Shape-dependence of a size illusion explained by spatial mapping in V1

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Introduction and summary

It is well known that context affects the perceived angular size of an image, leading to perceptual effects such as the Ponzo and hallway illusions [1]. Here we investigated how illusory size perception further depends on geometry and absolute size using two classes of objects: narrow bars and balls, which create (quasi-) one dimensional (1D) and two dimensional (2D) retinal images, respectively.

We found that the magnitude of the illusion decreases with ball size, but remains constant for bars. In the second part of the poster we propose an explanation for this finding based on the cortical magnification in primary visual cortex (V1) and our group's recent findings suggesting that the spatial extent of activity in V1 correlates with perceived angular size [2-4]. Our results suggest that the pattern of activity in V1 may constitute a basis for perception of angular size.

Methods

Participants: 2 observers, both authors (HB & KD)

Display system: Stimuli were presented on a computer-controlled 22-inch LCD monitor. Observers were seated 90cm from the screen in an otherwise dark room

Stimuli: Images of a cue-rich hallway scene and a weaker-cue railroad tracks scene were computer-rendered using Radiance [5] (18 by 13.8 (wxh) deg.). 5 different sizes of balls, and horizontal and vertical narrow bars were tested for size illusion (2.8, 3.7, 4.7, 5.6, 6.6 deg.) Observers repeated each condition 10 times (300 trials in total.)

Task: For bars the observers were asked to "adjust the length of the front bar to match that of the back such that the images would perfectly overlap in length if moved to the same location on the screen". For balls they were asked to "adjust the size of the front ball to match that of the back such that the images would perfectly overlap if moved to the same location on the screen". Size of the front object was the dependent, and the size of the back object was the independent variable.

Analysis: The magnitude of the size effect is defined b

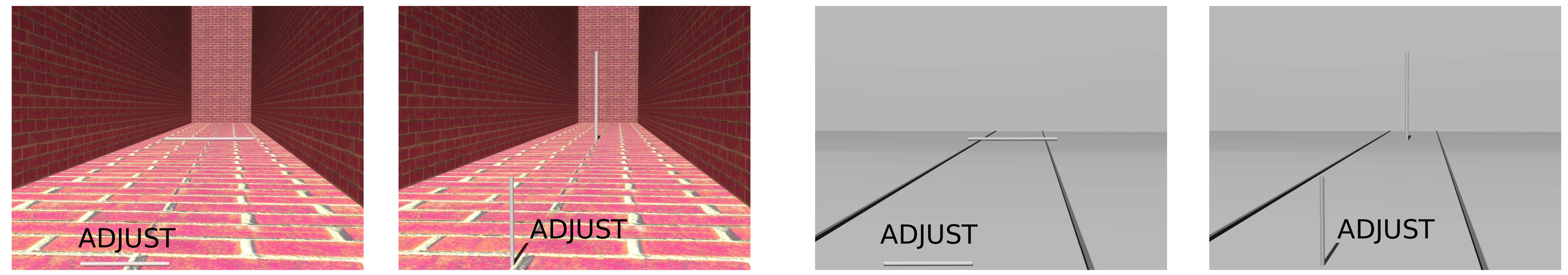
% perceptual effect = ((front/back)-1)*10

Experiment 1

Stimuli

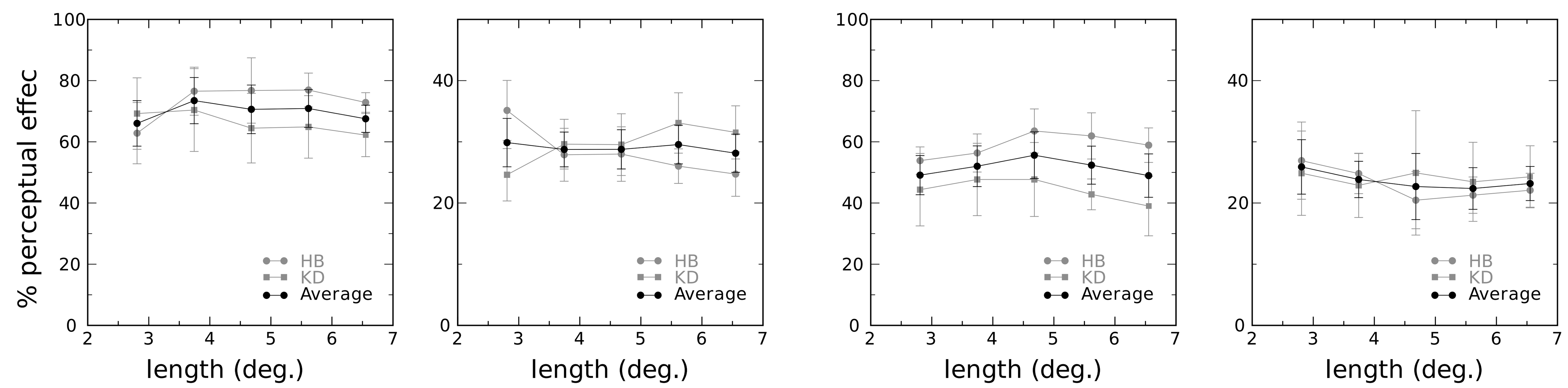
1D eccentricity effect in rich contex

1D eccentricity effect in weak contex



All bars have identical lengths (4.6 degrees under our experimental conditions) but the "far" ones look longer than the "near" ones. Note that the narrow dimension of the bars were kept constant (approximately 0.2 deg.)

Results



Average effect = 69

Average effect=29

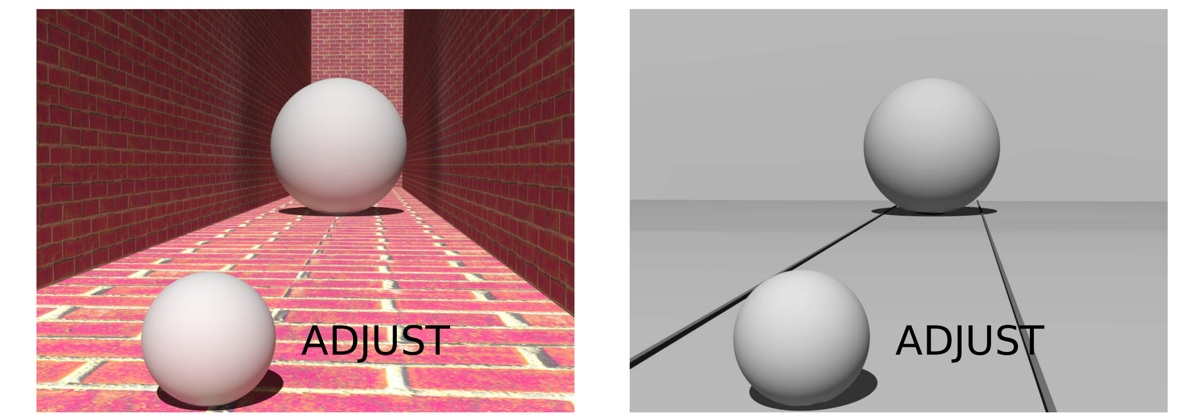
Average effect=52

Average effect=24

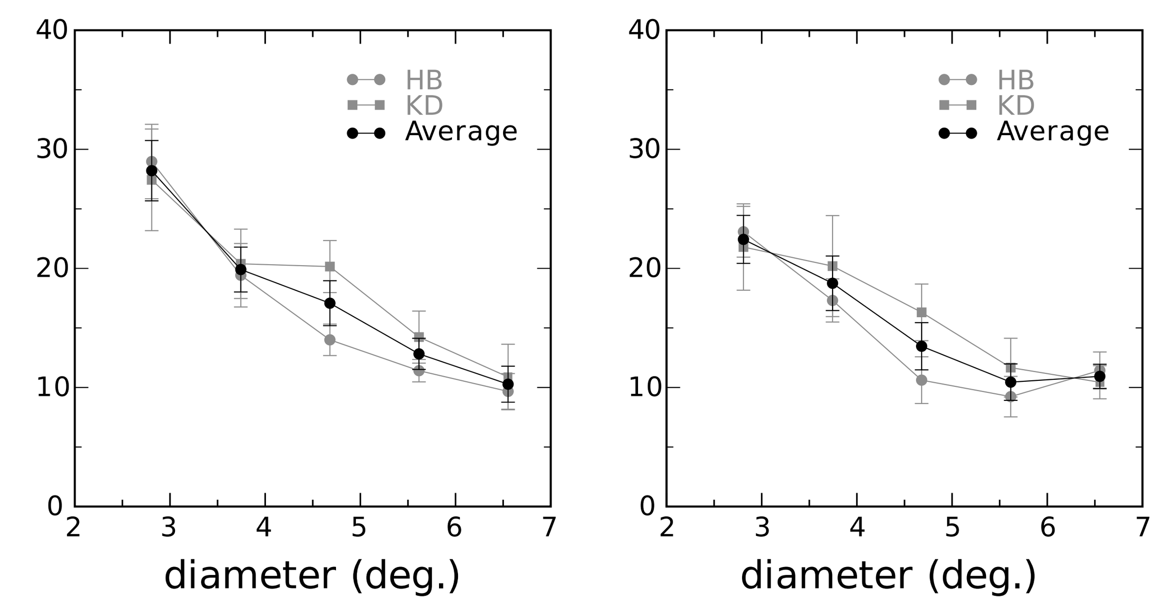
1D eccentricity effect is constant

Experiment 2

2D size effect in rich and weak context



Above all four balls have identical diameters (4.6 degrees under our experimental conditions), but the far balls look larger than the near ones.



2D size effect decreases with diameter

Summary of behavioral results

Consistent with the literature we found that context affects strongly the perceived angular size. Importantly, we found that while the 1D eccentricity is constant, the 2D size effect decreases with increasing diameter. Moreover, the 1D effect is larger than the 2D effect on the average. To explain this finding we next propose a possible cortical mechanism.

Note that the results also suggest that the effect is larger for horizontal bars than vertical bars, but we will not further address it on this poster.

References

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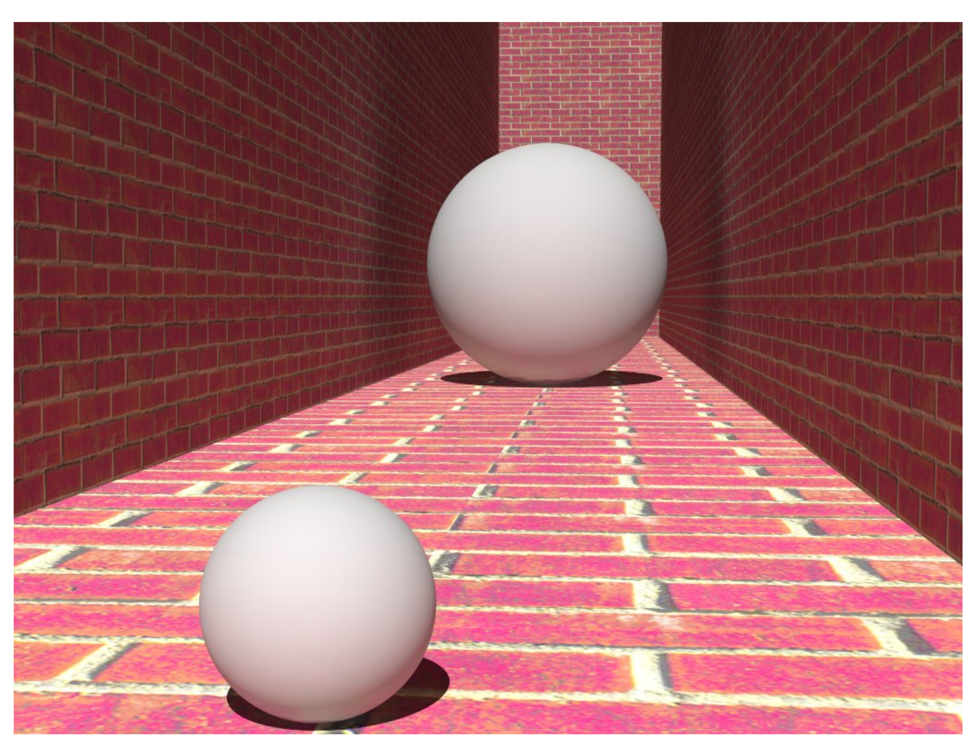
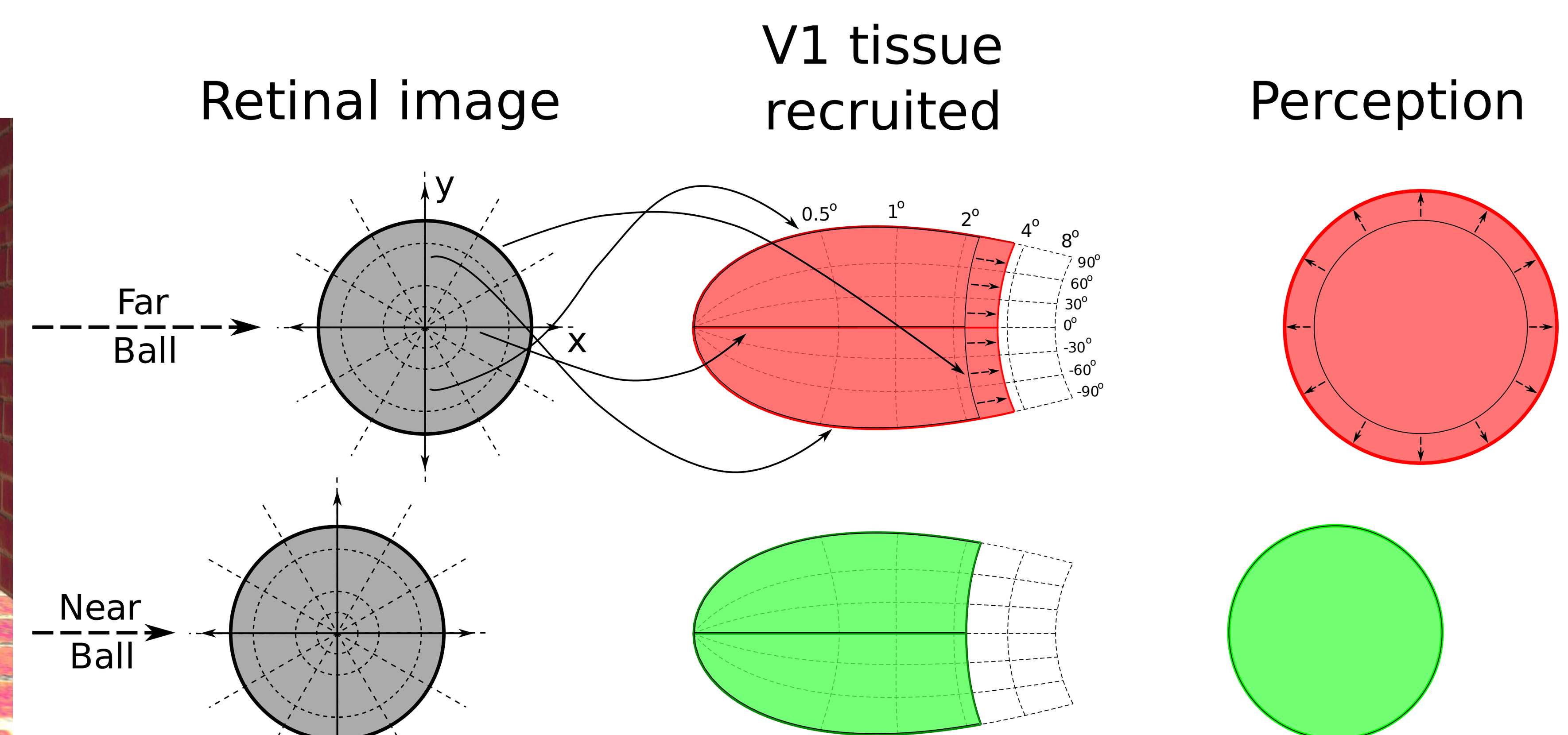
A cortical model





It was recently found that the spatial extent of activity in V1 correlates with *perceived* angular size [4]. Given those recent fi dings, we would like to find out whether one could predict the 2D size effect by considering the cortical areas recruited for the back and front balls. First, let us assume that the perceived diameters of the balls also follow the 1D findings, i.e. the "diameter" effect is constant across all ball sizes (constant 1D eccentricity effect.

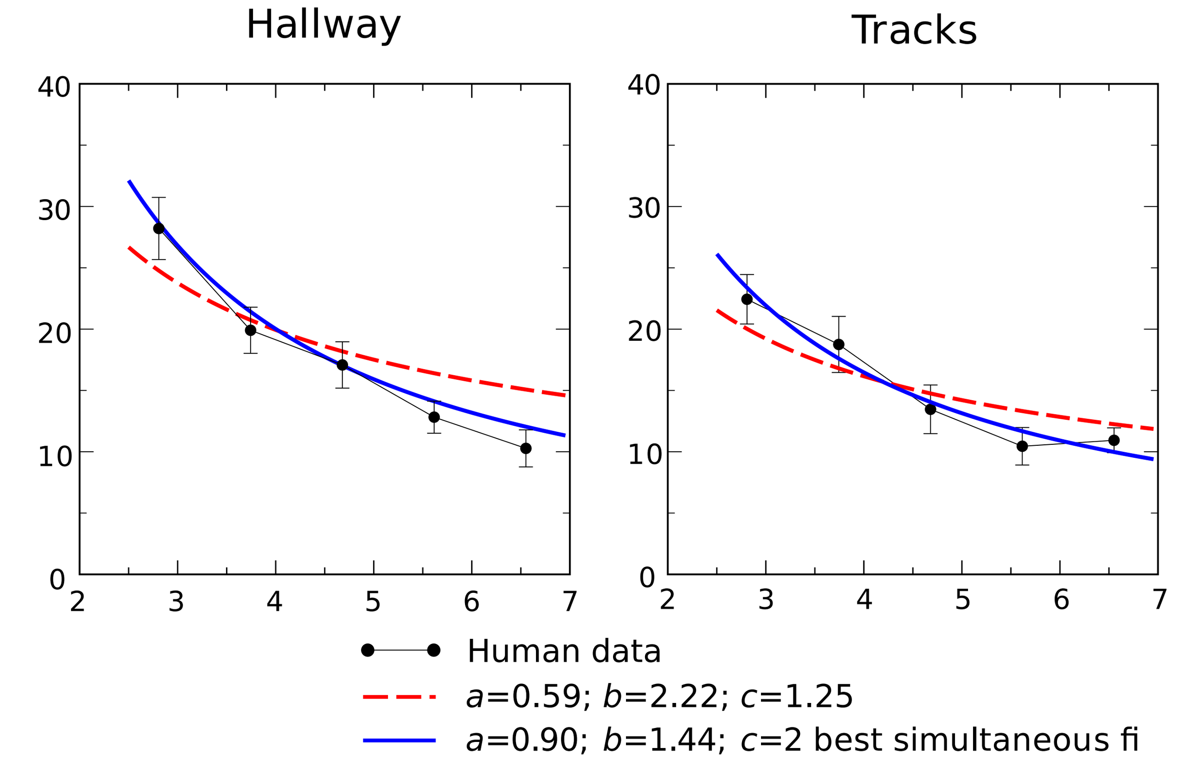
To compute the cortical area recruited, we used the following function for the mapping from retina to cortex

$$f(z) = 1/(b*(1-c)) * (a+b*z)^{1-c} \quad \text{for } c \text{ not equal to } 1$$

$$f(z) = 1/b * \ln(a+b*z) \quad \text{for } c=1$$

where $z=x+iy$ is a vector representation of the retinal image (i=sqrt of -1,) and a,b and c are constants (e.g. [6]). Using the above functional form we calculated the amount of cortical area recruited for the back and front ball at different absolute sizes, assuming a constant 1D eccentricity effect (49% for the hallway, 38% for the tracks). Shown above is the mapping with a=0.59, b=2.22, c=1.25.

Predicted 2D size effec



Finally we calculated the expected perceptual 2D size effect given the computed cortical areas for the far and near balls. The outcome, shown above, is consistent with the pattern of human data, i.e. the 2D size effect decreases with the ball size as a consequence of spatial mapping in V1. Note that the best simultaneous fit to both scenes has a rather high c value compared to the values reported in the literature. However the pattern is consistent with human data for any reasonable choice of constants.