Supplementary information

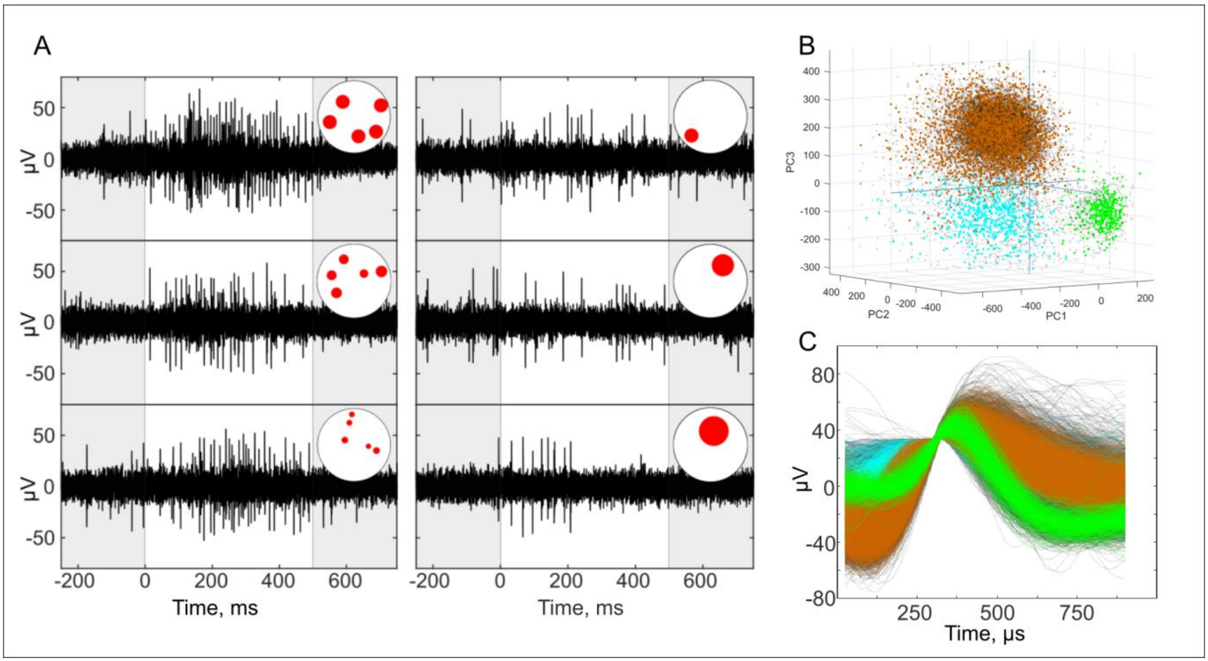

Figure S1. (A) Example of raw spike trains: electrical signal is shown after the high-pass filter was applied. Examples of single trials, representing neural response of the unit to numerosity 5 (left column), irrespective of the stimulus appearance (top: radius-fixed, middle: area-fixed, bottom: perimeter-fixed). Note the decreasing neural response to the numerosity 1 (right column). (B) The PCA clustering of the corresponding recording with waveforms of different units shown by different colours. The waveforms of the number-responsive unit are shown in orange, unsorted waveforms are shown in grey. (C) Spike waveforms of corresponding units isolated from the recording of one electrode.

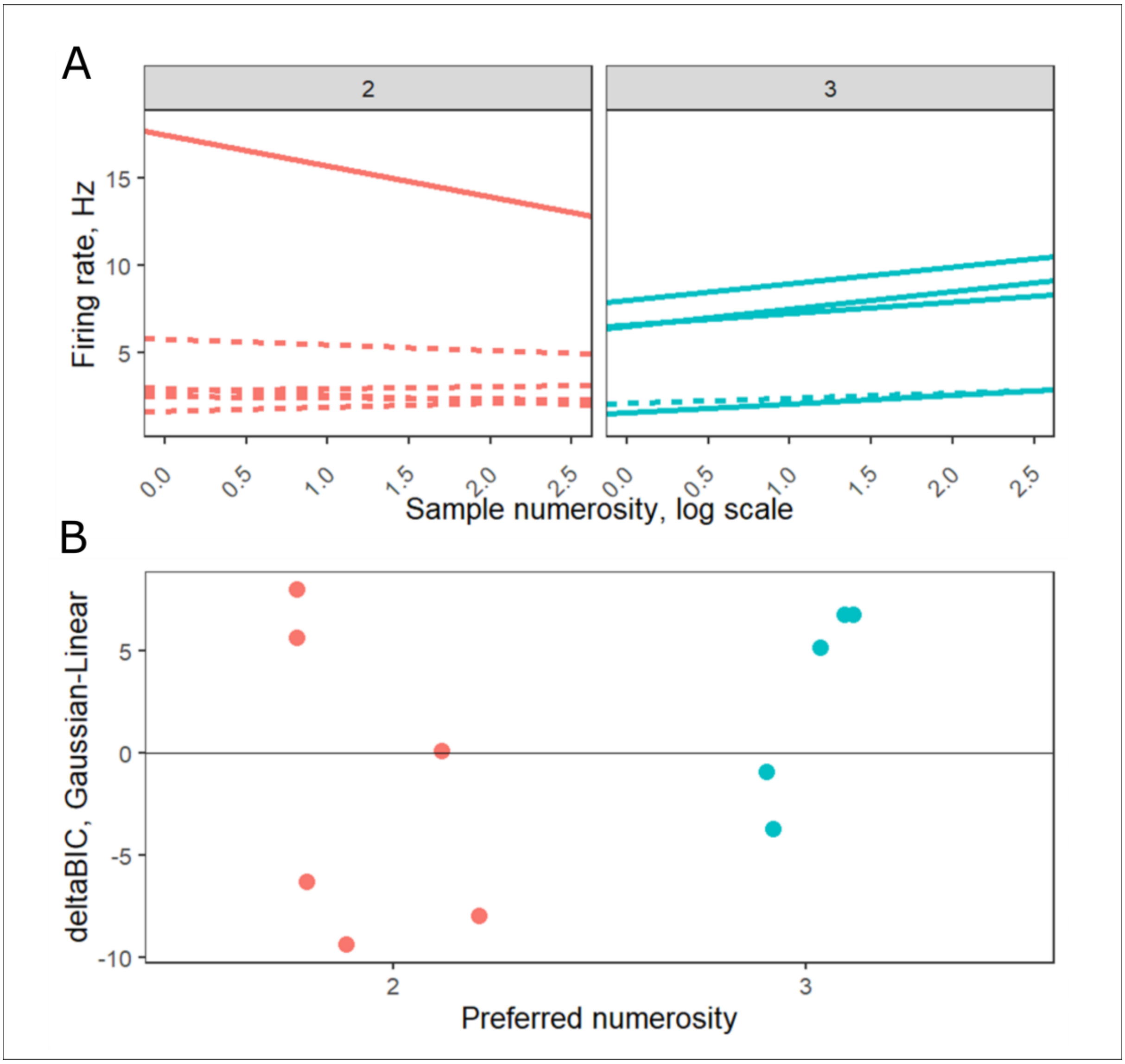

Figure S2. All numerosity-responsive neurons significantly ($p<0.01$) changed their firing rate in response to numerical stimuli, which was revealed by ANOVA with "numerosity" as a factor. If these neurons would be monotonically increasing/decreasing their firing rate with numerosity (according to the summation coding), we would expect their firing rate to be best explained by a linear model (the linear regression applied to the neural response of these neurons should be highly significant).This, however, is not the case for most neurons. (A) Linear regression lines applied to the raw neural responses of the neurons tuned to numerosity 2 (red) and 3 (blue). Solid lines – significant ($p<0.01$) decrease/increase of the firing rate with numerosity; dashed lines – non-significant regression. Please note that out of 11 number neurons, only 5 showed significant ($p<0.01$) decrease/increase of their firing rate with numerosity (solid lines). Out of these 5 cases, 4 belong to the neurons tuned to numerosity 3, which do have very broad and positively skewed tuning curves. Also note that among the 6 neurons that were tuned to numerosity 2, only 1 neuron has a significant linear decrease in the firing rate. Thus, the majority of the data does not follow this prediction of the summation coding theory. (B) ΔBIC (difference between Bayesian information criterion of a Gaussian fit and the linear regression) is plotted for neurons preferentially responding to numerosity 2 (red) and 3 (blue). If ΔBIC is lower than 0, the BIC for the Gaussian fit is smaller than for the linear fit and, hence, the corresponding unit response is better described by a bell-shaped behaviour according to a labeled-line code hypothesis. This analysis revealed that only for 5 out of 11 neurons there is a strong preference for the linear fit (suggesting monotonic coding). Thus, also in this case, while some of the neurons in our datasets seem to follow the linear fit, supporting the monotonic coding, this does not apply to the entirety or even the majority of our neurons.

Table S1. Summary of the two-way ANOVA for every recorded unit. Unit: id of the recorded unit. Preferred numerosity: numerosity stimulus that elicited the strongest response in the corresponding unit. ANOVA results (F-statistics and p-value) are summarized for the factor “Stimulus type” (radius-fixed, area-fixed, perimeter-fixed), “Numerosity” (numerosity “one” to “five”), or interaction between them.

Unit	**Preferred numerosity**	**ANOVA (Firing rate ~ Stimulus type * Numerosity)**		
		Numerosity	Stimulus type	Interaction
1	num1	F(4,546)=4.0327, p = 0.003	F(2,546)=0.5228, p = 0.593	F(8,546)=1.4242, p = 0.183
2	num1	F(4,197)=3.5672, p = 0.008	F(2,197)=0.4656, p = 0.628	F(8,197)=0.8763, p = 0.537
3	num1	F(4,202)=4.0268, p = 0.004	F(2,202)=1.7732, p = 0.172	F(8,202)=1.1967, p = 0.303
4	num1	F(4,565)=4.2588, p = 0.002	F(2,565)=0.0012, p = 0.999	F(8,565)=0.7852, p = 0.616
5	num1	F(4,270)=5.3565, p = 0	F(2,270)=1.2038, p = 0.302	F(8,270)=0.9519, p = 0.474
6	num1	F(4,270)=5.4507, p = 0	F(2,270)=0.0475, p = 0.954	F(8,270)=0.7056, p = 0.687
7	num1	F(4,239)=3.7861, p = 0.005	F(2,239)=0.4114, p = 0.663	F(8,239)=1.6597, p = 0.109
8	num1	F(4,419)=4.9175, p = 0.001	F(2,419)=1.0111, p = 0.365	F(8,419)=1.0988, p = 0.363
9	num1	F(4,399)=7.4226, p = 0	F(2,399)=2.8675, p = 0.058	F(8,399)=2.1769, p = 0.028
10	num1	F(4,366)=4.2597, p = 0.002	F(2,366)=0.9588, p = 0.384	F(8,366)=1.4233, p = 0.185
11	num1	F(4,364)=6.4075, p = 0	F(2,364)=0.2249, p = 0.799	F(8,364)=1.2606, p = 0.263
12	num1	F(4,490)=3.9053, p = 0.004	F(2,490)=1.1902, p = 0.305	F(8,490)=0.6286, p = 0.754
13	num1	F(4,251)=5.7273, p = 0	F(2,251)=0.9275, p = 0.396	F(8,251)=1.2411, p = 0.273
14	num1	F(4,186)=3.5545, p = 0.008	F(2,186)=1.1998, p = 0.304	F(8,186)=0.6334, p = 0.749
15	num1	F(4,233)=4.4063, p = 0.002	F(2,233)=1.138, p = 0.322	F(8,233)=0.3761, p = 0.933
16	num1	F(4,316)=3.6533, p = 0.006	F(2,316)=1.4135, p = 0.245	F(8,316)=0.8235, p = 0.582
17	num2	F(4,177)=4.5348, p = 0.002	F(2,177)=0.2742, p = 0.761	F(8,177)=0.6772, p = 0.711
18	num2	F(4,176)=4.1623, p = 0.003	F(2,176)=0.8853, p = 0.414	F(8,176)=0.8814, p = 0.533
19	num2	F(4,147)=3.6633, p = 0.007	F(2,147)=0.929, p = 0.397	F(8,147)=0.5183, p = 0.841
20	num2	F(4,145)=3.7461, p = 0.006	F(2,145)=0.514, p = 0.599	F(8,145)=0.5375, p = 0.827
21	num2	F(4,298)=3.4934, p = 0.008	F(2,298)=0.7184, p = 0.488	F(8,298)=1.0979, p = 0.364
22	num2	F(4,253)=3.5881, p = 0.007	F(2,253)=0.2355, p = 0.79	F(8,253)=0.454, p = 0.887
23	num3	F(4,213)=3.4856, p = 0.009	F(2,213)=0.6473, p = 0.524	F(8,213)=0.5014, p = 0.854
24	num3	F(4,184)=3.6183, p = 0.007	F(2,184)=0.5629, p = 0.571	F(8,184)=0.6608, p = 0.725

25	num3	F(4,472)=5.1242, p = 0	F(2,472)=2.8061, p = 0.062	F(8,472)=0.809, p = 0.595
26	num3	F(4,410)=3.7563, p = 0.005	F(2,410)=4.5228, p = 0.011	F(8,410)=1.3146, p = 0.233
27	num3	F(4,496)=5.8789, p = 0	F(2,496)=0.1179, p = 0.889	F(8,496)=1.4538, p = 0.173
28	num4	F(4,176)=3.926, p = 0.004	F(2,176)=1.1196, p = 0.329	F(8,176)=0.6298, p = 0.752
29	num4	F(4,178)=3.9175, p = 0.004	F(2,178)=0.4244, p = 0.655	F(8,178)=0.6897, p = 0.7
30	num4	F(4,267)=4.5852, p = 0.001	F(2,267)=0.6043, p = 0.547	F(8,267)=0.8609, p = 0.55
31	num4	F(4,371)=3.6503, p = 0.006	F(2,371)=1.9928, p = 0.138	F(8,371)=0.5894, p = 0.787
32	num4	F(4,430)=3.4615, p = 0.008	F(2,430)=0.3739, p = 0.688	F(8,430)=0.513, p = 0.847
33	num4	F(4,420)=4.4972, p = 0.001	F(2,420)=1.1432, p = 0.32	F(8,420)=1.1135, p = 0.353
34	num4	F(4,459)=6.5488, p = 0	F(2,459)=2.8234, p = 0.06	F(8,459)=1.3186, p = 0.232
35	num4	F(4,333)=3.4399, p = 0.009	F(2,333)=3.3226, p = 0.037	F(8,333)=1.5331, p = 0.145
36	num4	F(4,308)=4.2385, p = 0.002	F(2,308)=0.1141, p = 0.892	F(8,308)=0.9124, p = 0.506
37	num5	F(4,323)=5.0184, p = 0.001	F(2,323)=1.9782, p = 0.14	F(8,323)=0.3722, p = 0.935
38	num5	F(4,188)=3.5707, p = 0.008	F(2,188)=1.1655, p = 0.314	F(8,188)=0.5456, p = 0.821
39	num5	F(4,307)=5.1489, p = 0	F(2,307)=0.0322, p = 0.968	F(8,307)=0.4935, p = 0.861
40	num5	F(4,260)=5.1953, p = 0	F(2,260)=0.945, p = 0.39	F(8,260)=0.682, p = 0.707
41	num5	F(4,234)=4.65, p = 0.001	F(2,234)=0.7971, p = 0.452	F(8,234)=0.8709, p = 0.542
42	num5	F(4,232)=3.7216, p = 0.006	F(2,232)=0.0802, p = 0.923	F(8,232)=1.3969, p = 0.199
43	num5	F(4,484)=3.6509, p = 0.006	F(2,484)=0.1205, p = 0.887	F(8,484)=0.7686, p = 0.631
44	num5	F(4,458)=12.8202, p = 0	F(2,458)=0.7574, p = 0.469	F(8,458)=0.4219, p = 0.908
45	num5	F(4,192)=4.4432, p = 0.002	F(2,192)=2.0198, p = 0.135	F(8,192)=1.8229, p = 0.075
46	num5	F(4,415)=3.8044, p = 0.005	F(2,415)=1.618, p = 0.2	F(8,415)=0.5316, p = 0.832
47	num5	F(4,685)=14.1207, p = 0	F(2,685)=1.9687, p = 0.141	F(8,685)=1.4958, p = 0.156
48	num5	F(4,371)=6.7422, p = 0	F(2,371)=0.6683, p = 0.513	F(8,371)=1.6257, p = 0.115
49	num5	F(4,359)=4.1619, p = 0.003	F(2,359)=0.1355, p = 0.873	F(8,359)=0.4252, p = 0.906
50	num5	F(4,355)=13.4938, p = 0	F(2,355)=1.832, p = 0.162	F(8,355)=0.3219, p = 0.958
51	num5	F(4,354)=6.4972, p = 0	F(2,354)=0.6433, p = 0.526	F(8,354)=0.9821, p = 0.45
52	num5	F(4,288)=3.3897, p = 0.01	F(2,288)=2.1069, p = 0.123	F(8,288)=1.2445, p = 0.273
53	num5	F(4,460)=5.4865, p = 0	F(2,460)=1.4027, p = 0.247	F(8,460)=0.7622, p = 0.636

Table S2. The post hoc analysis of the two-way ANOVA based on the Tukey-Kramer method summarising p-values for every pairwise comparison between the most-preferred and other numerosities. Significant p-values <0.05 are highlighted in bold.

Unit	Preferred numerosity	Post hoc analysis, p-value				
		num1	num2	num3	num4	num5
1	num1		**0.016**	**0.022**	**0.019**	**0.007**
2	num1		0.081	**0.019**	**0.011**	**0.021**
3	num1		0.988	0.903	0.303	**0.003**
4	num1		0.974	0.315	**0.002**	0.209
5	num1		0.890	0.650	**0.000**	**0.027**
6	num1		0.176	0.063	**0.001**	**0.001**
7	num1		**0.035**	**0.048**	**0.006**	**0.020**
8	num1		**0.031**	**0.001**	**0.001**	**0.023**
9	num1		0.788	0.174	**0.000**	**0.000**
10	num1		0.465	**0.002**	**0.009**	0.169
11	num1		**0.033**	**0.000**	**0.000**	**0.001**
12	num1		**0.036**	**0.013**	0.090	**0.004**
13	num1		0.221	0.120	**0.001**	**0.000**
14	num1		0.147	0.142	0.061	**0.004**
15	num1		**0.031**	**0.002**	0.084	**0.004**
16	num1		0.304	**0.048**	**0.008**	**0.014**
17	num2	0.447		0.986	0.362	**0.001**
18	num2	**0.001**		**0.027**	**0.025**	0.206
19	num2	**0.023**		0.945	0.065	0.063
20	num2	**0.013**		**0.017**	0.826	0.608
21	num2	0.973		0.181	0.125	**0.011**
22	num2	**0.040**		0.312	0.075	**0.004**
23	num3	**0.005**	0.807		0.760	0.123
24	num3	**0.006**	0.094		0.504	0.899
25	num3	**0.001**	0.913		0.998	0.796
26	num3	**0.005**	0.059		0.370	0.857
27	num3	**0.000**	**0.024**		0.798	0.683
28	num4	**0.003**	0.282	0.120		**0.016**
29	num4	**0.020**	0.051	0.213		0.999
30	num4	0.710	**0.001**	**0.028**		0.103
31	num4	**0.007**	0.369	0.813		0.998
32	num4	0.059	0.059	0.936		0.999
33	num4	0.065	**0.007**	0.864		1.000
34	num4	**0.000**	0.092	0.419		0.968
35	num4	**0.004**	0.628	0.616		0.850
36	num4	**0.003**	0.194	0.981		0.928
37	num5	**0.002**	**0.002**	**0.007**	0.054	
38	num5	**0.022**	0.287	0.995	0.999	
39	num5	**0.000**	0.148	0.653	0.803	

40	num5	**0.000**	**0.026**	0.525	0.214
41	num5	**0.001**	**0.021**	0.226	**0.012**
42	num5	**0.008**	0.150	**0.010**	0.431
43	num5	**0.004**	0.097	0.111	0.725
44	num5	**0.000**	**0.000**	0.750	0.851
45	num5	**0.015**	**0.032**	**0.001**	0.080
46	num5	0.070	**0.002**	0.428	0.069
47	num5	**0.000**	**0.000**	**0.016**	0.868
48	num5	**0.000**	**0.003**	0.251	0.901
49	num5	**0.003**	0.394	0.940	0.997
50	num5	**0.000**	**0.000**	**0.034**	0.078
51	num5	**0.000**	**0.009**	**0.014**	0.801
52	num5	0.074	**0.023**	0.988	0.798
53	num5	**0.006**	**0.004**	0.276	0.998

Video S1

Examples of trials showing raw neural responses to numerosities 1 and 5. The firing rate increases in response to the most preferred numerosity 5 compared to the least preferred numerosity 1. The video-recordings of the corresponding trials show that the animal is observing the stimuli (shown on the right) with the contralateral (left) eye or with both eyes. The video is slowed down to 60% of the original speed.