# Perceived naturalness of human motion depends on internal consistency

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## INTRODUCTION

The details of the kinematics of a walk depend on a number of factors such as
- biological and psychological attributes (age, sex, health, mood)
- general physique of the walker's body (size, weight and weight distribution, proportions)

It also depends on the walking speed. A fast walk is not the same as a slow walk played back at a faster rate.

Our visual system seems to know a lot about these dependencies.

**What does the human visual system know about the relations between kinematics and walking speed?**

The question is important to design convincing motion for computer animation in movies and games, but also for the design of stimuli for biological motion experiments.

Here, we ask observers to rate the naturalness of point-light displays obtained from 100 individual walkers. Each of them was recorded at three different walking speeds and was then played back at three different speeds – only one of them being the veridical speed.
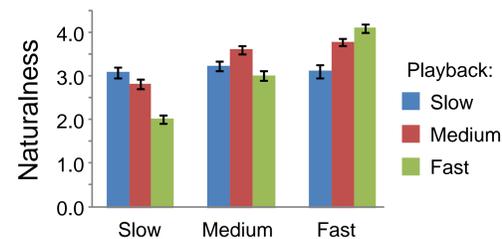
*playback speed*

| | | slow | medium | fast |
|---|---|---|---|---|
| | slow | 1 | 1.4 | 2.0 |
| *veridical speed* medium | | 0.7 | 1 | 1.4 |
| | fast | 0.5 | 0.7 | 1 |

*Recording was done on a treadmill. Subjects set the speed such that they walked most comfortably (medium veridical speed). For fast and slow recordings, the speed of the treadmill was increased and decreased by a factor of 1.4, respectively. Differences between playback speeds were also defined by the same factor. The table indicates playback speed relative to veridical speed.*
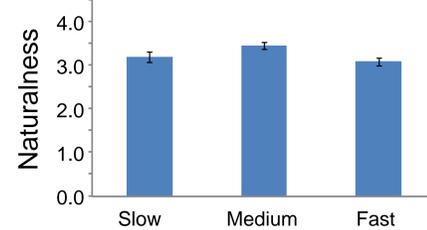
## REFERENCES

1. Hirokawa, S. (1989). Normal gait characteristics under temporal and distance constraints. Journal of Biomedical Engineering, 11(6), 449-456.
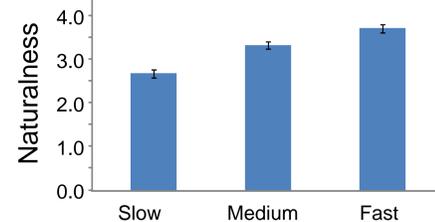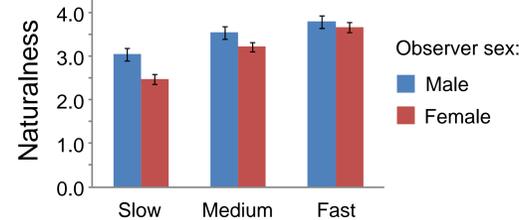
## RESULTS


Veridical Speed (Playback: Slow, Medium, Fast)


Playback Speed


Veridical Speed


Veridical Speed (Observer sex: Male, Female)

Naturalness was always highest when playback speed matches veridical speed
- $F_{(4, 128)} = 83.136$, $p < .001$
- Any inconsistency between recorded speed and playback speed was detected

Medium playback speed was perceived as most natural
- $F_{(2, 64)} = 10.148$, $p < .001$
- This can be explained in terms of the average difference between playback and veridical speed:


Playback Speed (Slow, Medium, Fast) — Naturalness vs Veridical speed (S M F)
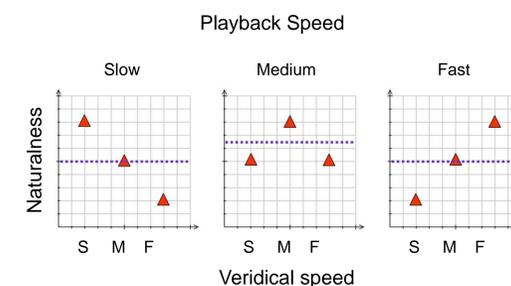
The fastest veridical speed looked most natural
- $F_{(2, 64)} = 131.783$, $p < .001$
- Maybe, even though we asked participants to adjust treadmill speed for comfortable walking they set speed lower than normal?
- Yes, that seems to be the case (see here)

Observer gender had a modest effect on perceived naturalness.
- Men found them more natural than women.
- $F_{(1, 31)} = 4.147$, $p < .05$

In female observers, the effect of veridical speed on naturalness was much more pronounced.
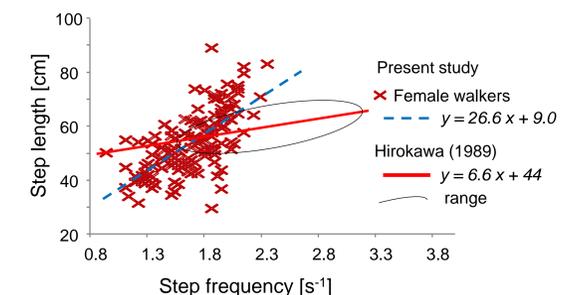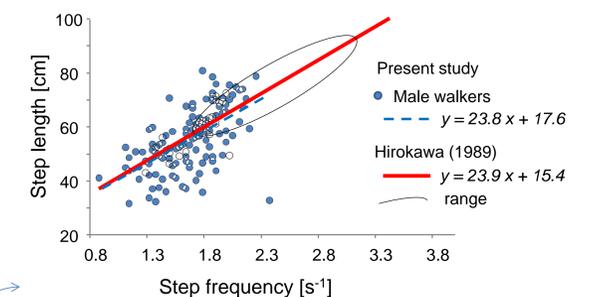- $F_{(2, 62)} = 6.168$, $p < .005$

No effects of walker gender!

## SUMMARY & DISCUSSION

As a walker changes speed, a whole number of parameters change as well:
- lateral body sway
- amplitude of arm swing
- amplitude of vertical movement, etc.

Two particularly obvious parameters are step length and step frequency: *speed = step length x step frequency*

In normal walking, frequency and step length relate almost linearly (Hirokawa,1989)


Step length [cm] vs Step frequency [s⁻¹]
Present study — Male walkers: $y = 23.8\,x + 17.6$
Hirokawa (1989): $y = 23.9\,x + 15.4$ range


Step length [cm] vs Step frequency [s⁻¹]
Present study — Female walkers: $y = 26.6\,x + 9.0$
Hirokawa (1989): $y = 6.6\,x + 44$ range

Varying the playback speed alters the walker's speed and step frequency, but doesn't change step length.
- Observers "know" about this (and probably other relations, too) and respond sensitively to deviations.
- In order to create visually convincing computer animation, we have to understand and appreciate the visual system's ability to pick up on subtle inconsistencies.

## METHOD

**Participants**

33 undergraduate students who received course credit for their participation
- 12 male observers, 6 presented with male walkers and 6 with female walkers
- 21 female observers, 10 presented with male walkers and 11 with female walkers

**Stimuli**

Individual point-light walkers presented in frontal view
- presented in frontal view, 15 white dots on black background
- 50 male and 50 female walkers
- 5.7 deg of visual angle at 80 cm viewing distance
- 2 s presentation, then 6-point Likert scale

**Design**

5 blocks per observer. Each observer saw either only male or female walkers.
- 10 x 3 x 3 = 90 trials per block
- 10 different new walkers in each block
- 3 different veridical speeds
- 3 different playback speeds