Supplementary Methods:

Participants

Seven participants with mean age of 27 years (range: 25-29 years), four of them female, took part in the experiment. All were right-handed as assessed with a German adaptation of the Edinburgh Handedness Inventory (Oldfield, 1971). Six of them were students of the University of Leipzig while the seventh had secondary school qualifications. All had normal or corrected-to-normal visual acuity. They were paid for participation after completion of the last session.

Stimuli

The stimulus set consisted of five categories of geometric shapes: triangle, square, parallelogram, trapezoid, and hexagon. Each category consisted of two exemplars which were identical in form but different in orientation. That is, one of the two counterparts was rotated by 90° in plane, except for the square, which was turned by 45°, because otherwise the rotated form would be indistinguishable from the original form. Stimuli were black line drawings presented on a gray background with contour thickness of 0.01° visual angle. The shapes’ maximum height was 1.6° visual angle, their maximum width was 1.3° visual angle at a viewing distance of 85cm. Two red rectangular frames of 2.2° side length served as cues. Four items were presented in a trial, two on each side of fixation. The center of the upper two was located 2.2° of visual angle above fixation and 3.3° to the left or the right of the midline. The stimulus sites in the lower half of the display were 2.2° of visual angle beneath fixation and also 2.2° to the left and to the right. This asymmetric arrangement follows a paradigm initially developed by Copeland (1995) and Copeland and Zaidel (1996), which was also used in a previous letter matching experiment from our group (Pollmann, von Cramon, & Zaidel, 2003). It minimizes a potential advantage of between hemifield matches due to the fact, that scanning from left to right might be faster than from top to bottom. Stimulus presentation, timing and response registration were controlled by the Experimental Run Time System (ERTS, Beringer, 1999) software.
Design and Procedure

In the physical-identity (PI) matching task, a difference in orientation between otherwise identical shapes precluded a "match"-judgment. In the category-identity (CI) matching task, participants had to match category membership (e.g. ‘triangle’, ‘hexagon’) irrespective of orientation. Match stimuli could appear either both in the right (RVF) or both in the left (LVF) visual hemifield, or they could be divided between hemifields.

A trial began with the presentation of a fixation cross for either 100ms or 600ms. This jitter was build in to improve the separability of successive BOLD-responses. Next, two red frames appeared for 100 ms and indicated the locations of the to-be-matched items with a validity of 100%. The cue was followed by presentation of four geometric shapes appearing simultaneously at the four display locations for 80 ms. The fixation cross remained on the screen throughout the trial. Participants had to indicate match or mismatch by pressing one of two buttons with their index finger or middle finger, respectively. Response time registration started with the onset of the target display and ended with participants’ response or after a maximum of 2220ms or 2720ms, resulting in a total trial duration of 3000ms. Participants received a 2000-Hz feedback tone contingent on every incorrect response.

An experimental session consisted of 8 blocks of 48 experimental trials and eight null-events each. The latter were a three-second trial equivalent involving the presentation of the fixation cross without any response requirement. Both the PI and CI tasks were performed throughout four successive blocks. Half of the participants performed the PI task first while the other half started with the CI task. At the beginning of the experiment, participants were reminded to steadily fixate the central cross and they were informed about the character of the matching tasks. They were instructed, that for physical identity matches, the items were required to be exactly identical, whereas for category matches, the two items were to be of the same type regardless of their orientation. They were given examples of “match” and “mismatch” pairs for both tasks. Furthermore, there was a total of 14 training trials preceding each task.
Within blocks, equal numbers of match and mismatch trials (50% each) were presented, and LVF, RVF, and bilateral (BVF) trials occurred equally often as well, e.g., each in one-third of the trials. The geometric shapes at the cued positions matched each other in one half of the trials. Cue positions, geometric shapes, and matches/mismatches were individually randomized between trials. Category matches never matched in physical form. Four participants began responding with their left hand, the other three began with their right hand, and response hand was changed following an ABBA scheme for the four blocks of one task. One experimental session lasted about 30 min. Task and hand order were pseudo-randomized between experimental sessions, so that each participant got two of the four combinations once and one of them twice (an example sequence might be: [PI-CI-Left Hand-Right Hand] [CI-PI-RH-LH] [PI-CI-RH-LH] [CI-PI-LH-RH] [PI-CL-LH-RH]).

MRI Scanning Procedure:

Functional images were collected at 3T with a Bruker 30/100 Medspec system (Bruker Medizintechnik, Ettlingen, Germany). A gradient-echo EPI sequence was used with a TE=30 msec, a flip angle of 90°, a TR=2000msec, and an acquisition bandwidth of 100kHz. The matrix acquired was 64*64 with a FOV of 19.2cm, resulting in an in-plane resolution of 3mm*3mm. The slice thickness was 4mm with an interslice gap of 1mm. Twenty-four axial slices were acquired, oriented parallel to the AC-PC plane, covering the whole brain.

To improve the effective sampling rate, the stimulus onset was varied in relation to the timing of image acquisition (Josephs, Turner and Friston, 1997; Miezin et al., 2000). Due to the difference in trial-length of 3s and TR of 2s, one half of the stimuli was presented at the beginning of image acquisition and the other half 1s later.

fMRI Data Analysis:

Analysis of fMRI data was performed using the LIPSIA software package (Lohmann et al., 2001). Movement artifacts were corrected using a matching metric based on linear correlation. Then, a correction for slice acquisition order using sinc interpolation was performed. The data were spatially smoothed with a Gaussian kernel with FWHM=7mm. All
functional data sets were individually registered into 3D-stereotactic coordinate system using the subjects’ individual high resolution anatomical images. The 2D-anatomical slices, geometrically aligned with the functional slices, were used to compute a transformation matrix, containing rotational and translational parameters, that register the anatomical slices with the 3D reference data set. Geometrical distortions of the EPI-T1 images were corrected using additional EPI-T1 refinement on the transformation matrices. These transformation matrices were normalized to the standard Talairach brain size (Talairach and Tournoux, 1988) by linear scaling, and then finally applied to the individual functional data. The normalized 3D-datasets had an isomorphic voxel size of 3mm side length.

The statistical evaluation was based on the general linear model for serially autocorrelated observations (Friston et al., 1995; Worsley and Friston, 1995). For each individual subject statistical parametric maps (SPM) were generated. The design matrix for event-related analysis was created using a synthetic model of the hemodynamic response function and its temporal derivative (Josephs and Henson, 1999). The model equation, including the observation data, the design matrix and the error term, was convolved with a Gaussian kernel with a dispersion of 4s FWHM. The data were high-pass-filtered with a cutoff frequency of 1/30Hz. The model includes an estimate of temporal autocorrelation. The effective degrees of freedom were estimated as described by Worsley and Friston (1995).

Group averages were computed by performing t-tests for known variance at corresponding voxels across participants. The significance criterion was set to \(\alpha=0.0001\), uncorrected for multiple spatial comparisons. Minimum size for activations was defined as 300mm\(^3\). All presented SPM\((z)\) were mapped onto an anatomical data set averaged out of the normalized individual high resolution anatomical datasets of the 7 subjects.

All events in the design file were logged to stimulus-onset. Only trials with correct responses entered the analysis. We extracted the pre-processed fMRI signal evoked by the geometrical stimuli and computed trial averages over a time window of 16 sec post stimulus onset. The average signal time courses in response to null-events were subtracted from the
corresponding signal time courses in the matching conditions and the differences were expressed as percent signal change from the null-event signal. The subtraction of null events from experimental trials was done separately for each task block to remove potential artifacts caused by slow signal drifts. Variance estimates were calculated using the jackknife bootstrapping technique (Efron, 1977; Ruge, Brass, Lohmann & von Cramon, 2003), in which the original data were resampled by computing \( n \) new elements, each of which represents the average of \((n-1)\) fMRI time series of the original sample. Adjusted formulae were devised to compute jackknifed estimates of the standard error of the mean accounting for reductions in variance due to resampling as well as for the standard error of the mean of differences used to compute the repeated measures t-statistic:

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se_{\text{DIFF}} = \sqrt{\frac{N-1}{N} \sum_{i=1}^{N} (d(i)-\overline{D})^2}
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(4).
References: