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Systemizing influences attentional processes during the Navon task: An fMRI study

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Abstract

Systemizing ability exists on a spectrum, with a high systemizing style meaning proficiency in analysing the rules of a system, to predict how that system works. This study uses fMRI to investigate a spectrum of low to high systemizing, to assess whether individuals with a high systemizing style exhibit an attentional bias towards local details. This is the first study to test for the neural correlates of systemizing. Participants with a range of scores on the Systemizing Quotient (SQ) were given a version of the Navon task during fMRI, which elicits perceptual conflict between local and global levels of visual attention. SQ score was correlated with a focus on local detail in the behavioural study. During conditions eliciting perceptual conflict SQ score was associated with increased activation in the lateral prefrontal, parietal and extrastriate visual cortices. However, neural investigations did not imply a neural correlate of systemizing during local processing per se. Results are discussed in terms of a heightened ability to maintain an attentional set in those with a high systemizing cognitive style.
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Keywords: Systemizing; fMRI; Navon; Attention

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1. Introduction

Individual differences are seen in the degree to which an individual systemizes; that is, the drive to analyse the rules underlying a system, in order to predict its behaviour (Baron-Cohen, 2002, 2003). Systems are found in a broad range of domains: technical (e.g. tools); natural (e.g. ecosystems); abstract (e.g. mathematics); social (e.g. the managerial structure of a company), and spatial (e.g. mental rotation). Regardless of the domain in which a system exists, they all share the same INPUT–OPERATION–OUTPUT tripartite structure. Inputs and outputs are defined as initial actions on and subsequent effects of a system. Operations are defined as interactions between different components or variables within a system that transform input into output.

There are within and between sex differences in systemizing, with males being more likely to be high systemizers. On average, male score higher on the Systemizing Quotient (SQ-R), a self-report questionnaire tapping interest in a range of systems (Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003; Billington, Baron-Cohen, & Wheelwright, 2007; Wheelwright et al., 2006). Similarly, males are also more likely to score higher on performance tasks which tap systemizing ability, such as predicting physical systems (Lawson, Baron-Cohen, & Wheelwright, 2004); constructing 3-D models and predicting what 2-D plans of 3-D shapes would look like (Kimura, 1999); geospatial navigation (Galea & Kimura, 1993; Harrell, Bowlby, & Hall-Hoffarth, 2000; Ward, Newcombe, & Overton, 1986) and some branches of mathematics (Benbow & Stanley, 1983; Geary, 1996). This is not to say that females cannot achieve high systemizing scores, but that on average there is a bias towards higher systemizing in males. A recent study found that SQ in childhood is positively correlated with levels of foetal testosterone (FT) measured during amniocentesis (Auyeung, Baron-Cohen, Chapman, Knickmeyer, Taylor, & Hackett, 2006). This may be part of the explanation for the observed sex differences in systemizing, since FT has organising effects on brain development and is produced in greater quantities in males (Baron-Cohen, Knickmeyer, & Belmonte, 2005).

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In this paper we have two aims. First, we investigate the relationship between systemizing and field independence (the ability to attend to local detail whilst ignoring gestalt distractors) at the cognitive level. This is motivated by the finding that groups with a high systemizing style, such as scientists and mathematicians, perform better on perceptual tasks of field independence (Chao, Huang, & Li, 2003; Van Blerkom, 1988). Second, we investigate the neural basis of systemizing and field independence, using fMRI. Regarding the first of these aims, given that systems comprise of several components and the interactions between them, and assessing relationships between elements should be more efficient in the absence of any distraction from stimuli extraneous to the system, an ability to ignore perceptual distractors coupled with a bias towards local detail prior to holistic/Gestalt pattern-detection would be expected to facilitate systemizing by allowing for an assessment of the patterns between events within a system.

A Navon figure consists of hierarchically organised visual stimuli in which a larger (global) letter is composed of smaller (local) letters. Stimuli can either be congruent (if the local letters are identical to the global letter) or incongruent (if the local and global letters are different). In incongruent stimuli the target can be placed at either the local or the global level, reflecting local and global target conditions respectively. Navon (1977) claimed that in the general population a global precedence effect was apparent; that is, a bias towards attending to the global level compared to local level (global advantage) and slower processing of targets at the local level as a result of interference from information at the global level (global interference). Thus, not only is an individual's performance on the Navon task influenced by perceptual bias (local/global), it is also influenced by attentional control mechanisms (Kinchla, Solismacias, & Hoffman, 1983; Lamb & Robertson, 1988) which act to reduce behavioural interference from non-target distractors (Lavie, 1995). On such a task it might be expected that high systemizers would be faster on incongruent trials when the target was at the local level (local precedence), consistent with local advantage and local interference effects.

Neural models of selective attention propose that the anterior cingulate cortex (ACC) is responsible for resolving conflict (Kerns et al., 2004; MacDonald, Cohen, Stenger, & Carter, 2000; Magno, Foxe, Molholm, Robertson, & Garavan, 2006), whilst the lateral prefrontal cortex (LPFC) is responsible for driving selection of task relevant information and maintaining an attentional set (Banich et al., 2000; Kerns et al., 2004; Miller & Cohen, 2001), especially when task irrelevant information is more difficult to override (Flombaum, McCandliss, Thomas, & Posner, 2003; Milham et al., 2001; Sakai & Passingham, 2003, 2006; Sakai, Rowe, & Passingham, 2002). Weissman, Mangun, and Woldorff (2002) assessed the neural correlates of distractor incongruency and cued attention using the Navon task. They found activation in regions of the left and right LPFC and the ACC, both when participants directed attention to the target level and during interference. Furthermore, areas of parietal and extrastriate visual cortex were activated when participants experienced interference from a non-target distractor. The authors suggest that this reflects top-down attentional control systems boosting processing at the perceptual level, in order to increase attention towards target level stimuli.

We predicted that increasing systemizing score would be associated with a reaction time preference for local targets, reflecting a local precedence effect during the processing of hierarchical stimuli. Conversely, we predicted decreasing systemizing score would be associated with a reaction time preference for global target, reflecting a global precedence effect. These behavioural predictions suggest that there may be a negative correlation between SQ and activation in the LPFC and ACC when the target is only at the local level, since less interference would be experience from the non-target letter at the global level in those towards the higher end of the scale. Conversely, in the presence of a globally orientated target letter and local distractors that are more difficult to override, SQ should show a positive correlation with activation in the LPFC or ACC, reflecting the need to overcome interference or maintain task relevant information respectively. Perceptual interference may also be associated with heightened activity in parietal and extrastriate visual cortex, reflecting the need to boost target-related visual attention. In addition, we assessed neural activation during incongruent compared to congruent conditions and its association with systemizing. Such an analysis would discern whether systemizing is associated with differential strategies in dealing with interference from either non-target level, regardless of behavioural bias.

In summary, the study reported below aimed to assess: (1) whether a high systemizing style is associated with a bias towards local precedence effect when processing hierarchical stimuli; (2) whether systemizing is associated with differential brain activation in the presence of local and global targets and distractors. Finally, we tested that sex is not a mediating factor in the relationship between systemizing and processing style.

2. Methods

2.1. Participants

Twenty right-handed participants (11 females, 9 males; ages 18–32) were scanned. Each participant was scanned for 10 min of echo planar imaging (EPI) and 15 min for a structural scan. All participants were free from psychiatric or neurological conditions. All participants gave informed, written consent for participation in the study, following a protocol approved by the Local Research Ethics Committee. All participants were given the National Adult Reading Test (NART), a standardized measure of verbal IQ (Nelson, 1982). Average IQ score was 116.09 (S.D. = 6.09). Note that the NART correlates highly with the Wechsler full scale IQ test (Crawford, Parker, Stewart, Besson, & Delacey, 1989).

2.2. Navon task

Letter stimuli (A, H, K and X) were employed for this version of the Navon task in which larger letters constructed from a series of smaller letters were presented for 665 ms, see Fig. 1 for dimensions and design. Trials of interest were presented alongside filler trials with randomly varied stimulus onset asynchronies (1150–1300 ms) in order to enhance sensitivity between trials (Josephs & Henson, 1999). Trials of interest consisted of those trials in which the target A was present: congruent (large A made of smaller A's); local (either X, H or K made of small A's); and global (large A made of H's, K's or X's). In such trials response to the target would occur under conditions of perceptual conflict from the non-target level if the stimulus was incongruent and under no perceptual conflict if the stimulus was congruent. The remaining trials (congruent stimuli

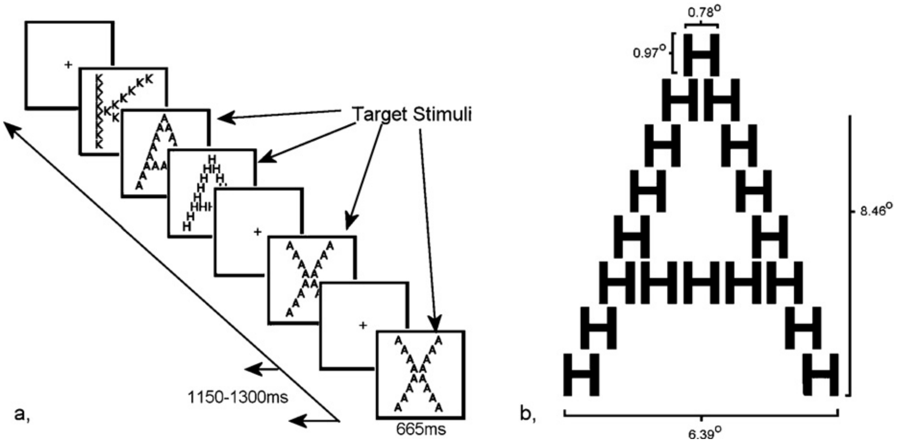

Fig. 1. Navon stimuli, including angles at which local and global level stimuli subtended the fovea.

containing no A's; non-congruent stimuli containing no A's; and stimuli requiring no attentional demands involving a central fixation "+") were used as filler trials.

Participants were told to make a binary button box response to indicate whether or not they detected an A on the screen, pressing the left button with their left hand for a 'no' response and the right button with their right hand for a 'yes' response. Overall, there were an equal number of yes and no responses in order to evade response bias. Participants were told to press either button on seeing the non-attentional "+" stimuli.

2.3. *Systemizing quotient revised: SQ-R*

The SQ-R, a questionnaire that assesses an individual's interest in a range of systems (mechanical, natural, abstract, social, and collectible) was given to all participants (Wheelwright et al., 2006). Although the questionnaire is designed to assess several domains of systemizing, there is no factor structure to the SQ-R. The SQ asks questions such as "I like music shops because they are clearly organised" and "When I learn a language I become intrigued by the grammatical rules". People can score 0, 1 or 2 on each item of the SQ-R, with half the items on the SQ-R being reverse scored in order to avoid response bias. Thus, total scores on this test ranged from 0 (disinterest in systemizing) to 150 (maximum score, thus extremely high systemizing). It was used in the present study in order to sample individuals across the SQ-R space, as it is sensitive to individual differences.

2.4. *fMRI: data acquisition and analysis*

fMRI was carried out using echo planar imaging (EPI) on a 3T Bruker scanner with a standard head coil. Functional images were collected using 21 slices covering the whole brain (slice thickness 4 mm, inter-slice distance 1 mm, in-plane resolution 2.2 mm × 2.2 mm) with an echo planar imaging sequence (TR = 1.1 s, TE = 27.5 ms, flip angle = 65.5°). 450 scans (including 11 dummy scans) per run were acquired. This study employed an event related design and all fMRI data analysis was carried out using SPM2 software (Wellcome Department of Cognitive Neurology, London). Prior to analysis, all images were corrected for slice timing using the middle slice as a reference slice. Images were realigned to the first image in the sequence. Distortions in the EPIs were corrected using field maps and a custom toolbox (Cusack, Brett, & Osswald, 2003). All images were normalized using affine and smooth non-linear transformations to an EPI template in Montreal Neurological Institute (MNI) space. Finally, all images were smoothed with a full width half maximum Gaussian kernel of 8 mm.

Each run was split into events reflecting the Navon task conditions outlined above. Individual statistical contrasts were set up by using the general linear model to fit each voxel with a combination of functions derived by convolving the standard haemodynamic response with the time series of the events and removing low-frequency noise with a high-pass filter with a frequency cut off of 128 s. Five contrasts were generated to look at activation during locally and globally directed attention (global target > local target; local target > global target) as well as activation during interference (local target − congruent; global target − congruent) and the conjunction of these two contrasts ([local target + global target] − congruent). Following group analysis, SQ-R scores were regressed against all five contrasts. Given that there is a high degree of colinearity between sex and systemizing, contrast estimates (uncorrected) were extracted using the SPM2 VOI function and subject to regression analysis against SQ-R score in SPSS, correcting for sex.

All peaks had to pass an uncorrected threshold of $p < 0.001$ and exceed 50 voxels in volume. All reported coordinates underwent a transformation from normalized MNI space to Talairach space (http://imaging.mrc-cbu.cam.ac.uk/imaging/MniTalairach), in order to ascertain more precisely the site of activation relative to the atlas of Talairach and Tournoux (1988). A region of interest analysis was carried out on the ACC with coordinates taken from Duncan and Owen (2000). The ACC ROI consisted of a 10mm radius sphere surrounding the coordinates $x = 0$, $y = 31$, $z = 21$. ROI analysis was carried out using in house software (http://www.mrc-cbu.cam.ac.uk/Imaging/marsbar.html).

3. Results

3.1. *Behavioural*

3.1.1. *Group results*

Means and 95% confidence intervals for the five Navon task condition reaction times and error rates are shown in Figs. 2 and 3. A one-way within-participant ANOVA was conducted on the Navon task reaction times (RTs). There was a significant effect of condition ($F_{(1,19)} = 45.22$, $p < 0.000$). Post hoc paired *t*-tests, using a Bonferroni correction, indicated that this was because there was a significant difference ($p < 0.001$) between the congruent condition and all incongruent conditions. There was no significant difference between the local, global and no A conditions. The number of error responses in each condition was minimal and there were no significant differences across condition ($F_{(1,19)} = 3.61$, $p = 0.07$), thus error rates will not be included in the following analysis.

Four scores were created from the Navon task RT:

1. local/global precedence (LGP) = local RT − global RT;
2. global interference (GI) = local RT − congruent RT;
3. local interference (LI) = global RT − congruent RT;
4. overall interference (I) = average RT of incongruent trials − average RT of congruent trials.

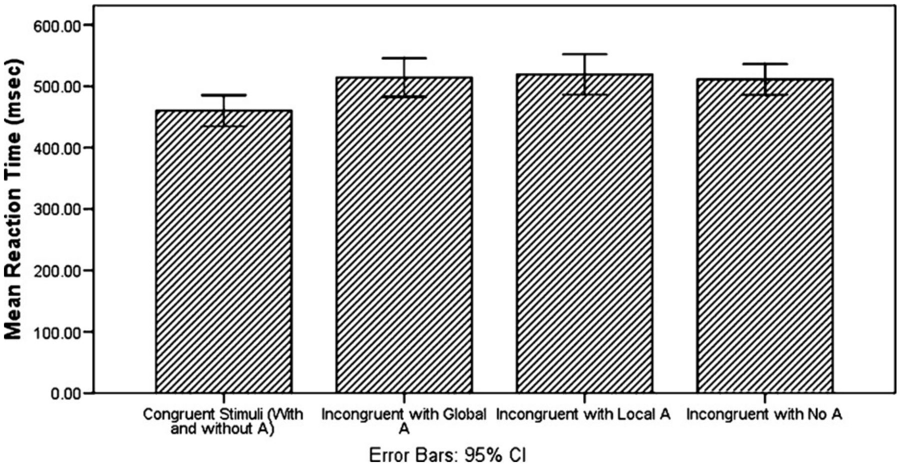

Fig. 2. Means and 95% confidence intervals of Navon task reaction time data.

The average LGP score was −5.16 ms (S.D. = 29.77) suggesting that, overall, there was no significant local or global precedence effect for the group (i.e. the LGP value did not significantly differ from zero; $t = -0.78$, d.f. = 19, $p = 0.448$). Thus, group local interference scores ($M = 53.98$, S.D. = 38.25) and global interferences scores ($M = 59.14$, S.D. = 34.17) did not significantly differ. The presence of perceptual distractors in the incongruent conditions (I) caused, on average, a significant 54.65 ms (S.D. = 28.76) delay in RT ($t = -7.65$, d.f. = 19, $p < 0.001$).

3.2. Correlates of systemizing

The average score on the SQ-R was 58.20 (S.D. = 27.79), which is close to the mean score in previous studies (Wheelwright et al., 2006). Males obtained higher scores on the SQ-R (males = 60.22, S.D. = 25.65; females = 56.55, S.D. = 30.57). However, a Mann–Whitney U test revealed this was non-significant ($p = 0.710$), probably reflecting sample size, since previous sex differences on the SQ have been based on much larger samples.

SQ-R score did not correlate with verbal IQ as measured by the NART, Spearman's $\rho = -0.272$, d.f. = 20, $p = 0.246$ (Nelson, 1982). The local/global precedence score was significantly correlated with SQ-R score when corrected for sex (partial $r = 0.570$, d.f. = 17, $p < 0.005$), suggesting that those with a higher systemizing score showed a bias towards the local level of the hierarchically organised Navon stimuli (see Fig. 4). In conjunction with this, there was also a significant tendency for high systemizers to experience more local interference (partial $r = 0.446$, $n = 17$, $p < 0.05$). Although this could be considered a small sample size, the power of this result was calculated at > 0.6 and the results could be considered representative. Neither global interference, nor overall interference effects were

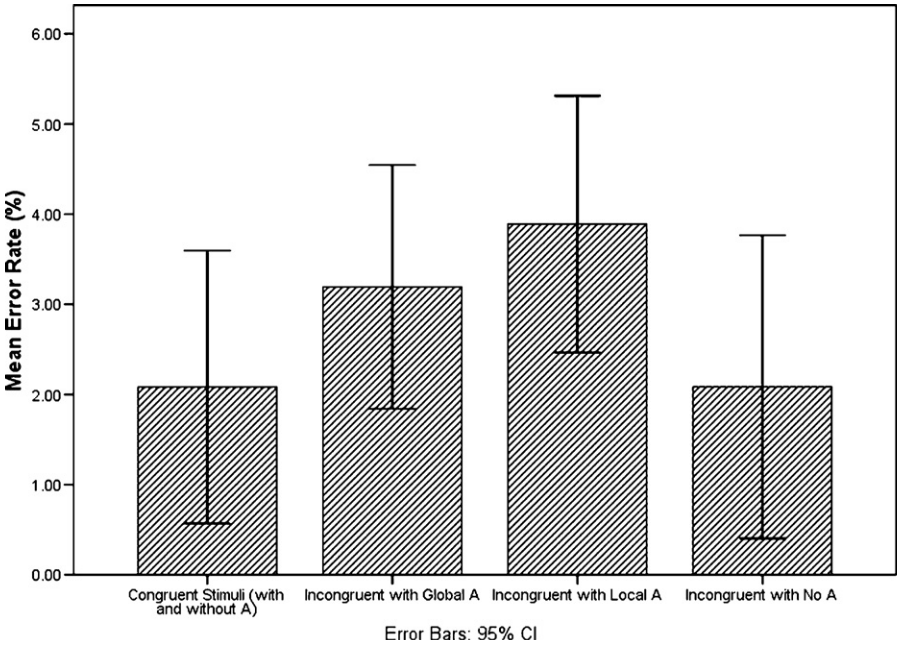

Fig. 3. Means and 95% confidence intervals of Navon error rate data.

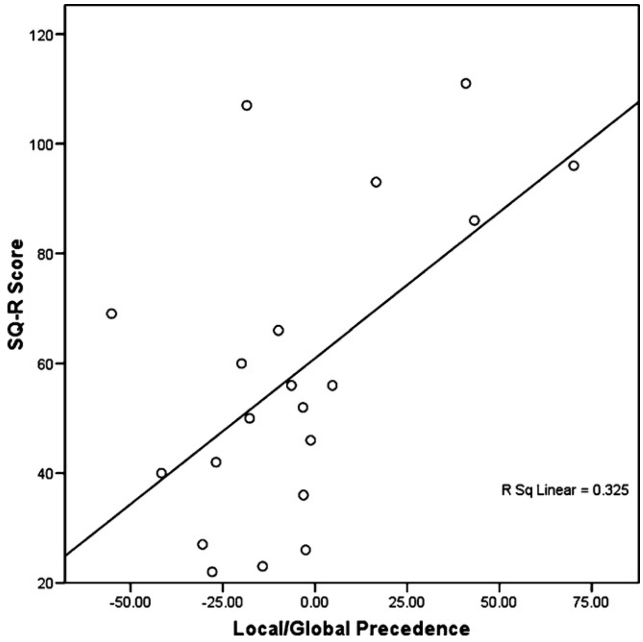

Fig. 4. Scatterplot to show the correlation between systemizing score and local/global precedence score.

predicted by SQ-R score. These results reflect an increasing local precedence effect with increasing SQ-R score, associated with both a bias to attend to the local level of stimuli and a tendency to experience increased distraction from this level. Bivariate non-parametric correlations suggested that SQ-R was not associated with faster reaction times on any of the six conditions, or overall.

3.3. Imaging

3.3.1. Group

At a group level there were no significant differences between the local target and the global target. However, extensive activation was seen in the presence of incongruent compared to congruent stimuli ([global + local] − congruent), with the LPFC in particular showing the strongest activation (see Fig. 5). As predicted, the middle frontal gyrus, ACC, regions of the occipital and parietal lobes were also significantly activated (see Table 1). The incongruent conditions were considered separately in order to look at activation in the presence of local interference when attending to the global level and vice versa (see Table 2). Attending to the global level with local interference (global > congruent) activated several areas of the prefrontal cortex, as well as the cingulate gyrus, anterior cingulate and superior parietal lobe and parietal cortex. Global interference whilst attending to the local level (local > congruent) activated the same region of the cingulate gyrus as local interference, as well as a posterior region of the middle frontal gyrus and extrastriate visual cortex.

3.4. Systemizing

Systemizing was not positively or negatively correlated with activation during either the local > global contrast or the

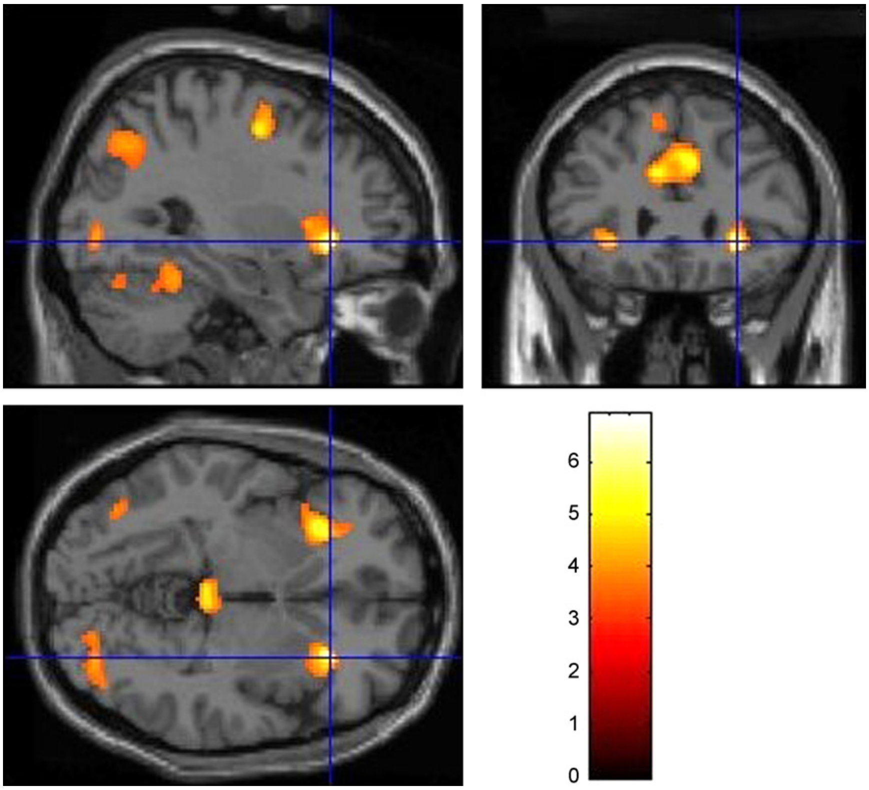

Fig. 5. Group activation during incongruent conditions (uncorrected, $p < 0.001$). The bar depicts voxel level t scores. Activations are superimposed on sections from the canonical T1-weighted brain image of SPM 2.

Table 1
Group activation in incongruent compared with congruent conditions

Region	BA	Voxel volume	x	y	z	T
Inferior frontal gyrus	47	212	30	27	−5	6.91*
	47		−32	23	−5	5.51
	47		−26	15	−11	4.58
	9	95	46	3	27	4.69
Middle frontal gyrus	46	1084	28	−4	46	6.1
	46	90	−34	44	20	4.73
	6	85	−24	−7	52	4.34
Cingulate gyrus	32		−6	30	26	5.47
Postcentral gyrus	2	75	−46	−25	45	4.54
	7		−42	−30	57	3.76
Superior parietal lobule	7	114	28	−66	44	4.29
Fusiform gyrus	37	131	36	−45	−11	4.24
Precuneus	19	89	−24	−78	26	4.51
Middle occipital gyrus	19		34	−80	2	4.25
Cuneus	18	142	22	−83	10	4.77

All reported peaks have an uncorrected threshold of $p < 0.001$ and were at least 50 voxels in volume. All peaks with an asterisk passed a more conservative correction threshold (FWE) of $p < 0.05$ (Worsley et al., 1996). Activation peaks without reported volumes belong to the last reported volume. Coordinates are in Talairach Space (Talairach & Tournoux, 1988).

global > local contrasts at the predefined thresholds. Under conditions of interference ([global + local] − congruent), systemizing was positively correlated with activation in the inferior frontal gyrus. Activation was also present in several additional areas of the LPFC (BA 47 and BA 9) as well as the inferior parietal lobe, motor cortex and extrastriate visual cortex (BA 18 and BA 19) (see Table 3). Activation in the ACC for this contrast was not correlated with systemizing scores. In case this lack of activation was due to insufficient power, a supplementary ROI analysis was carried out on the ACC. This analysis also failed to show any activation in this region ($t = 0.66$, $p = 0.26$ uncorrected). Systemizing did not negatively correlate with cortical activation during the incongruent > congruent contrast.

Table 2
Group activation associated with local and global interference

Brain region/condition	BA	Voxel volume	x	y	z	T
Local interference						
Cingulate gyrus		285	−6	30	26	5.8
Medial frontal gyrus			10	37	35	5.79
Anterior cingulate			6	26	24	4.17
Inferior frontal gyrus		165	−30	21	−6	5.52
Middle frontal gyrus	10	58	−34	42	18	4.96
			−38	34	22	3.67
		317	26	−1	48	5.38
Superior frontal gyrus			12	11	55	5.15
Superior parietal lobe		53	−28	−62	51	4.11
Global interference						
Middle frontal gyrus		342	28	−4	46	5.9
Cingulate gyrus	32	150	6	27	30	4.92
Postcentral gyrus	2	103	−46	−25	45	4.81
			−36	−33	48	4.18
Middle occipital gyrus		62	38	−78	2	4.12

See Table 1 for details.

Table 3
Regions positively correlated with systemizing in incongruent conditions

Region	BA	Voxel volume	x	y	z	T
Inferior frontal gyrus	47	143	50	25	−1	7.24
Superior frontal gyrus	9	177	38	38	31	5.49
	6	34	−14	15	60	5.03
	6		18	16	56	4.13
Middle frontal gyrus	6	70	22	9	60	4.99
Inferior parietal lobe	40	29	38	−49	28	4.52
		25	48	−49	34	4.14
Lingual gyrus	18	81	−16	−87	−1	5.47
Middle occipital gyrus	19		−24	−79	8	4.12

See Table 1 for details.

In order to confirm that these results were indeed an indication of the neural correlates of systemizing and not associated with sex differences, clustered contrast estimates were extracted for all nine coordinates shown in Table 3. Regression analyses for the strongest three activations (inferior frontal gyrus, superior frontal gyrus and lingual gyrus) are shown in Fig. 6. The results indicate that SQ-R score significantly predicts neural activation in these regions, even when corrected for sex. Furthermore, although sex is also a significant predictor of superior frontal gyrus activation, it is females who elicited stronger activation, despite having marginally lower overall SQ-R scores. Regression analysis on the remaining activation clusters also revealed SQ-R, not sex, was the determining factor in activation (see Table 4).

The incongruent conditions were also considered separately to look at the neural correlates of local and global interference in relation to systemizing (see Table 5 and Fig. 7). Under conditions of global interference activation associated with systemizing was located in the right LPFC. For the local interference contrasts, systemizing trait scores correlated with activation in similar regions of the LPFC. Additional activation in relation to systemizing was exhibited bilaterally in the LPFC and visual cortex. There were no negative associations with systemizing for these contrasts.

The local > congruent contrast was used as a mask in order to determine whether the observed additional activation during the global > congruent contrast was significant. Activation exclusive to local interference was located in the LPFC (middle frontal gyrus ($t = 5.25$, $x = 34$, $y = 40$, $z = 27$; $t = 4.13$, $x = 40$, $y = 29$, $z = 35$) and superior frontal gyrus ($t = 4.35$, $x = 30$, $y = 52$, $z = 23$)). No activation was exclusive to global interference.

4. Discussion

The aims of this study were to test whether high systemizers have a bias towards attending to local level detail in a visual scene and whether this preference was associated with differential neural activity during a Navon task paradigm. Participants were slower to find the target in the presence of a distracter, repli-

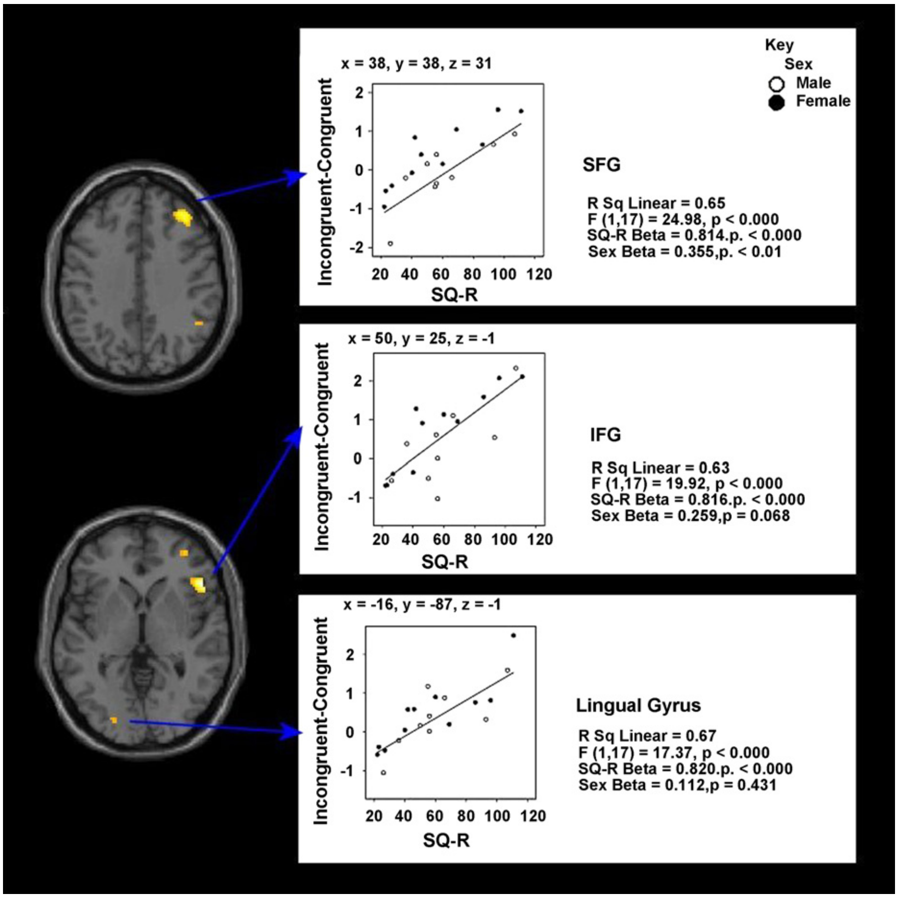

Fig. 6. Activation correlated with SQ-R scores in regions of the IFG, SFG and lingual gyrus (uncorrected, $p < 0.001$). Activations are superimposed on sections from the canonical T1-weighted brain image of SPM 2 along with regression analysis controlling for sex.

cating results in the literature (Navon, 1977). However, there was no group bias towards the local or global level, despite previous claims of a global level processing bias in the general population (Navon, 1977). Correlations were found between local precedence and SQ-R scores. This, coupled with a correlation between SQ-R and local but not global interference, indicates a preference for attending to the local target as well as an increased effect of local level distractors in those towards the higher end of the systemizing spectrum and vice versa in those towards the lower end of the spectrum.

At the group level, our neuroimaging data is largely consistent with previous studies using the Navon task, as well as more general models of attention and conflict resolution (Banich et al., 2000; Fan et al., 2003; Kerns et al., 2004). Attending to local or global levels (with global and local level distractors respectively) resulted in activation in the ACC, and LPFC, consistent

Table 4
Regression analyses, predicting contrast estimates in the incongruent > congruent trials using SQ-R and sex on regions of the inferior parietal lobe and middle occipital gyrus

Region	Model			Predictor Variables			
	Adjusted R^2	$F(2,17)$	Significance	SQ-R		Sex	
				β	Significance	β	Significance
Inferior parietal lobe	0.495	10.31	0.001	0.740	0.000	−0.098	0.558
	0.423	7.96	0.004	0.696	0.001	−0.082	0.644
Middle occipital gyrus	0.620	16.51	0.000	0.813	0.000	−0.107	0.461
Superior frontal gyrus	0.536	11.96	0.001	0.765	0.001	−0.010	0.950
	0.445	8.62	0.003	0.707	0.001	−0.129	0.461
Middle frontal gyrus	0.616	16.22	0.000	0.781	0.000	−0.275	0.071

The overall significance of the model (with sex and SQ-R as regressors) in predicting contrast estimates as well as the significance of the individual predictors in within this model.

Table 5
Regions positively correlated with systemizing for local and global interference

Condition/brain area	BA	Voxel volume	*x*	*y*	*z*	*T*
Local interference						
Inferior frontal gyrus	45	142	48	25	1	4.71
			38	33	4	3.85
Middle frontal gyrus	9	315	40	33	33	5.25*
			36	40	27	5.03*
Superior frontal gyrus	9		30	52	23	5.07
		51	−34	53	14	5.23*
Lingual gyrus	19	113	24	−78	−3	4.41
Middle occipital gyrus		50	−38	−70	5	4.32
Global interference						
Superior frontal gyrus	9	60	38	39	33	5.22
Inferior frontal gyrus	45	65	50	23	−1	4.87
			50	35	−2	3.82

See Table 1 for details.

with the view that these regions are involved in the resolution of conflict and the maintenance of attentional set (Kerns et al., 2004; MacDonald et al., 2000; Magno et al., 2006) in our perceptual task. Extrastriate visual cortex and parietal areas were also activated, presumably, due to an increase in selective attention to target stimuli (Weissman et al., 2002). The lack of activation in the frontal eye field suggests that activation related to differences in eye movement across conditions played a less crucial factor.

In attending to incongruent stimuli compared to congruent stimuli, right LPFC activation (BA 47 and BA 9) was positively correlated with systemizing. However, activation in the ACC was not correlated with the degree to which an individual systemizes. Given the complementary role of the PFC and ACC in maintaining an attentional set and conflict monitoring respectively (Banich et al., 2000; Kerns et al., 2004; MacDonald et al., 2000; Magno et al., 2006; Miller & Cohen, 2001), these results indicate that high systemizers may respond to conflict by recruiting additional processes to maintain an attentional set, rather than attempting to resolve the conflict directly. In line with this, high systemizers exhibited additional parietal and extrastriate visual cortex activation in incongruent conditions, possibly reflecting enhanced target-based perceptual processing as a consequence of raised attentional set (Weissman et al., 2002). The activation associated with systemizing in the LPFC during local interference (when high systemizers were shown to experience heightened conflict) again suggests that regions of the LPFC are recruited under higher conditions of conflict in individuals with higher SQ-R scores. The positive association between motor cortex activation during incongruent conditions and systemizing may reflect motor components of attentional processing and response conflict (Cisek & Kalaska, 2001; Praamstra, Boutsen, & Humphreys, 2005), again perhaps modulated by top down attentional mechanisms. Given the lack of differences in overall reaction times between high and low systemizers, it may be that systemizing is associated with increased neural activity during both direction of attention and during motor response to conflicting stimuli. However, an increased attentional set may aid systemizing when viewing more complex visual scenes, further studies using more complex visual search paradigms would address this question.

Systemizing was correlated with local bias on the Navon task and additional activation was elicited in high systemizers during

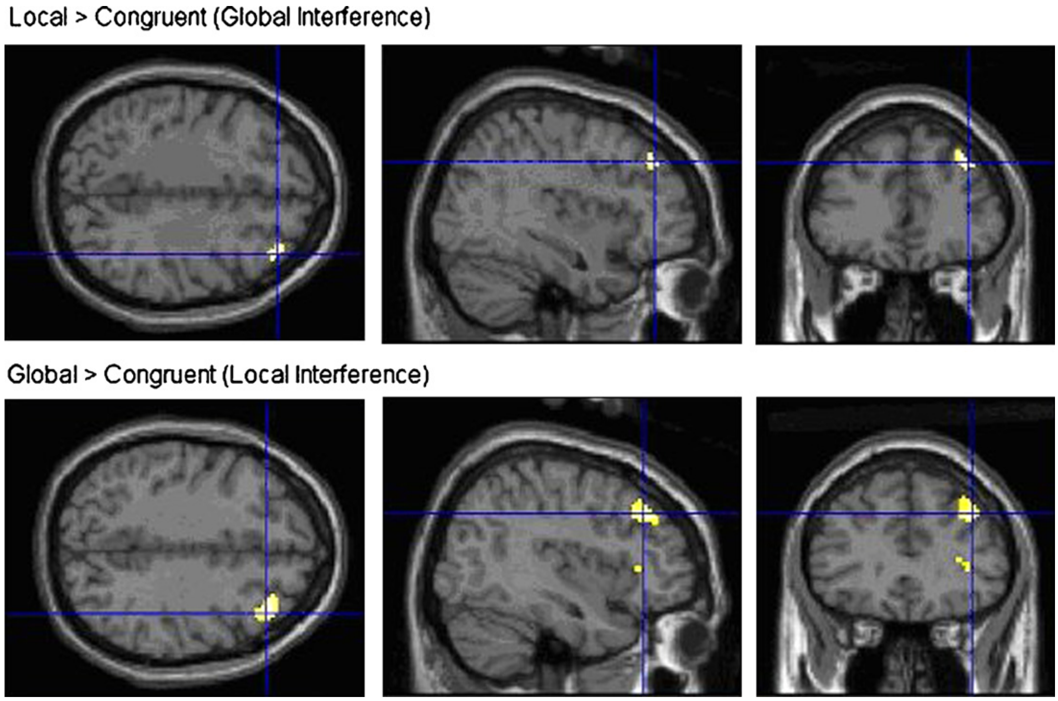

Fig. 7. Superior frontal gyrus activation positively correlated with systemizing trait for both the local interference and global interference condition. Uncorrected $p < 0.001$.

conditions eliciting local interference. Therefore, it was surprising that, although LPFC and extrastriate cortex activation was apparent when processing both these types of target in comparison to congruent conditions, there was no additional activation in these regions associated with systemizing when comparing the global to the local incongruent condition directly. It is possible that the local preference exhibited behaviourally was not substantial enough to result in differential activation in regions involved in maintaining attentional set or perceptual processes. Although global processing occurs subsequent to local processing it is not altogether absent, thus these two processes may have been temporally ambiguous in an MRI scanner. This suggestion could be explored in future neuroimaging studies using techniques associated with greater temporal resolution (such as EEG or MEG to disambiguate such processing stages).

In summary, this study provides both behavioural and neural evidence for the association of a field-independent cognitive style with systemizing. Systemizing was associated with an increased local bias and increased interference from the local level in hierarchical stimuli. Furthermore, systemizing was associated with increased activation in brain regions associated with increasing and maintaining attention. It may be this heightened attentional set, coupled with local orientating and ability to focus on detail, which leads to improved pattern and rule perception elicited in domains such as 'intuitive physics' (Baron-Cohen, Wheelwright, Scahill, Lawson, & Spong, 2001; Lawson et al., 2004) in those with high systemizing cognitive styles.

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