Supplementary Materials

a) Preliminary experiment

In a preliminary experiment, we aimed to examine the interaction between extrinsic grouping cues (i.e. common region and connectedness; see Brooks, 2015, for a review) by means of an indirect method, i.e. repetition discrimination task (RDT; Palmer & Beck, 2007), in order to obtain an unbiased measure of the competition between common region and connectedness cues acting within the same display.

We first conducted a scaling task to select the appropriate stimuli in order to ensure that the grouping strength of both cues was equated, as was recommended by Kubovy and van den Berg (2008). Therefore, we obtained individual ratings of grouping strength for every participant from the scaling task, which were used to personalize the stimulus set displayed in the subsequent RDT. In the scaling task, participants had to equate the grouping strength of both principles by adjusting the luminance contrast of the connectors with the ovals acting as common region cues from a homogeneous luminance between them (RGB: 190) to the maximum contrast (RGB: 0) (see Figure S1).

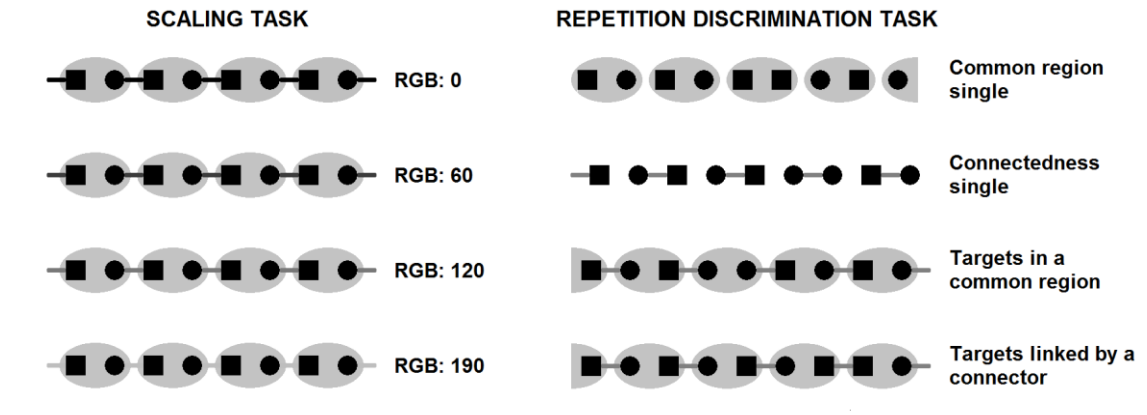

Figure S1. Examples of some stimuli displayed in the scaling task and in the RDT.

Method

Participants.

Twelve undergraduate students (six men; age range: 19-45 years, M = 26.6, SD = 8.8) from the UNED participated in the experiment and received course credits for their participation. All of them had normal or corrected-to-normal vision. The experimental procedure was approved by the Local Ethics Committee and conforms to the Declaration of Helsinki.

Apparatus

The stimuli were displayed on a 19-inch LCD-LED color monitor with a 75-Hz refresh rate, a 5:4 aspect ratio, and a resolution of 1280 x1024 pixels, controlled by a personal computer running E-Prime 2.0 software (Psychology Software Tools, 1996-2013). Viewing distance was approximately 60 cm. Responses were recorded via a standard keyboard.

Stimuli

The stimulus set was based on Palmer and Beck's (2007) displays. The basic display consists of a row of nine dark (RGB: 0; 0.06 cd/m2) equidistant elements that alternate between squares and circles, which subtended 9 × 9 mm (0.86º v.a.). The entire array of nine elements measured 152 mm (14.22º v.a.) vertically. The edge-to-edge distance between elements was 9 mm (0.86º v.a.).

For the RDT, forty-eight different stimuli were drawn (see Figure 1b), twenty-four for the single conditions and the other twenty-four displays for the competing conditions. The nine elements alternated between squares and circles except for a single pair of adjacent similar shapes somewhere within the middle seven elements. In the common region only condition, four light grey (RGB: 195; 35.7 cd/m2) ovals (33 × 21 mm; 3.15º × 2.01º v.a.) and a semi-oval were added on to the pattern as common region cues. In the connectedness only condition, five connectors (9 × 3 mm; 0.86º × 0.29º v.a.) were added on as connectedness cues. The luminance value of the connectors was personalized for each participant based on the results collected from the scaling task (see Results section). In the competing conditions, both ovals and connectors were included as part of the stimuli.

In the scaling task, all the stimuli were competing patterns alternating square/circle shapes with absent target pairs (i.e. without a repeated pair of elements; see Figure 1a). A total of twenty different stimuli were created by manipulating the luminance value of the connectors from 0 to 190 RGB by 10-units increments (RGB values: 0, 10, 20…170, 180, 190).

Design and procedure

The 2×2 design included two within-subjects factors: Stimulus type (single or competing grouping cues) and Grouping cue joining the target pair (common region vs. connectedness). These four different types of stimuli were combined with six different positions of the target pair (elements 2-3, 3-4, 4-5, 5-6, 6-7, 7-8, counting from the left), two shapes of the target pair (squares vs. circles) and two repetitions to obtain 96 trials in each experimental block. RTs, as well as error rates, were taken as dependent variables.

Participants were tested individually in a dimly lit room in two different sessions, one for the scaling task, and another one for the RDT. Firstly, in the scaling task,

participants were instructed to adjust the luminance of the connectors between elements until their grouping strength appeared as equally strong as the grouping strength of the common region cue. Each participant completed six scaling trials, three trials starting with 0 RGB and another three beginning with 170 RGB. The order of presentation of the increasing and decreasing trials was alternated. Participants increased or decreased the luminance of the connectors by pressing the right or left arrow of the arrow keys of the keyboard using the index fingers of both hands. They verbally confirmed their final decision and the specific RGB value was recorded by the experimenter without informing the participant. There was no time limit. A mean RGB value collapsing the six judgments was computed for each participant, which was implemented as the luminance value of the connectors in the stimuli included in the subsequent RDT (see Results section).

In the RDT, participants responded as quickly as possible while avoiding errors by pressing one of two keys (i.e. "Z" and "M") with their left or right index to indicate the shape (circle or square) of the repeated pair of elements. The keys were counterbalanced over participants. The stimulus array was presented on the centre of the screen and remained until response. The inter-trial interval was 800 ms. There were a practice block with 48 trials and six experimental blocks consisting of 96 trials each, for a total of 576 experimental trials. Feedback was provided only for the practice trials.

Results

Scaling task

The results for each participant are available in Figure 2a. The range of mean RGB adjusted values fluctuated between 35 and 163 (mean = 99, SD = 41.3), showing a remarkable variability among participants in their perception of relative grouping strength, as expected. In contrast, participants were very consistent in their judgments across the trials, as is indicated by the rather small standard errors

Repetition discrimination task

Median RTs of correct responses and mean accuracy rates were submitted to separate analyses of variance (ANOVAs) with Stimulus type and Grouping cue joining the target as within-subjects factors.

RT analysis. Inaccurate responses (102 of 6,912; 1.5% of trials) and RTs greater than 4000 or less than 200 ms (14 of 6,810; 0.2% of trials) were excluded from the RT analysis. Analyses on RTs showed a significant main effect of Stimulus Type, $F(1, 11) = 98.5$, $MSe = 11557.9$, $p < .001$, $\eta p2 = .90$, indicating that RTs for single trials (766 ms) were shorter than those for competing ones (1074 ms). The main effect of Grouping cue was also significant, $F(1, 11) = 66.3$, $MSe = 18184$, $p < .001$, $\eta p2 = .86$, showing that targets included in common region (762 ms) were responded to faster than targets

joined by connectors (1078 ms). Finally, the interaction between the two factors was also significant F (2, 30) = 81, MSe = 11310.6, $p < .001$, $\eta p2 = .88$, indicating that the interference effect of common region on the discrimination of targets grouped by connectedness (the difference between single and competing stimuli) was much greater (Δ585 ms) than the interference of connectedness on the discrimination of targets grouped by common region (Δ31 ms). Pair-wise comparisons applying the Bonferroni correction showed significant differences between all pairs from the experimental conditions (all $p \leq .01$).

Additionally, analyses of correlation between the mean RGB value of the connectors and the mean RT in the three conditions that displayed connectedness cues were conducted across all participants. None of the correlations reached significance (all $p > .10$), supporting independency between subjective grouping strength and the response in the RDT.

Accuracy analysis. Hit rates oscillated between 95% and 100%. The same ANOVA computed with RTs was conducted on accuracy rates, revealing a marginally significant effect of Grouping cue, F(1, 11) = 4.67, MSe < .001, $p = .054$, $\eta p2 = .30$, which showed a trend to respond more accurately to targets included in a common region (98.8%) than to those linked by a connector (98.4%). No other main or interaction effects were found to be significant.

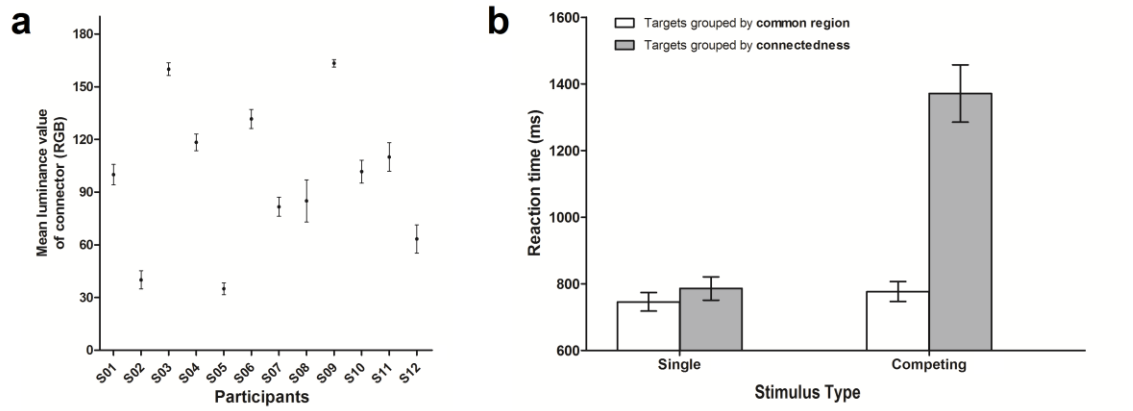

Figure S2. (a) Mean RGB adjusted values for each participant in the scaling task. (b) Median reaction times (ms) and standard error bars for the experimental conditions of the RDT.

Discussion

The pattern of results clearly shows that grouping by common region dominated the perceived organization of the display. For the competing stimuli, the responses were considerably faster when the target elements were within the same oval compared to those observed in displays in which they remained in different ovals. The single

conditions also showed speeded responses for targets grouped by common region compared to targets grouped by connectedness. The relative dominance of common region over other grouping factors corroborated previous data obtained by means of direct measures based on both scaling and choice-reaction time tasks (Luna & Montoro, 2011; Montoro & Luna, 2015; Luna et al., 2016).

It could be argued, however, that in this experiment common region cues were afforded by large high contrast ovals whereas the connectedness by a thicker line, so a confound between cue type and contrast could account in part for current data. In order to overcome this possible confound, we conducted the main study described in the manuscript.

References

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Kubovy, M., & van den Berg, M. (2008). The whole is equal to the sum of its parts: A probabilistic model of grouping by proximity and similarity in regular patterns. Psychological Review, 115, 131-154.

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b) Analysis of individual performance

In order to further explore the relationship between the scaling task and the RDT, we introduce two tables with the individual performance in the RDT (including two differential variables showing the "*advantage*" of common region over connectedness both in single and competing conditions) and the mean adjusted values from the scaling task from both the preliminary experiment presented above (Table S1) and the main experiment described in the manuscript (Table S2).

Table S1. Individual responses to the scaling task and RDT in the preliminary experiment.

	Single conditions		Competing conditions				
Subject	Conectedness (CN)	Common region (CR)	Targets connected	Targets in common region	Scaling task: mean adjusted value	Diff. Singles (CN - CR)	Diff. Competing (CN - CR)
1	543	562	857.5	586	100	19	272
2	737	750	1250.5	765.5	40	13	485
3	666	678	1152	675	160	12	477
4	833	834	1781.5	863	118	1	919
5	732	733.5	1043	742	35	1.5	301
6	637	672	1224	639.5	132	35	585
7	813	827.5	1467.5	848.5	82	14.5	619
8	850.5	929	1380	912	85	78.5	468
9	847.5	886	1377	863.5	163	38.5	514
10	765	897.5	1387	753	102	132.5	634
11	824	958.50	1782	897	110	134.5	885
12	700.5	707.00	1344	783	63	6.5	561
Mean	**746**	**786**	**1371**	**777**	**99**	**41**	**593**

Table S2. Individual responses to the scaling task and RDT in the main experiment (see Montoro et al., 2017).

	Single conditions		Competing conditions				
Subject	Conectedness (CN)	Common region (CR)	Targets connected	Targets in common region	Scaling task: mean adjusted value	Diff. Singles (CN - CR)	Diff. Competing (CN - CR)
1	750	694	1485	715	8	56	770
2	518	504	780	521.5	9	14	259
3	793.5	773	1428	785	14	21	643
4	754	711.5	1247	759	11	43	488
5	764	748	1259	772.5	7	16	487
6	603	556	1054	605	18	47	449
7	866	808	1698	858	16	58	840
8	761	776	1307	793.5	15	-15	514
9	698	659	1233	665	8	39	568
10	876	752	1154	905	15	124	249
11	724	679	1401	712.5	16	45	689
12	806	727.5	1353.5	737	7	79	617
Mean	**743**	**699**	**1283**	**736**	**12**	**44**	**548**

A comparison between the values from the scaling task and the RTs did not show any clear pattern relating both measures in either the preliminary or the main experiment. In fact, the analyses of correlation show no significant relations between these measures. Additionally, the correlation between differential variables for single and competing conditions was also non significant (preliminary experiment: r = -.068, p = .83; main experiment: r = .37, p = .23). These findings support a relative independence between the responses to the single stimuli and the dominance in competing conditions.

A more detailed inspection of the individual data shows some interesting findings. In this sense, in the main experiment (see Table S2) results from participant #8 indicate a slightly faster response to connectedness than to common region in the single condition. However, the dominance of common region was clear in the competing condition (Δ514 ms). Additionally, participants #10 and #8 selected the same thickness

in the scaling task (15 pixels). Nevertheless, responses in the RDT to #10, showed a stronger advantage for common region in the single trials (Δ124 ms) compared to #8 but the shortest difference for all participants between grouping in the competing conditions (Δ249 ms). Similarly, individual data from the preliminary experiment (Table S1) showed that participant #4 had only a Δ1 ms advantage in the common region compared to the connectedness single condition but the strongest dominance of common region in the competing condition Δ919 ms. Also, participants #8 and #9 gave equal luminance values in the scaling task (i.e., 82 and 85 RGB, respectively) but their results were very different in the RDT since #8 has a smaller advantage for common region in the single trials than #9 (Δ15 vs Δ79 ms) but a greater dominance of common region in the competing condition (Δ619 vs Δ468 ms).

To sum up, a visual inspection of the individual data from both the preliminary and the main experiments indicates a motley assortment of individual responses in both the scaling task and the single conditions. In contrast, we found a consistent and systematic pattern of results in the competing conditions, supporting a clear dominance of common region over connectedness.