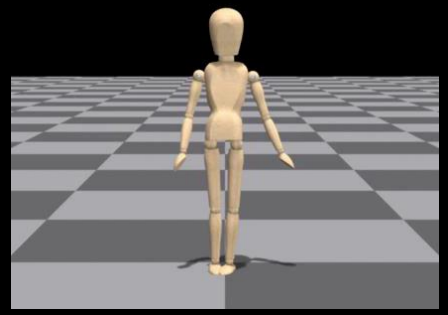
Child



Actor 921



Dynamically scaled actor 921



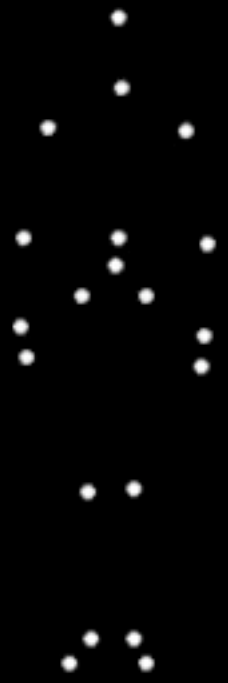
Actor 290

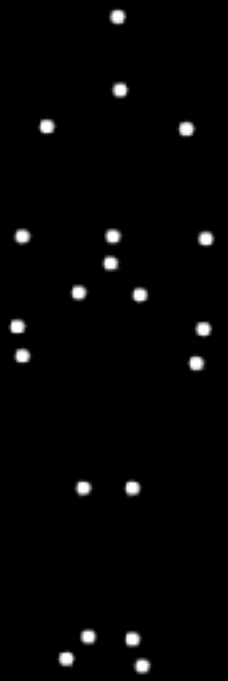
# Walk

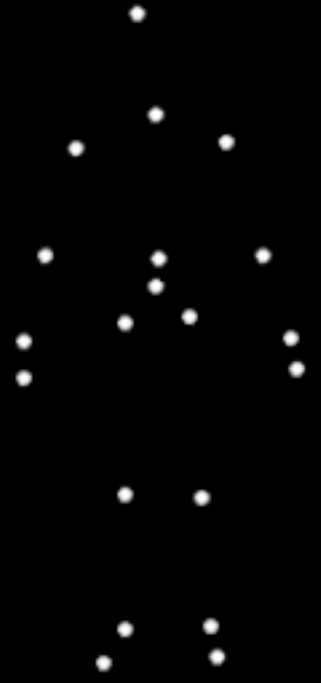
Adult

Our result (Dynamic Scaling Procedure)

Child







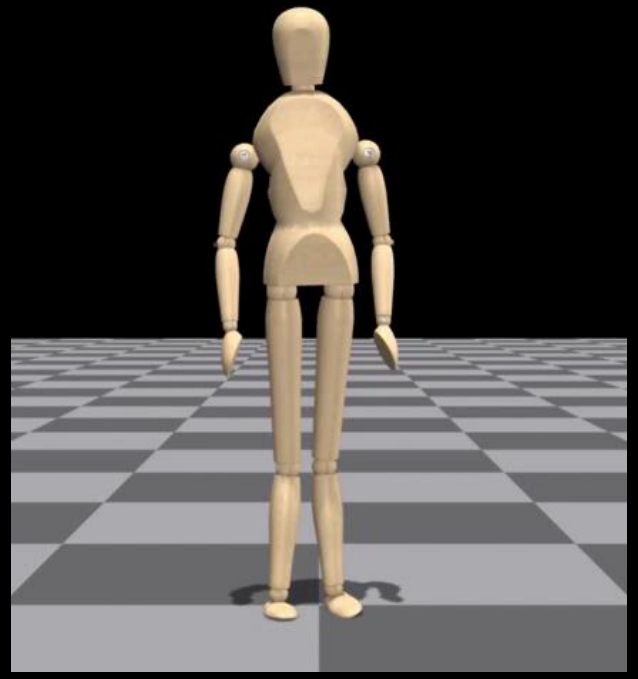
Actor 921

Dynamically scaled actor 921

Actor 290

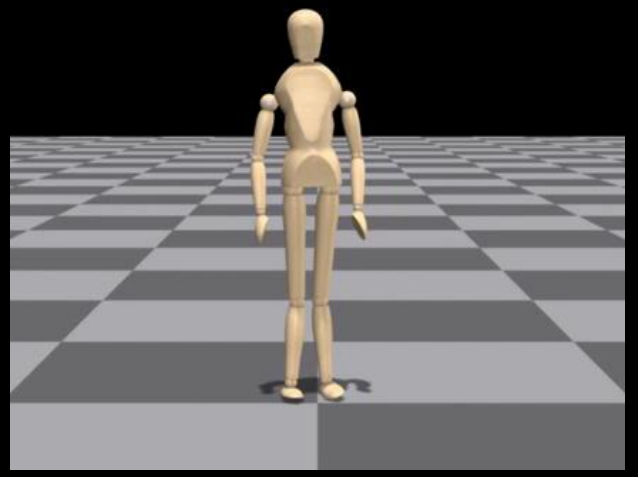
# Run Fast

Adult



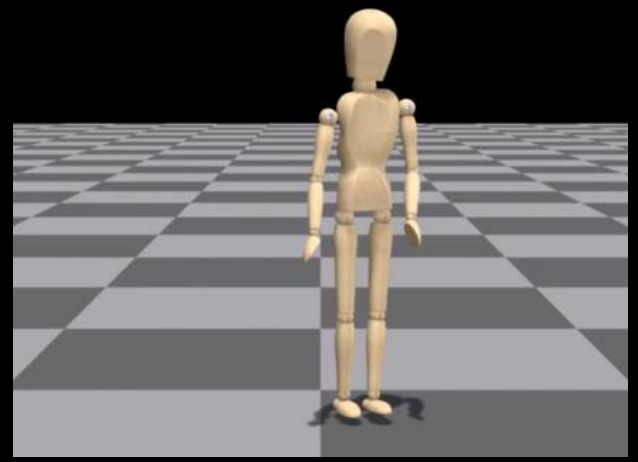
Actor 921

Our result



Dynamically scaled actor 921

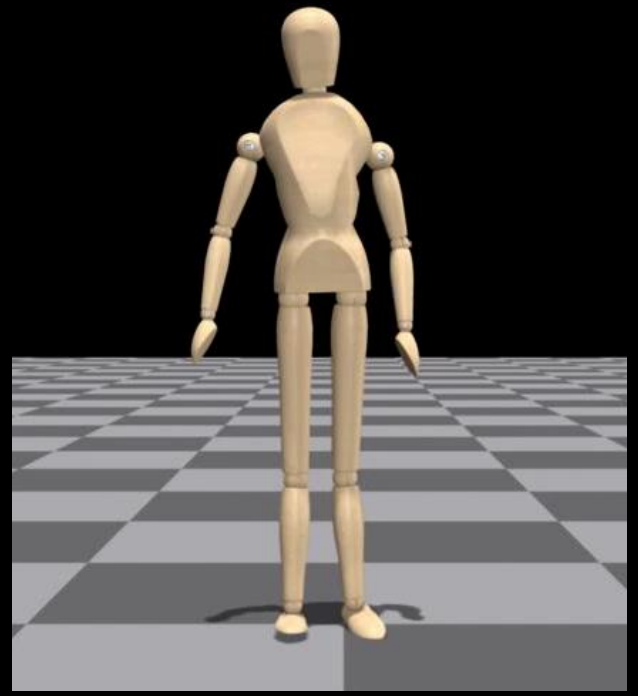
Child



Actor 290

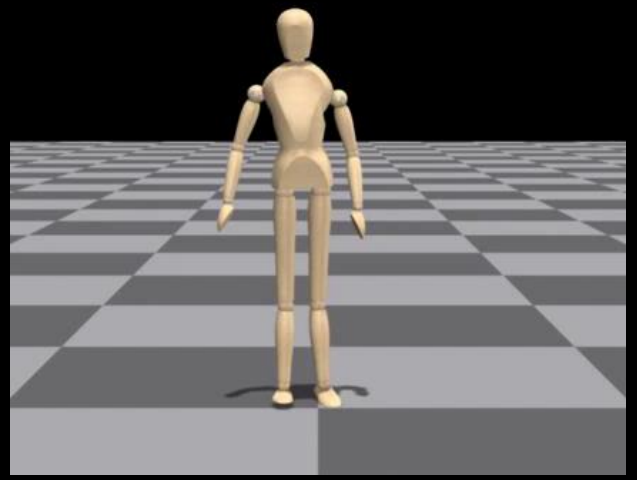
# Fly Like a Bird

Adult



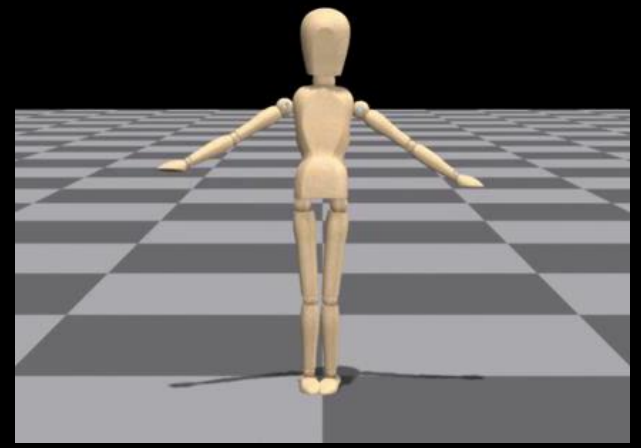
Actor 921

Our result



Dynamically scaled actor 921

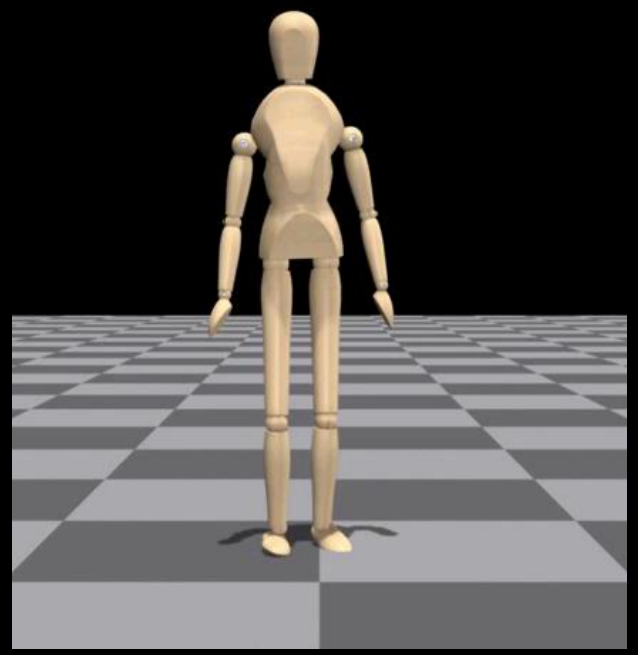
Child



Actor 290

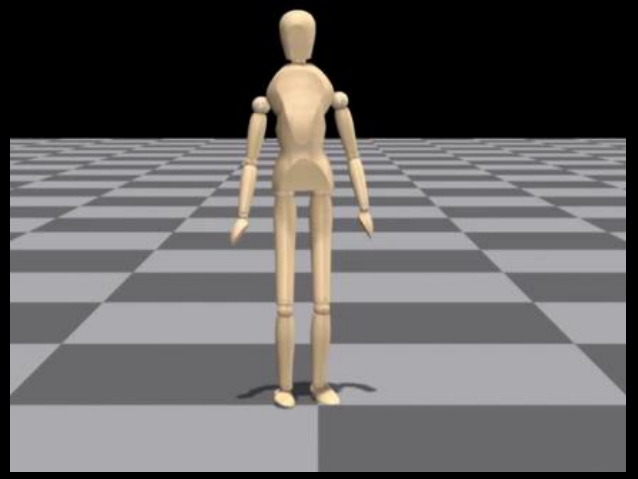
# 5 Jumping Jacks

Adult



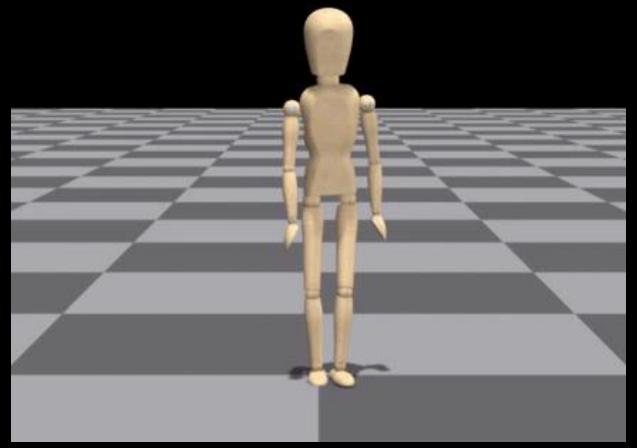
Actor 921

Our result



Dynamically scaled actor 921

Child



Actor 290