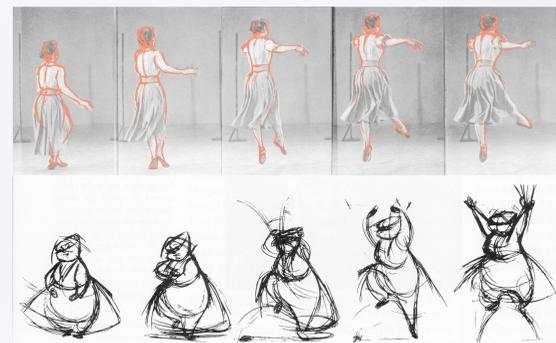
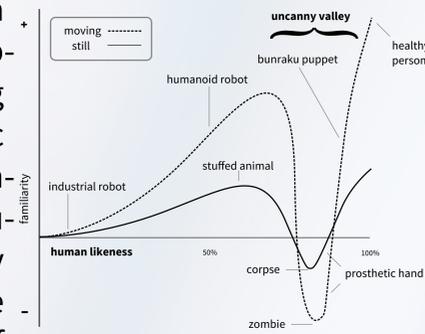


# Exploring the Uncanny Valley

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## Problem.

Mori's *Uncanny Valley* phenomena isn't limited to robotics. It has been observed in many other areas, including the fine arts, especially photorealistic painting, sculpture, computer graphics, and animation. Furthermore, heuristic practices in the arts, especially those of traditional animation, have much to offer to our understanding of



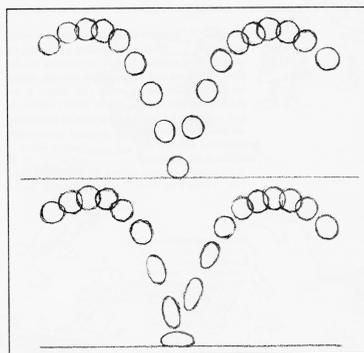
the appearance of phenomenological reality. One interesting example is the use of exaggeration to mitigate uncanny valley phenomena in animation. Action captured from live performance is frequently exaggerated so as to appear less uncanny.

## Animation's solution.

Since the earliest days of animation, artists have sought to depict the *Illusion of Life*. At Disney, the tools of the trade were codified into the classic *Twelve Principles of Animation*. Work that ignores these rules looks awkward and unnatural, e.g., *uncanny*.

- The Twelve Principles of Animation**
1. Squash and Stretch
  2. Anticipation
  3. Staging
  4. Straight Ahead / Pose to Pose
  5. Follow Through / Overlap
  6. Slow in, Slow Out
  7. Arcs
  8. Secondary Action
  9. Timing
  10. Exaggeration
  11. Solid Drawing
  12. Appeal

Respect for the rules gives the work 'life'. The most important of these rules revolve around the exaggeration of shape and motion over time. Here we experiment with the perception of exaggeration in its most primitive form, Rule 1 — *Squash and Stretch*.

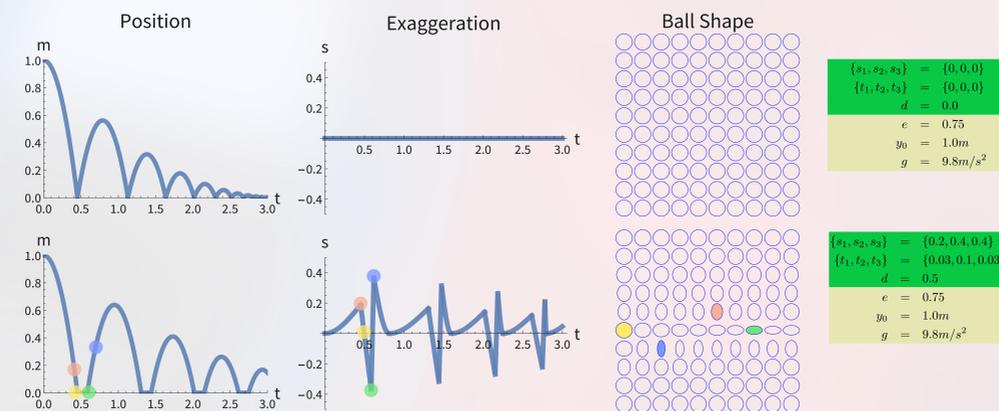


## Method.

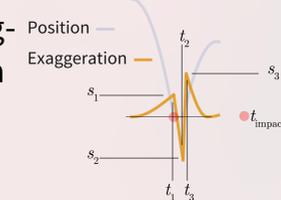
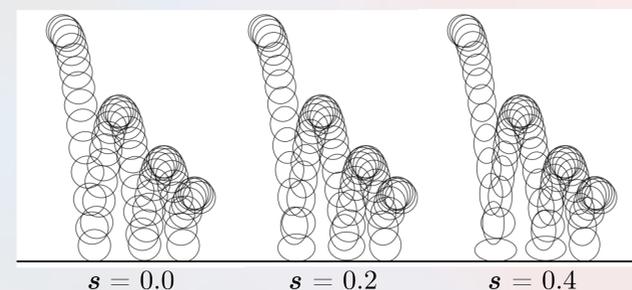
We performed a series of experiments to probe the detection and perceived plausibility of bouncing balls. We developed a physically accurate model that integrates parametrically adjustable exaggeration in a manner consistent with traditional animation practice.

## Model.

The basis is a simple inelastic collision of a falling body with a solid floor, each with a coefficient of restitution,  $e$ . We add an exaggeration function that controls squash-and-stretch (e.g. deformation) as a function of velocity and position. With 0 exaggeration, the model behaves like a simple bouncing ball. There are 10 parameters in two classes — **physically plausible** and **hyperrealistic**.



This gives control over the timing,  $t_i$  and the magnitude of the squash and stretch,  $s_i$  along with a velocity-scaled decay,  $d$ .



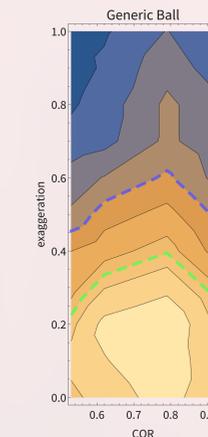
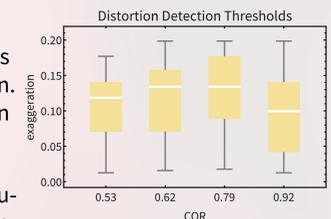
The effect of varying  $s$ , where all three are the same magnitude, is illustrated here.

## Experiments.

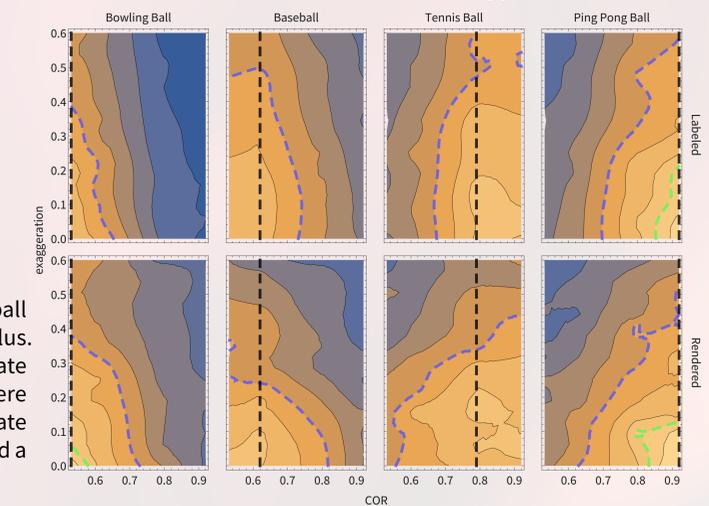
	COR	
Bowling	0.53	
Baseball	0.62	
Tennis	0.79	
Table Tennis	0.92	

We selected four different types of balls to cover a range of 'bounciness' (e.g., CORs). For Experiments 1–3 we rendered animations using a schematic circle to represent the ball and a line for the floor. Experiment 4 used a realistically rendered ball and environment. All movies were presented in  $\approx 7^\circ \times 10^\circ$  visual angle at 60 fps. Each stimulus depicted a 1 s static image of the background followed by 3 s of animation. In all experiments only two model parameters were varied: the COR/ $e$  and the magnitude of exaggeration with  $s_1 = s_2 = s_3$ . All other parameters were held constant and all balls were depicted at the same size,  $\approx 1^\circ$ , regardless of type.

**1 • Detection.** Observers performed multiple interleaved staircases for each ball to estimate a detection threshold for the exaggeration. On average, detectability was at 10% with no difference between CORs. Some observers were able to reliably detect as little as 1%.



**2 • Plausibility.** Observers rated stimuli as being a 'plausible' or 'implausible' depiction of a bouncing ball. Observers rated stimuli with small amounts of exaggeration as being more plausible than those without. The effect is relatively independent of COR and is driven mainly by exaggeration.



**3 • Labeled.** The type of ball was presented with each stimulus. Observers used a 0-1 scale to rate plausibility. Higher ratings were located closer to the appropriate COR but observers still tolerated a large amount of exaggeration.

**4 • Rendered.** Stimuli were depicted photorealistically. Like Experiment 3, plausibility continued to shrink around the veridical COR, but now there appears to be a more distinct interaction between the parameters.

## Conclusions.

Observers welcomed distortions in the generic condition regardless of the balls' physical properties. Specific depiction constrained ratings but observers still preferred significant exaggeration. More realistic depiction limited but did not eliminate exaggeration effects.