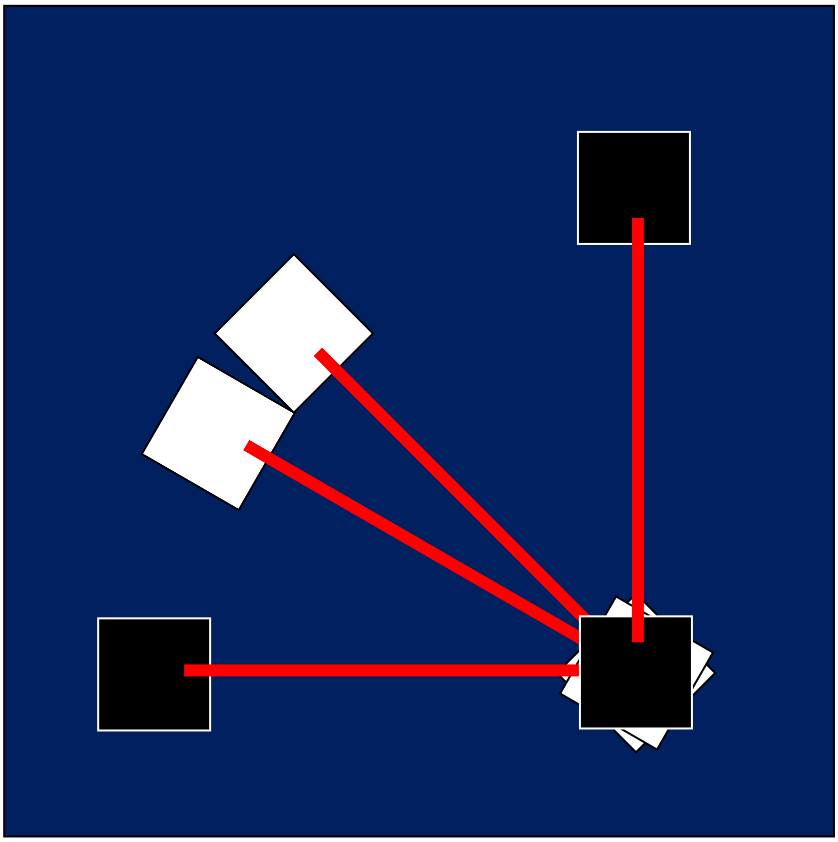
Variants of the Baldwin Illusion



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1. Introduction

Among the best known visual illusions related to the apparent length of a line are the Mueller-Lyer (1889) and the Baldwin illusion (Baldwin, 1895; Restle and Merryman, 1968; Brigell, 1977; Pressey, Di Lollo, and Tate, 1977; Pressey and Smith, 1986; Wilson and Pressey, 1988). Plotting the perceived length of a shaft with context elements as a function of the framing ratio, a smooth maximum is observed, in case of the Baldwin as well as the reversed Mueller-Lyer illusion (Pressey et al., 1977). “Reversed” means that that the apparent shortening of the shaft, which is characteristic for the Müller-Lyer illusion when fins are pointing outwards, is partly compensated by a gap between the shaft and the fins. Most experiments have been performed with horizontal stimuli. For comparison, Brigell et al. (1977) rotated figures and response scale by 90^0. They report identical results. Due to Kersten (2000) length illusions are caused by the systematic manipulation of size ratios.

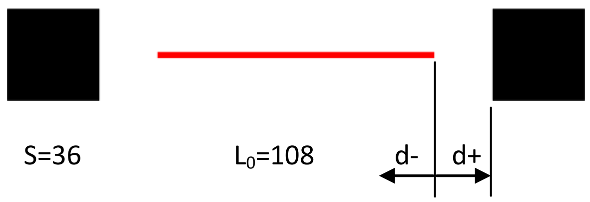
2. Experiments

2.1 Experiment 1

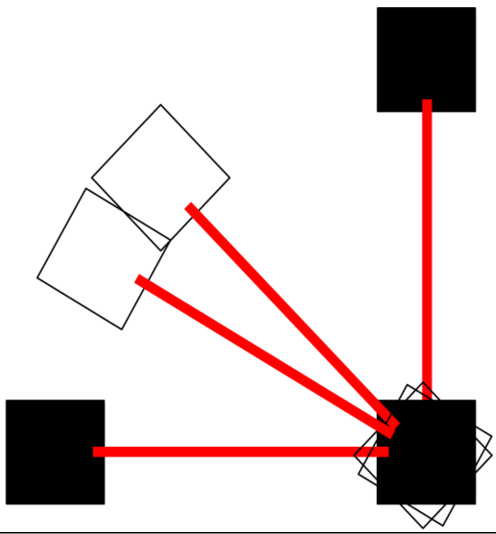
2.1.1 *Subjects*. Nine (five in the 30^0 experiment) healthy volunteers took part, mainly elderly people. Sight was corrected to normal. All of them were naive.

2.1.2 *Stimuli.* The stimuli (a red line, 108mm long, and 2 solid black squares with side lengths of 36mm) were printed on a DIN A3 white glossy cardboard. 4 Sets of stimuli were employed (Fig. 1): Horizontal orientation, tilted by 30^0 with respect to the horizontal, 45^0, and vertical. One set consisted of 13 transparencies. Within each set, the framing ratio FR was varied between 0.67 and 3.08, corresponding to a distance of the facing sides of the squares between zero and 261 mm. The framing ratio FR= 1.67 corresponds to the situation where

Fig. 1. The stimuli were presented in four different sets, where the red bar was oriented either horizontally or vertically or inclined by 30 and 45 degrees, respectively.



Framing ratio: $FR=(2S + 2d + L_0)/L_0$;
d may be either positive (gap as shown) or negative (distance of the facing sides of the squares shorter than the length of the target line).



the squares are attached to the ends of the line. A set of seven (dark blue) horizontal lines with increasing length from top to bottom, serving as standards, was shown on the left side below the stimulus (Fig. 2).

Within one set the length of the standard lines varied by approximately 40%. Different sets were employed, the shortest line ranging from 85mm to 115mm. Examples of transparencies are given in Fig. 2, below.

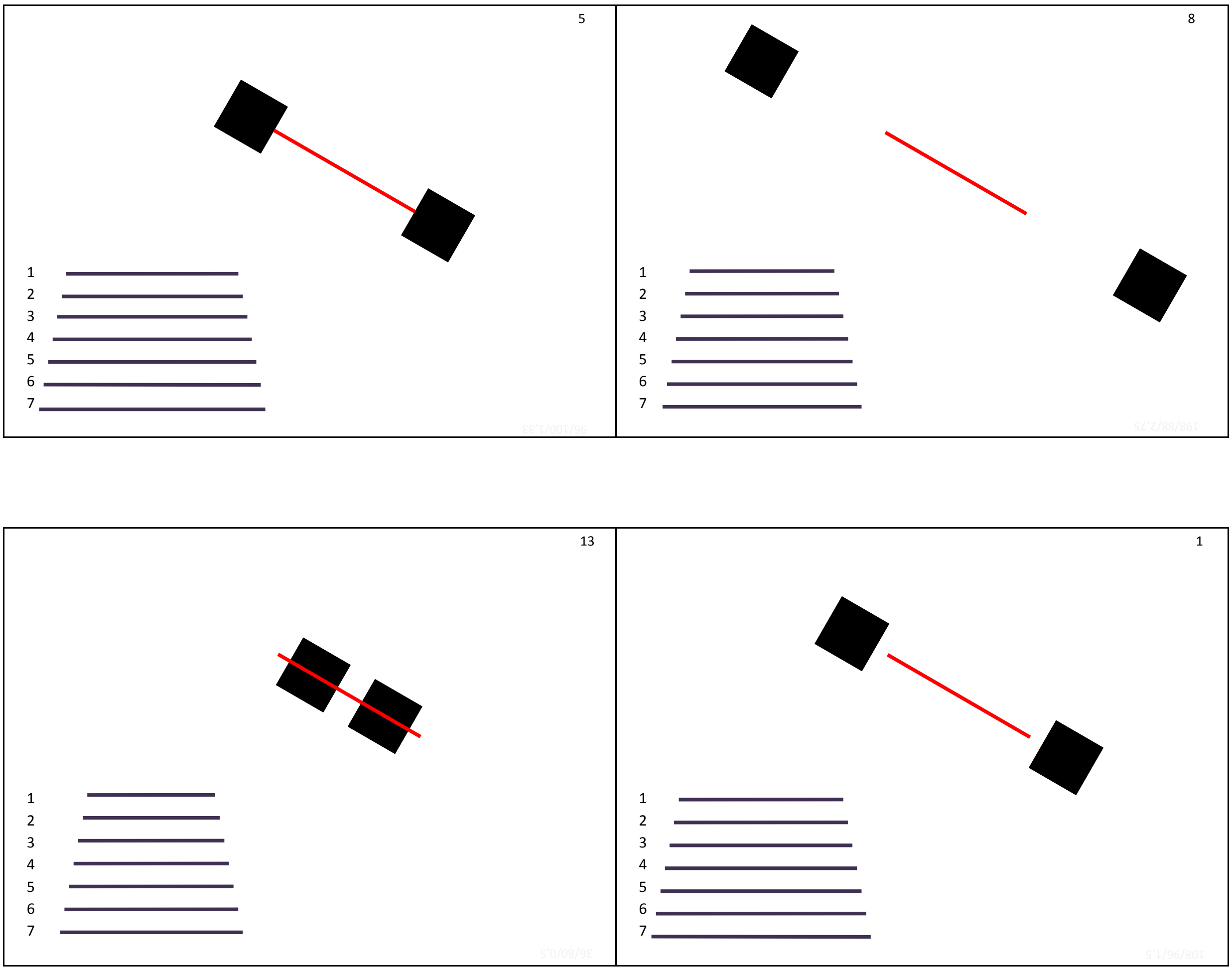


Fig. 2. Examples of transparencies where the stimulus is inclined by 30^0 with respect to the horizontal. In addition, stimuli of horizontal and vertical orientation have been employed as well as ones tilted by 45^0. For each of the four orientations a set of 13 transparencies was presented.

2.1.3. *Procedure*. Within each of the four sets, the 13 transparencies were presented in random order, 8 seconds each, followed by a blank of 3 seconds. Viewing distance was between 2m and 5m. The subjects indicated the perceived length of the target line by selecting one of the standards, which were always oriented horizontally.

2.1.4 *Results*. Fig. 3 gives the perceived length of the red bar, obtained from the four sets, in each of them the stimulus being oriented at a different angle. In Fig. 4 all data are collected.

A substantial difference is observed between the horizontal orientation of the stimulus and an inclination of 30^0, while there is hardly any difference between 45^0 and vertical.

2.1.5. Fitting of the mathematical function

The expression $L(perc)/L_0 = D + C*x + A*\exp[-B*abs((3*x-5)/2)]$ was fitted to the experimental values. It gives the perceived length y (in units of the true length) as a function of the framing ratio (x-axis). The exponent is zero for FR=x= 5/3, where the function reaches its maximum. Results are given in Table 1.

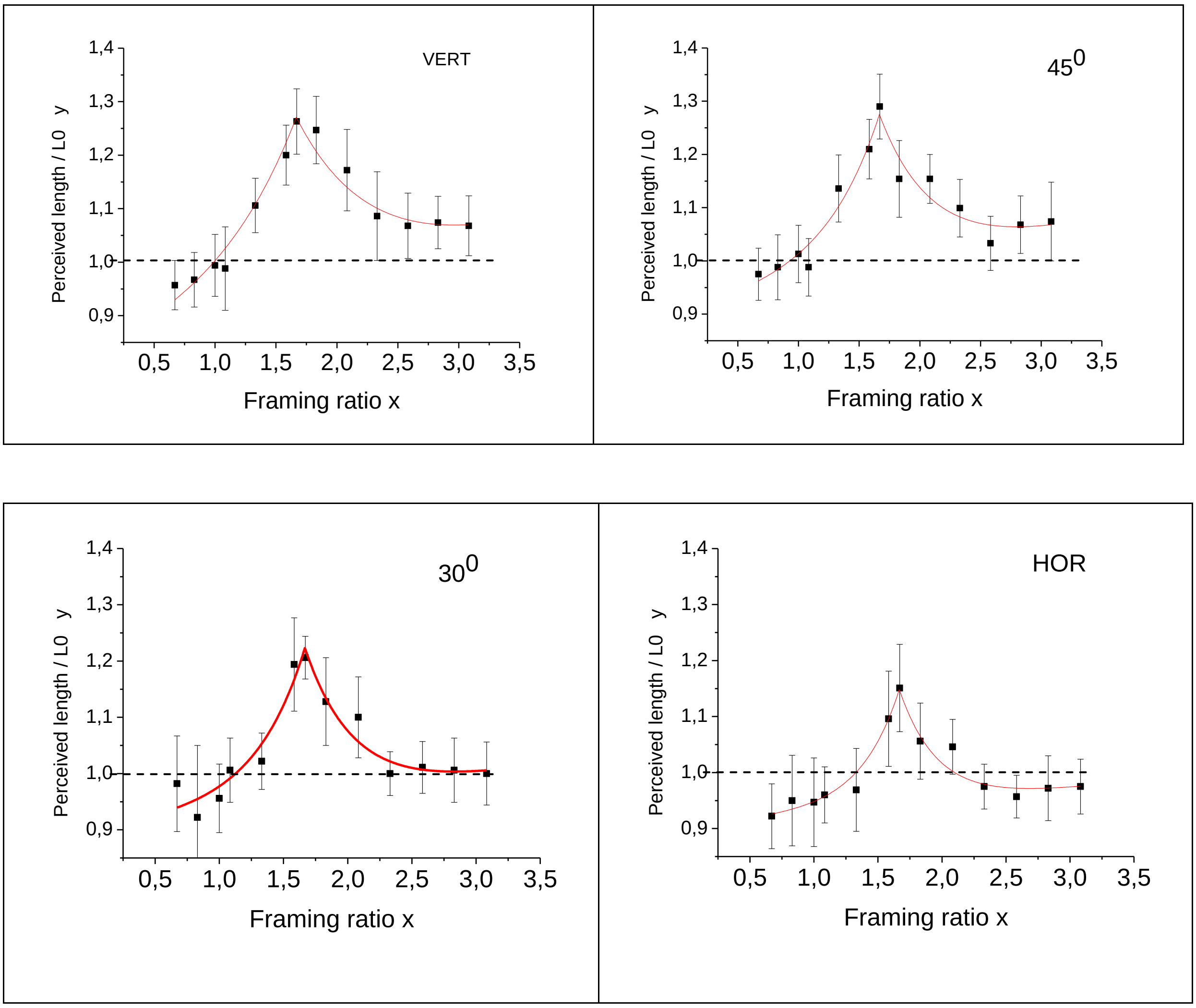


Fig. 3. Perceived length (in units of the true length) of the stimulus at different orientations. The dashed line indicates the true length.

Table 1. Results. Values of the parameters

	VERT	45^0	30^0	HOR
A	0.344(48)	0.292(32)	0.271(29)	0.207(18)
B	1.01(34)	1.51(50)	1.76(57)	2.23(57)
C	0.073(11)	0.052(12)	0.033(12)	0.0230(78)
D	0.805(64)	0.897(46)	0.898(39)	0.903(21)

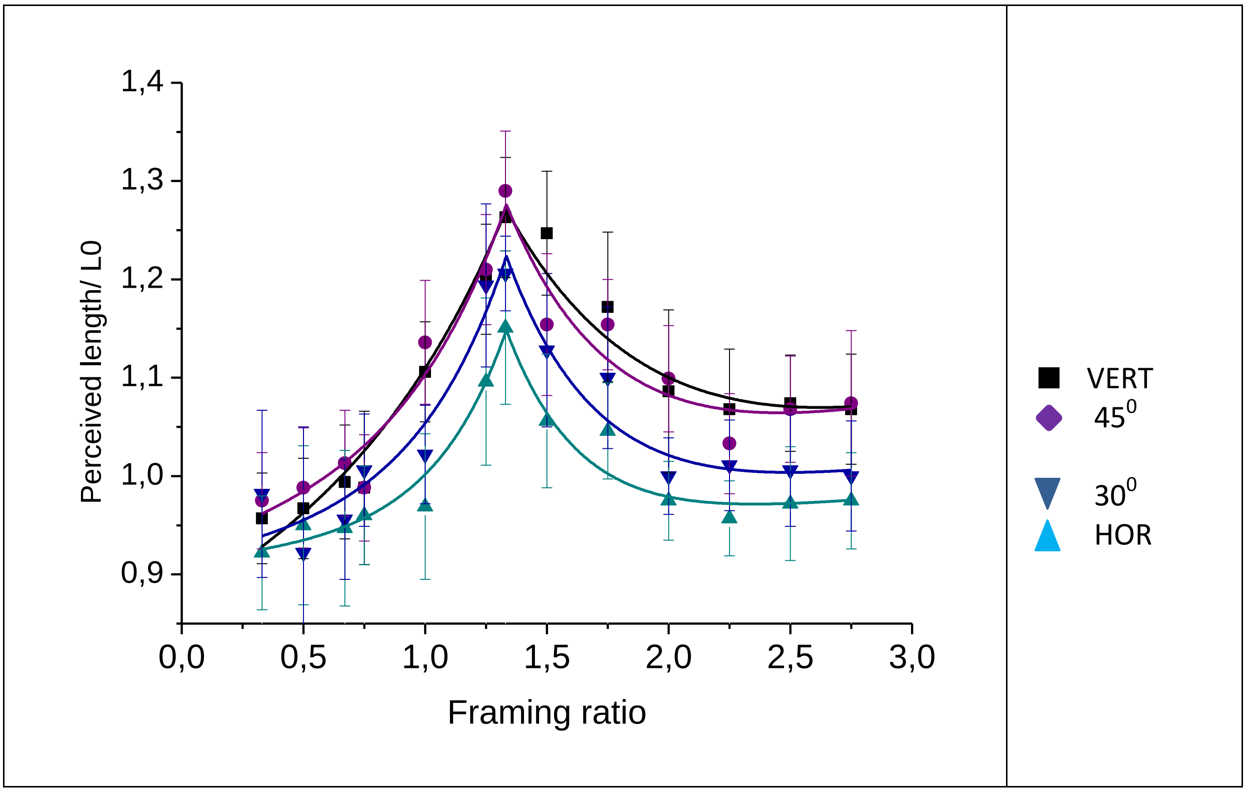


Fig. 4. Perceived length, collected results. For the perceived length of the shaft hardly any difference was found between vertical orientation of the stimulus and an angle of 45 degrees.

Due to the conceptual model, an assimilation/averaging effect is believed to contribute in a twofold way. This is discussed in chapter 3. Averaging means that different geometric elements approach each other in size when perceived as a single structure.

2.2 Experiment 2

This concerns the so called dumbbell variant of the Baldwin illusion, the discovery of which is ascribed to Delboeuf (1892, 1893).

2.2.1 Subjects: Sixteen healthy volunteers took part, mainly elderly people. Sight was corrected to normal. All of them were naive.

2.2.2 *Stimuli.* 25 transparencies were presented, one of them showing the shaft only. In the middle, upper half, the bright blue horizontal shaft was shown together with two solid dark blue (50% black) spheres in symmetric position along the axis of the shaft. On a DIN A4 print the shaft was 72mm long, diameter of the spheres was 24mm. Framing ratios varied from 0.61 to 2.94. Even for small framing ratios, the blue shaft was always visible in front of the spheres (Fig.6). One transparency gave the shaft only. Seven horizontal lines (lilac, 50%

black), in the lower part to the right, served as standards (Fig. 6). Different sets of standards were employed.

2.2.3 *Procedure:* The stimuli were projected with a beamer onto a screen which was ≈2m (W) x 1.5m (H) in size and presented for 8 seconds, followed by a blank of 2 seconds. Viewing distance ranged from 3.6 up to 8.1m, the target subtended an angle between $130 \cdot 10^{-3}$ rad and $58 \cdot 10^{-3}$ rad. The participants indicated the perceived length of the shaft by choosing one of the standards.

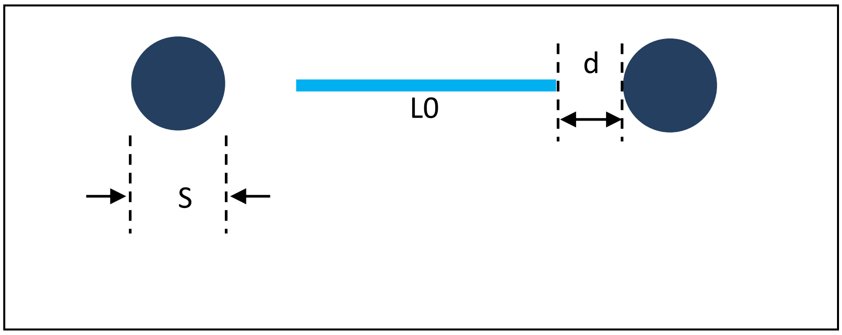


Fig. 5. Dumbbell variant. Framing ratio x = (2S+2d+L0)/L0.

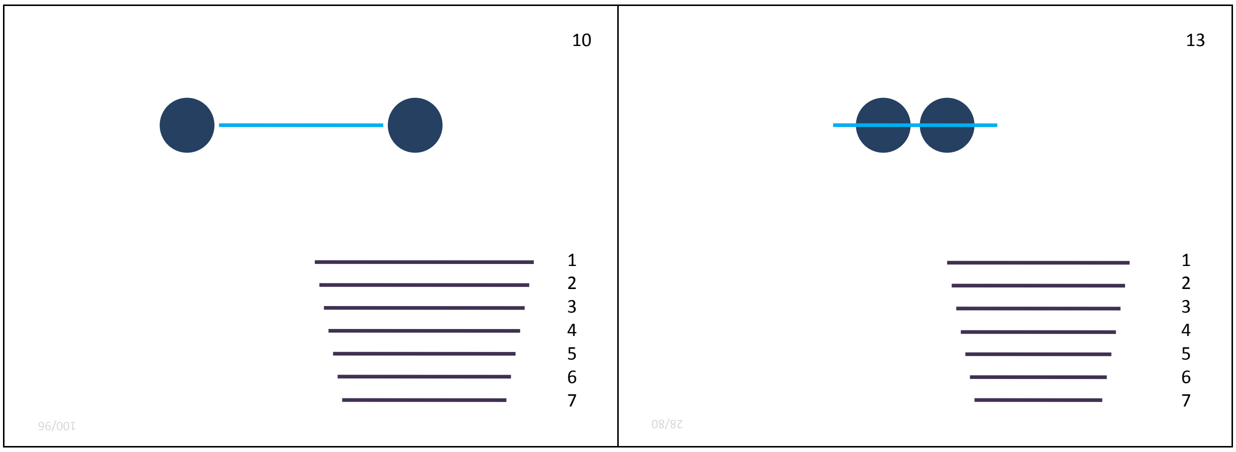
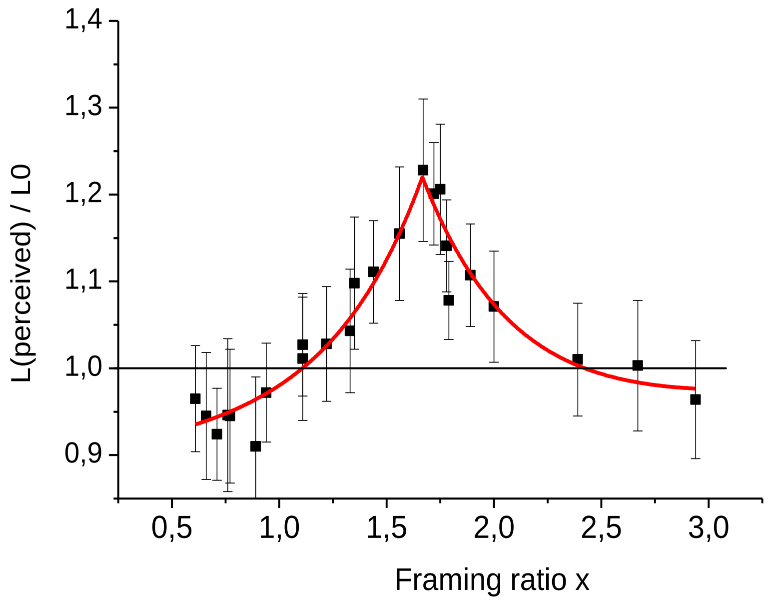


Fig. 6. Two of the 25 transparencies presented. Right: The spheres were positioned behind the shaft, so it was always to be seen in full length.

2.2.4 *Evaluation*. From the transparency showing the shaft without context elements, its perceived length, $L0_{perceived}$, was determined. It turned out to be slightly larger than the true length (72.3mm instead of 72mm, on a DIN A4 print). Results from 24 transparencies are presented in Fig. 7 which gives the perceived length of the shaft as a function of the framing ratio x = (2S+2d+L0) /L0 (Fig. 5). The data are normalized to the perceived length of the shaft without context elements ($L0_{perceived}$). At low framing ratio, the perceived length is considerably smaller than the true length. Then, a steep increase occurs, up to a maximum at FR= 5/3 = 1.67, where the spheres just touch the bar without leaving a gap. Then the apparent length of the shaft decreases again, coming close to its true length. Parameters obtained from fitting are given in Table 2.

Table 2	Fig. 7a	Fig. 7b
A	0,286(21)	0.296(21)
B	1.54(37)	1.66(40)
C	0.219(92)	
D	0.897(27)	0.931(23)



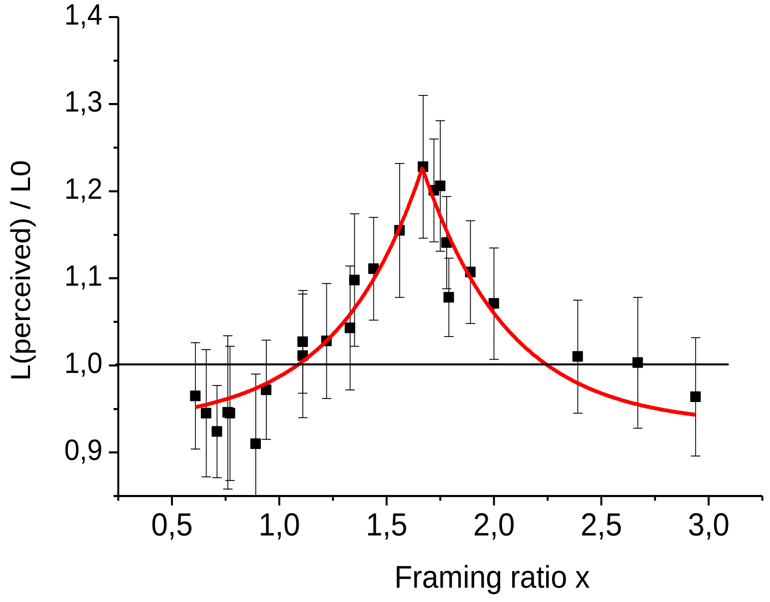
a)

Algebraic function:

y=D+C*x+
A*exp(-B*abs((3*x-5)/2));

D 0.897(27)
C 0.0219(92)
A 0.286(21)
B 1.54(37)

Chi^2/DoF = 0.00072
R^2 = 0.92971



b)

Algebraic function
y=D+
A*exp(-B*abs((3*x-5)/2));

D 0.931(23)
A 0.296(21)
B 1.66(40)

Chi^2/DoF = 0.00087
R^2 = 0.90977

Fig. 7. Perceived length of the blue shaft as a function of the framing ratio x. a) Fit with four and b) three parameters. The horizontal line indicates the perceived length of the shaft without spheres (L0).

3. Algebraic function

The function employed for fitting

$$y(x) = D + C*x + A*exp(-B*abs((3x-5)/2))$$

is based on three assumptions (Kreiner, 2011):

1: Compared to the constant term, D, the other terms are regarded as to be fairly small.

2: Averaging: Close distance of the context elements will cause the shaft to appear shorter than in case of long distance of the context elements. This is taken into account by the term C*x, where, to low order of approximation, proportionality to the framing ratio is assumed.

3. Averaging will be most effective when the spheres are just attached to the shaft, so that all elements together form a unity. Its influence will decrease as soon as the elements leave this position. This is taken into account by the exponent B*abs((3*x-5)/2) in the last term. It contains the gap size d and causes the exponential function to gain its maximum when the gap is equal to zero, but to decay strongly when the framing ratio x deviates from 5/3. In case the spheres are at infinity, they will have no effect at all. In Fig. 7b, the second term has been omitted.

4. Results and Discussion

Two variants of the Baldwin illusion have been investigated, where context elements of constant size are moved symmetrically along the axis of the shaft, being positioned either within the length of the shaft or outside. In the first variant squares served as context elements and the stimulus was observed in four different orientations. In the second experiment, presenting the so called dumbbell variant, the stimulus was oriented horizontally. Concerning the apparent length of the shaft as a function of the framing ratio, very similar effects have been observed for both variants. In contrast to the classic Baldwin illusion, where the perceived length of a bar as a function of the framing ratio exhibits a smooth maximum, a rather sharp maximum is observed in these cases. This occurs when the context elements just touch the ends of the shaft. This is mainly ascribed to two averaging effects, a linear and a nonlinear one. The increasing slope towards larger values of the framing ratio is believed as due to a perceived stretching of the stimulus as a whole. It is described by the linear term. The steep slope on either side of the maximum is ascribed to the fact that averaging has its strongest impact when the interacting elements are regarded as a uniform geometric structure. The situation changes rapidly, as soon as the context elements are removed from their unique positions at the ends of the shaft. This is described by an exponential decay function.

The apparent length of the shaft depends on the orientation of the stimulus as well. For the first variant, in addition to vertical and horizontal orientation, inclinations of the shaft by 30^0 and 45^0 with respect to the horizontal have been investigated. The illusion is most pronounced for vertical orientation.

Citations

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