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BRIEF REPORT

Brief Report: Altered Horizontal Binding of Single Dots to Coherent Motion in Autism

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Abstract Individuals with autism often show a fragmented way of perceiving their environment, suggesting a disorder of information integration, possibly due to disrupted communication between brain areas. We investigated thirteen individuals with high-functioning autism (HFA) and thirteen healthy controls using the metastable motion quartet, a stimulus consisting of two dots alternately presented at four locations of a hypothetical square, thereby inducing an apparent motion percept. This percept is vertical or horizontal, the latter requiring binding of motion signals across cerebral hemispheres. Decreasing the horizontal distance between dots could facilitate horizontal percepts. We found evidence for altered horizontal binding in HFA: Individuals with HFA needed stronger facilitation to experience horizontal motion. These data are interpreted in light of reduced cross-hemispheric communication.

Keywords Apparent motion · Bistable perception · Binding · Interhemispheric communication · High-functioning autism

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Introduction

Although not part of diagnostic criteria, individuals with autism spectrum disorders (ASD) often report a fragmented way of perceiving or attending to the world (Frith 2003). They may show enhanced detail or feature perception while ignoring context information, also including an absent susceptibility to visual illusions, and a superior performance for pattern parcellation or visual search tasks (Dakin and Frith 2005; Shah and Frith 1993). By contrast, their performance on tasks involving grouping, perceptual integration or contextual processing is often impaired (Brosnan et al. 2004). An influential account, the "weak central coherence" (Happe and Frith 2006; Shah and Frith 1993), conceptualized such peculiarities as a special cognitive processing style present in ASD: While in normal subjects, local features or pieces of information are integrated into coherent wholes; in ASD this disposition is weak.

To date, the underlying pathophysiology of this disturbance is not clear. It has been suggested that ASD are disorders of information integration at the cognitive and neural level (Brock et al. 2002; Minshew and Williams 2007). Frith (2004) discussed the possibility of ASD representing a disconnection syndrome similar to schizophrenia (Crow 1998), in which the information transfer between brain regions, such as hemispheres, may be interrupted. Evidence from diffusion tensor imaging (DTI) offers support to this idea showing disintegrity of the corpus callosum in ASD as the largest commissural white matter pathway connecting both hemispheres (Alexander et al. 2007).

Here we investigated the integration of information into coherent wholes in ASD or, more specifically, the binding of visual motion signals into a coherent motion percept,

using the "metastable motion anisotropy" stimulus or metastable motion quartet (Chaudhuri and Glaser 1991; Ramachandran and Anstis 1986). In this stimulus, two dots are alternately presented at the different corners of a hypothetical square, thereby being perceptually bound to appear as a single stimulus inducing a coherent motion percept. Like other bistable stimuli (e.g., the Neckar cube), the respective motion percept allows two possible interpretations: The apparent motion can individually be perceived as being vertical or horizontal, presumably due to binding of motion signals within or across cerebral hemispheres (Chaudhuri and Glaser 1991; Rose and Büchel 2005). Based on previous evidence on weak central coherence in ASD (Happe and Frith 2006), we predicted that individuals with autism show a deficit in their ability to bind distinct single visual dots into a coherent motion percept. Second, based on the hypothesis of large-scale disconnection in ASD we expected a specific deficit in perceiving horizontal motion, which presupposes binding across hemispheres.

Methods

Subjects

We examined 13 participants with high-functioning autism (HFA; mean age 33.7 ± 8.8 years; 4 female; education 20.5 ± 6.5 years; IQ 119.2 ± 15.2) and 13 healthy control participants (CON; age 28.6 ± 8.1 years; 2 female; education 18.5 ± 3.4 years; mean IQ 119.5 ± 13), who did not significantly differ in age (t (24) = 1.55, p = .135), gender (χ^2 = .867, p(Fisher, two-tailed) = .657), education (t (24) = .98, p = .338) and IQ (t (23) = −.06, p = .952; one control participant missing). HFA participants were recruited from the autism outpatient clinic at the Department of Psychiatry in Cologne, where data were also collected. Control participants were recruited through on-campus advertisement. Physicians (incl. author KV) explored autistic traits according to current diagnostic criteria (ICD 10). All participants had normal or corrected-to-normal vision and gave written consent before participation. The study was ethically approved.

Task

Stimuli consisted of two filled white circles (diameter: 2.76°) presented on a black screen of an ASUS M6000 notebook (15-inch, 1,024 × 78 resolution) using the *Presentation* software (Version 12.0, Neurobehavioral Systems). The two dots simultaneously appeared for 200 ms at two diagonally opposite corners of a hypothetical square, which had a horizontal and vertical distance of 11°, and were then extinguished and replaced by the dots appearing at the opposing two corners (timepoint/position 2; Fig. 1a). A trial consisted of two such flips or cycles (1,700 flips in total). Such a dynamic presentation induces an apparent motion percept. As the probability of a horizontal versus vertical percept also depends on the distance between the dots (Hock et al. 1993), we exploited this effect to test the efficiency of binding mechanisms and additionally in/-decreased the horizontal distance between dots 0.11° per presentation cycle (schematically shown in Fig. 1a). The participants' task was to continuously fixate a centered small line, the orientation of which had to be adjusted according to their current percept, that is, horizontally or vertically, using the left mouse button (see Rose and Büchel 2005).

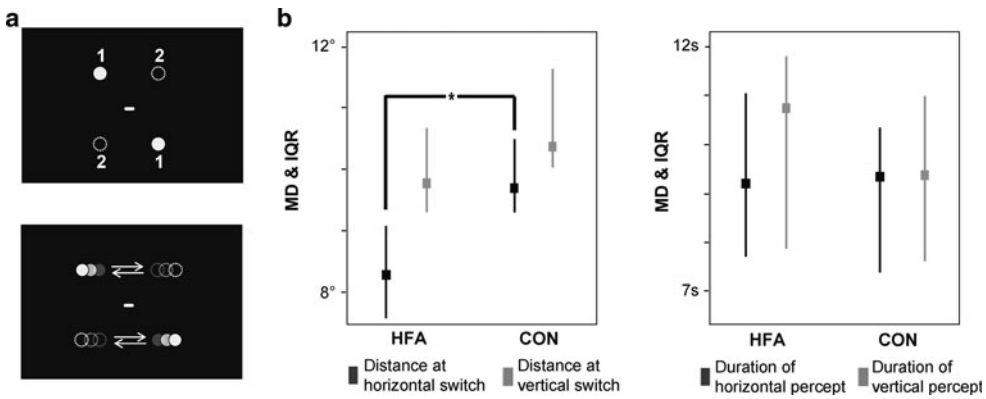

Fig. 1 Stimulus layout and main results. **a** Apparent-motion stimulus layout. Two dots simultaneously appeared at position 1 and then 2 (for 200 ms). Subjects maintained central fixation and adjusted the fixation bar either vertically or horizontally depending on their current percept. The horizontal distance between dots was varied to induce percept changes. **b** Distance between dots and duration for each percept type. Significant group differences were observed for horizontal binding. The high-functioning autism (HFA) group tended to report horizontal motion only when the visual dots were in closer proximity compared to the control (CON) group. *Units* represent degrees visual angle and seconds. *MD* median, *IQR* interquartile range

Results

Because dependent variables did not always approximate a normal distribution, non-parametric statistics were applied (Mann–Whitney U test) at a significance level of $p < .05$. Results revealed that significantly shorter dot distances characterized horizontal percepts in HFA. In particular, the horizontal distance of the dots *at the moment* a perceptual switch to horizontal motion occurred was significantly shorter in HFA compared to controls (HFA: 8.3°, CON: 9.7°; $U = 39.5$; $p = .019$; Fig. 1). There were no significant group differences with respect to dot distance for vertical motion percepts (HFA: 9.8°, CON: 10.4°; $U = 54$; $p = .125$). The duration of horizontal (HFA: 9.2 s, CON: 9.4 s; $U = 82$; $p = .92$) or vertical percepts (HFA: 10.8 s, CON: 9.4 s; $U = 73.0$; $p = .579$; Fig. 1) did not differ significantly between groups.

Discussion

Here we investigated apparent motion perception in HFA and healthy control participants. As predicted, the two groups showed significant differences in their ability to bind visual dots into a coherent motion percept with respect to horizontal binding. By contrast, vertical binding was not affected in HFA. What may be underlying such perceptual differences? Animal studies showed that binding of visual features across the hemifields is mediated by synchronization of neural signal via callosal connections (Engel et al. 1991). Using the metastable motion quartet, a recent electroencephalographic study revealed increased interhemispheric coupling as indexed by increased coherence (i.e., a measure indicating phase synchronization of neural activity across frequency domains) between extrastriate visual regions for the horizontal compared to the vertical percept (Rose and Büchel 2005). Chaudhuri and Glaser (1991) suggested that the integration of information in long-range apparent motion would be weakened by interruption of signal transmission across the two hemispheres. We suggest that a weaking of interhemispheric synchrony (Engel et al. 1991; Rose and Büchel 2005) in HFA may account for the present findings. Although here we did not directly assess interhemispheric coupling, other authors offered support to our speculation providing structual—yet not functional—evidence (Alexander et al. 2007; Kilian et al. 2008). Future studies applying the present paradigm to autism using neurophysiological methods such as electro- or magneto-encephalography might uncover reduced interhemispheric coherence underlying impaired horizontal binding.

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