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Drawing on the right side of the brain: A voxel-based morphometry analysis of observational drawing

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Structural brain differences in relation to expertise have been demonstrated in a number of domains including visual perception, spatial navigation, complex motor skills and musical ability. However no studies have assessed the structural differences associated with representational skills in visual art. As training artists are inclined to be a heterogeneous group in terms of their subject matter and chosen media, it was of interest to investigate whether there would be any consistent changes in neural structure in response to increasing representational drawing skill. In the current study a cohort of 44 graduate and post-graduate art students and non-art students completed drawing tasks. Scores on these tasks were then correlated with the regional grey and white matter volume in the cortical and subcortical structures. An increase in grey matter density in the left anterior cerebellum and the right medial frontal gyrus was observed in relation to observational drawing ability, whereas artistic training (art students vs. non-art students) was correlated with increased grey matter density in the right precuneus. This suggests that observational drawing ability relates to changes in structures pertaining to fine motor control and procedural memory, and that artistic training in addition is associated with enhancement of structures pertaining to visual imagery. The findings corroborate the findings of small-scale fMRI studies and provide insights into the properties of the developing artistic brain.

Introduction

The production of representational art is one of the most complex and intangible human behaviours; a form of expression which is almost as old as the modern human and far predates evidence of written communication. The earliest known rock art found in Africa arguably dates back to about 75,000 years ago, with cave art found in the caves of Chauvet, Lascaux and Altamira in France and Spain dating back roughly 40,000 years (Blum, 2011).

As a result of the infancy of research into representational art making, a sparse amount is known about how the brain accomplishes such a task, contrasting with other complex creative tasks such as musical production, whose neural bases have received much attention in the past decade (Bangert et al., 2006; Gaser and Schlaug, 2003; Koeneke et al., 2004; Schlaug, 2001; Schlaug et al., 1995; Zatorre, 2003). Representational *drawing* in particular lends itself to empirical study in this domain as input can be compared directly with output to provide a quantitative measure of ability.

Neurological and neuroimaging research concerning representational drawing previously focused upon the distinct roles of the two cerebral hemispheres, with different drawing pathologies manifesting with left and right-brain damaged patients (Chatterjee, 2004). This was compounded by the popularity of 'Drawing on the Right Side of the Brain' (Edwards, 1989) which conjectured that switching into 'R-Mode' (engagement with the right brain and its putative holistic perceptual processes) helps novices to master representational drawing skills. Although Edwards (1989) was influential, the use of right and left in the text was to a large extent metaphorical rather than neuropsychological.

Neuropsychological research into constructional apraxia implicates brain regions that underpin the integration of multimodal perceptual data, largely involving the parietal cortices (Gainotti, 1985). Neuroimaging data have corroborated the findings of neuropsychological studies as parietal regions have been found to be functionally more active when drawing faces compared to drawing geometrical figures (a motor control; Solso, 2001), when drawing stimuli from memory compared to visually encoding them (Miall et al., 2009) and when drawing stimuli compared to naming them (Makuuchi et al., 2003). In addition, activation in motor regions and the cerebellum was found when drawing was compared with encoding and naming tasks (Miall et al., 2009). As

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well as transient functional changes in neural activity in relation to drawing, evidence has been found for structural and functional changes over time as a result of artistic training. Schlegel et al. (2012) found that novices who had undergone an intensive drawing and painting course showed increased activation in the right cerebellum whilst performing gestural drawing revealed through functional classification, and structural changes in right inferior frontal regions revealed by fractional anisotropy (FA). This study suggests that structural changes occur in the brain as a result of artistic training, in much the same way as been found previously in various populations of experts from musicians (Gaser and Schlaug, 2003) to taxi drivers (Maguire et al., 2000; Woollett and Maguire, 2011).

Whilst there appear to be short-term functional changes in brain regions associated with motor ability in response to drawing practice (Schlegel et al., 2012) it is unclear whether the same or functionally higher-level brain regions are implicated in longer-term drawing skill development that takes place over years rather than months. Furthermore, drawing tasks used in previous studies have been conducted inside the MRI scanner, and may lack ecological validity (Ferber et al., 2007). Therefore, a more extensive voxel-based morphometry study of drawing ability in art and non-art graduate and post-graduate students was undertaken in the current study. It was hypothesised that individuals with greater representational expertise might show increased cortical grey and white matter bilaterally in parietal regions, more specifically the superior parietal lobule and intraparietal sulcus on the basis of prior functional evidence (Makuuchi et al., 2003). Functional studies also point toward the involvement of the frontal regions, particularly the supplementary motor areas (Ferber et al., 2007; Makuuchi et al., 2003; Miall et al., 2009) and the cerebellum (Makuuchi et al., 2003; Schlegel et al., 2012) and therefore these regions were also hypothesised to be correlated with drawing ability. The effect of artistic training on brain structures was also of interest in addition to the more specific skill of representational drawing. Therefore a structural group comparison was made between an art student group and a non-art student group, taking individual differences in representational drawing ability into account.

Materials and methods

Participants

Art students

Participants ($n = 21$; 14 female; mean age = 26.0 ($SD = 5.9$) years) were recruited from respondents of a larger questionnaire based study ($N = 88$) conducted in September 2011. That sample included undergraduate ($n = 14$) and post-graduate ($n = 74$) students attending art and design courses in London at Camberwell College of Art (CAM) and The Royal College of Art (RCA) respectively. There were 6 students from CAM and 15 students from RCA in the neuroimaging sample. Each art college has entrance criteria based on the assessment of artistic talent, primarily in the form of a portfolio of work. CAM requires completion of a foundation diploma in art and design (a one-year diagnostic course) to a high standard and a portfolio of work, and RCA requires a high quality portfolio of work indicating competence in a specific discipline within the general field of art and design practice, for example painting, product design or photography. The majority of students had completed a BA in an arts subject and many were practising artists seeking to consolidate or broaden their artistic practice. Four of the art student participants were left-handed, the remaining 17 participants were right-handed.

Controls

Control participants ($n = 23$; 16 female; mean age = 25.8 ($SD = 7.1$) years) were recruited from the undergraduate and post-graduate student population at University College London (UCL). Participants studied a range of non-visual-arts degrees and did not differ significantly in age, $t\ (42) = .06$, $p = .95$, to the art student sample. Within the control group 17 participants had no artistic experience, 5 reported pursuing artistic activities in their spare time very occasionally, and one participant reported often pursuing artistic activities in their spare time. One control participant was left-handed, the remaining 22 participants were right-handed.

Ethics

The study was approved by the Ethical Committee of the Clinical, Educational and Health Department of Psychology of UCL.

Procedure

Participants were tested individually on all tasks within one testing session lasting between 1 and 1.5 h at the psychology department at UCL. Tasks were administered in the order presented in the experimental procedure.

Questionnaire measures

Participants completed a questionnaire consisting of four A4 sides, presented as a single folded sheet of A3 paper. The questionnaire included questions on:

Drawing and painting experience (art students only). Art students were asked how much time they spent drawing and how much time they spent painting both currently and over each of the previous two years using an 11-point scale ranging from '*most days for 4+ hours*' to '*never*'.

Artistic experience (Controls Only). Control students were asked if they undertook any artistic activities including painting, drawing or photography and responded on a 4 point scale from '*none*' to '*as part of my university course*'. This measure was taken to assess the control participants' involvement in artistic related activities to ensure differences in the degree of artistic training across the two participant groups.

Shortened form of Ravens Advanced Progressive Matrices

To account for potential IQ-based confounds between the art students and non-art students, a shortened form of Ravens Advanced Progressive Matrices (RAPM) was administered (Arthur and Day, 1994). This form has been validated and normalised (Arthur et al., 1999) and as such represents a valid predictor of non-verbal IQ (NVIQ). Participants were given one practice item from Set I of the RAPM. They were then given 12 items from Set II of the longer 36 item RAPM to complete in 15 min. Stimuli were presented on paper and participants gave their responses verbally. All participants completed the task in the allotted time.

Observational drawing tasks

Drawing tasks were completed on A4 (297 × 210 mm) heavyweight art paper (130 $g \cdot m^{-2}$). Participants were provided with B pencils, erasers and sharpeners. Stimuli were presented via timed slides within a Microsoft Office PowerPoint presentation on a 13 inch liquid crystal computer screen with a 60 Hz refresh rate (see Fig. 1 for photographs of stimuli). Participants were instructed to make an accurate drawing of a photograph of a hand holding a pencil, and of a block construction (5 min per image).

Drawing rating procedure

Black and white digitised images of the drawings and the original image were printed out onto sketching quality paper, reduced from A4 to A5 size. The images were then rated by a convenience sample of ten non-expert judges consisting of post-graduate and undergraduate students at UCL. Each judge was required to rate the drawings from best to worst by sorting them into seven categories. Judges were