Drawing Conclusions: An Exploration of the Cognitive and Neuroscientific Foundations of Representational Drawing

Rebecca Susan Chamberlain

Research Department of Clinical, Educational and Health Psychology

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Declaration

'I, Rebecca Susan Chamberlain confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.'

Publications

The work in this thesis gave rise to the following publications:

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Abstract

The present thesis describes an exploration of cognitive, perceptual and neuroscientific foundations of representational drawing. To motivate experimental hypotheses, an initial qualitative study of artists' attitudes and approaches to drawing was conducted. Themes from the qualitative data, predominantly concerning the relationship between perception and drawing, were developed into a large scale survey study of over 600 art students at undergraduate and postgraduate level. The survey study assessed the role of personality and demographic factors as well as perceptual styles and abilities, isolating the role of approaches to study, practice and technique use on externally-rated drawing ability. The qualitative and survey studies provided the foundation for further empirical work, the first of which was an exploration of the use of image manipulation and shape analysis for measuring the accuracy of drawings, with the intention of providing more reliable and valid dependent measures in the study of drawing. This investigation revealed differences in the way individuals judge the accuracy of drawings according to the stimuli they represent and presents a novel method for comparing aesthetic and accuracy judgments of drawing.

The three experimental chapters of this thesis describe investigations into visual perception and memory in association with drawing in students of arts and non-arts subjects with an emphasis on angular/proportional perception, local-global visual processing and long and short-term visual memory. These studies revealed that individual differences in visual perception and visual long-term memory when rendering explain a large proportion of individual differences in drawing ability. The final empirical chapter reports a voxel-based morphometry study of structural neural correlates with individual differences in drawing and artistic ability. The results of this study emphasize the role of procedural memory and fine motor control in the development of long-term drawing expertise. The enquiry culminates in the presentation of a toolbox for drawing which includes visual, educational and motor modules. Its potential use in art and design education in teaching protocol is then discussed. The research findings could have a significant impact on the way in which art schools employ artistic training and could provide early diagnostic tools for identifying talent in the arts.

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Michelangelo

(p. 322, Holroyd, 1911)

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'Art relates to perception, not nature'

Roy Lichtenstein

(Kimmelman, 1998)

1.1   The Primacy of Drawing

Drawing as a form of expression is almost as old as the human race itself, far predating 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). By the time of the Aurignacian era 40,000-28,000 years ago artistic activity was prolific, seeing the creation of paintings, sculpture, musical instruments and jewellery (Blum, 2011). Early artistic expression provides evidence of the ability to symbolize, communicate, and crucially produce novelty and thus is one of the key indicators of the cognitive progression of *Homo sapiens* during its evolution. Furthermore, these artworks are early evidence of the human species mastering technical skills of representation,

> We now know that more than 30,000 years ago ice age artists had acquired a
> complete mastery of their technical means, presumably based on a tradition
> extending much further into the past (Gombrich, 1996, p.10)

Whilst Gombrich argues that the sophistication of representations found in ancient caves resulted from cultural and perhaps even genetic inheritance, other art theorists posit that these early artworks represent a pure connection with representing the visual world faithfully,

> The realistic drawings of these primitive peoples are not to be regarded as a result
> of long practice and a well-kept tradition, but as the expression of a mind whose
> original talent for drawing has remained unspoilt (Bühler, 1930, p. 123)

The latter notion is one that resonates within the context of the current thesis; is it by innocence of the eye or by culturally determined schemata that artists harness the power of representation?

Throughout much of ancient history, drawings were not seen as artworks in and of themselves, but as preparatory works for other art forms (Kenin, 1974). Furthermore, through drawing ancient civilisations made little attempt to utilise tricks to project the feeling of depth, a tradition that persisted until the advent of linear perspective in the Renaissance era. The renaissance was a great epoch in art history which saw a flourishing of the representational arts, particularly in the media of painting and drawing, as well as the prevalence of humanist approaches to science and culture. The diverse nature of media and accessibility of paper around that time brought with it a new freedom of expression and

drawing became more than just preparatory efforts for works of art. Throughout the Italian Renaissance drawing formed the basis of representational art and 'draughtsmanship was regarded in all the representational arts as a seminal font from which sprang the union of theory and idea with execution' (Kenin, 1974, p.81). However, with the Impressionist era of the 19th century came a reorientation of focus, with drawing falling subordinate to colour and a stylistic emphasis on light and formal. As a result representational art fell out of fashion. Drawing was also overlooked as a medium of expression and as a feature of art education during the course of the twentieth century; a victim of continued post-modern attacks on traditional modes of artistic practice in favour of more conceptual approaches (Cannatella, 2004; Petherbridge, 2007; Steinhart, 2004). While art education in the late 19th century consisted largely of industrial drawing and handicrafts, placing a focus upon realism, children's interests came to feature more prominently within the teaching programme in the 1920s, before mass media technologies and popular culture received greater emphasis in the latter stages of the 20th century (Freedman & Stuhr, 2004). The development of artistic education over the course of the 20th century mirrored the artistic concerns of society, with a decreased focus upon skill and an increased focus upon expression.

1.1.1   Drawing in Contemporary Society

Recently however conversations have begun revolving around the importance of drawing once more, demonstrated by academic symposia on art and architecture held in the past year such as 'Thinking Through Drawing' and 'Is Drawing Dead?' hosted by Columbia and Yale Universities (drawingandcognition.pressible.org, www.architecture.yale.edu/drupal/events). In 2004 during a Royal Academy exhibition with a special focus on drawing the artist David Hockney stated that,

> Drawing has been neglected for the last 30 years in art education…That was based on the idea that photography would suffice as a view of the world…people are now aware that photography can be digitally manipulated and may no longer reflect reality…It is time for us to look at how images are made, to place greater value on drawings and draughtsmanship…practically everything comes to life on a drawing board.

The resurgence of drawing as an art form is also evidenced by the *modus operandi* of artistic institutions and public initiatives in the UK such as 'The Big Draw' (a month long festival held in October consisting of drawing events for children and adults as part of The Campaign for Drawing, see www.campaignfordrawing.org). In February 2008 the

University of the Arts in London established a centre for drawing. Their mission statement was,

> To provide a focus for research into the investigative and generative languages of drawing; the material procedures of drawing as a tool for the realisation of ideas; and the critical and conceptual apparatus of drawing

[www.arts.ac.uk/research/centre-drawing, accessed online 17/03/11]

Alongside academic approaches to the study of drawing, the practice itself has received increasing focus, reflected in the availability of short courses in drawing at institutions across the UK, undergraduate courses such as the BA in Drawing and Applied Arts at the University of the West of England (UWE) and the BA in drawing at University College Falmouth, and postgraduate research courses in drawing at SMU and Loughborough University. The drawing studio at the Royal College of Art was established to provide a space in which all postgraduate students could engage with drawing, regardless of discipline,

> The importance of drawing is recognised within every single discipline of the College. The Drawing Studio………seeks to cater for students who wish to experiment with new approaches to drawing as part of their personal development as artists and designers, as well as those who simply want to improve their drawing skills in more traditional ways

[www.rca.ac.uk, accessed online 25/2/11]

Finally, in the most recent review of the curriculum, the current coalition government have pledged to place more emphasis on the development of drawing and painting skills within the secondary school curriculum, suggesting a reemphasis upon more traditional skill-based artistic media, in line with a renewed interest in drawing in society at large.

In parallel, the use of drawing as a vehicle for the investigation of perceptual processing, expertise and manifestations of creativity by cognitive scientists has proliferated in the last two decades, reflecting an interest in the process and product of this previously maligned art form. Some researchers have used the study of drawing to answer more broad questions about visual perception, emotion or cognition, while others are interested in the process and product of artistic activities themselves. The reason for the surge in interest in drawing from a scientific perspective may relate to changing traditions in art theory and education but may also be a product of more sophisticated experimental methods in the

cognitive field. As the production and perception of art remains a uniquely human and remarkably complex behaviour, it is understandable that it was not systematically experimentally explored until the late 20th century, with some notable exceptions (Cain, 1943). As such the investigation presented in the current thesis is conducted at a fortuitous moment in time; when both the artistic and scientific worlds are becoming curious about representational drawing once more. At various stages in the thesis I attempt to ascertain the importance of representational drawing for the subjects of the exploration themselves; the art students and practising artists. Placed within the context of real-world experience of artists, this thesis becomes not only of theoretical importance but of practical importance as well. As Joseph Goguen notes on a special issue on 'Art and the Brain' in the Journal of Consciousness Studies,

> There is little doubt that artists and art lovers can learn some valuable things from scientific studies of perception, as well as from related subjects such as the neurophysiology and cognitive psychology of vision; e.g., psycho-acoustics is a well developed area of musicology that has been applied many ways in music. (Goguen, 2000, p.13)

This exploratory thesis aims to characterise the perceptual, memorial, cognitive and motoric underpinnings of representational drawing. It is hoped that the conclusions drawn from the investigation contained herein will help to frame and guide future teaching practices within the art educational field and provide working artists with meaningful insights into their own practice.

1.2   The Drawing Instinct

'Every child is an artist. The problem is how to remain an artist once we grow up'

Pablo Picasso

(Peter, 1977, p.25)

In a manner parallel to the way in which society abandoned representational art forms in the latter stages of the 20th century, so children appear to abandon the practise of drawing at a certain stage of development. Although children's drawings are not an explicit focus of the current thesis, the study of their art works consists of a far larger body of work than of those studying the drawing behaviours of adult artists. Therefore it is of theoretical worth to provide a brief synopsis of the development of drawing in children before moving into more directly relevant explorations into the psychology of drawing in adults.

Drawing is a ubiquitous form of expression for children, who engage in it prolifically and without inhibition throughout their early years. As a result drawing and artistic expression are viewed as vital media of communication for children (Harris, 1963; van Sommers, 1984; Werner, 1948) and drawing abilities have been used as a test of child development (Goodenough & Harris, 1950; Harris, 1963; Scott, 1981; also see, Strauss, 1978). In early drawing behaviour (18-30 months), artworks often take the character of abstract forms, expressing movement and emotion; artistic activities in which the process is as important as the product (Arnheim, 1956; Thomas & Silk, 1990). Children then start to draw recognisable shapes, starting with the 'primordial circle' from which drawings of the human form arguably originate (Arnheim, 1956; Kellogg, 1970; Winner, 1982, see Figure 1.1). Later (2½-5 years), children tend to engage in symbolic realism (e.g. the portrayal of tadpole figures using previously mastered geometric shapes) and appear to have representational goals in mind before they start to draw (Thomas & Silk, 1990).

Figure 1.1 The Primordial Circle: first attempts at drawing a person (Leo Chamberlain, aged 2½ years)

In subsequent stages of drawing development (3½ years onward) depictions become more detailed and children become more concerned with relationships between elements of the drawing. From this stage onward drawings show a better sense of proportion and become more realistic (Harris, 1963). By the time they leave primary school, children's

representations start to incorporate linear perspective, conveying the feeling of depth from particular predefined viewpoints.

Despite the vast majority of children engaging in drawing behaviours to some extent throughout their childhood, at some stage all but a few 'gifted' children abandon drawing, becoming increasingly entrenched in a world that favours linguistic competency over visual expression (Arnheim, 1969). Development of verbal ability increases children's ability to abstract, generalise and symbolize, which acts as anathema to a true depiction of the visual world, much in the way perhaps that linguistic development might have impacted upon the representations produced by early man in cave paintings (Bühler, 1930). Those that do continue to draw beyond this stage tend to develop unique imagery, characters and caricatures, thereby retaining a certain degree of freedom in their artistic output (Gardner, 1980). The pressure to represent the world in a realistic manner and the failure of the majority of children to do this successfully is the most likely catalyst of children's abandonment of drawing. They find themselves floundering in the 'doldrums of *literalism*: the pedantic preoccupation with the photographic aspect of drawings [which] undermines the child's involvement in the expressive genius of the graphic medium' (Gardner, 1980, p.148).

The resolution of the conflict between literalism and expression is also at the core of the debate about the relevance of representational forms in the contemporary art world. Whilst the current thesis focuses predominantly on a literal observational approach to drawing, it is hoped that by providing a strong psychological framework for technical aspects of representation, this field of research can provide meaningful conclusions about the transition between technical mastery and expressive fluency, encouraging more children to pursue representational arts beyond school age. What follows in this introductory chapter is a summary and analysis of the main themes of psychological and neuroscientific research into observational drawing, with the intention of providing context for the research questions that will be addressed in the subsequent empirical chapters.

1.3   A Model of Drawing Ability

One of the earliest attempts to characterise the drawing process was by van Sommers (1984; 1989). The model he developed serves as a good basis from which to outline the various investigations conducted into the psychological underpinnings of drawing of the last three decades. Van Sommers' model was inspired by neuropsychological case studies whose pattern of deficits suggested that the drawing system could be partitioned into different modules, each representing a different stage in the drawing process (Figure 1.2). As a result he separated the drawing process into two hierarchical systems; the visual perceptual and the

graphical production system. The segmentation of the drawing system reflects Van Sommers' focus upon depictive processes during drawing as well as the buffer that functions as a workspace for previously stored and incoming visual representations. The visual perception component of the model draws upon existing visual perceptual models that propose a hierarchical system of visual processing in increasing numbers of dimensions (face processing (Bruce & Young, 1986) and object recognition (Marr & Nishihara, 1978)).
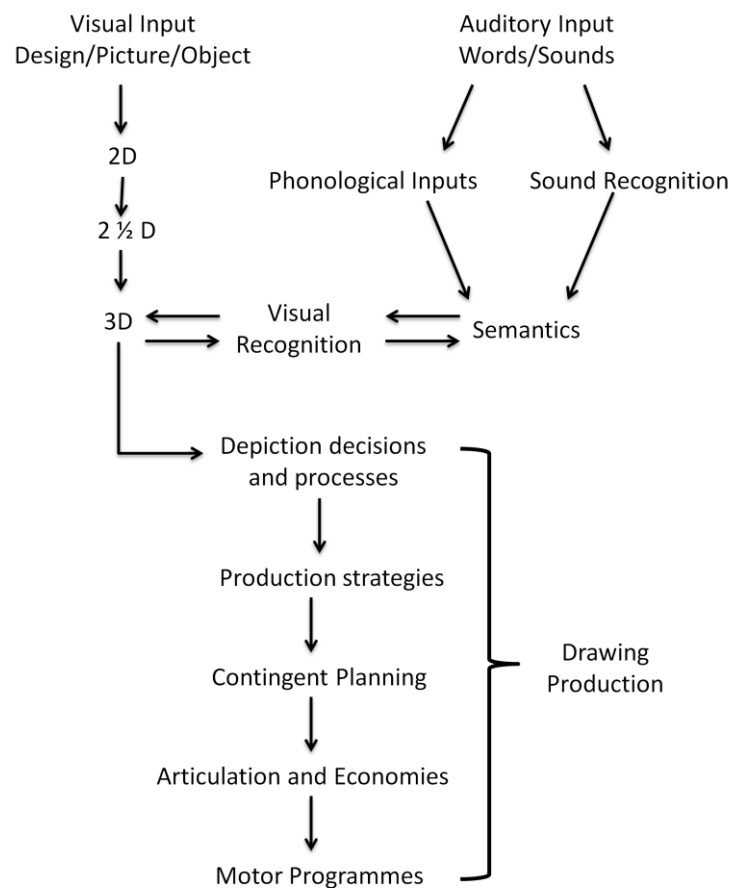
Figure 1.2 Van Sommers Model of Drawing (1989)

An important feature of van Sommers' model is the internal visual buffer, 'the pivot around which the graphic system turns' (van Sommers, 1989, p. 140). Van Sommers draws on Farah's (1984) proposal that the visual buffer is a key component of the visual processing system and is the means by which long term representations are brought into conscious visual awareness. He argues that existing long-term visual representations are used to aid drawing production by segmenting the incoming visual input, in a similar manner to Ernst Gombrich's visual schemata (Gombrich, 1960). This chunking of the visual input feeds directly into drawing production. Van Sommers' model is an integration of visual perceptual accounts that explain how the to-be-drawn stimulus is perceived and models of visual memory that explain how drawings are created by referencing knowledge from previously

stored representations. The model highlights four key components that may contribute to successful drawing: visual perceptual processing, visual imagery, memory and motor processes. Each of these components of the drawing process will now be discussed in turn with reference to existing research. As the first temporal stage of the drawing process is perception of the object, the role of perceptual processing in drawing will first be outlined and discussed.

1.4   The Role of Visual Perceptual Processing

The contemporary argument for the prominence of perceptual ability in drawing stemmed from a seminal exploratory study by Cohen and Bennett (1997) in which the authors assessed drawing accuracy in relation to motor coordination, representational decisions and misperception of the subject. They concluded that misperception of the to-be-drawn object was likely to be the greatest source of drawing errors, but did not posit precisely which perceptual errors were most likely to yield inaccurate depictions. Their study provoked research focusing on one or more of these exploratory factors, with an emphasis on misperception as the most likely basis for drawing inaccuracy.

Kozbelt (2001) conducted the most extensive analysis of characteristics of artists' perceptual abilities in relation to drawing tasks. A number of visuo-spatial tasks including out-of-focus pictures, Gestalt completion, embedded figures, and mental rotation were used alongside a series of line drawing tasks of varying complexity. Artists outperformed novices on all of the perceptual and line drawing tasks, and a large proportion of the variance (40%) in perceptual and drawing scores was shared, suggesting that drawing performance was substantially predicted by visual perceptual ability. A proportion of the remaining variance which separated novice from expert artists in the study was attributed to visuomotor processes. A number of attempts have been made to explain artists' superior perceptual functioning highlighted by Kozbelt's study. Such explanations fall roughly into two types; those that propound top-down cognitive influences over lower level perceptual processing and those that argue that a bottom-up 'innocent eye' enhancement of low level processes underpins superior perceptual skills.

Top-down visual processing and cognitive penetration both exert influence over identification and reproduction of the visual world. Cognitive penetration (Pylshyn, 1999) is the meaningful effect of goals and knowledge on the function of the visual system, whilst top-down processing in vision refers to the effect of earlier visual interpretations computed by early vision on later visual interpretations. Both kinds of higher influence may play a role in superior representational drawing but are referred to as top-down processing for clarity of

expression and to retain terminological cohesion with existing research within the current discussion.

1.4.1 The Role of Schemata

Top-down influences on artistic perception were popularised by Ernst Gombrich who argued that schemata (stored groupings of visual features in long term memory) underpin artistic creation by shaping the way in which individuals anticipate and interpret incoming perceptual information (Gombrich, 1960; Kozbelt & Seeley, 2007; Kozbelt, Seidel, ElBassiouny, Mark, & Owen, 2010; Solso, 2001; Thouless, 1932; Wilson & Wilson, 1977). A similar perspective toward vision was championed by James Gibson, who argued that, 'the notion of a patchwork of colours comes from the art of painting, not from any unbiased description of visual experience' (Gibson, 1979, p.286), suggesting that picture-making defined how visual images are seen in perspective. In this line of argument the viewer is not presented with a highly ambiguous set of visual inputs; rather the visual world is constrained such that information available to the viewer is specific to the layout and properties of the environment. In 'Drawing Distinctions: The Variety of Graphical Expression' (2005) Patrick Maynard makes a literal and analogical example of the effect of top-down processing on drawing ability:

> It is easy to show that drawings of objects, from observation or not, tend to be controlled by identification of distinct objects and their parts, often verbally, as Rawson says: heads (with eyes, nose, mouth), necks, bodies, arms – in that order, as we have a strong tendency to draw the body from the top down (the shoulder is a non-anatomical entity of particular difficulty for novices) (p.138)

Schemata enable the artist to focus on the most pertinent aspects of the image needed to produce an accurate rendition, by shaping an individual's attentive processes whilst they are drawing (Kozbelt & Seeley, 2007). By identifying which elements differ to an ideal schema of the to-be-drawn object, individuals can produce a more accurate rendering (Hayes & Milne, 2011), as well as using the schema to emphasise pertinent parts of the image, or a 'plausible rendering of visual effects that create the illusion of life-likeness' (Gombrich, 1960, p.291). Top-down effects on drawing are likely to be learnt and developed through practice, therefore it is likely that they will result in domain-specific enhancement, as in many other areas of expertise (Chase & Simon, 1973). For example, chess experts show domain-specificity by possessing superior memory ability for chess board matrices but not for shape matrices (Djakow, Petrowski, & Rudik, 1927). Furthermore, while their ability to memorise meaningful board configurations is far superior to novices, chess experts'

superiority decreases when they are presented with random board configurations for memorisation (Chase & Simon, 1973; Gobet & Simon, 1996; Lories, 1987).

Kozbelt (2010) argues that top-down effects are likely to shape artistic ability as realistic depiction is a highly selective process. He demonstrated this by asking participants to complete a minimal line drawing task in which they were to represent an image using a fixed number of pieces of adhesive tape (Figure 1.3). It was found that artists were superior to non-artists at this task, and Kozbelt concluded that a facet of artistic ability concerns the selection of the most important information for realistic representation, over and above advantages in lower level perception.
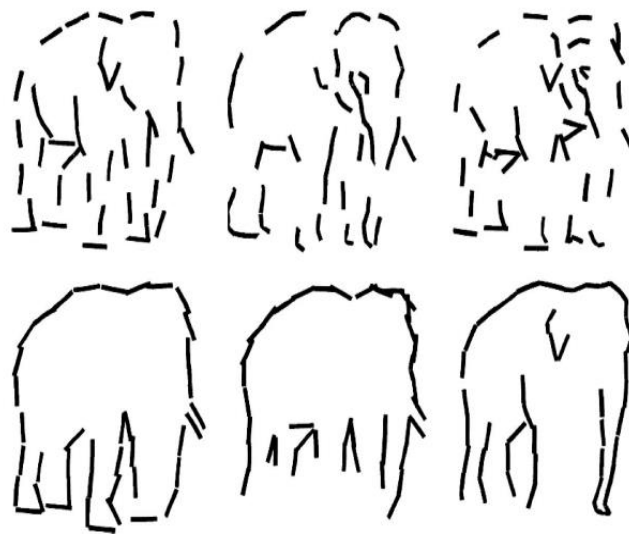
Figure 1.3. Visual selection task (Kozbelt et al., 2010; Ostrofsky, Kozbelt, & Seidel, 2012). Artists' reproductions are presented above novices' depictions.

In a subsequent study Ostrofsky, Kozbelt and Seidel (2012) analysed visual selection ability in direct relation to observational drawing ability, finding that it correlated highly with freehand drawing accuracy. Artists also produce more vertices (L, T and fork junctions) consistent with reproduction as a means for facilitating recognition of the target object (Biederman, 1987). However these effects seem to be more likely to be cases of cognitive penetration rather than top-down within-vision effects. On the other hand, top-down control of eye and hand movements through fixation stability, duration and targeting efficiency also seem to play a role in the acquisition of representational drawing accuracy, are more likely to be within-vision processes, and are evaluated in the discussion of hand-eye coordination in relation to drawing ability in section 1.7 in this chapter (Miall & Tchalenko, 2001).

1.4.2   The Innocent Eye.

Whilst top-down influences on perception can positively affect the way in which incoming visual material is interpreted and selected for representation, there is also evidence for negative top-down interference on accuracy (Cohen & Jones, 2008; Edwards, 1989; Mitchell, Ropar, Ackroyd, & Rajendran, 2005; Ostrofsky, Kozbelt, & Seidel, 2012; Reith & Liu, 1995; Sheppard, Mitchell, & Ropar, 2008). Established knowledge about stereotypical visual characteristics of objects and scenes can interfere with accurate representation of a particular instance of the same object or scene, by biasing representations towards the norm. Inexperienced artists thus have a tendency to depict objects in orientations which reveal the structural features necessary for their recognition rather than their actual orientation relative to the viewer; known as the 'canonical bias' (Reith & Liu, 1995). This can result in inaccurate renderings biased by prior experience. Shape and size constancy effects can also skew representations, a phenomenon termed 'phenomenal regression' as representations regress back to canonical forms (Matthews & Adams, 2008; Thouless, 1932). Mitchell et al (2005) found that when adults draw parallelograms from life or memory they are likely to draw them as more rectangular when they are presented as table-tops as opposed to two-dimensional shapes. Drawing accuracy was also found to be correlated with a reduction in shape constancy effects in a non-rendering task (Cohen & Jones, 2008, although see ; McManus, Loo, Chamberlain, Riley, & Brunswick, 2011). Several theorists have posited that percepts devoid of phenomenal regression and faithful to the raw perceptual content of images are the key to successful representational drawing,

> The whole technical power of painting depends on our recovery of what may be called the *innocence of the eye*; that is to say, of a sort of childish perception of these flat stains of colour, merely as such, without consciousness of what they might signify, - as a blind man would see them if suddenly gifted with sight. (Ruskin, 1856, p.27)

The bottom-up account of drawing ability posits that the 'innocent eye' (Rosenberg, 1963; Ruskin, 1856) provides direct access to fundamental spatial relationships and is the most effective way of producing accurate graphical depictions (Cohen & Bennett, 1997; Edwards, 1989; Nicolaides, 1941). This relates to Marr's theory of vision and its sensory core, which entails a 'low-level, depthless representation of a scene, which is then processed by the perceiver to reconstruct a spatial and meaningful world' (p. 17, Costall, 1995). From the perspective of the innocent eye, the ideal is for the artist to regain access to the sensory core.

Evidence for bottom-up mediation of perceptual advantages is provided in the case study of an autistic gifted draughtsman, in which lower level context-independent percepts assume precedence (Mottron & Belleville, 1995; 1.5. The Role of the Autistic Savant provides a more extensive summary of research concerning autistic individuals with precocious drawing abilities). In another more recent study (Glazek, 2012) expert artists showed no deficit in accuracy when copying familiar versus novel shapes, whereas novice artists did. This suggests that expert artists treat incoming familiar visual information as if they were seeing it for the first time, thus reducing interference by expectation and existing (biasing) knowledge. It has also been argued that stereopsis (perception of depth generated from conflicting information from the two eyes) may actually inhibit the production of accurate representations (Livingstone, Lafer-Sousa, & Conway, 2011), and indeed the closing of one eye is a drawing technique that has been advocated and used by artists for some time as it helps to flatten out a 3D image by eliminating binocular depth cues (Ruskin, 1856). There is some debate however as to what the 'innocent eye' style of perception entails in terms of drawing output. Cohen and Earls (2010) found that inverting an image did not enhance accuracy, contrary to Betty Edwards seminal approach (1989), suggesting that whilst eliminating the canonical percept may change the quality of drawing, it may not necessarily increase accuracy.

1.4.3   Top-down and Bottom-up: A Unified Account.

 In all likelihood both top-down and bottom-up influences on processing aid realistic drawing ability. Kozbelt et al (2010) suggested that bottom-up approaches may be most pertinent for the representation of detail and proportional relationships, whereas top-down processing may come into play for visual selection and planning. The former suggestion is explored in this thesis in a study assessing accurate perception of simple angular and proportional relationships in rendering and non-rendering contexts (Chapter 5).

Top-down and bottom-up processing accounts of drawing allow researchers to make specific predictions about the conditions under which perception should be enhanced in draughtsmen. A bottom-up advantage is more likely to underpin a domain-general perceptual heightening, especially if this perceptual enhancement has an innate basis (Cain, 1943). A top-down processing benefit however, is more likely to be specific to rendering scenarios, as artists use domain-specific knowledge to plan and execute schemata (Glazek & Weisberg, 2010; Ostrofsky et al., 2012). Claims concerning top-down and bottom-up processing in drawing can be tested by comparing performance on equivalent tasks in rendering and non-rendering situations, to assess in which circumstances enhanced perceptual functioning occurs. If an ability is shown to be enhanced in both rendering and

non-rendering situations it can be suggested that this is a result of bottom-up processing as task-specific top-down stored information is presumed to only be used in rendering situations. Such analyses have been conducted in the perceptual and memory tasks included in Chapters 5 and 7 in which artists and non artists are tested on their ability to represent angles and proportions whilst in rendering or non-rendering contexts, to see whether performance changes as a function of context.

An extension of the innocent eye approach to visual processing in drawing has been adopted by researchers investigating special skills in autism. These individuals possess an almost preternatural ability to ignore top-down influences on the structure of visual objects and scenes in order to produce hyper-realistic representations. They appear to attend to non-symbolic aspects of visual experience and structure their representations as patterns (edges, contours and shapes) rather than as classes of objects or symbols (Selfe, 1985). Investigations into the etiology of their special talents will now be addressed.

1.5   The Role of the Artistic Savant

Autistic savants are a group of individuals with autism spectrum disorder (ASD) who show high levels of functioning in a particular domain relative to their residual cognitive and non-cognitive functioning (Belleville & Mottron, 1993). Whilst savant syndrome can occur in any population with learning deficits, savantism occurs in a far higher number of individuals with ASD (10%; Rimland, 1978) compared with other groups with developmental disorders (0.1%; Saloviita, Ruusile, & Ruusila, 2000), leading some researchers to propose that it results from perceptual processing characteristics specific to ASD. Savant skills range from enhanced memory (Hill, 1977) musical talent (Heaton, Hermelin, & Pring, 1998; Hermelin, O'Connor, & Lee, 1987), poetic composition (Dowker, Hermelin, & Pring, 1996) mathematical and calendrical calculation (Hermelin & O'Connor, 1986; O'Connor & Hermelin, 1984) and perspective drawing (Mottron & Belleville, 1993; Mottron & Belleville, 1995; Pring & Hermelin, 1993; Pring, Hermelin, Buhler, & Walker, 1997). Famous artistic savants such as Nadia (Selfe, 1978) and Stephen Wiltshire (Pring et al., 1997) are able to produce hyper-realistic representations of their surrounding environment (Figure 1.4). The rate of 'hyper-realism' appears to be greater in the ASD population (~6%) than in the general population (Drake, Redash, Coleman, Haimson, & Winner, 2010). Artistic savants demonstrate particular command over size constancy and linear perspective relative to their peers (Mottron & Belleville, 1995; Pring et al., 1997; Ropar & Mitchell, 2002).

Figure 1.4. Extract from Panorama of London by Savant Artist Stephen Wiltshire

A number of attempts have been made to explain how savant skills such as perspective drawing arise in individuals with ASD. One theoretical position is that savant skills may result from a processing style that is more locally oriented (Frith & Law, 1995; Frith, 2003; Happé & Frith, 2006; Happé & Booth, 2008).In support of this it has been shown that individuals with ASD do not benefit from segmentation of stimuli in the Block Design Task (Caron, Mottron, Berthiaume, & Dawson, 2006; Shah & Frith, 1993), do not perceive illusions to the same extent as controls (Happé, 1996, although see; Ropar & Mitchell, 1999), have difficulties in processing context-dependent features when reading sentences (Booth & Happé, 2010; Happé, 1997) and detect hidden figures faster than controls (Jolliffe & Baron-Cohen, 1997; Ryder, Pring, & Hermelin, 2002). It is argued therefore that savant artists' highly realistic portrayals result from a bias toward local, concept-independent processing of perceptual stimuli (Frith, 2003; Happé & Frith, 2006; Mottron & Belleville, 1995). There is debate as to whether such a bias is due to weak central coherence (WCC; Happé & Frith, 2006); a reduced ability to cohere local parts into a whole, or enhanced perceptual functioning (EPF; Happé & Booth, 2008; Mottron, Dawson, Soulieres, Hubert, & Burack, 2006; Plaisted, Saksida, Alcantara, & Weisblatt, 2003); intact coherence coupled with a reduction in global interference which is characteristic of typical visual processing.

Table 1.1. Summary of Populations and Methodologies of Studies Investigating Local-Global Processing in Observational Drawing

	Population Details				Local-Global Tasks			
	ASD	N-ASD	Children	Adults	BDT	EFT	LP	VI
Booth et al (2003)	✓		✓				✓	
Drake & Winner (2009)		✓	✓		✓		✓	
Drake et al (2010)	✓	✓	✓		✓	✓	✓	
Drake & Winner (2011)		✓		✓	✓	✓		
Drake & Winner (2012)	✓		✓		✓	✓	✓	✓
Jolliffe & Baron-Cohen (1997)	✓	✓		✓		✓	✓	
Mottron & Belleville (1993)	✓			✓			✓	✓
Mottron & Belleville (1995)	✓	✓		✓			✓	
Mottron *et al* (1999)	✓	✓		✓			✓	
Pring et al (2010)	✓	✓		✓	✓	✓		

Note: ASD =Autism Spectrum Disorder, N-ASD = Non-Autism Spectrum Disorder, BDT =Block Design Task, EFT=Embedded Figures Task, LP=Local Progression in Drawing, VI=Visual Illusion.

A number of researchers have investigated local processing and drawing in ASD and non-ASD populations to assess whether local processing can characterise artistic savantism and, by extension, expert drawing in the general population. Such studies are of three broad types (methods for each study are summarised in Table 1.1):

1. Studies comparing individuals with ASD but without special skills with IQ matched controls to assess drawing characteristics individual to ASD

2. Studies comparing artistic savants with individuals with ASD to assess perceptual traits individual to artistic savantism

3. Studies comparing artistically gifted non-ASD populations with non-artistically gifted controls to asses ASD-type perceptual traits associated with artistic ability and/or drawing ability

1.5.1   Local Progression in Drawing.

In a case-study of an artistic savant, EC, Mottron and colleagues found that they demonstrated a random order of graphical construction consistent with a bias toward local processing (Mottron & Belleville, 1993). Drawing appeared to be piece-meal and to neglect global properties of the image in favour of local progression from one proximal feature to another. Mottron, Belleville and Menard (1999) later observed controls and children with ASD copying the Rey Osterrieth Complex Figure (Rey & Osterrieth, 1993; Figure 1.5) and making drawings of objects and non-objects. They found that participants with ASD produced fewer global details in the first section of their drawings than controls and were also less likely to copy the outline of the Rey figure first. This was replicated in a study comparing children with ASD to children with attention deficit hyperactivity disorder (ADHD; Booth, Charlton, Hughes, & Happé, 2003).
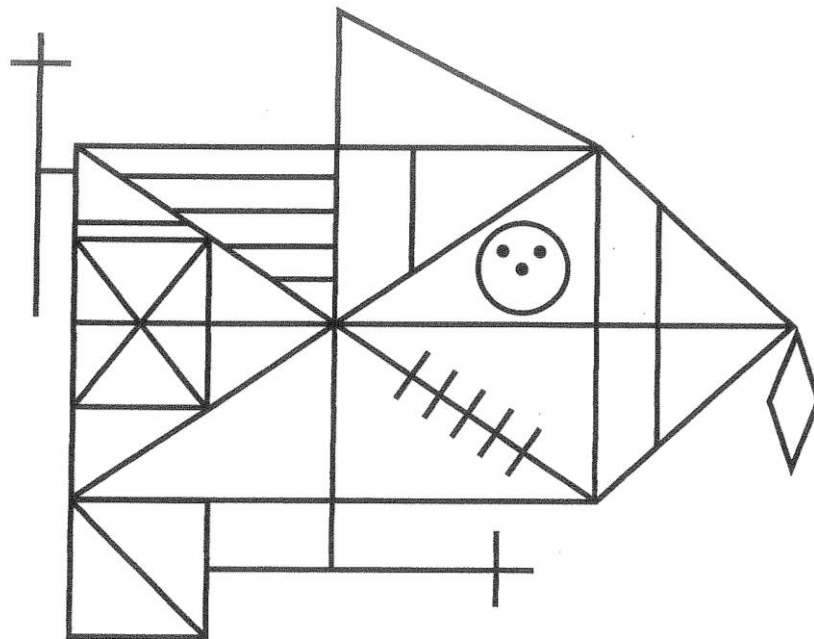
Figure 1.5. The Rey Osterrieth Complex Figure

In contrast, Jolliffe and Baron-Cohen (1997) found no differences in construction strategy between adults with ASD and controls on a modified version of the Rey Osterrieth task. It is likely that these discrepant findings in relation to local progression could be due to differences in experimental stimuli; some visual stimuli may be more delineated in terms of their global and local features and therefore easier to classify as one or the other. Whilst evidence is equivocal for a local progression strategy in individuals with ASD, studies have demonstrated that a local proximity strategy to drawing is not used by non-ASD precocious

realists and typical adults (Drake & Winner, 2009; Drake & Winner, 2012). Local proximity has not yet been investigated in a population of talented adult draughtsmen.

1.5.2 Local Processing Ability.

Local processing has also been explored in an adult population of artistic and non-artistic individuals with and without ASD in order to test the hypothesis that a local processing style is characteristic of both artistic ability and ASD (Pring, Ryder, Crane, & Hermelin, 2010). Participants completed meaningful and abstract forms of the group embedded figures task (GEFT; Witkin, Oltman, Raskin, & Karp, 1971) and the Block Design Task (Caron et al., 2006; BDT; Shah & Frith, 1993). No differences were found in EFT performance in any of the experimental groups and in an abstract BDT both individuals with ASD and gifted artists performed better than controls. This contrasts with earlier findings which revealed differences in both the BDT and the EFT between artists and non-artists (Ryder et al., 2002). Pring et al (2010) explained their finding by suggesting that the EFT is a passive perceptual task whereas the BDT required active construction, implying that visuomotor transformation is a contributing factor to savant artistic ability. Savant artists appear to be better than controls when recalibrating visual feedback into motor ability (Ryder, 2003). Again, empirical findings appear to be equivocal with regard to whether there is a link between artistic ability and a local processing bias.

More recent research suggests that there may be evidence of enhanced local processing in individuals without ASD who are proficient at realistic drawing, rather than artistic ability more generally. Drake, Redash, Coleman, Haimson and Winner (2010) found that performance on tasks that required local processing correlated with the extent to which children with and without ASD could produce realistic drawings. In their study local processing scores in the BDT were produced by calculating the difference in accuracy and completion times between segmented and unsegmented items. Accuracy difference scores but not differences in completion times were predicted by drawing ability on maximally and intermediately cohesive block designs as well as accuracy on the GEFT. This finding was then replicated in a sample of adult non-ASD, non-artistic individuals in which enhanced local processing as evidenced by the BDT and the GEFT was correlated with realistic drawing ability (Drake & Winner, 2011). Support for a local processing bias in adults with realistic drawing talent has also been found in a study of individuals experienced in portraiture, in which those experienced in drawing faces showed reduced holistic processing of faces compared with controls (Zhou, Cheng, Zhang, & Wong, 2012). Furthermore, Glazek (2012) found that shorter encoding durations and smaller encoding breadths characterised expert drawing in artists for both novel and familiar stimuli, suggesting a local

processing strategy for visual analysis. The role of local processing in relation to drawing realism and artistic ability in experts and novices is the subject of investigation in Chapter 6 of this thesis.

1.5.3   The Latent Savant.

Artistic savant-type skills have been induced in novices using neuro-magnetic stimulation (Snyder et al., 2003; Snyder, 2009). The authors argued that savant-type skills are inherent in all individuals, and are manifested in individuals with ASD as a result of the impairments they have in other forms of social and linguistic processing, giving them 'privileged access' to bottom-up visual processing. Snyder et al (2003) applied repetitive trans-cranial magnetic stimulation (rTMS) to the left anterior temporal lobe during a drawing task in which participants were asked to draw pictures of a dog, a horse or a face from memory. The rTMS altered the quality of drawings produced whereas sham rTMS did not. More specifically, TMS produced a difference in the schema and convention of the drawings; the images appeared to change from stereotype caricatures to more complex and lifelike. In a similar study, TMS to the left fronto-temporal cortex resulted in drawings that were ranked higher by artists according to the Goodenough-Harris drawing test guidelines (Young, Ridding, & Morrell, 2004). The fact that these results are seen as a result of inhibition of the left hemisphere of the neocortex would suggest a theory of drawing along the lines of Betty Edwards' (1989) seminal drawing thesis, 'Drawing on the Right Side of the Brain' in which she argues that the development of superior drawing skills is dependent upon engaging in cognitive processes particular to the right hemisphere. Whilst striking, these results must be approached with caution due to the subjective appraisal of changes in the participants' drawings and the fact that the authors do not offer an explanation of how autistic individuals have special access to these savant-like abilities (Mottron, Dawson, & Soulieres, 2009). Further neuroimaging approaches to studying drawing ability are discussed later in this chapter (section 1.8. Drawing and the Brain), and are indicative of more bilateral involvement of the cortical lobes in representational drawing (Makuuchi, Kaminaga, & Sugishita, 2003). Nevertheless, it is interesting to consider the connection between skills present in individuals with ASD, and experts without impairments in social and linguistic functioning. It is now considered highly likely that autistic traits exist on a continuum that are normally distributed in the general population (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001), termed the broader autism phenotype (Dawson et al., 2002). Therefore, if the traits associated with ASD are not qualitatively distributed in the population, the etiology of skills present in individuals with ASD may not be qualitatively different to skills in individuals without ASD diagnoses. In particular, if the perceptual

attributes associated with ASD can be shown to be dimensional then studies that explore visual perception in ASD can provide illuminating insights into visual perception in artistically gifted subjects. Studies suggest that these perceptual enhancements do extend to the normal artistic population (Drake & Winner, 2009; Drake & Winner, 2011; Zhou et al., 2012), and therefore this is a rich avenue of exploration. One topic in the literature that is still debated is whether enhanced local processing in individuals comes at the expense of successful global processing. This is investigated in Chapter 6 of the current thesis, as it is expected that while local processing may facilitate the adoption of an innocent eye approach to drawing, appreciation of global properties of an image such as proportion or tonal contrast are also critical to producing an effective representation. Artists' ability to switch between global and local modes of processing is also tentatively addressed in Chapter 6, and will be the focus of future work in this area which is discussed in the final chapter.

It has been argued that some autistic savants possess eidetic imagery alongside enhanced local visual processing (Roberts, 1965; Selfe, 1978; Treffert, 2009) and that this could to some extent explain savant talent for perspective drawing, especially when such activity is conducted from memory. Eidetic imagery is the ability to form a visual representation based on prior stimulation and is akin to perceiving the stimulus itself, as opposed to normal visual imagery which is not percept-like in character (Haber & Haber, 1988). However, Mottron et al (2009) argue that this view is contradicted by the transformations that savants consistently perform on their material of expertise, as transformation is not thought to be possible on highly static and rigid eidetic images. Evidence suggests that those with high attention to detail ASD traits and low negative social ASD traits show enhanced visual working memory (Richmond, Thorpe, Berryhill, Klugman, & Olson, 2013). The visual buffer was pivotal to van Sommers (1989) early drawing model and continues to feature in discussions about the etiology of drawing ability, suggesting that internal visual representations do play a role in the drawing process. I will now consider the arguments for involvement of various visual representations in the drawing process, including visual imagery and visual long and short- term memory.

1.6 The Role of Visual Representations

1.6.1 Visual Imagery

Visual imagery could be implicated in the drawing process through its tight connection with visual perception, which has already been shown to play a fundamental role in drawing accuracy (Cohen & Bennett, 1997; Kozbelt, 2001; Ostrofsky et al., 2012). Finke (1980; 1985) contends that the visual imagery system employs much the same perceptual processes

as those used to perceive the same stimulus, although it has been argued that the two cannot be accessed simultaneously because both systems utilise the same operations and substrates (McMahon, 2002). Ganis, Thompson and Kosslyn (2004) reported an overlap between brain regions recruited during visual imagery and visual perception of at least 90%, and many studies have demonstrated interference between visual imagery and visual perception (for a review see Craver-Lemley & Reeves, 1992). Perez-Fabello and Campos (2007) suggest that if, 'processes involved in mental imaging are closely related to those involved in the perception of real objects, subjects with greater imaging capacity should have a greater capacity to visualize and draw scenes' (p.133). Despite its proximity to perceptual processes, the role of mental imagery in observational drawing is as yet undetermined and relatively understudied. There are known to be individual differences in mental imagery (Borst & Kosslyn, 2010), and therefore it is possible that such differences may underpin, or be caused by, engagement with the visual arts.

Weisberg (1993) argued that mental imagery could also be used during the creation of new artwork by bringing stored representations to mind. It could be argued that such a faculty may be employed in representational drawing when the drawer must recall features of an object without looking back at it, or in the retrieval of appropriate schemata to guide representation and segmentation of the incoming stimulus (Gombrich, 1960; Seeley & Kozbelt, 2008), as well as during comparison of the drawn image with its subject. In support of this it has been found that vividness of mental imagery and control of mental imagery is correlated with attainment in drawing at art college (Perez-Fabello & Campos, 2007) and that individuals with low IQ but exceptional drawing talent are better at identifying incomplete pictures (thought to be associated with mental imaging capacities) than IQ-matched controls (O'Connor & Hermelin, 1987a). However, it is not clear whether the results of the former study pertain specifically to representational drawing or other forms of imaginative drawing that would be expected to be more closely connected with visual imagery processes. The relationship between various forms of self reported imagery abilities are assessed in relationship to representational drawing specifically in the survey study in Chapter 3 of this thesis.

Visual imagery research has revealed two distinct forms of visual mental imagery, each of which could play a role in online perception during observational drawing. One form of visual imagery is object imagery, which includes representations of the literal appearance of objects such as size, colour and shape. The other form, spatial imagery, includes representations of the relationships between object or object-part locations (Blajenkova, Kozhevnikov, & Motes, 2006). Object imagery would aid the transfer and retention of fine-grained details in drawing, whereas spatial imagery would underpin the spatial relations

between elements of a complex scene or object. Rosenberg (1987) demonstrated that visual artists characterized their images as vivid and clear, and that artists reported higher object imagery scores whilst scientists reported higher spatial imagery scores, suggesting that object imagery is the most pertinent form of visual imagery for visual artists. Neuropsychological evidence however suggests that visual imagery is not necessary for representational drawing, as a patient with a severe visual imagery deficit was still able to produce detailed, proficient observational drawings, which reduced to simplistic and schematic when produced from memory (Botez, Olivier, Vezina, Botez, & Kaufman, 1985). This suggests a dichotomy in the role of visual imagery for online drawing versus drawing from memory. In a more recent study Calabrese and Marucci (2006) found that there were no differences in self report imagery scores between artists and non-artists, suggesting that visual imagery is not implicated in the majority of processes associated with representational drawing.

Despite a putative overlap between visual perceptual and visual imagery processes, it appears that there is little evidence yet for a link between imaging capacity and drawing ability. In Botez et al's (1985) study it would appear that visual imagery processes interacted with processes that support the retention of stimuli in visual memory, such that drawing was impaired only when visual memory was involved. However, the link between visual imagery and visual memory is itself unclear. Researchers have argued that there is a representational distinction between visual imagery and visual memory, making it conceivable that visual memory processes could be employed in drawing without the need for involvement of adjoining visual imagery processes (Hollingworth, 2004; van Sommers, 1989). Higher level perceptual systems such as long and short- term memory are likely to exclude precise metric information in favour of more abstract, conceptual representations, and are not expected to be imagistic (Hollingworth & Luck, 2008). In support of this it has been shown that scores on the Vividness of Visual Imagery Questionnaire (VVIQ) do not correlate with objective measures of visual working memory performance (Dean & Morris, 2003; McKelvie, 1995) whilst Dynamic Visual Noise (DVN) disrupts visual imagery processes (Quinn, 1996) but not short- term memory (Andrade, Kemps, Werniers, May, & Szmalec, 2002).

1.6.2 Visual Memory

As Kimon Nicolaides (1941) notes in his instructional book on representational drawing,

> With the exception of the contour study, there is no drawing that is not a memory drawing because, no matter how slight the interval is from the time you look at the model until you look at your drawing or painting, you are memorizing what you have just seen.(p.40)

Depending on the specific conditions, this interval between looking at the model and looking at the drawing could last within the region of milliseconds to seconds. Individuals who can make the transfer efficiently and veridically should be at an advantage, by reducing the likelihood of mismatch between their representation and the true character of the visual stimulus. Both the fidelity of representations and their duration may be important, but distinct components underpinning accurate representational drawing. By contrast, it can be posited that certain schematic representations within visual long-term memory may hinder the production of visually realistic drawings, biasing toward denotative rather than realistic impressions (Cohen & Jones, 2008; Edwards, 1989; Mitchell et al., 2005; Reith & Liu, 1995; Sheppard et al., 2008).

Long-Term Visual Memory (LTM) If an expertise account of observational drawing is considered, it is likely that the development of long-term memory structures, or spatial schemata (Seeley & Kozbelt, 2008) play a role in the acquisition of drawing skill. Chess players have been shown to have enhanced memory for domain-specific visual material, which enables them to quickly and efficiently evaluate possible play outcomes (Chase & Simon, 1973). In the same way, experience with domain-specific material may help artists to quickly and efficiently evaluate visual stimuli. Kozbelt (2001) additionally suggests that the development of artistic skills may enhance procedural structures, which enable effective processing of incoming visual information and feature in Glazek's (2012) account of long-term working memory (LT-WM) in drawing. The association between procedural memory and perceptual processing also features in Seeley and Kozbelt's (2008) model of perceptual advantages in drawing, shown in Figure 1.6, in which procedural knowledge (motor plans for rendering stimulus features in a particular medium) affects attention for rendering as well as feature extraction and object recognition processes in the visual system.

Visual Buffer (V1, LGN) → Feature Extraction (MT, V4, TEO) → Object Recognition (TE) → Long Term Memory → Spatial Working Memory

Procedural Knowledge (Rostral SMA & PMC)

Shift Attention
Priming: Signal-to-Noise

Priming: Diagnostic Features

Priming: Diagnostic Features
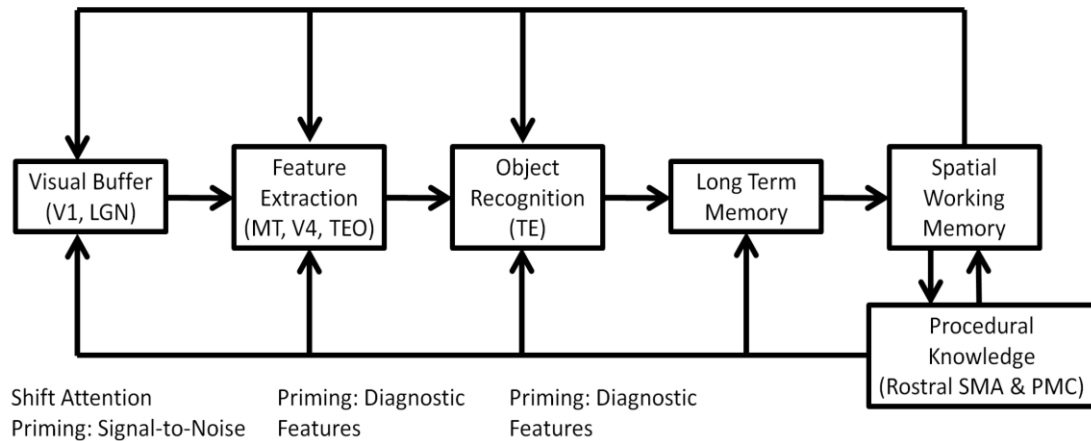
Figure 1.6. A simplified version of Kozbelt & Seeley's (2007) Visuomotor Model for Artists' Perceptual Advantages

Evidence suggests that superior visual memory and artistic ability are related (Casey, Winner, Brabeck, & Sullivan, 1990; Rosenblatt & Winner, 1988; Sullivan & Winner, 1989; Winner & Casey, 1992). Rosenblatt and Winner (1988) conducted tests of artist and non-artists' incidental memory for 2D and 3D stimuli. They found that artists outperformed controls for 2D material when they were required to recall line quality, but not composition. Artists were also better at remembering changes in a 3D environment. Sullivan and Winner (1989) found that art students outperformed psychology students on a visual memory test in which small segments of a picture were altered. Glazek and Weisberg (2010) reported that visual artists demonstrate superior short-term recognition memory for simple and complex stimuli in a change detection task compared to novices, concluding that the faster encoding speeds demonstrated by the experts allowed them to increase the amount of time they can dedicate to associative and creativity thinking. They also found that artists changed their encoding strategy less in response to stimulus novelty and increasing complexity, favouring the 'innocent eye' approach to perceptual advantages in expert draughtsmen.

Glazek (2012) argued for the role of long term visual working memory (LT-WM) as a method of retrieving fine motor programs from memory during the act of sketching. This approach implies that the role of long term memory (LTM) is not purely visual, but interacts with motor plans by linking a visual stimulus was an accurate motor program to render that stimulus with. Glazek's LT-WM model predicted that expert artists capture more of the visual scene per fixation when viewing a visual stimulus in rendering and non-rendering situations. In a subsequent study, he measured the eye movements and motor output of artists and non-artists whilst drawing novel and familiar stimuli, which were manipulated for

complexity. It was found that experts used shorter encoding durations and covered a smaller area of the visual scene during each encoding period. Glazek argues that experts develop the ability to process familiar stimuli as if they were novel, reducing the interference of canonical representations in LTM, even in circumstances in which drawing is not required. Finally, McManus *et al* (2010) found that delayed recall of the Rey Osterrieth Complex Figure (ROCFT) correlated with drawing ability, supporting the notion of some involvement of long term memory processing in drawing. The positive role of visual long term memory (VLTM) in this context is likely to be due to the role of VLTM in online scene representation or attentional guidance, rather than retention of the target image (Hollingworth, 2004; Seeley & Kozbelt, 2008). It has been shown that LTM experience for naturalistic scenes guides spatial attention, aiding identification of events in the perceptual domain during active vision (Stokes, Atherton, Patai, & Nobre, 2012; Summerfield, Lepsien, Gotelman, Mesulam, & Nobre, 2006; Summerfield, Rao, Garside, & Nobre, 2011).This is further investigated in a series of VLTM tasks in Chapter 7.

Despite evidence to suggest that LTM representations may help with the interpretation of incoming visual information whilst drawing, contrary evidence from the population of gifted individuals with ASD suggests that superior visual memory does not explain their talents. Researchers found that artistic savants perform according to IQ in recall and recognition tests of visual memory, but performed at the level of gifted controls in picture matching and copying tasks, suggesting a more dominant role of visual perception than memory in representational drawing (Hermelin & O'Connor, 1990; O'Connor & Hermelin, 1987b; O'Connor & Hermelin, 1990).

Premotor Planning. Tchalenko and colleagues (Miall & Tchalenko, 2001; Seeley & Kozbelt, 2008; Tchalenko & Miall, 2009; Tchalenko, 2009) present an alternative argument of the role of long and short-term visual representations in drawing. They contend that visual memory is precluded by premotor planning in expert artists, as they effectively segment and translate small sections of the image directly,

> By the process of segmentation, the original was progressively subdivided into simple lines, each one immediately executed onto the copy paper. In this way the use of working memory was minimized or even completely avoided. Such a ''just in time" strategy was a deliberate choice by the expert who could have stored in memory and drawn a second segment in continuity with the first. (p.799)

Ballard, Hayhoe and Peltz (1995) argue that human memory representations used in drawing result from a *deictic system*, which stores pointers to the location of perceptual information in the visual scene rather than storing the perceptual information directly. Such

a system minimizes the use of working memory (WM) during drawing by postponing the gathering of relevant perceptual information until it is required, resulting in increased gaze frequency but reduced memory load. This has been found in other natural tasks in which there are 'trade-offs' between gaze and WM (Droll & Hayhoe, 2007; Hayhoe & Ballard, 2005). In the context of drawing, if gaze frequency is lowered and WM load increases, the deictic system breaks down, and drawing accuracy is decreased. In support, Cohen (2005) found that gaze frequency accounted for 33% of the variance in drawing accuracy scores. When gaze frequency was manipulated by alternating highlighting the to-be-drawn object and the paper, drawing accuracy was affected by enforced lower gaze frequencies, suggesting a decrease in performance with increased memory load. In an eye-tracking study artists and novices were asked to copy a line drawing of a nude human figure (Tchalenko, 2009). Artists demonstrated shorter initial fixations and lower dwell ratios which Tchalenko argued reflected the use of a chunking strategy to encode visual information.

Research suggests that LTM may be implicated in the drawing process through the interaction between existing representations and incoming visual information that required interpretation and segmentation for an accurate depiction. There is sparse evidence of a connection between visual short-term memory (VSTM) fidelity or capacity and drawing ability, and as a result it has been argued that premotor plans may circumvent the need to rely on short-term representations. This line of argument highlights the role of an interactive visuomotor system in drawing. Hand-eye interactions will now be discussed in relation to the development of drawing accuracy.

1.7   The Role of Hand-Eye Coordination

Glazek (2012) notes that whilst there is a proliferation of work pertaining to perceptual processing in drawing, there is a distinct lack of research exploring late stages of drawing production, despite the fact that this stage of the drawing process is a fundamental one, and not necessarily easily mastered by all,

> Seeing is a prerequisite for drawing, but by no means can most people (eidetic or
> not) effortlessly draw what they see. Nadia [an autistic savant] had in some way
> to realize through fine motor patterns, those forms that were so vividly impressed
> in her mental imagery (Gardner, 1980, p.185)

The complex task of production in the drawing process is acknowledged in van Sommers model (1989) shown in Figure 1.7.
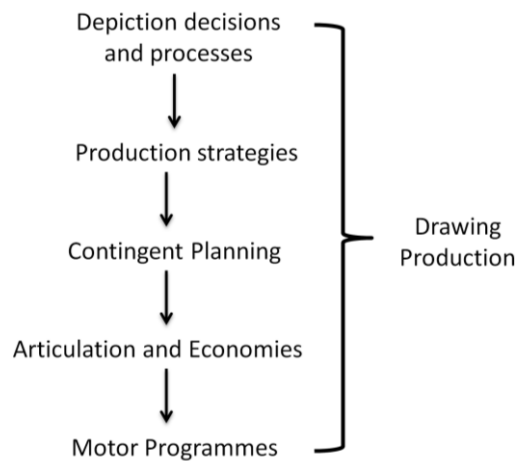
Figure 1.7. The drawing production of component in van Sommers' model of drawing ability

Neglect of hand-eye coordination in drawing research could be due to earlier exploratory studies of drawing which eliminated motor coordination as a predictive factor for individual differences in accuracy. Edwards (1989) stated that, 'contrary to popular opinion, manual skill is not a primary factor in drawing. If your handwriting is readable, or if you can print legibly, you have ample dexterity to draw well' (p.3). In support, Cohen and Bennett (1997) came to the conclusion that motor coordination was not a significant factor by comparing participants' tracings of a photograph with free hand drawing of the same photograph. They argued that tracing requires the same hand-eye motor coordination as drawing does and therefore if a discrepancy in accuracy was found between a tracing and a free-hand drawing, the discrepancy is due to perceptual difficulty rather than motor coordination demands, which remain similar in both tasks. Gross motor control may not be strongly implicated in individual differences in drawing ability, however hand and eye movements are known to have strong bidirectional influences (Hayhoe & Ballard, 2005; Land, Mennie, & Rusted, 1999). Coen Cagli, Coraggio, Napoletano and Boccignone (2008) characterise representational drawing as, 'a good example of the "looped" influence between active vision and motor planning/control' (p.2) and therefore it is highly likely that the interaction between fine motor movement and eye movements is a fundamental component of individual differences in drawing ability.

1.7.1 Eye-hand interaction in experts and novices

Glazek (2012) measured both hand and eye movements in a naturalistic drawing task to assess whether motor output showed characteristics of expertise as well as perceptual output. In this study the author derived a visual/motor ratio by dividing the motor output

(duration and breadth of lines created by a stylus on a tablet) by the amount of visual input (visual encoding breadths and duration). Glazek argued that if this ratio was shown to differ between experts and novices, particularly in the case of familiar stimuli, there is evidence for enhanced interactivity between visual input and motor output as a result of drawing expertise. No difference was found between experts and novices in terms of their overall sketching time in the study. However, experts' individual sketching durations were marginally longer than novices', and their motor output to visual input ratios were larger. Motor output to visual input ratios also correlated with sketching accuracy. This implies that expert artists are able to produce more motor output per unit of visually encoded material. The study also showed that artists were more spatially focused in their motor output for familiar compared to novel stimuli.

Collectively these results suggest that expert artists possess more efficient motor output than novices with respect to sketching tasks, and that the basis of this efficiency may be a more efficient coupling of visual input with motor output. However, the experts in Glazek's study still showed an effect of familiarisation on motor output; their motor units becoming more focal and constrained for familiar stimuli. This suggests that whilst the eye may be able to separate itself and become 'innocent', the hand falls prey to influence of familiarity. This is surprising in light of some evidence that suggests that, while the eye is subject to various illusions, the hand is not (Aglioti, DeSouza, & Goodale, 1995; Bruno, 2001; Franz, Fahle, Bülthoff, & Gegenfurtner, 2001; Ganel, Tanzer, & Goodale, 2008). Thus it would seem more likely that the hand would express a less biased impression of the world than the eye.

1.7.2 Characterising eye-hand interaction

Gowen and Miall (2006) performed a study to characterise the interaction between hand and eye movements whilst non-experts drew or traced a series of simple shapes. They focused upon three types of hand-eye interaction;

1. Gaze locking (the eye locks onto the target until the hand reaches it)

2. Predictive hand processing (the eye moves from the target before the hand reaches it)

3. Reductions in hand velocity coinciding with saccade speed reduction

Data showed that participants 'gaze locked' at important junctions of the visual stimulus (e.g. at the corners of a square) while drawing. Tchalenko and Miall (2009) also conducted a study in which they simultaneously recorded hand and eye movements during a drawing task. They characterised eye-hand coordinated movements during drawing as representing

either close pursuit, where the eye roughly pursued the hand, or as gaze locking. In the former coordinated movement the hand led, whereas in the latter the eye led. Tchalenko and Miall argue that both experts and novices use a combination of both of these modes while drawing. Nevertheless, through this acute coupling of eye and hand movements, 'the shape of the line to be drawn is acquired by the hand during the time that the subject is looking at the original' (p. 370). A motor programme is formulated whilst looking at the subject, that can be deployed as soon as the artist moves their attention back from the paper, with the eye helping to spatially position the beginning of the line on the paper, and monitor the resulting hand movement.

Neuropsychological and neuroscientific evidence in relation to drawing can be used to further characterise the drawing process, particularly where the involvement of certain functions are under dispute. An intimate interaction between the eye and hand would predict the involvement of the cerebellum in drawing, which has been shown to have both sensory and motor functions linked with the control of finely coordinated movement (Miall & Reckess, 2002; Miall, Reckess, & Imamizu, 2001), and the parietal cortex, which also plays a role in hand-eye coordinated movements (Carey, 2000; Desmurget et al., 1999). Furthermore, degree of activation of these sites may differ between experts and novices, or may be more greatly associated with activation in other regions associated with higher level cognitive functioning. Whilst the majority of insights into drawing ability have been made at the behavioural level, there is increasing interest in utilising neuroscientific techniques to address the various aspects of the drawing process already presented here. Early studies in this area drew on the neurological patient literature, particularly from patients with hemispheric damage (Chatterjee, 2004; Gainotti & Tiacci, 1970; Halligan, Fink, Marshall, & Vallar, 2003; Kirk & Kertesz, 1989; Larrabee & Kane, 1983), visual agnosia (Trojano & Grossi, 1992) and various forms of dementia (Mell, Howard, & Miller, 2003; Mendez, 2004; Miller, Cummings, & Mishkin, 1998; Moore & Wyke, 1984), whilst neuroimaging studies have started to accumulate in the last decade (Bhattacharya & Petsche, 2005; Ferber, Mraz, Baker, & Graham, 2007; Makuuchi et al., 2003; Miall, Gowen, & Tchalenko, 2009; Solso, 2001). The main findings from this growing body of research into the neural correlates of drawing ability will now be discussed as they pertain to the final experimental chapter of this thesis (Chapter 8) which focuses upon gross structural changes in grey and white matter in the brain that differ as a function of drawing expertise.

1.8   Drawing and the Brain

Neurological and neuroimaging research has previously focused upon the distinct roles of the two cerebral hemispheres of the brain in representational drawing. This may be due to

the use of drawing as a diagnostic tool for many hemispheric neglect conditions, and was probably 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 Edward's argument was compelling at the time of release due to the prominence of Roger Sperry's (1973) work, subsequent research has offered a much less simplistic conception of hemispheric laterality and its relation to gross skills such as drawing. For example, Magnus and Laeng (2006) studied an individual who could make proficient drawings with both the left and the right hand. They found that drawings made with the left hand were rated higher than drawings made by the right, but that they were not characterised by properties indicative of right or left 'modes' associated with either hemisphere.

1.8.1   Neuropsychological Research

The drawings of patients with damage limited to one cortical hemisphere can provide insights into the role of neural structures implicated in drawing and precede research that depends upon technological advances in neuroimaging. Constructional apraxia is the term used to denote disability in drawing and other constructional tasks, without general impairment in IQ, visual or motor functioning. It is usually associated with damage to the parietal lobes in either hemisphere (Gainotti, 1985; Makuuchi et al., 2003) and the study of patients with these deficits has revealed which brain structures are necessary for drawing. Gainotti and Tiacci (1970) found that right hemisphere lesioned patients' drawings displayed lack of understanding of spatial relations, neglect for the left hemifield, piece-meal construction and difficulty in representing perspective. On the other hand, left hemisphere lesioned patients' drawings were over simplified, laboriously constructed and demonstrated a particular difficulty with the representation of angles. In a case study an artist with progressive aphasia, AA, showed significant atrophy to the inferolateral frontal cortex, frontal insula, striatum bilaterally although more so in the left hemisphere (Seeley et al., 2008). AA's art took a progressively more realistic character as her condition progressed and voxel based morphometry (VBM) analysis of her brain at various time points throughout her condition showed a structural increase in grey matter in the right intraparietal sulcus (IPS), the right superior parietal lobule (SPL) and the right superior temporal sulcus (STS). The authors argue that these regions are of import as they serve to integrate multimodal perceptual data. This early neurological framework provided researchers employing neuroimaging techniques with brain regions of interest, which were focused upon in subsequent structural and functional studies.

1.8.2   Neuroimaging Research

In an early neuroimaging study, Solso (2001) asked a skilled portrait artist, Humphrey Ocean, to draw in an magnetic resonance imaging (MRI) scanner, and then compared activations in the cerebral cortex in the artist with those of novices. It was found that whilst drawing the artist showed reduced activation in regions associated with face processing (the right posterior parietal cortex) relative to the activation of the same area in novices. The artist also showed increased activation in the right medial frontal lobes relative to the novices. Considered alongside one another these two sites of activation suggest that Humphrey Ocean experienced more efficient processing of face-like stimuli and a higher-order representation of visual stimuli in this category, suggesting that the artist is seeing beyond the mere facial features (Solso, 2000). This study represented an intriguing starting point for neural examinations of drawing ability, but as it was limited to one subject it is unlikely that the findings can be generalised to a larger population of expert draughtsmen with different domains of expertise. In response to the one-subject approach of Solso (2000) the current thesis aimed to bring together a sample of artists with a wide range of artistic expertise to investigate more general neural correlates of drawing ability (Chapter 8).

In a more systematic study with a larger sample and greater control over task demands, Miall, Gowen and Tchalenko (2009) segmented the drawing process into three stages: visual encoding, visual memory and execution. They explored these three components in a blocked design fMRI study in which participants either copied a face or drew a previously seen face from memory, without visual guidance of the hand and no visual feedback from their drawing. Compared to a baseline arithmetic task condition, they found that the drawing tasks activated sensory motor cortical regions, the supplementary motor area (SMA), premotor and parietal regions as well as right anterior and posterior cerebellar lobes. This wide-spread activation was summarised as activation of the dorsal stream which is used to control and guide the hand, and regions of the cortex responsible for planning the complex hand movement sequence. An added memory component isolated memory-related drawing activity to the dorsal and ventral prefrontal cortex, the anterior cingulate and the left inferior parietal cortex. The analyses revealed that the act of drawing blind remains consistent with visually guided action, despite lack of direct visual input. In a similar study in which activation during gestural finger drawing and naming an object was compared with activation whilst only naming the object Makuuchi et al (2003) found bilateral activation in parietal regions (BA 7/40), sensorimotor cortices (BA 1-4), premotor regions (BA 6/44), the cerebellum and the thalamus. They constructed a model of neural pathways involved in drawing (Figure 1.8) demonstrating the relative roles of the dorsal and

ventral streams, insinuating contrary to Miall et al (2009), that both visual processing streams are implicated in drawing.
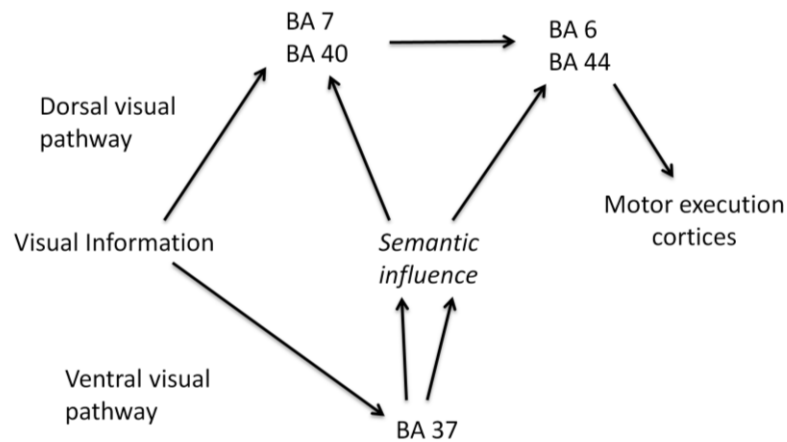
Figure 1.8. Makuuchi et al's (2003) schema of the brain mechanism of drawing.

In a later study Ferber et al (2007) developed a drawing tablet for use in an MRI scanner and used this to measure drawing behaviour in four conditions: drawing from memory, copying a real object, copying a nonsense object and tracing the progress of a drawing on a video playback of a previous drawing trial. The authors found that when comparing drawing from memory and tracing they found increased activation in the anterior cingulate and the medial frontal gyrus. When comparing copying an object and tracing increased activation was found in the anterior cingulate, the medial frontal gyrus, the left occipital gyrus, the cuneus and finally the lingual gyrus. Finally when comparing drawing from memory and copying there was increased activation in the right anterior cingulate, the middle and medial frontal gyri and the right superior parietal lobe. The authors argue that increased activation in the cuneus and lingual gyrus is evidence of cross-modal (visual-tactile) processing in drawing, and that their findings conflict with Makuuchi et al (2003) in failing to find bilateral parietal activations or activations of the sensorimotor cortices in the copying vs. tracing condition.

In a training study, Schlegel et al (2012) found that novices who had undergone an intensive drawing and painting of course of four months showed functional changes 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) through diffusion tensor imaging (DTI). This study suggests that it is possible that structural changes occur in the brain as a result of artistic expertise, in much the same way as been found previously in various populations of experts, from musicians (Gaser & Schlaug, 2003) to taxi drivers (Maguire et al., 2000).

Somewhat unsurprisingly, drawing activates a wide range of neural regions, but the question remains as to what extent the brain changes in response to prolonged activation through training and practice. There are also shortcomings of the current neuroimaging data. Whilst there appear to be short-term changes in brain regions associated with motor ability in response to drawing practice (Schlegel et al., 2012) it is unclear whether other brain regions are implicated in longer-term, more focused skill development. Furthermore, tasks previously used have been conducted in the scanner, and may lack ecological validity (Ferber et al., 2007). Therefore, a more extensive voxel based morphometry study of drawing abilities in expert and novice artists is presented in Chapter 8 of this thesis, which investigates long-term expertise associated changes in grey and white matter density in the brain regions highlighted by the functional and structural studies presented here, and utilises ecologically valid tasks external to the scanner. It was expected that there would be structural changes associated with drawing expertise in parietal, pre-motor, motor and cerebellar regions in line with previous findings (Makuuchi et al., 2003; Miall et al., 2009; Schlegel et al., 2012). The opportunity also arose to explore other facets of perceptual processing which correlated with drawing ability, such that it was possible to investigate whether there were overlapping brain regions employed during local processing tasks and drawing. Assessment of the overlap elucidated the nature of connections between visual perceptual abilities and the drawing process, providing a more meaningful analysis of neuroimaging findings beyond localisation of the process to a particular region of the brain.

1.9   Summary of Literature Review and Aims of the Thesis

The opening arguments of this thesis have shown drawing to be a rejuvenated art form that constitutes a crucial form of communication and creative development in children, abandoned in later life through lack of ability to represent the world 'as it really is'. The question of how artists represent the world as it really is has become the preoccupation of cognitive psychologists who seek to understand the processes involved in observational drawing and why the output of expert and novice artists differs so greatly. It is the intention of this thesis to continue the research programme by presenting a series of studies that deconstruct the drawing process and identify cognitive faculties that determine drawing ability.

Van Sommers' model highlighted four key components that may contribute to successful drawing: visual perceptual processing, visual imagery, memory and motor processes. Experimental focus initially was laid heavily upon the first of this tetrad of components; visual perceptual processes. In relation to visual perceptual processing we now know that a reduction in perceptual constancies, enhanced visual selection and ability to

process local detail are all associated with drawing. Furthermore, these perceptual advantages may confer advantages at the memorial level, by allowing artists to encode stimuli quickly and more efficiently without interference from long term representations, enabling more time for associative and creative thought. It remains unclear whether visual imagery is used in the drawing process as previous investigations have conflated drawing and artistic ability. In reference to the latter stages of Van Sommers' model, evidence suggests that perception cannot be construed in isolation when discussing the drawing process. Vision appears to interact with motor planning to eliminate unnecessary burdens placed on WM. These findings are supported by the results of neuroimaging studies that implicate parietal and motor regions foremost in connection with drawing ability. However, behavioural research into drawing is still in its primary stages, as cognitive scientists attempt to formulate research questions which will provide the most illuminating answers concerning the nature of artistic ability. As a result of the infancy of drawing research in general, a very sparse amount is also known about how the brain accomplishes such a task, contrasting with other complex artistic tasks such as musical production whose neural bases have received much attention in the past decade (Bangert et al., 2006; Gaser & Schlaug, 2003; Koeneke, Lutz, Wustenberg, & Jäncke, 2004; Schlaug, Jäncke, Huang, & Steinmetz, 1995; Schlaug, 2001; Zatorre, 2003). With a broad background to this topic provided by the literature review I will now provide a summary of the content of each of the following empirical chapters that constitute the remainder of this thesis.

1.10   Thesis Framework

Due to the scarcity of research in the field both in behavioural and neuroscientific respects, the work reported in this thesis is exploratory in nature, tracking the drawing process from first glimpse of the subject, to the production of marks on the page, with a foray into the neural structures that underpin expertise in the observational drawing domain and encompassing both qualitative and quantitative approaches to research. The investigation into the psychological processes underpinning drawing ability in the current thesis begins by establishing a conversation with artists themselves, asking them to reflect upon the way in which drawing shapes perception and perception shapes drawing (Chapter 2). This sets the scene for range of lines of enquiry that take place within the empirical chapters that follow.

Firstly, factors that may be related to drawing ability are examined by using survey data from a large cohort of art students (~600) collected over five years which is summarised in Chapter 3. More focused experimental work then follows the survey study. Factors that may affect drawing including personality, laterality, study habits, learning difficulties and imagery are investigated. There is then a brief deviation to consider

methodological issues that are critical for later experimental investigations, particularly concerning the nature of analysis of drawing accuracy (Chapter 4). The relative benefits of shape analyses compared with the use of subjective rating data are discussed within this chapter. Chapters 2, 3 and 4 provide the foundation for more detailed experimental examinations of perceptual and memorial processes that constitute the remainder of the thesis.

The most extensive body of evidence concerning the etiology of drawing ability exists in the perceptual domain, through work with expert artists and savants with ASD. This is vindicated by the emphasis on perception highlighted in the qualitative interview study. Consequently the majority of the empirical exploration in this thesis focuses upon perceptual processing, which encompasses investigations into the perceptual content of memory representations. The first of these experimental studies (Chapter 5) examines the role of low level perception of angles and proportions as the bedrock for higher level representational abilities, inspired by an early study into representational drawing (Cain, 1943). The perception of angles and proportions are explored in both rendering and non-rendering contexts. The second experimental study draws on the literature surrounding special skills in individuals with ASDs by investigating the role of weak central coherence and enhanced perceptual functioning in gifted draughtsmen without ASD (Chapter 6). This investigation provides further evidence for perceptual advantages relating to low level visual processing that is meaning and context-independent. The relationship between enhanced local processing and low level perception of angles and proportions is then investigated in order to merge together these two studies into perceptual processing in drawing. The following empirical chapter (Chapter 7) moves from online perceptual processing to the retention of representations in long and short-term visual memory, ensuing from earlier research implicating VLTM in drawing (McManus et al., 2010). This study examines varying forms of short and long term memory to assess the validity of claims that visual memory is enhanced in visual artists (Glazek & Weisberg, 2010; Glazek, 2012) or precluded by existing premotor plans (Tchalenko & Miall, 2009; Seeley & Kozbelt, 2008). The final empirical chapter explores potential neural bases for the skills acquired in drawing expertise, and reveals a neural focus on motor rather than perceptual areas, highlighting the importance of hand-eye coordination mechanisms and premotor planning in expert drawing (Chapter 8). In reviewing the body of evidence as a whole, a toolbox for successful drawing ability is constructed that integrates perceptual and memorial processes with visuo-motor transformations to characterise the drawing process, alongside background variables that may mediate the acquisition of expertise over longer time scales (Chapter 9). The toolbox is presented below (Figure 1.9) and is discussed thoroughly in section 9.3.
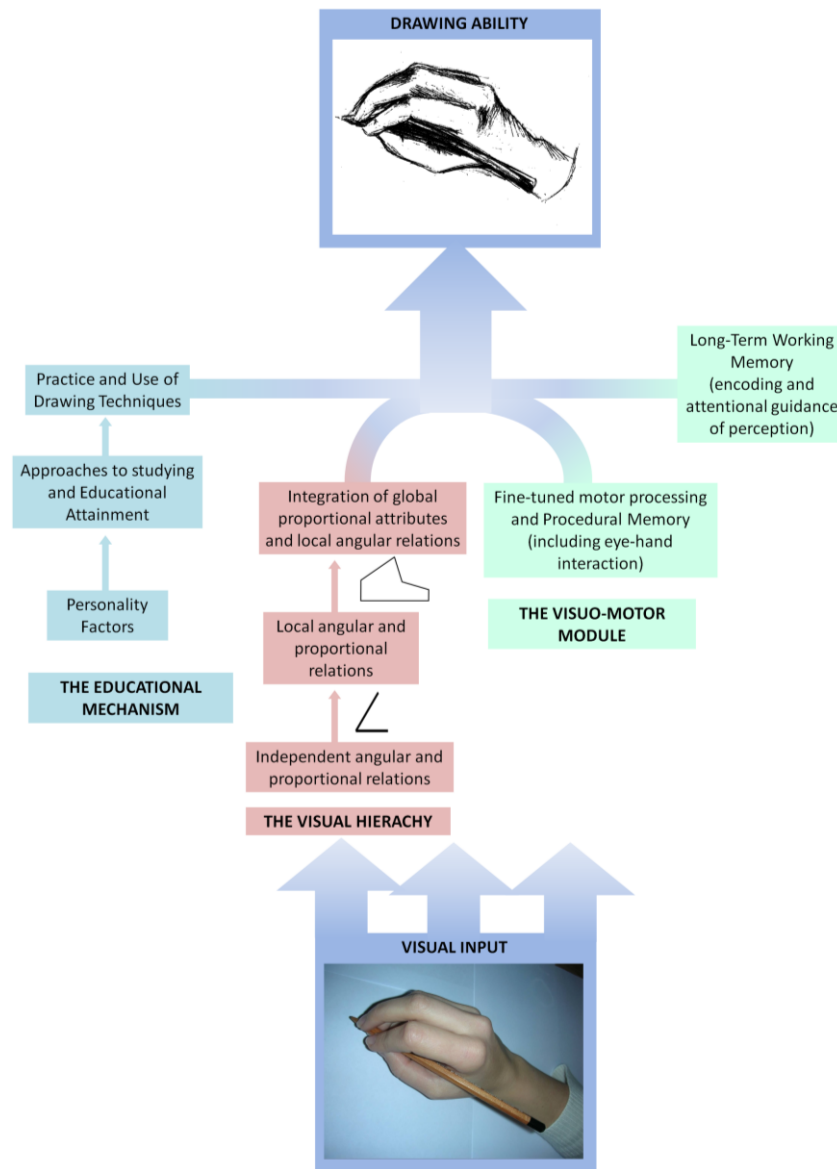
Figure 1.9 A Toolbox for Drawing Ability

From a preliminary argument for the renewed importance of observational drawing and an extensive summary of the relevant literature I will now move on to some preliminary interview data concerning artists' attitudes toward observational drawing, presented both in a larger artistic framework and in a more focused manner with reference to drawing's particular impact on visual perception. This serves to ground both the opening argument of this thesis and motivate particular directions of experimental research concerning visual perception and memory presented in the latter chapters of this thesis (Chapters 4-7).

Chapter 2.   Conversations with Artists: The Importance of Drawing

'It is only by drawing often, drawing everything, drawing incessantly, that one fine day you discover to your surprise that you have rendered something in its true character.'

Camille Pisarro

(Abel, Pissarro, Pissarro, & Rewald, 2002, p.32)

2.1   Introduction

'In nature, light creates the colour. In the picture, colour creates the light'

Hans Hoffman

(p.117, Rose, 1975)

As the quote in this thesis illustrate, artists have long been eloquent in reflecting upon artistic craft. Here Hans Hoffman, an abstract expressionist painter, emphasises the relationship between light, colour and contrast, which has subsequently been explored using experimental techniques (Graham & Field, 2007; Graham, Friedenberg, & Rockmore, 2009). However, reflections such as these are seldom systematic or empirically supported, instead representing anecdotal evidence that illuminates only small and disparate fragments of the artistic process. Despite the idiosyncratic nature of these observations, insights from artists themselves can provide the critical impetus for scientific investigations into artistic production. The catalyst for the current thesis was a dialogue between a group of students at the Royal College of Art (RCA) and the college dyslexia tutor Qona Rankin. The discussion revealed that students often struggled with acquiring the drawing skills necessary for success as practising artists,

> I'll try and draw a circle and it's never a circle, I can never do what I want — what I can see in my head I can't really get it on the paper — um — so one of the things that happens is that if I've got a client then I [pause] I'm drawing them a cross-section of a ring so they get the idea of what the shape might be like it's, it's — I just confuse people.

(McManus et al., 2010, p.19)

The statement above encapsulates the difficulties many artists face when they are required to draw in their working lives, and outlines the dichotomy between internal creative processes and skill oriented outputs. It also reveals the potential for artists to reflect on the challenges of drawing which could in turn explicate elements of the drawing process. Whilst in isolation the above quotation tells us little about the nature of drawing. However, as the interviewee demonstrates an understanding of the inherent discontinuity between internal imagery and motor output in observational drawing, it serves as a starting point for explorations into visuo-motor transformations in drawing. The observations of artists can be used to determine critical features of the drawing process which can then be systematically

tested using quantitative paradigms. The use of first-hand artistic observation is crucial in order to construct clear, generalisable and ecologically valid models of artistic processes.

Quantitative work in the field of observational drawing remains in its infancy. Qualitative research that probes the cognitive processes of drawing in adult artists can inform and guide the growing body of experimental research, by indicating the general directions that experimental work could take. A more concrete example of the importance of the personal impressions of artists in the scientific study of drawing regards the use of negative space (see Figure 2.1; Edwards, 1989; Petherbridge, 2010; Ruskin, 1856),

> She holds up the pen and uses it to measure off proportions on Wade's figure.
> Then she holds the pen over the drawing to mark off the units of measurement.
> She has said to me, "The ability to measure and the ability to see negative space
> are the greatest assets of drawing"

(Steinhart, 2004, p.5)
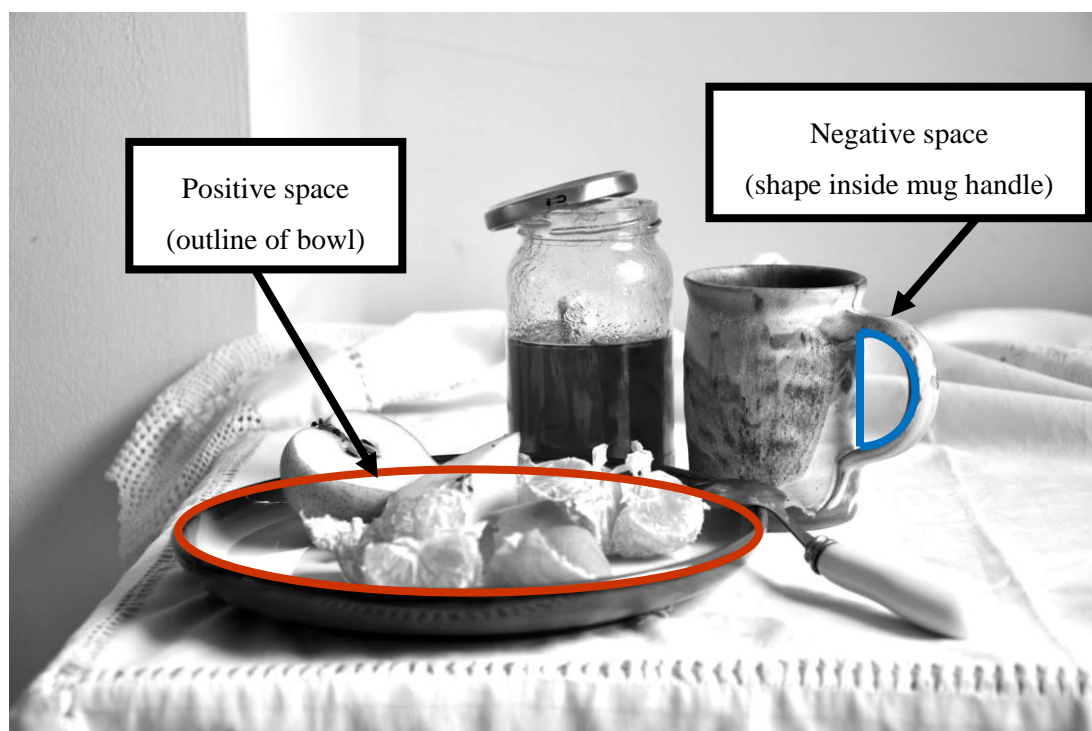
Figure 2.1. Example of positive and negatives spaces in a typical still life scene

Focus on negative space is cited by many artists in the qualitative study reported in this chapter as an effective drawing tool. It manipulates visual perception by limiting the kind of visual information that is processed. A logical next step has been taken by Linda Carson and

colleagues who investigated the extent to which positive and negative spaces are rendered accurately in realistic drawing. They showed that negative spaces are less subject to visual bias and tend to be drawn more accurately than positive spaces (Carson & Allard, 2013). This example demonstrates how the interplay between historical, qualitative and experimental perspectives of art functions to provide a richer explanation of a proposed phenomenon.

Instructional drawing tomes have previously informed quantitative studies with unexpected effects (for example, Betty Edwards' (1989) inverted drawing technique has been tested by Cohen and Earls (2010) who found no improvement in drawing accuracy when a stimulus image was drawn upside-down). However, qualitative research has seldom been employed to explore the cognitive processes in drawing, with one exception. Fayena-Tawil, Kozbelt and Sitaras (2011) conducted a protocol analysis of artists' thought processes whilst constructing creative observational drawings and found that artists rely less upon local plans, adopting a more global approach to the progression of their drawings than novices. Their findings support experimental eye tracking studies that show that expert artists take a much more systematic perceptual approach to drawing than novices (Tchalenko, 2009). These examples further demonstrate how qualitative and quantitative approaches can be integrated to support anecdotal evidence concerning the drawing process. When quantitative approaches validate qualitative conclusions one is closer to producing an ecologically valid account of artistic processes. However, excluding Fayena-Tawil *et al's* (2011) study, qualitative research into drawing has been largely confined to its role within specialist domains such as engineering (Ullman, Wood, & Craig, 1990), design (Garner, 1990; Schenk, 1991) and to children's learning (Anning, 2002; Coutts & Dougall, 2005; Hawkins, 2002; Rose, Jolley, & Burkitt, 2006) and neglects the drawing process in its own right. Furthermore, there is some scepticism concerning the ability of artists to reflect on their own methods with regards to observational drawing,

> While the [life] models can be articulate, perceptive and precise about what it is
> that they are doing, it is hard to find artists who can explain what they are doing
> when they draw (Steinhart, 2004, p.9)

The interview study reported in this chapter tested the assumption made by Steinhart by looking to obtain meaningful observations about the drawing process by artists. A semi-structured interview technique was used. The content of the interview questions was guided by the literature cited within the introductory chapter of the current thesis. This qualitative evidence can provide the framework for the survey and experimental work concerning

visual perception and memory which are to follow in subsequent chapters of this thesis. This will provide a richer and more valid account of the drawing process that originates from real life experiences of artists. This can then be formalised using quantitative, empirical methods.

As discussed in the literature review in Chapter 1, it has been suggested that accurate perception is a fundamental element of drawing expertise (Cohen & Bennett, 1997; Kozbelt, 2001; Mitchell et al., 2005; Ostrofsky et al., 2012; Sheppard et al., 2008). I sought to assess whether this claim was valid with respect to the phenomenological experiences of the artists themselves. The claim that accurate perception is related to drawing ability was addressed in two ways. Firstly, interviewees were asked about the role of drawing within their practice, to determine whether perceptual enhancement or manipulation was related to the aims of drawing as a means or an end. Secondly, they were asked about devices they use to create drawings and challenges they face when drawing, to ascertain how artists harness perception in drawing, and the kinds of strategies they employ to supplement their perceptual capacities. It was found that drawing played a critical role in the artistic process, predominantly as a means to gaining perceptual expertise and attaining communicative goals. Artists used a wide range of techniques for drawing, but a common theme was that artists restricted visual input and productive output in order to achieve their depictive goals.

2.2   Qualitative Data Collection

An opportunistic sample of 10 art students participated in the interview study, consisting of past or present students at the Prince's Drawing School (PDS), a post-graduate art school in East London, and a drawing tutor at Central St Martin's College of Art and Design. Post-graduate students were chosen as they were assumed to have a high level of specialisation whilst still engaging in drawing tuition. In addition, those students at PDS themselves were involved in the teaching of drawing, and so offered a rare insight into experience of both learning and teaching of drawing simultaneously. The current study was approved by the ethics committee of the Clinical, Educational and Health Psychology department at University College London.

Semi-structured interviews were conducted (a common approach in thematic analysis) in which all participants were asked the following questions:

1. *How important do you think drawing is for artists?*

2. *How important is drawing for your own practice?*

3. *Have you had any experiences of teaching drawing – how has this informed your own work?*

4. *Are there any devices/techniques that you use when drawing?*

5. *How do you start your drawings?*

6. *Do you use different drawing techniques for different media?*

7. *What do you find the most difficult element of drawing?*

Thematic analysis was chosen for the current study, as the methodology allows for open undirected interviews and works as an iterative process, which is ideal for exploratory research in which inductive rather than deductive reasoning prevails. Thematic analysis is a qualitative methodology that possesses the same characteristics as other methodologies in the field such as content and discourse analysis. It can support a number of disparate qualitative approaches (Boyatzis, 1998) but has more recently been considered as an independent approach to qualitative research (Braun & Clarke, 2006). Thematic analysis involves analysing interview literature for common 'themes' pertaining to a phenomenon of interest. A cohort of interviews is analysed with a view to extracting salient topics that are repeatedly mentioned or alluded to by the cohort. As a result of the initial analysis, a coding scheme is constructed which summarises these themes so that the interviews can be coded independently by researchers and checked for reliability. Themes are often broken down into subthemes and codes assigned to each subtheme (the codes for each theme and subtheme in the current study can be found in Table 2.1). The interviews are then fully coded using the developed thematic system through an iterative process. The most salient topics can be interpreted in terms of the research phenomenon to which they relate and in relation to other themes that have emerged from the data.

The cohort of interviews was transcribed from audiotapes and a thematic analysis was conducted on the transcripts according to established guidelines (Braun & Clarke, 2006). Three meta-themes were extracted from the data which were then divided into six subthemes (See Table 2.1). In the analysis the most pertinent examples of the derived themes are presented with accompanying quotations which best represent each theme as it is described. Further examples of supporting quotations can be found in Appendix A.

Table 2.1. Summary of meta-themes and sub-themes of interview data, with frequencies of respondents who referred to each theme

Meta-theme	Sub-themes		Number of participants who mentioned theme
The role of observational drawing within artistic practice	*Perception*		3
	Communication	*i. External*	5
		ii. Internal	2
The drawing agenda in education	*Desire for more drawing in art education*		5
	Lack of drawing training at school or art college		6
Approaches to drawing	*Approaches to perception*		5
	Approaches to production		5

2.3   Thematic Exploration of Qualitative Data

The thematic exploration of the data can be separated into two broad strands. Firstly themes that relate to the argument presented at the beginning of this thesis were explored; the importance of drawing as a practice within art education and for the current artistic practices of the artists interviewed. Subsequently I addressed themes that pertain to later studies in this thesis; the way in which drawing interacts with perception.

2.3.1   The role of drawing within artistic practice.

Drawing to enhance perception.

I think it's a basis for seeing, you see more of the world if you draw.

[Female, 35, Painter]

The most important aspect of drawing for artists in the current study was the use of drawing to develop more sophisticated ways of perceiving the external environment. They suggest

that the act of observational drawing elicits a form of heightened perception, sometimes likened to a flow state (Csikszentmihalyi & Csikszentmihalyi, 1988) that forces the draughtsman to look in a more focused and persistent manner at specific elements of the visual environment.

> After a while your eyes click, this is the experience I have anyway, my eyes click into something .... I don't know how to explain it, yeah, you start to kind of have a hyper awareness

> [Female, 27, Draughtsman and Animator]

Heightening of perception induced through observational drawing is seen as an integral part of the creative process for artists. This applies to any pictorial artist, be they intent on representing the world in a faithful or an abstract manner. Heightened perceptual analysis in drawing is not viewed as an innate artistic quality by the current sample. Rather it is perceived as being the result of consistent and effortful practice in order to be constantly and meaningfully engaged with the visual world.

Drawing to enhance communication. A common theme to emerge from the reflections of artists on the role of drawing in theirs and others' work was the use of drawing as a language of expression. This notion of drawing as language can be viewed in the conventional way; as a means of communicating the artistic message to others (external communication), but also can be extended to the artist's internal language and thought processes (internal communication).

  i. *External Communication*

> You're trying to create a process of communication and if you can't translate it onto paper yourself, how are you going to translate it to anybody else? You have to be able to get your ideas down before you get them out there

> [Female, 27, Illustrator]

Drawing as an external communicative enterprise was considered by respondents to be crucial to artistic outcomes. This directly relates to the quote given by the student at the RCA at the beginning of this chapter, which demonstrated a fundamental problem for artists; the challenge of representing their ideas quickly and efficiently to professional clients. Observational drawing is not perceived solely as an end to the work of art students, but as a means to a variety of non-graphical goals. In their view, drawing enables artists to engage

and connect with the chosen subject matter, by facilitating effective communication, be it external or internal. Indeed both external and internal communication appear to be very tightly woven in the context of observational drawing, where there is a bidirectional interaction between the two.

ii. Internal Communication

When you're learning to draw you're learning that you're not just copying what you see, you're figuring out a language of marks to represent it, and that language has to be coherent. So in that sense this is a problem solving exercise.

[Male, 27, Painter]

Drawing is construed by the interviewees as an internal language, a method of thinking about the visual world. It is used by the current sample as a form of visual note-taking; forcing the artist to think about ways in which to represent what is seen. Many artists use observational drawing as a way to think through and experiment with novel ideas. In this way it does not represent a process of passively collecting perceptual information faithfully translated to paper, but an active selection process designed to deconstruct the visual environment in very specific ways with particular pictorial goals in mind.

2.3.2   The drawing agenda in education

Desire for more drawing in art education

I definitely think whether it is more traditional drawing or not it's important to learn to draw from observation

[Male, 30, painter]

Interviewees expressed that there was a lack of drawing education both at school and university level. They regard this as part of the reason why some children abandon the practice prematurely, and why young artists fail to develop their technical skills at university. One interviewee expressed the view that compulsory life drawing courses for art undergraduate students would be desirable. Others emphasised that the purpose of education in drawing was to enhance perception, not merely artistic skill.

The drawing education that they need I think is a basis of learning how to wake up their eyes

[Female, 28, Mixed Media]

It appears then that some artists value observational drawing and believe it should be an intrinsic element of the art and design curriculum. Many reflect on the need for more formal drawing training beyond school and into university education, supporting the comments from the students at the RCA, that provided the catalyst for the current research.

Lack of drawing training at secondary school or Art College

I just don't think people are given that grounding, I don't think they are in school and then in university, from what I can see the trend of universities now are even more against a taught solid ground, so it felt like jumping off a cliff into nothing
[Female, 28, Mixed Medias}

Interviewees expressed frustration at the poor and idiosyncratic methods in observational drawing taught during undergraduate and postgraduate art courses at art colleges. They value the experiences at the current drawing school in which observational drawing is not necessarily taught in a traditional and dry form, but encourages the artists to develop their perceptual abilities and to extract interest from the visual environment. The majority of interviewees felt that grounding in observational drawing is beneficial to artistic ability in general. The question of whether observational drawing teaching is important to art students is followed up in the subsequent survey study in Chapter 3.

2.3.3   Approaches to drawing.

On addressing particular approaches to drawing it became clear that many techniques were unique to individuals, reflecting the wide variation in experience of drawing tuition the students had prior to the commencement of their studies at PDS. Indeed, this is mirrored in the wider artistic community, in which there is very little agreement as to how drawing should be taught (for an elaboration on this point, see the exploration of drawing devices and attitudes in section 3.4.2 of the survey chapter). However, there were recurring methods that permeated artistic practice. These are presently discussed and can be separated into those that restrict the way visual stimuli are perceived, and those that restrict the way visual stimuli can be represented on the drawing surface.

Approaches to perception.

> I can look at the world and break it into forms. That's what I do when I need to convey something from reality to drawing.

> [Male, 30, Painter]

> I mean one thing about observational drawing is that there's no hierarchy. It's sort of about giving attention to the whole of the surface, so it might be that you begin with a negative space or something else.

> [Female, 27, Mixed Media]

Artists repeatedly cited methods to selectively restrict the visual input that they received in order to simplify the image for rendering. The ability to use these methods automatically and appropriately to the visual subject was viewed as a critical component of artistic expertise by the interviewees. The limitation of visual input could take many different forms: focusing upon tonal contrast, the textures present within elements of the visual scene and the direction and relationship of lines. The purpose of such limitation is to reduce reality down to form, perhaps as a means of creating more abstract and malleable artistic impressions. Two particular techniques of limiting visual input were mentioned repeatedly: squinting to focus upon tonal relationships, and focusing on negative space, which will now be discussed in more detail.

A number of artists spoke of the importance of blurring their vision to derive global information about the image. This was viewed as particularly useful when constructing tonally based drawings. This technique is a method of simplifying the visual scene by reducing extraneous detail, so that the artist can focus upon areas of light and shade. As a result of this loss of detail, meaning can also be abstracted from the identity of the elements of the visual scene. The current sample suggested that perceptions of semantic importance may bias the tonal representation of a visual scene resulting in an inaccurate or flat tonal rendering. This has a bearing on local-global visual processing in drawing, which is the subject of investigation of Chapter 6 of the present thesis.

The use of negative space to capture spatial relationships in a scene has been a prominent feature of literature concerning drawing (Edwards, 1989). It is also a technique that the current sample of artists consistently referred to using in observational drawing. The use of negative space, in much the same way as the squinting rule, enables the artists to break free of the implicit semantic hierarchy present in visual scenes and look at form over

meaning. It functions to focus the artist's eyes on features of the visual scene that have no semantic content thereby reducing the visual input to pattern, tone and line.

Approaches to Production.

> By limiting the kind of mark I can make, it means I give the same focus to everything, because I can't change my language to take in things that wouldn't appear within that way of looking.

> [Male, 27, Painter]

> Fast drawings are always really helpful, because your brain just works at a different speed so you just stop thinking, if you have a long pose you tend to get bogged down and you start to overthink.

> [Female, 35, Painter]

Many of the artists talked of self imposed restrictions not only upon visual input but also upon expressive output. The use of particular materials for drawing was often cited as a way of restricting output, such as using only the base of a glass jar to draw around, or drawing only using a ruler. Drawing is a bidirectional response to the environment. The response is dependent on the media and the choice of media depends on what the artist is looking to encapsulate in the drawing. Simplification is something that is striven for in the production of competent drawings. A proportion of the artists interviewed perceived that one of the most difficult elements of drawing was the ability to finish a drawing without overworking it (n=3). This can be overcome if the artist controls the form of output, as fast drawings were seen to produce more successful drawing than longer, more studied poses. The resistance to 'overworking' an image is the productive equivalent of restricting visual input. By reducing the work to a few simple but highly evocative lines, the artists feel that they may be able to capture the essence of the visual subject.

2.4   Discussion

2.4.1   Observational drawing is a crucial means of developing perception

The results of the thematic analysis suggest that art students view observational drawing as a crucial artistic activity that facilitates internal and external communication. They expressed frustration at a lack of structured observational drawing tuition both at secondary school and university level, and a desire for a more pronounced emphasis on drawing to enhance

perception in the art and design curriculum. This provides support for the argument put forward in the introductory chapter in which it was contended that observational drawing is witnessing resurgence both in art education and in society at large. It is coming under increased focus in the current development of the school curriculum by the coalition government. However, it must be noted at this stage that the sample consisted of students who actively pursued a post graduate course that focused upon drawing. It is therefore crucial that the finding that drawing is of high importance is generalised to the art student population more widely; to those with more broad artistic interests. Therefore, this question remains a fundamental component of the wider survey study presented in the next chapter, in which over 600 art students of varying creative backgrounds and interests reported on their attitudes toward observational drawing.

Despite the variation in techniques used by the participants within their own drawing process, it was possible to extract common approaches, which were tied together by their relationship to restricting visual input or productive output. The former of these approaches, restriction of visual input, is of central importance to this thesis as a whole. The key question for quantitative approaches from here onward is how artists restrict their visual input and what impact this has on their perception.

Figure 2.2. Attention to detail: A drawing by interviewee Alice Shirley ('Giant Clam Shell', 2011, chalk on paper)

2.4.2 Drawing and Perception.

The use of drawing as a way of enhancing visual perception is particularly interesting in the light of research that suggests that artists may have developed perceptual expertise as a result of drawing (Kozbelt, 2001) and consequently the misperception of the intended visual subject is responsible for drawing errors (Cohen & Bennett, 1997). It highlights the pivotal question of whether drawing influences perception such that experience is predictive of perceptual enhancements or whether those that possess perceptual enhancements from early life are more likely to engage and be precocious at observational drawing. Quantitative evidence is sparse concerning the causative link between observational drawing ability and perceptual expertise and, although not explicitly tested due to the correlational design of the studies herein, will be the subject of discussion in the remaining chapters of this thesis.

Many respondents cited the need to dispel the semantic hierarchy implicit in visual scenes. This relates to a strong tradition within drawing research of interest concerning the impact of semantic knowledge on drawing accuracy. Individuals have a tendency to depict objects in orientations which reveal the structural features necessary for their recognition (Edwards, 1989; Cohen & Jones, 2008; Mitchell et al., 2005; Reith & Liu, 1995; Sheppard et al., 2008). By focusing on unrecognizable objects such as an out of focus image or an undefined negative space, one can reduce or even eliminate the influence of canonical biases (that is the influence of stereotyped schematic representations of objects that are non viewpoint-specific). It appear that as artists develop drawing expertise they become aware of being more adept at ignoring semantic influences on their depictions, eventually being capable of focusing quickly and easily on abstract forms and non-semantic features such as tone, pattern and line. Similarly, focus on individual elements appears to characterize drawings by individuals with ASD. The artists in the current study appear to be using techniques that enhance their local visual processing abilities (Figure 2.2). By contrast, blurring the image appears to be reducing the influence of local properties of the image, and is used for gaining a sense of global proportions of the subject, or overall tonal variation without semantic influence over brightness (Blommaert & Martens, 1990).

The participants in the qualitative sample were selected on the basis that drawing constitutes a large proportion of their artwork and therefore it is not surprising that they see an enhancement of perception as a result of drawing in particular. It has been emphasised previously in this chapter that it is necessary to validate the small sample of impressions here with empirical studies that include larger samples of participants and enable statistical hypothesis testing. In the experimental chapters to follow, artistic ability is assessed with respect to perceptual enhancements in drawing, to determine whether drawing or artistic

ability in general induces a heightened perception. From the 'flow state' experienced whilst drawing referred to by some participants, it appears that perceptual heightening remains specific to the period of time when the artist is drawing. This would suggest that any perceptual effects witnessed by artists would be temporal and domain-specific; but this remains a conjecture that needs to be tested experimentally. Domain-specific and domain-general perceptual and memorial processing are the subjects of investigation in Chapter 5 and 7 in the present thesis.

Many drawing techniques used by individuals were not applicable to the wider sample of the interview study. The prevalence of idiosyncratic methods such as triangulation and framing will be assessed in the following survey chapter (Chapter 3). The interview study has provided a wide range of drawing devices that can be explored with a larger and more representative sample, such as focus on negative space, pattern and texture, using squinting to emphasize tonal contrast, and framing the visual world in order to break down shapes and contours. This demonstrates that while there may be commonalities of approach amongst art students, due to fluctuations in teaching and artistic experience, no two artists draw in exactly the same way. Approaches to drawing are highly dependent upon the intended outcome of the drawing and thus many approaches may be medium-specific, making it crucial for those investigating drawing ability to retain sight of nuances in approach that cause the final outcomes of artists to be so different. Further analysis of the results briefly presented here may be able to illuminate which devices and techniques are used by artists using different media. The idiosyncratic nature of some approaches (such as triangulation or understanding anatomy of the human body which were only mentioned by one interviewee) has potential impact on drawing training in higher education, as it would not be practical to teach strategies that only produce noticeable improvements in a minority of students. The aim of these studies will be to identify approaches that are workable for the majority of artists, and produce tangible effects. From there, artists can build upon a perceptual foundation for their own specific creative goals. The application of the current research to drawing training is the focus of section 9.4.3 (The Impact of Drawing Research on Educational Strategies) in the final chapter of this thesis.

One of the primary aims of the interview study was to identify elements of perception in drawing that can stimulate quantitative research. In this study it was found that simplifying visual input enabled the interviewees to produce better drawings. If individuals produce successful drawings through simplifying visual input, it can be inferred that those who have the ability to simplify scenes and replicate these simple features should be more capable of producing observational depictions. The ability of exceptional draughtsmen to simplify a visual scene was tested using the embedded figures task (Witkin et al., 1971) in

Kozbelt's study of the perceptual abilities of artists and controls (Kozbelt, 2001). It was found that performance on a range of perceptual tasks correlated with drawing tasks. However, the authors did not state whether the ability to extract figure from ground specifically predicted drawing ability. In the experimental studies presented later in this thesis (Chapters 5, 6 & 7), a more in-depth exploration of the ability to extract local and global details, and the ability to simplify complex visual stimuli, will be explored in relation to drawing ability.

The following survey chapter addresses many aspects of the psychological underpinnings of drawing that have been highlighted in the first two chapters. Self-report imagery has been a focus of research in the past but a previous study lacked control (Perez-Fabello & Campos, 2007) and therefore survey studies were used as an opportunity to assess direct correlations between imaging abilities and drawing by using self-report measures. Extra-artistic abilities that have been linked with drawing in the past were also a focus, and therefore participants' learning difficulties, attitudes to mathematics and more general study habits were explored. Finally it was of interest to establish whether personality factors may predispose individuals to be good at drawing. Therefore personality, masculinity and femininity, autistic spectrum traits and schizotypy scores were explored (which has been linked to some aspects of drawing ability; see Glazek, 2012).

Chapter 3.   Covariates of Drawing Ability: Personality and Demographic Factors

'The academic teacher bent on accuracy of representation found, as he still will find, that his pupils' difficulties were due not only to an inability to copy nature but also to an inability to see it.'

Ernst Gombrich

(Gombrich, 1960, p.11-12)

3.1 Introduction

As outlined in the discussion of the previous chapter, this survey chapter investigates a range of psychological functions and characteristics that, through association with skill acquisition and expertise, are likely to be associated with drawing ability. These include: approaches to learning, handedness and lateralization, sex differences and stable personality traits. By taking into account a broad range of factors that underpin the acquisition and maintenance of skill in observational drawing a toolbox for drawing skill acquisition is presented in the final chapter of this thesis. This takes into account demographic and personality driven underpinnings of the development of talent in drawing. I will now outline each group of variables to be analysed with respect to drawing ability in the current survey study, with directional hypotheses where possible.

3.1.1 Artistic Ability and Interests.

A pertinent issue that arose from the interview study in Chapter 2 was that observational drawing supported a broad range of artistic activities. In the current survey study participants were asked to rate their ability on a range of artistic tasks, as well as their artistic interests in general, to explore how this related to engagement and proficiency for observational drawing. The perceived importance of observational drawing for participants and their knowledge of a range of drawing devices using the techniques alluded to in the interview study were also assessed, to further expand on the theme of observational drawing as a crucial artistic medium. Participants were asked about the importance of drawing for them to validate the more general rationale for the thesis; to provide insights into drawing that are useful for practicing artists. It was expected that drawing ability would interact with other artistic abilities as well as the kinds of artistic activities participants wanted to pursue in their careers, but no directional hypotheses could be made at this stage. However, as they were highlighted as the most recurrent themes in the interview study, it was expected that devices such as the use of negative space and blurring to eliminate detail would be popular techniques that were known of and used frequently by the students in the current studies.

3.1.2 Visual Imagery.

As outlined in the introductory chapter, visual imagery has been implicated in an existing model of the drawing process (van Sommers, 1989). One of the most efficient ways to measure imaging abilities is to employ self-report questionnaires, which have been shown to have validity in relation to true visual imaging capacity assessed by objective measures and perceptual tasks (Blajenkova et al., 2006; Marks, 1983; Wallace, 1990). In a previous study

visual artists characterized their images as vivid and clear, reported higher object imagery scores than non-artists, and scored higher on the Vividness of Visual Imagery Questionnaire (VVIQ) if they were proficient at drawing at art school (Perez-Fabello & Campos, 2007; Rosenberg, 1987). Therefore It was predicted that drawing ability in the current study and scores on visual imagery questionnaires would be correlated. The current study employed two different questionnaires that measure self-report visual imagery to assess the validity of the claim that visual imagery correlates with self-perceived or objective measures of drawing ability. The exploration of imagery is a precursor to the more extensive investigation of the role of visual memory in drawing described in Chapter 7. If visual imagery is found to be linked to drawing, this finding will have ramifications for the discussion of both visual perception and visual memory in relation to drawing accuracy.

3.1.3   Personality and Demographics.

A range of other demographic and personality factors that potentially play a role in drawing ability were explored in the current study. Learning difficulties and handedness were addressed, as these have provoked interest in drawing research in the past, and if related to drawing ability, should be included as covariates in future experimental studies. A range of personality factors that are pertinent to the study of drawing ability which should be taken into consideration in future explorations were also tested. The Big Five personality inventory was used to explore conscientiousness, openness to experience, neuroticism, agreeableness and extroversion (Furnham, McManus, & Scott, 2003; McManus & Furnham, 2006). I will now discuss the theoretical justifications for investigating personality and demographic traits by outlining evidence to suggest direct or indirect links with observational drawing, beginning with the role of learning difficulties and lateralization, and moving on to personality factors including sex differences and the potential role of schizotypy.

3.1.3.1 Lateralization and Learning Difficulties

Handedness. Handedness may play a role in drawing ability through its connection with proposed correlations between drawing proficiency and hemispheric lateralization, in that drawing processes arguably harness the right side of the brain (Edwards, 1989), so may be associated with left-handedness. In a study of drawings made by an ambidextrous individual, it was shown that drawings made with the left hand were judged as more aesthetically pleasing than those drawn with the right hand but that they were not characterised by properties indicative of right or left 'modes' associated with either hemisphere (Magnus & Laeng, 2006). However, it remains unclear whether left handedness

is a more frequent occurrence in artists (but see Lanthony, 1995; Lanthony, 2005; Mebert & Michel, 1980), and thus there remains sparse evidence of a connection between left-handedness and drawing ability. In this survey study handedness was measured for correlations with measures of drawing or artistic ability. Constructional problems such as dyspraxia were also investigated in relation to drawing ability.

Dyslexia. Winner, von Karolyi and Malinsky (2000) found that dyslexics underperformed in a number of visuo-spatial tasks, which suggests that dyslexia may confer problems with observational drawing. In terms of visual deficits, dyslexics show impaired detection of temporally modulate gratings (Ben-Yehuda, Sackett, Malchi-Ginzberg, & Ahissar, 2001) and reduced performance in visual search (Iles, Walsh, & Richardson, 2000). A deficiency in magnocellular cells particularly in the visual pathway in dyslexia could result in longer lasting visual persistence and less sensitivity to low contrast (Stein, 2001). Frith and Law (1995) suggest that dyslexics might also have a particular problem with visuo-motor integration, a function that is particularly necessary for observational drawing. Such research therefore suggests that dyslexics may suffer impairments in drawing. The link between dyslexia and drawing impairment is explored in the following study by employing self-report diagnosis of dyslexia, alongside a short spelling test which has previously been shown to be predictive of dyslexia (McManus et al., 2010).

Mathematical Ability. Researchers in educational psychology have proposed that there is a relationship between learning drawing and learning mathematical concepts, particularly in the realm of geometry. It has also been reported that dyslexic children who are poor at maths tend to be less good at remembering the Rey-Osterrieth figure (Figure 1.5, Helland & Asbjørnsen, 2003). In a previous study our research group also noted that students with lower GCSE maths grades and those with lower drawing accuracy tended to be less good at drawing the Rey-Osterrieth figure (McManus et al., 2010). Therefore it is possible that there is a link between drawing and maths, potentially mediated by visual memory or non-verbal intelligence (Kyttala & Lehton, 2008; Raghubar, Barnes, & Hecht, 2010). In the present survey study attitudes and aptitude at maths were evaluated in relation to drawing ability, as well as whether a diagnosis of dyscalculia related to drawing problems.

3.1.3.2 Personality Factors

The Big Five. The Big Five Personality Scale (Furnham et al., 2003; Furnham & McManus, 2004; McManus & Furnham, 2006) measures five aspects of personality: neuroticism, extraversion, openness to experience, agreeableness and conscientiousness. Conscientiousness is a personality trait that reflects dependability, thoroughness,

organization and perseverance (Yeo & Neal, 2004). Conscientiousness may relate to the ability to engage in deliberate practice. Deliberate practice refers to practice that is conducted with the instrumental goal of improving performance and which (a) is performed in a daily, work-like manner; (b) requires effort and attention; (c) does not lead to immediate social or financial rewards; and (d) is frequently not enjoyable to perform (Ericsson, Krampe, & Tesch-Romer, 1993; Ericsson & Charness, 1994; Ericsson, 1996). In their exploration of expertise in chess Chase and Simon (1973) suggested that ten years of deliberate practice was required to reach the level of chess masters. The ten year rule has also been found to apply to other domains extending to music (Ericsson et al., 1993; Hayes, 1981; Sosniak, 1985), mathematics (Gustin, 1985), swimming (Kalinowski, 1985), distance running (Wallingford, 1975), and tennis (Monsaas, 1985). The volitional traits associated with the construct of conscientiousness may induce individuals to try hard and persevere, characteristics which could be essential for the pursuit of deliberate practice (Yeo & Neal, 2004). Therefore, of particular interest in the Big Five in the current study is the subscale of conscientiousness. In a previous study there were found to be small effects of conscientiousness on self-perceived observational drawing ability (McManus et al., 2010), and consequently it was hypothesised that in the current study there would be a significant relationship between levels of conscientiousness and self-perceived and actual drawing ability which is mediated by the amount of drawing practice participants engage in.

Study Habits and Practice. The ability to engage in deliberate practice may also relate to more general approaches to learning taken by participants. A simple prediction in the current studies is that amount of time spent drawing would relate to self-perceived and actual measures of drawing ability. Furthermore, the desire to practice may be mediated by approaches to learning. Chris McManus has investigated the relationship between learning styles and performance in medical students for the fifteen years and found that approaches to learning relates to success in this domain (Fox, McManus, & Winder, 2001; McManus, Richards, Winder, & Sproston, 1998; McManus, Smithers, Partridge, Keeling, & Fleming, 2003; McManus, Keeling, & Paice, 2004). Fox and colleagues (Fox et al., 2001) developed a shortened form of the widely used Study Process Questionnaire (SPQ- Biggs, 1987) which has a three dimensional structure: surface, deep and achieving (also referred to as strategic). Surface approaches reflect fear of failure and rote learning of facts without interest in the context of the learning opportunity. Deep learning reflects interest in the subject matter and a desire to relate ideas to each other and to evidence. The achieving style reflects the desire to achieve high grades with an emphasis on competition and success, with the level of understanding varying according to its relationship to the goal of achieving high grades (Biggs, 1987; Fox et al., 2001). As they have proven predictive over long time scales in

medical students (McManus et al., 1998; McManus et al., 2004), it can be argued that the investigation of learning styles could prove useful to studying performance within disciplines outside of medicine. It could be expected that those that show deep motivation for study rather than shallow or strategic motivation would be more likely to engage in meaningful and productive practice and thus develop a higher level of observational drawing expertise.

Sex Differences and Masculinity-Femininity. The role of gender differences in spatial ability is still of much debate and greatly task dependent (for a meta-analysis of spatial ability and sex differences see Voyer, Voyer, & Bryden, 1995). If the kinds of spatial abilities inherent in drawing are also those that are found to be mastered more proficiently by men, it is possible that a difference in drawing performance due to gender will be seen. However the overlap between gender and gender-identified traits may also be involved. It can be conjectured that more masculine personality types may be more proficient at drawing through an interaction with spatial skill or a tendency toward instrumentality (the tendency to be self-assertive, competitive and objective). In a previous study it was found that both self-perceived and actual masculinity predicted higher drawing ability (Sappington, Martin, Smith, & Cowan, 1996). The authors argue this both supports the theory that foetal androgenisation through testosterone exposure results in amplification of spatial reasoning skills (Geschwind & Galaburda, 1987), and theories that predict that *self-perceived* gender roles have an impact upon spatial reasoning (Berfield, Ray, & Newcomb, 1986; Krasnoff, Walker, & Howard, 1989). However, another study by Hassler (1991) found that artists and non-artists did not differ in their levels of salivary testosterone and that instead androgyny was associated with talent in music. The role of real or perceived masculine-feminine traits in drawing and artistic talent remains of some debate. The current study presented participants with a masculinity-femininity questionnaire to test for a potential relationship between gender role identification and drawing ability, as well as testing for sex differences in drawing ability.

Schizotypy. Glazek (2012) proposed that schizotypic personality traits may correlate with accuracy in sketching. Glazek argues that this relationship is explained by the role of the prefontal cortex (PFC) in drawing, as demonstrated in TMS studies by Snyder and colleagues, who altered drawing performance by applying stimulation to the PFC (Snyder, 2009). Attenuated PFC function is a characteristic of schizotypal personality disorder, which is in turn an attenuated form of schizophrenia. Therefore, it would be expected that those who show high trait levels of schizoptypy would be better at drawing, due to its relationship with reduced PFC functioning. The Schizotypal Personality Questionnaire (SPQ; Raine & Benishay, 1995) was used to address this question. It can be broken down into three factors:

cognitive-perceptual aberrations, interpersonal dysfunction and disorganization. Glazek (2012) found that expert artists scored higher across all factors in the SPQ than novices. There were significant differences between experts and novices in the disorganization factor, and a marginally significant difference on the cognitive-perceptual aberrations factor. The relationship between PFC functioning, schizotypy and drawing remains unclear, and it is hoped that through analysis of the SPQ responses, the association between these three factors can be explained.

3.1.4 Summary of aims of survey study

The first aim of the survey study was to extend the conclusions of the interview study and investigate attitudes to drawing in a more systematic manner with a larger sample. To that end, a large cohort of undergraduate and postgraduate art students were questioned on their knowledge of the drawing devices that were raised in the interview study. In an extension to the interview study, the role of personality, lateralization and individual differences in internal visual representations with respect to drawing ability were also explored. The scope of the survey investigation remains very broad due to the exploratory nature of the thesis. A role of these investigations is to eliminate erroneous factors from a toolbox for drawing expertise, presented in the final chapter. At the conclusion of the survey chapter, evidence from both the interview and survey data will be combined and focused empirical questions pursued in subsequent chapters will be introduced, having established a more concrete theoretical foundation during the course of discussion during the first three chapters.

3.2 Method

3.2.1 Participants.

Questionnaire data collection was conducted in the years 2007, 2010, 2011 and 2012. Participants were foundation year students from Swansea Metropolitan University (SMU, n=357) and first year post graduate students from the Royal College of Art (RCA, n=255). The total sample consisted of 612 participants. The mean age of the participants was 27.03 years (SD=8.59 years) and 67.2% of the sample was female.

Artistic Experience. Each art college has entrance criteria based on the assessment of artistic talent, primarily in the form of a portfolio of work. For the foundation course at SMU, applicants must submit a portfolio of their visual work that demonstrates their artistic potential. In addition the majority of candidates will have pursued art at A-level or equivalent. The RCA, as a postgraduate degree course requires a high quality portfolio of work in the field related to their chosen field of study; the majority of students will have

completed a BA in an arts subject and many are practicing artists seeking to consolidate or broaden their artistic practice.

3.2.2 Apparatus and Stimuli.
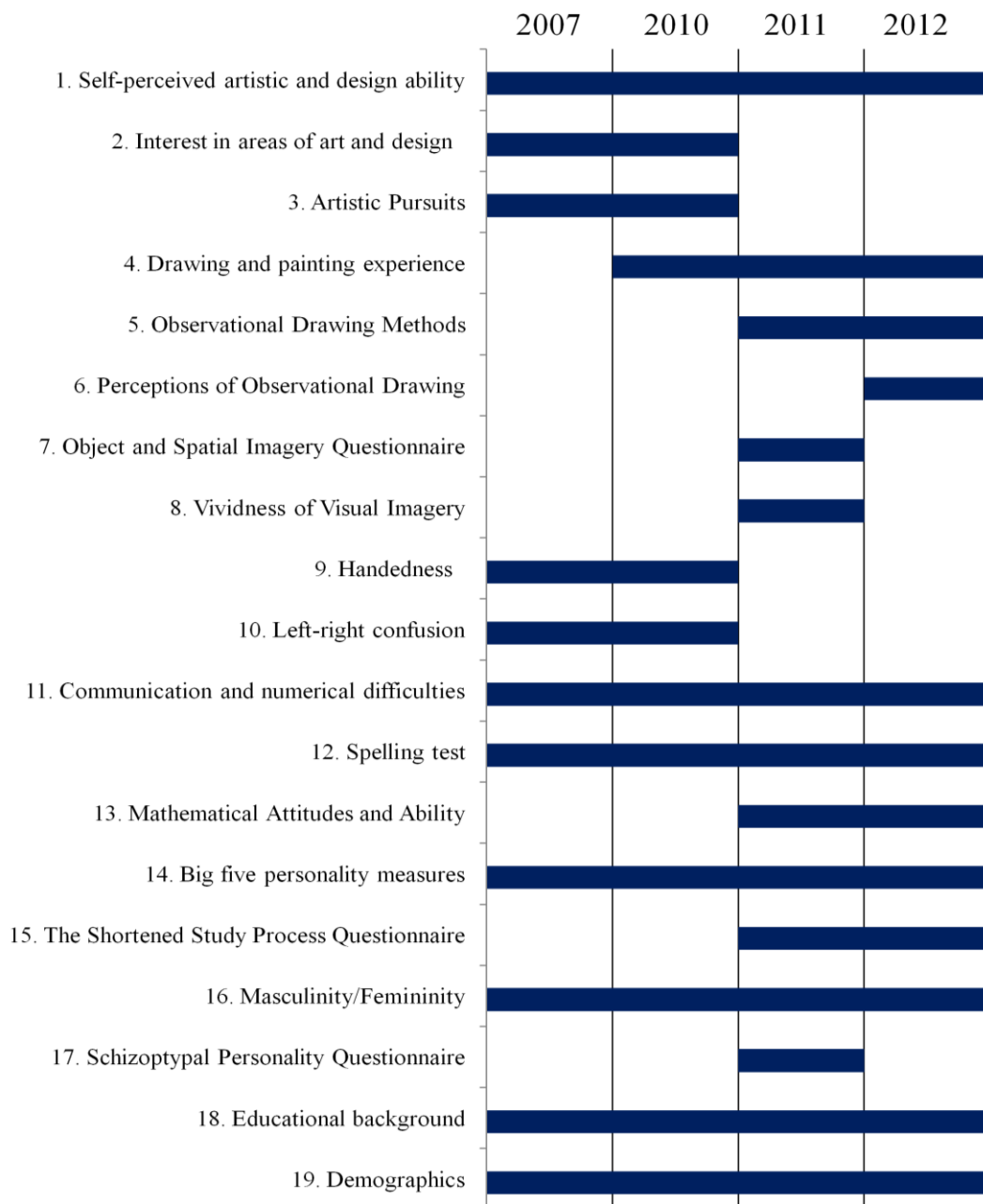
Figure 3.1. Components of the questionnaires and number of years administered. (N.B – questionnaire data was not collected in the years 2008 & 2009)

As the questionnaire data were collected over a period of five years (2007-2012) and on four separate occasions, some questions were added and excluded from the questionnaire format over time, due to space and time constraints. Particularly, those measures that were found

not to be predictive over time were excluded in later editions of the questionnaire, where new topics and questions could be included instead. The number of participants who completed each section of the questionnaire is included in a table at the beginning of the description of each component and an overview of the administration of the various components of the questionnaire included over time is presented in Figure 3.1. The complete questionnaire can be found in Appendix B.

3.2.2.1 Questionnaire

Artistic Ability and Interests

1. *Self-perceived artistic and design ability*. Performance for a range of artistic skills in relation to others studying art and design. Responses were indicated on a 5-point Likert-type scale ranging from *'much above average'* to *'much below average'*.

2. *Interest in areas of art and design*. Preference for specific artistic practices such as painting, sculpting and illustration on a 3-point scale rating from *'very interested'* to *'not really interested'* with an additional scalar point if considered as a career option.

3. *Artistic Pursuits.* Frequency of leisure time pursuing artistic activities such as visiting the theatre, reading novels and listening to classical music on a 7 point scale rating from '*everyday'* to '*never'*.

4. *Drawing and painting experience*. Amount of time spent drawing and painting currently and over the last year on an 11-point scale ranging from *'most days for 4+ hours'* to *'never'*.

5. *Observational Drawing Methods.* Experience of a variety of observational drawing devices on a 4-point scale ranging from *'use it frequently'* to *'never heard of it'*. Participants were also asked how important learning to draw was to them whilst at art college with a 4 point response scale ranging from *'Not at all important'* to *'Very Important'*.

6. *Perceptions of Observational Drawing.* Perceptions and competence at various aspects of drawing including seeing negative space, judging lengths and angles and fitting the drawing within the sheet of paper on a 4-point scale ranging from '*strongly disagree'* to *'strongly agree'*.

Visual Imagery

7. *Object and Spatial Imagery Questionnaire (OSIQ, Blajenkova et al., 2006).* Object or spatial imagery ability rated on a 5-point scale, ranging from '*strongly disagree'* to '*strongly agree'.*

8. *Vividness of Visual Imagery (VVIQ, Marks, 1973).* Mental visualisation of a verbally described visual scene and rated vividness of resulting image on a 5-point scale ranging from '*No image at all, I'm just thinking about the object'* to '*Perfectly clear and vivid as normal vision'.*

Lateralization and Learning Difficulties

9. *Handedness.* Preferred hand/foot for a number of activities including writing, throwing and kicking a ball.

10. *Left-right confusion.* Difficulties distinguishing left and right in a spectrum of everyday situations on a 5-point scale with response categories ranging from '*never'* to '*all the time'.*

11. *Communication and numerical difficulties.* Family history or a personal diagnosis of dyslexia, dyspraxia, dyscalculia, stuttering or stammering.

12. *Spelling test.* Correct spelling of a word from 4 alternative spellings for 20 commonly misspelled words (Brunswick, McManus, Chamberlain, Rankin, & Riley, 2013)

13. *Mathematical Attitudes and Ability.* Response to a range of statements on attitudes to mathematics on a 4-point scale ranging from '*strongly agree'* to '*strongly disagree'.*

Personality and Demographics

14. *Big five personality measures.* Response to a 15 item list from the Household Panel Survey based on the Big Five Inventory (John, Donahue, & Kentle, 1991; John, Naumann, & Soto, 2008) or response to a 17 item from the NEO-FFI (Furnham, McManus, & Scott, 2003; Furnham & McManus, 2004; McManus & Furnham,2006; McManus, Mitchison, Chung, Stubbings, and Martin, 2003).

15. *The Shortened Study Process Questionnaire (Fox et al., 2001).* Response to statements concerning approach to study on a 4-point scale ranging from '*strongly agree'* to '*strongly disagree'.*

16. *Masculinity/Femininity (Spence & Helmreich, 1978).* Masculine and feminine traits rated on a 7-point scale e.g. *'not at all independent-very independent, very rough-very gentle'.*

17. *Schizoptypal Personality Questionnaire (SPQ-B, Raine & Benishay, 1995).* Short-form of the SPQ-B with 4-point response scale ranging from *'strongly agree'* to *'strongly disagree'.*

18. *Educational background.* GCSE, AS and A-Levels attained for all subjects including art and design

19. *Demographics.* Gender, date of birth, nationality, and parental practice and sympathy toward the arts.

3.2.2.2 Drawing Exercises.

A proportion of the sample (n=201) participated in drawing exercises to derive objective measures of drawing ability alongside self-perceived drawing ability elicited by the questionnaire. The drawing tasks were completed in one A4 size paper booklet. Participants were provided with HB pencils, erasers and sharpeners to complete the tasks. All visual stimuli were presented via a Microsoft Office PowerPoint presentation, presented on a 4x3m projector screen (Figure 3.2). Participants were tested in groups of up to 15.

Hand Photograph. Copy of a photograph of a hand holding a pencil (5 mins)

Block Construction. Copy of a block construction (5 mins)
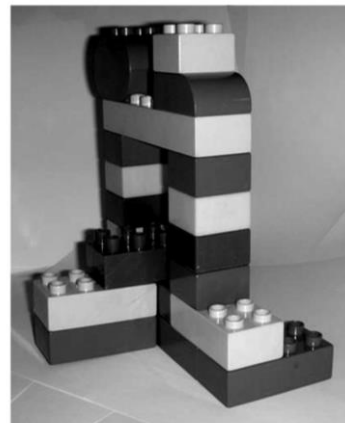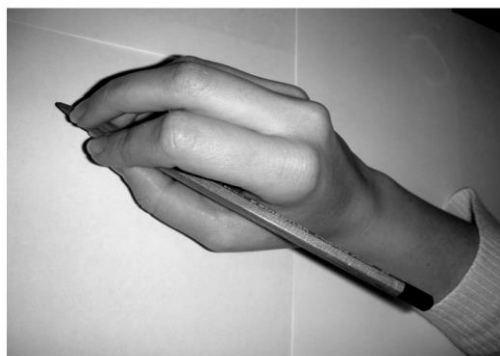
Figure 3.2 Hand and Block Drawing Tasks

3.2.3   Data Preparation

3.2.3.1 Drawing Rating Procedure for Hand and Block Drawings.

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 postgraduate 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 informed that quality of drawing was to be determined solely on the basis of accuracy, and not on aesthetic appeal. Exemplars of the quality of drawing accuracy in each category from a previous study were given to the judges in order to aid the rating process. The judges were not restricted in terms of how many drawings they put into one category.

When the judges were satisfied with their distribution of drawings, each drawing was assigned the number of the category it was placed in (8 – best, 2 – worst). If the judge felt that a particular drawing was better than the best exemplar, that drawing would receive a score of 9, and if a drawing was rated as worse than the worst exemplar, it would receive a score of 1, although these extremes of the scale were used rarely. In the first cohort of drawings taken in 2008 (N=38), a scale from 1-12 was used instead. This was rescaled to fit the later scaling system of 1-9.

3.3   Results

3.3.1   Observational Drawing Ratings.

Participants' scores for the hand and block drawings were averaged across the ten non-expert raters. Inter-rater reliability was high, with Cronbach's alphas of .92 for hand drawing ratings and .93 for block drawing ratings. Participants were rated as slightly more accurate in the hand drawing task (M=4.94, SD=1.73) compared with the block drawing task (M=4.61, SD=1.80). Hand drawing ratings significantly positively correlated with block drawing ratings, r (198) =.67, p<.001, and therefore a composite drawing rating was produced by averaging drawing ratings for the hand and blocks for each participant.

3.3.2 Artistic Ability and Interests

Table 3.1 shows the number of participants who responded to the various questions pertaining to artistic ability and interests.

Table 3.1. Response rates to artistic ability and interest questions

Questionnaire Variable	Max N responses
1. Self-perceived artistic and design ability	588
2. Interest in areas of art and design	378
3. Artistic Pursuits	276
4. Drawing and painting experience	253
5. Observational Drawing Methods	198
6. Perceptions of Observational Drawing	87

3.3.2.1 Artistic Ability.

The artistic skill questions were analysed in a principal components analysis (PCA) which revealed five artistic ability factors: mechanical skills, 3D skill, colour skills, creative skill and drawing skill. Participants rated themselves most highly at skills involving the use of colour and creativity (Table 3.2).

Table 3.2. Descriptive statistics for artistic skills

Artistic Skill	Mean	SD
Mechanical Skills	3.21	.75
Three-Dimensional Skill	3.20	.64
Colour Skill	3.45	.68
Creative Skill	3.35	.80
Drawing Skill	3.17	.65

3.3.2.2 Self-Perceived Drawing Skill.

Drawing skill was rated as the lowest ability across participants and was normally distributed (Figure 3.3).
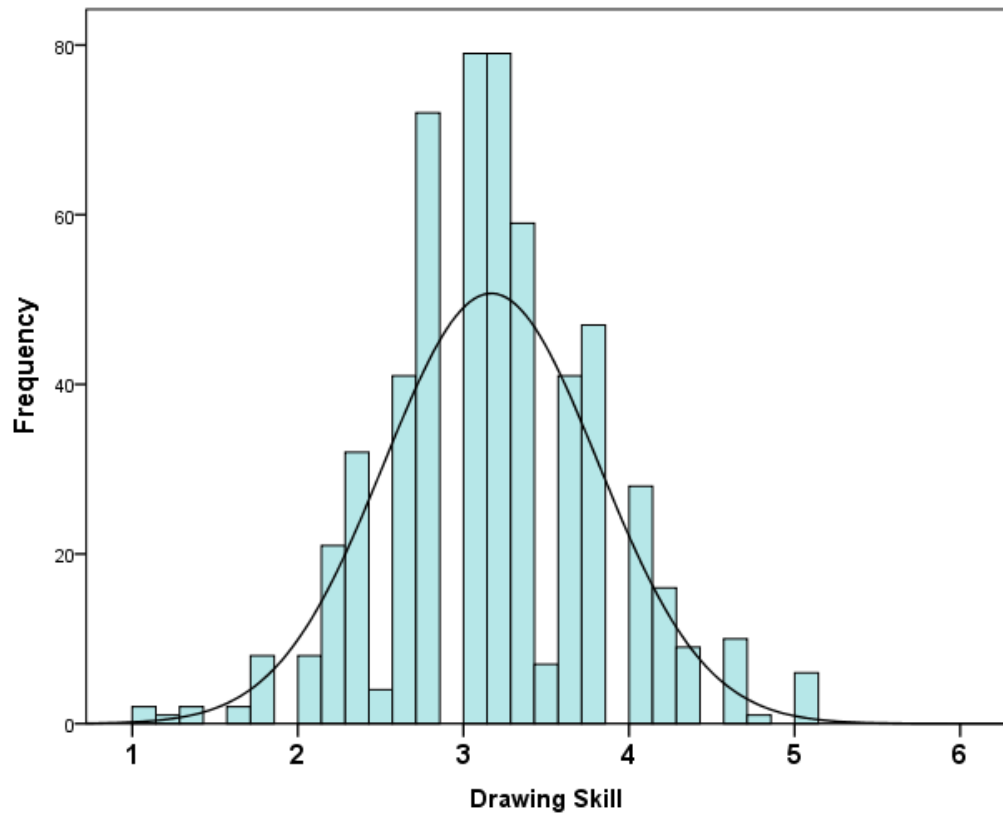
Figure 3.3. Distribution of drawing skill scores

Self-perceived drawing skill was highly correlated with externally rated drawing ability, r (195) =.42, p<.001 (Figure 3.4).
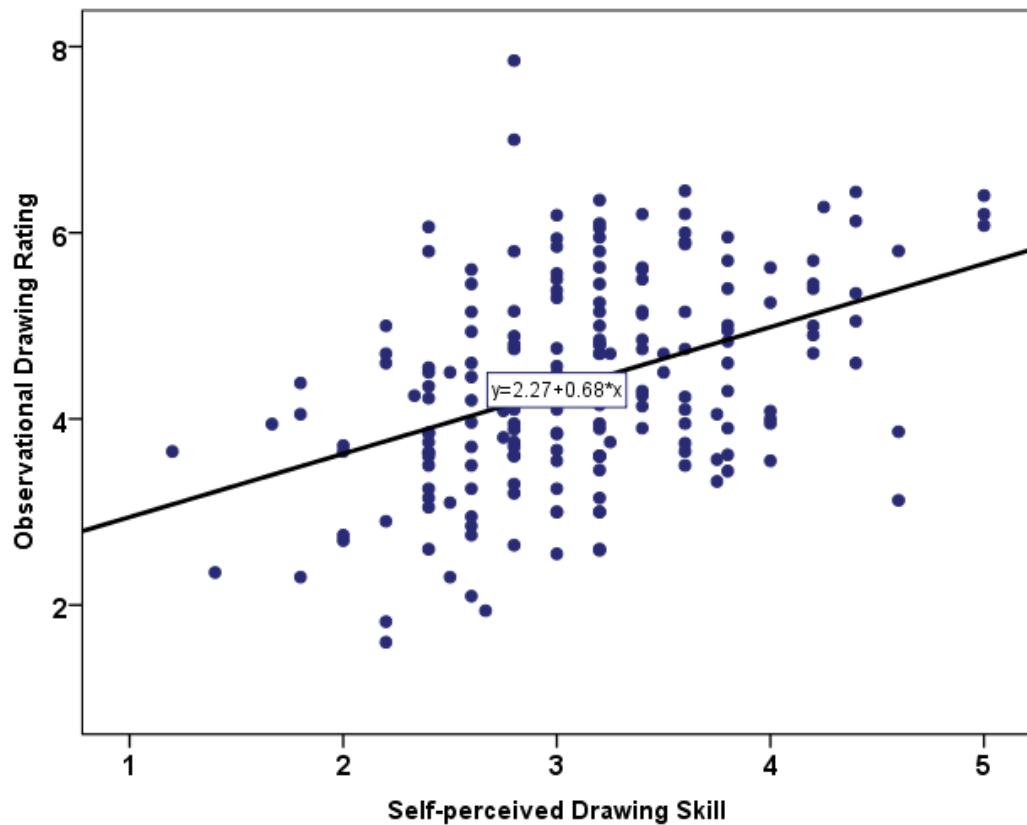
Figure 3.4. Relationship between self-perceived and externally rated drawing ability scores

In a multiple regression with drawing skill as the dependent variable and the remaining artistic ability factors entered as predictors, the regression model was significant, F (5, 542) =111.28, p<.001. Mechanical skill, t (542)=-4.31, p<.001), 3D skill, t (542)=17.66, p<.001, and colour skill, t (542)=4.37, p<.001, were significant predictors. Self-perceived creative skill was not predictive of self-perceived drawing skill. In the same regression model but with externally rated drawing ability as the dependent variable the model was significant, F (4, 182) =8.30, p<.001, but only three-dimensional skill was a significant positive predictor of drawing ability, t (178) =5.46, p<.001, whilst mechanical skill was a significant negative predictor, t (178)=-3.08, p<.01.

3.3.3   Observational Drawing Ability and Devices

3.3.3.1 *Importance of Observational Drawing.*

The majority of the survey sample perceived the learning of observational drawing to be 'very important' (N=84, 70%), roughly a fifth of the sample found learning observational drawing to be 'quite important' (N=23, 19.%), and the remaining proportion found learning

observational drawing to be 'somewhat unimportant' (N=5, 4%), or 'not at all important' (N=8, 7%).

3.3.3.2 Drawing Devices.

Drawing technique usage was determined by summing the responses to each drawing technique question together. Drawing technique usage correlated with both self-rated, r (196) =.40, p<.001, and externally rated, r (56) =.34, p<.05, drawing ability. Responses to the drawing devices and abilities questions were then analysed using PCAs. In the case of the use of drawing devices generally speaking if an individual used one device they used all others, with the use of a plumb line being exceptional and loading onto an independent factor. Figure 3.5 shows the percentage of participants who frequently used each observational drawing device. Drawing quickly to eliminate detail and sketching out the pivotal points on the image were the most favoured techniques adopted to achieve good observational drawings; these devices were used by a quarter of the sample. Around 15% used negative space, blurring and focus on texture and pattern to improve their ability. More mechanical devices were less popular, such as using a frame to capture part of the visual field, or a plumbline to derive vertical axes.
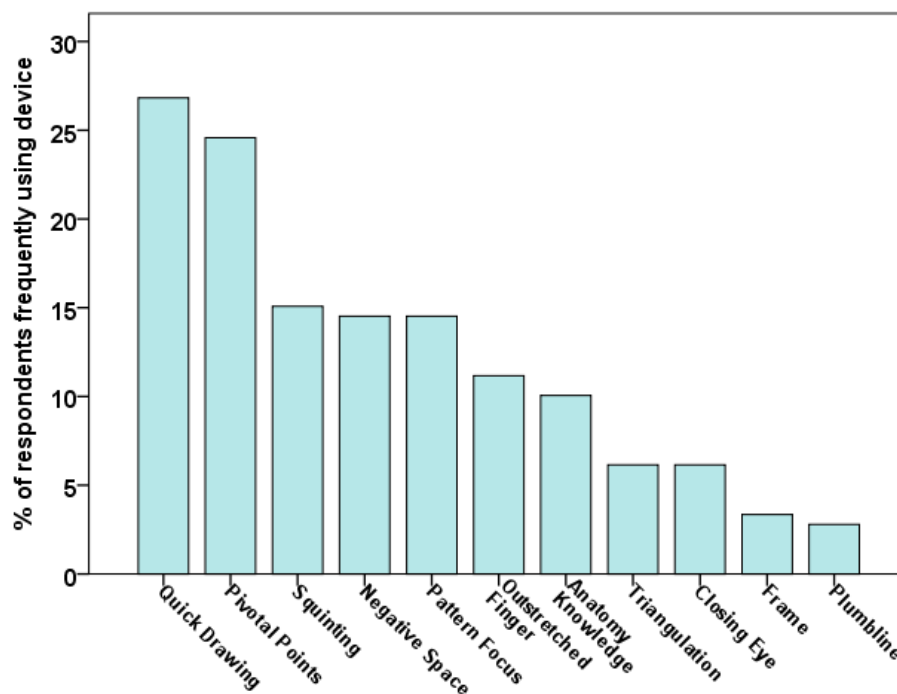
Figure 3.5. Percentage of respondents who frequently use a range of drawing devices

3.3.3.3 Observational Drawing Abilities.

The PCA of the abilities in observational drawing question revealed a three factor structure to responses. The first factor, labelled the 'geometry' factor, encompasses abilities pertaining to the judging of geometric relationships within a visual scene, including judging length and proportion, defining the principle axes in a scene and scaffolding the drawing. The second factor, labelled the 'perceptual factor' pertained to the importance of understanding how vision works, how it interacts with language, and seeing elements in the image such as contrast. The last factor, labelled the 'Boundary factor' particularly referred to accurately defining the boundaries of the image, such as using negative space and getting the outline correct. In a multiple regression with self-perceived drawing skill as the dependent variable and the three observational ability factors as predictors, the model was significant with only the geometry factor being a significant predictor of drawing skill, t (82)=2.43, p<.05. In a second multiple regression with externally rated drawing skill as the dependent variable and the three observational ability factors as predictors, the regression model was significant and again only the geometry factor was a significant factor predicting drawing skill, t (80) =2.11, p<.05.

3.3.3.4 Interaction with Artistic Interests and Hobbies.

It was of interest to ascertain the extent to which skill and interest in observational drawing interacted with skill and interest in other artistic domains. Responses to the *'Interests in areas of art and design'* questions were analysed using PCA from which four factors of artistic interest were derived. These were interest in design, interest in film, interest in applied arts (jewellery, ceramics etc.) and interest in fine arts (painting, sculpture etc.). In a multiple regression it was found that an interest in design was a significant positive predictor of self-perceived drawing skill, t (356) =2.25, p<.05. However the regression model was not significant when externally-rated drawing was entered as the dependent variable and none of the artistic interests were shown to predict drawing ability.

Responses to the *'Artistic Pursuits'* component of the questionnaire were also analysed with respect to drawing ability. A mean score was calculated for responses across all types of artistic activity as a PCA revealed a one factor structure. There was no correlation between the degree to which individuals engaged with artistic pursuits and their self-perceived drawing skill.

3.3.4   Visual Imagery

Table 3.3 shows the number of participants who responded to the various questions pertaining to self-report visual imagery.

Table 3.3.Response rates to visual imagery questions

Questionnaire Variable	Max N responses
1. Object and Spatial Imagery Questionnaire	112
2. Vividness of Visual Imagery	110

To calculate a score for the VVIQ, responses for all four questions were averaged, and for the OSIQ responses were split into those pertaining to spatial and object imagery and then were averaged independently. This resulted in three visual imagery scores: VVIQ, OSIQ-Object and OSIQ-Spatial (Figure 3.6).
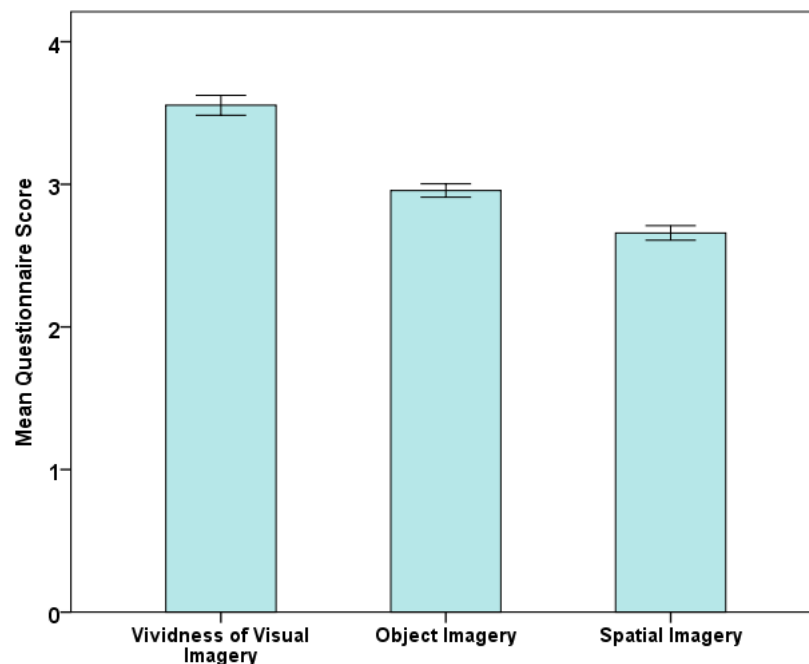
Figure 3.6. Participants' scores on the VVIQ and the object and spatial components of the OSIQ

A correlation matrix was produced to assess the relationship between self-perceived and objective drawing accuracy and the measures of visual imagery in the questionnaire (Table 3.4). VVIQ scores correlated significantly with OSIQ-Object scores but not with OSIQ-Spatial scores. The two OSIQ scores correlated significantly with one another. There was dissociation in correlations between subjective and objective measurements of drawing skill.

Self-perceived drawing skill correlated highly with all three visual imagery measurements, whilst rated drawing skill did not correlate with any of the measures of visual imagery (Table 3.4).

Table 3.4. Correlations between visual imagery scores and self-perceived and externally rated drawing skill. (n range =110-112)

	Objective Drawing Skill	Self-perceived Drawing Skill	VVIQ	OSIQ-Spatial
VVIQ	-.09	.26**	-	-
OSIQ-Spatial	.04	.31**	.14	-
OSIQ-Object	.07	.27**	.51**	.26**

Notes: ** p<.01

3.3.5   Lateralization and Learning Difficulties

Table 3.5 shows the number of participants who responded to the various questions pertaining to lateralization and learning difficulties.

Table 3.5. Response rates to lateralization and learning difficulty questionnaire items

Questionnaire Variable	Max N responses
1. Handedness	376
2. Left-right confusion	379
3. Communication and numerical difficulties	555
4. Spelling test	555
5. Mathematical Attitudes and Ability	287

3.3.5.1 Handedness.

Handedness scores were derived by calculating the mean response to all questions pertaining to handedness (e.g. throwing a ball, threading a needle etc.). The majority of participants used the right hand for all activities all of the time (53%) whilst a small minority were strongly left handed (6%), comparable with previous estimates of the prevalence of left handedness (McManus, 1991). There was no evidence of a relationship between handedness and externally-rated or self-perceived drawing skill (both p>.50).

3.3.5.2 Right-Left Confusion.

Figure 3.7 displays the frequency of right-left confusion in the art student sample, and demonstrates a positively skewed distribution, suggesting that the majority of students had little trouble distinguishing left from right.
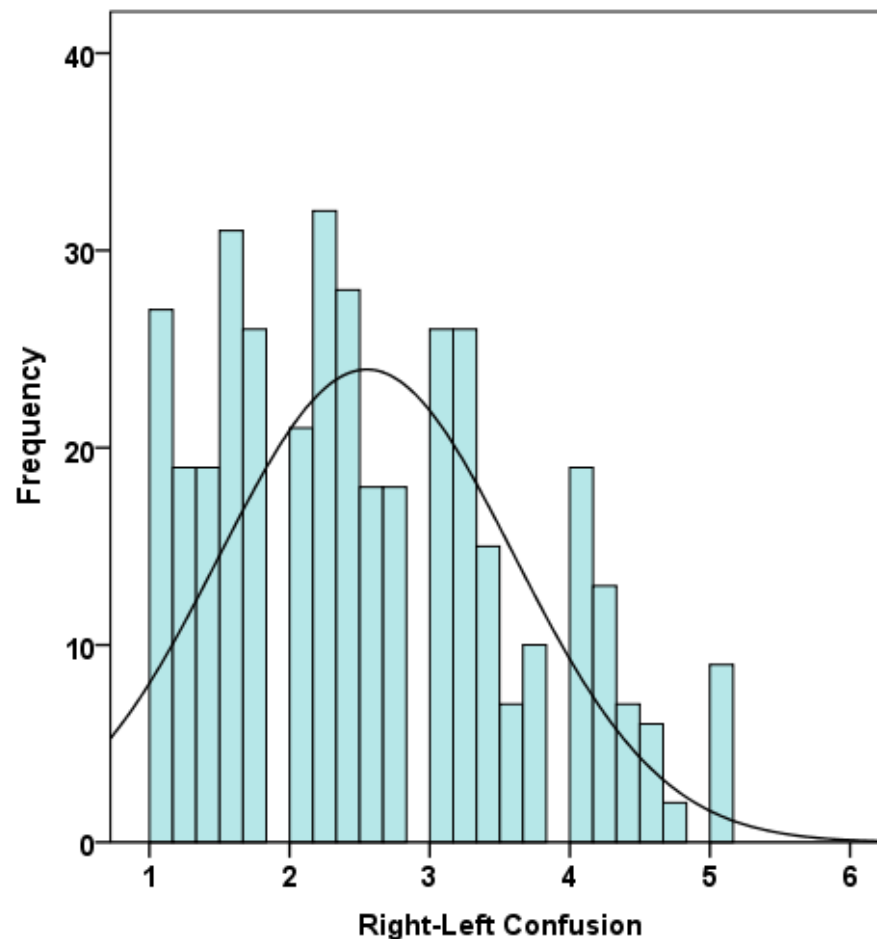
Figure 3.7. Frequency of right-left confusion

There was a significant correlation between right-left confusion and self-perceived drawing ability, r (364) =-.13, p<.05, but not with rated drawing ability, r (362) =.10, p=.36. There was no relationship between dyspraxia and either measure of drawing ability.

3.3.5.3 Dyslexia and Spelling.

Within the sample 13% of participants said they had received a diagnosis of dyslexia, 19% said they wondered if they were dyslexic and the remaining participants reported that they did not have dyslexia. There was no relationship between dyslexia and the two measures of drawing ability (all p>.10). The mean number of correct responses in the spelling test were calculated and then correlated with both measures of drawing ability. There was a weak but significant correlation, r (192) =.18, p<.05, between spelling scores and rated drawing

ability (Figure 3.8), but no correlation between self-perceived drawing ability and spelling ability (p>.8).
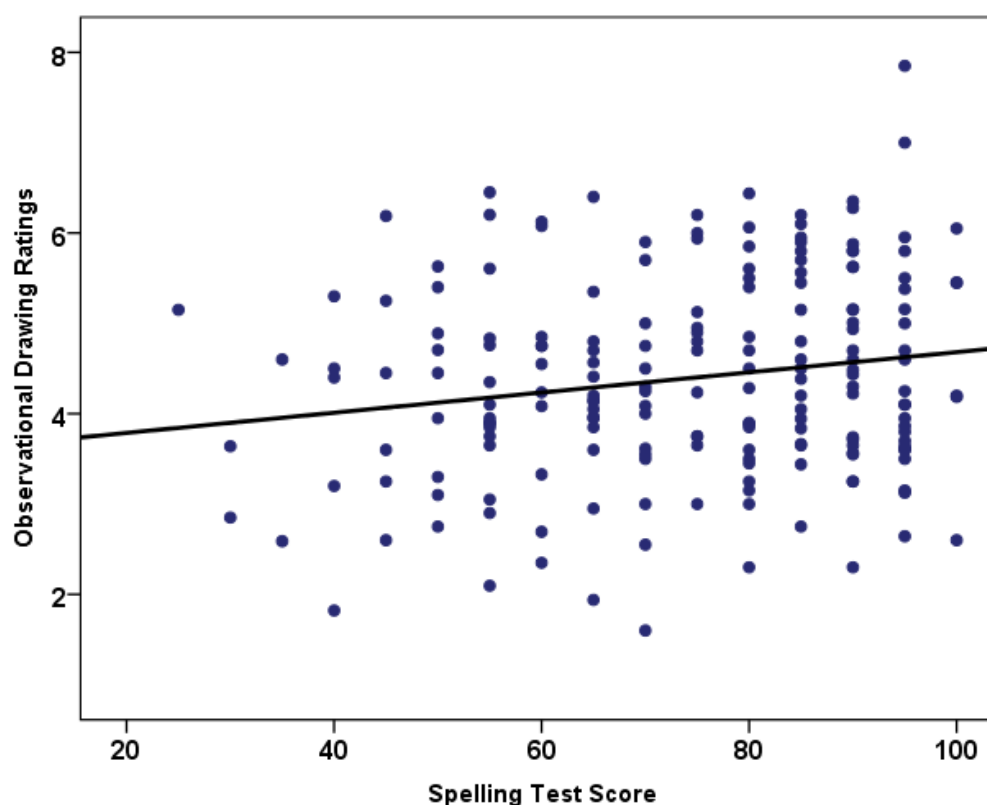
Figure 3.8. Relationship between spelling ability and rated drawing ability

3.3.5.4 *Mathematical ability and dyscalculia.*

Questions pertaining to mathematical attitudes were analysed in a PCA from which two factors were drawn; the first related to enjoyment of maths and the second related to the perceived usefulness of maths. Alongside these attitudinal measures, maths GCSE, AS and A-Level scores were analysed with respect to drawing ability. The correlation matrix reveals that self-perceived drawing skill is mildly related to perceived enjoyment of maths but negatively related to its perceived utility (Table 3.6). The same relationship was found in regard to drawing rating scores. However, in the case of academic attainment at maths, self-perceived drawing skill was not found to be related to ability at any level, whilst drawing rating was correlated with mathematical ability at GCSE and A-Level standard. Diagnosis of dyscalculia was not significantly correlated with either measure of drawing ability.

Table 3.6. Correlations between drawing ability and mathematical attainment (n range 10-314)

Drawing Measure	Maths Enjoyable	Maths Useful	Maths GCSE Grade	Maths AS-Level Grade	Maths A-Level Grade
Self-perceived Drawing Skill	.14*	-.18**	.09	.05	-.09
Objective Drawing Skill	.28**	-.17*	.24**	-.07	.71*

Notes: *p<.05, ** p<.01

3.3.6 Personality and Demographic Factors

Table 3.7 shows the number of participants who responded to the various questions pertaining to personality and demographic factors.

Table 3.7. Response rates to personality and demographic questionnaire items

Questionnaire Variable	Max N responses
1. Big five personality measures	564
2. The Shortened Study Process Questionnaire	193
3. Masculinity/Femininity	465
4. Schizoptypal Personality Questionnaire	110
5. Educational background	366
6. Demographics	561

3.3.6.1 The Big Five.

The existing categorisation of the Big Five personality questionnaire was used to explore personality factors in relation to drawing ability. Figure 3.9 shows the average scores for each of the five factors. Participants scored highest on the 'openness to experience' factor and lowest on the 'conscientiousness' factor.
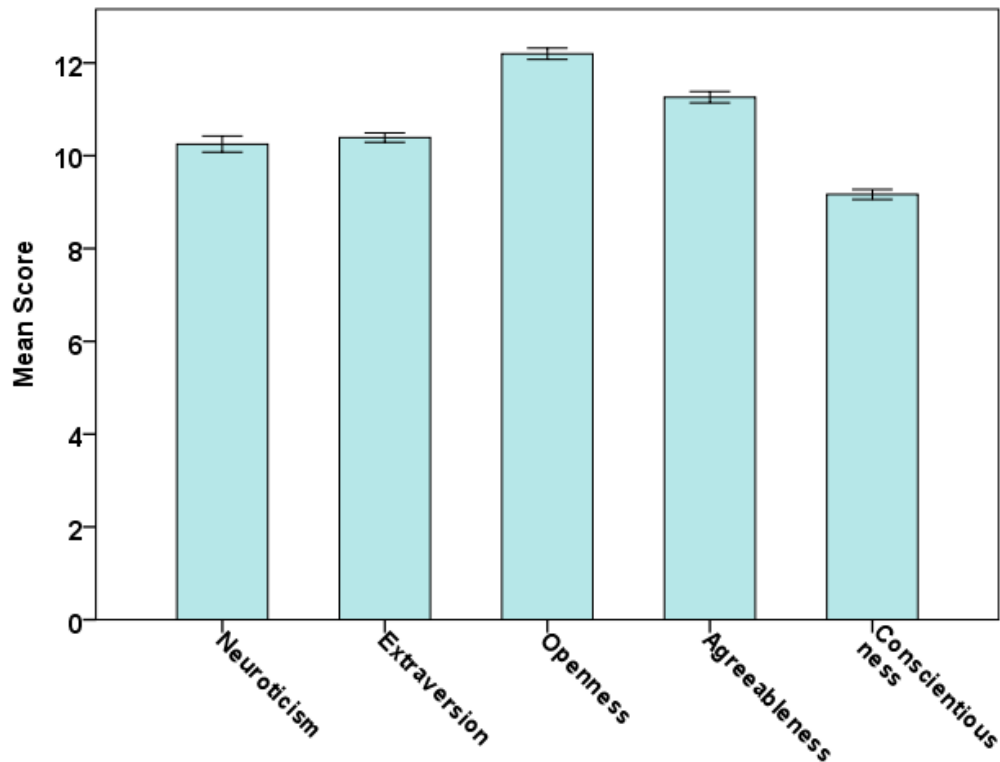
Figure 3.9. Average scores for each factor on the Big Five Personality Scale

Multiple regressions were conducted with the two drawing measures as dependent variables and the five personality factors as predictors. In the first regression the model was significant, $F (5, 185) = 4.26$, p<.01, and neuroticism was a significant negative predictor of self-perceived drawing ability, $t (180) =-3.5$, p<.01, whilst openness to experience was a positive predictor of self-perceived drawing ability, $t (180) =2.6$, p<.05. In the following regression in which rated drawing ability was a dependent variable, the regression model was not significant and none of the five personality factors predicted drawing ability.

3.3.6.2 Study Habits.

The three study habit styles (deep, achieving and surface) were derived by summing the relevant responses to target questions pertaining to each of the three styles. In a regression, the model was significant, $F (3, 54) =3.77$, p<.05; surface strategies to learning were negatively predictive of drawing rating, $t (51) =-2.21$, p<.05, whilst an achieving approach to learning was positively associated with drawing ratings, $t (51) =2.86$, p<.01. In a regression with self-perceived drawing ability as a dependent variable the regression model was significant, $F (3,187) =3.98$, p<.001, but there were no significant predictors of drawing skill, suggesting multicollinearity.

3.3.6.3 Drawing Practice.

It was of interest to determine whether the amount of time respondents spent drawing and painting in the last two years predicted their own perception of their drawing ability. The amount of time spent drawing and painting over the last two years were significantly correlated with each other, r (244) =.74, p<.001. A regression model with self-perceived drawing ability as the dependent variable and time spent drawing and painting in the last two years as predictors was significant, F (2, 236)=13.73, p<.001, with time spent drawing, t (236)=4.73, p<.001, as a positive predictor and time spent painting negatively predicting drawing skill, t (236)=-2.00, p<.05. In a second regression analysis again the model was significant, F (2, 125) =3.09, p<.05, and time spent drawing, t (123) =2.49, p<.05, but not time spent painting predicted externally rated drawing ability.

3.3.6.4 Masculinity-Femininity and Sex Differences.

Sex differences were explored with regard to both self-perceived and externally rated drawing ability. In independent samples t-tests, males consistently rated themselves as more proficient at drawing, t (545) =5.21, p<.001, however in the case of externally rated drawing ability there were no significant differences between males and females. Within the masculinity-femininity scale, there were two separable scales: instrumentality (independent, competitive, self-confident, does not give up easily) and expressiveness (emotional, gentle, kind, aware of the feelings of others). An overall masculinity score was derived by summing instrumental and expressive factors separately and then subtracting expressiveness scores from instrumentality scores. Males showed significantly higher masculinity scores compared to females, t (443) =5.69, p<.001. In a regression with self-perceived drawing skill as the dependent variable, the model was significant, F (2, 439) =23.54, p<.001, and instrumentality positively predicted scores, t (437) =6.58, p<.001, whilst expressiveness negatively predicted scores, t (437) =-2.79, p<.01. There was a significant correlation between masculinity scores and self-perceived drawing skill, r (440) =.29, p<.001. In a subsequent regression analysis, the model was not significant, F (2,168) =1.85, p=.16, and neither instrumentality or expressiveness were predictors of externally-rated drawing ability. Neither masculinity nor neither of its subscales was significantly correlated with time spent drawing or painting in the last two years.

It was of interest to assess whether masculinity scores interacted with learning style. In a linear regression, F (3, 177) =3.58, p<.05, surface approaches to learning were found to be significantly negatively correlated with masculinity scores, t (174) =-2.78, p<.01. The same pattern was found in a regression with instrumentality as a dependent variable, F (3,

180) =13.66, p<.001, however in this instance surface approaches were found to be negatively correlated, t (177) =-4.23, p<.001, but achieving approaches were also found to be a significant positive predictor, t (177) =3.83, p<.001. However, when expressiveness was entered as the dependent variable, F (3, 178) =3.42, p<.05, only achieving approaches to learning were a significant predictor, t (175) =1.99, p<.05.

3.3.6.5 Schizotypy.

Total schizotypy scores were calculated by summing scores for all items. There was no correlation between total schizotypy scores and either self-perceived or externally rated drawing ability. The schizotypy scale was then separated into three factors: cognitive-perceptual aberrations (ideas of reference, magical thinking, unusual perceptual experiences and paranoid ideation), interpersonal dysfunction (social anxiety, lack of close friends and blunted affect) and disorganization (odd behaviour and speech) by summing groups of items within the scale that pertained to each factor. In two regressions with the three subscales of the SPQ-B as predictors and the two drawing measures as dependent variables neither regression model was significant and there were no significant predictors.

3.3.7   Educational Background and Demographics

3.3.7.1 Educational Attainment.

A number of demographic and educational variables were analysed with respect to the drawing ability measures. Firstly a mean GCSE, AS-Level and A-Level score was computed for each participant, and these were correlated with self-perceived and externally rated drawing scores (Table 3.8).

Table 3.8. Correlations between educational attainment and self-perceived and externally rated drawing skill. (n range 92-236)

Drawing Skill Score	Mean GCSE	Mean AS-Level	Mean A-Level
Externally-Rated	.37**	.24*	.16
Self-Perceived	.11*	-.05	-.09

Notes: *p<.05, ** p<.01

It can be seen that externally rated drawing ability is significantly correlated with mean GCSE and AS-Level results but not with mean A-Level results. Academic attainment appears to reduce in predictive power as academic experience increases. Mean AS and A-

Level results were uncorrelated with self-perceived drawing ability, but there was a low but significant correlation between mean GCSE results and self-perceived drawing ability.

3.3.7.2 Demographics.

The role of age and parental practice and sympathy toward the arts was also explored. There was no correlation between age and externally rated drawing ability or self-perceived drawing ability. There was no relationship between whether participants' parents practised or were sympathetic to the arts and either of the drawing skill measures or time spent drawing in the last two years.

3.3.8 Path Analysis of Predictors of Externally Rated Drawing Ability

In order to interpret the large number of correlations between background variables and drawing ability it was necessary to conduct a path analysis. This helped to clarify the relationships between the background variables, and how they interact to affect drawing ability, by using assumptions about the causal structure underlying their pattern and removing non-significant pathways.

3.3.8.1 MVA Replacement of Missing Data

Data on all variables could not be collected from all participants for practical reasons (see Figure 3.1), resulting in a patchwork data set. In order to conduct a successful path analysis it was necessary to produce estimated values on all variables for each participant. To do this Missing Values Analysis in SPSS was used with an Expectation-Maximisation (EM) approach. The EM algorithm assumes a normal distribution for the partially missing data and makes inferences upon the likelihood under that distribution. The analysis consists of two steps within each iteration of the process. The 'E' step finds the conditional expectation of the missing data, given the observed values and current estimates of the parameters, and then substitutes these expected values for the missing ones. The 'M' step then computes maximum likelihood estimates of the parameters as though the missing data were filled in.

3.3.8.2 Correlation Matrices for Original Sample and EM Substituted Values

Table 3.9 shows the variables of interest that were entered into the model and their relationship with each other. The two correlation matrices within Table 3.9 show the relationship between the variables in the path analysis before (unshaded region) and after (shaded region) EM substitution. In the correlation matrix after EM value substitution (Table 3.9 – shaded region) there are a greater number of flagged significant correlations due to the increased sample size (N=612). However all significant correlations in the

primary sample of data are present in the EM substituted matrix, and the pattern of results is similar in each. Table 3.9 demonstrates a complex correlational interaction between the background variables in this survey study. Drawing rating is predicted by the use of drawing techniques, higher GCSE grades, and achieving strategy to studying and increased neuroticism, whilst use of drawing techniques appears to be predicted by a different approach to studying (deep), time spent drawing and openness to experience. Time spent drawing again shows a different underlying correlational structure, being predicted by surface approaches to learning and conscientiousness. The Big Five personality inventory does indeed seem to interact with approaches to study and therefore personality could be affecting drawing ability through study processes. The relationship between drawing ability, amount of time practising and the uptake of techniques for improvement is evidently a complex one and will be understood better in a causal network model rather than considered independently in relation to drawing.

A number of variables were excluded from the path analysis model as they were not predictive of drawing rating in the prior analyses presented in this chapter and did not theoretically relate to any of the other variables that were predictive of drawing ratings. The excluded variables were masculinity, schizotypy, artistic interests, visual imagery, lateralisation, learning difficulties and parental sympathy for the arts. The Big Five Personality Inventory remained in the model as these variables exert influence on other variables, based on the correlations in both the non-EM and EM substituted matrices. In total 13 variables were included in the path analysis, which is displayed in Figure 3.10 and described in the following section.

Table 3.9. Correlation matrix of background variables from survey sample with (N=612) and without EM substitution (n range = 53-253)

Notes: *p<.05, **p<.001. Consc= Conscientiousness, Neurot= Neuroticism, Extrov= Extroversion, Open= Openness to experience, Agreeab= Agreeableness.

Unshaded region indicates correlates between non-EM substituted variables, shaded region indicates correlations between EM substituted variables.

		Rating	Technique	Time	GCSE	Deep	Achieve	Surface	Consc.	Neurot.	Extrov.	Open.	Agreeab.	Sex
Drawing	Rating	-	**.34***	.14	**.37****	.16	**.31***	-.17	.07	.09	.07	.01	.03	-.04
	Techniques	**.33****	-	**.28****	.10	**.22****	.10	**-.25****	.09	-.07	.12	**.29****	.08	.06
	Time	**.17****	**.33****	-	-.00	-.01	.15	**.27****	**.24****	-.07	.08	.10	.11	.01
	GCSEs	**.28****	.06	-.01	-	-.08	.11	.09	.04	-.04	-.16	-.06	-.15	.09
SPQ	Deep	**.25****	**.34****	**.21****	**-.09***	-	**.54****	-.00	**.35****	-.01	.10	**.32****	.13	-.05
	Achieve	**.34****	.08	**.24****	.02	**.71****	-	**.34****	**.20****	.00	**.20****	.05	**.15***	-.12
	Surface	.03	-.05	**.35****	-.05	**.24****	**.47****	-	**-.29****	.04	.11	**-.34****	.08	-.11
Big 5	Consc.	.07	.04	**.10***	.07	**.17****	**.26****	**.08***	-	.03	-.13	**.15***	.08	.06
	Neurot.	**.09***	.04	.03	-.07	.05	**.18****	.07	-.04	-	-.09	**-.01***	.06	**.15***
	Extrov.	.05	**.11****	**.09***	-.01	**.21****	**.27****	.07	**.09***	.01	-	.13	**.17***	.01
	Open.	.01	**.25****	.04	**.09***	**.22****	.00	**-.37****	.07	**.15****	**.09***	-	**.23****	-.10
	Agreeab.	**-.16****	.05	.05	-.06	.03	-.06	**-.14****	**.19****	.05	**.20****	**.25****	-	.14
	Sex	**-.13****	.03	.07	.07	-.06	**-.15****	-.05	.04	.03	.01	-.03	**.11****	-
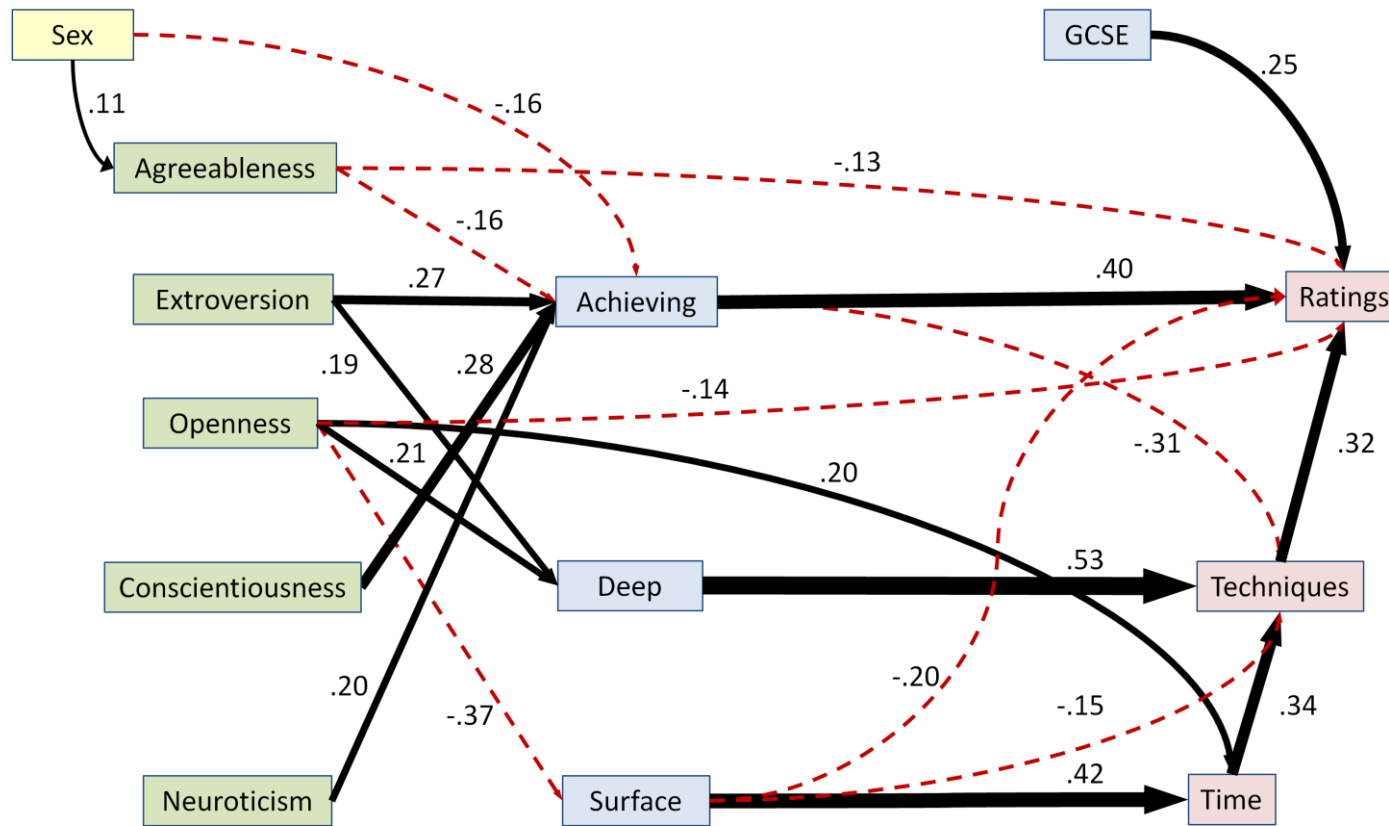
Figure 3.10 Path diagram showing the relationship among measures of personality, study approaches and drawing variables. The width of arrows is proportional to the strength of an effect, which is shown alongside each line as a path (beta) coefficient. Negative effects are shown as red, dashed lines. Ratings=Drawing ratings, Techniques=Drawing technique usage, Time=Time spent drawing in the last two years, GCSE= Mean GCSE grade.

3.3.8.3 Path Analysis

The initial structure of the path diagram (Figure 3.10) was developed intuitively according to the temporal order in which the variables were thought to be manifest. Sex is determined at conception and therefore is placed at the far left hand side of the model. Personality manifests itself in childhood and is construed as a trait variable so it is placed to the right of sex. Approaches to studying then follow, being part-state, part-trait variables which are somewhat fixed but can be influenced by the educational context during development. These study approaches predate the attainment of GCSE exams, so mean GCSE grades are placed to the right of approaches to studying. The amount of time spent drawing in the last two years also follows GCSE as all participants had completed their GCSEs more than two years ago. Techniques for drawing require engagement in drawing practice and therefore are placed after time spent drawing. Finally drawing ratings are placed at the far right hand end as they represent drawing ability on the day of testing.

The path diagram was analysed using a series of forwards multiple regressions, based on the intuitive temporal structure of the model previously described. Measures to the left can causally influence measures on the right. At each step of the model the weight of the dependent variable was changed according to the sample size of the variable in focus (N range =190-555) in reference to the EM substituted dataset sample size of 612 to avoid the possibility of making a Type I error due to the large EM substituted sample size. The probability level required to include a variable in each regression model was $p<.05$.

The path diagram shows the effects of personality, education and approaches to studying upon drawing time, drawing technique uptake and subsequently upon drawing ratings. It can be seen that performance at GCSE level independently predicts drawing ratings after all other variables have been taken into account. Time spent drawing influences the amount of drawing techniques used, which in turn has a positive impact upon drawing ratings. An interesting finding from the path analysis is the different contributions of the three scales of the Study Process Questionnaire on the three drawing variables. An achieving strategy to study strongly predicts drawing ratings, whilst a deep approach to study stimulates the uptake of drawing techniques. Finally, a surface approach to studying only positively impacts upon time spent drawing and has a negative impact on drawing ratings. An achieving strategy toward learning positively predicted GCSE results which in turn predicted drawing ability.

The relationship between the Big Five Personality Inventory and drawing also varied according to their prediction of the three approaches to studying. Agreeableness negatively predicted both an achieving approach to learning and drawing ratings. Extroversion

positively predicted achieving and deep approaches to learning, with a stronger correlation with achieving compared with deep. Conscientiousness also predicted achieving approaches to learning. Increased neuroticism predicted achieving approaches to learning, while openness to experience positively predicted deep approaches to learning, time spent drawing and technique usage and negatively predicted surface approaches to learning. Apart from agreeableness, it can be seen that none of the Big Five personality measures directly predict drawing ability, but they exert influence through approaches to learning, which in turn impact upon either time spent engaged in drawing practice, willingness to try and adopt new techniques through drawing, or observational drawing ability itself. Sex negatively predicted an achieving approach to learning, meaning that females took a less achieving approach to learning than males in the survey study sample but did better at their GCSEs.

3.4   Discussion

Table 3.10 presents a summary of the results of the survey analysis in relation to both self-perceived and externally-rated drawing ability. I will now proceed to discuss each variable in turn with a view to eliminating variables that do not appear predictive and to carry forward those that are predictive into a toolbox for drawing ability presented in the discussion at the conclusion of this thesis (Chapter 9). Each factor will first be discussed independently and then where interactions between personality, demographic and perceptual factors can be inferred, they will be discussed in the latter stages of this discussion as a network of psychological processes and attitudes that support observational drawing. A model of educational drawing skill acquisition based on the results from this survey chapter is also presented in the final chapter (9.2.1. An Educational Model of Drawing Ability).

Table 3.10. Summary of results of the survey study – statistical tests that were non-significant, significant to <.05 (weaker significance) or significant to <.001 (stronger significance)

Questionnaire Measure		Self-perceived Drawing			Externally-rated Drawing		
		None	*p<.05*	*p>.001*	*None*	*p<.05*	*p>.001*
Artistic Skill	*Mechanical*		✓			✓	
	3D		✓				✓
	Colour		✓		✓		
	Creative	✓			✓		
Observational Drawing	*Geometry*		✓			✓	
	Perceptual	✓			✓		
	Boundary	✓			✓		
Artistic Interests	*Design*		✓		✓		
	Film	✓			✓		
	Applied Arts	✓			✓		
	Fine Art	✓			✓		
Visual Imagery	*VVIQ*		✓		✓		
	OSIQ-Object		✓		✓		
	OSIQ-Spatial		✓		✓		
Lateralization	*Handedness*	✓			✓		
	R-L Confusion		✓		✓		
Learning Difficulties	*Dyslexia*	✓			✓		
	Dyspraxia	✓			✓		
	Dyscalculia	✓			✓		
Spelling and Maths	*Spelling*	✓				✓	
	Maths Enjoyable		✓			✓	
	Maths Useful		✓			✓	

Questionnaire Measure		Self-perceived Drawing			Externally-rated Drawing		
		None	*p<.05*	*p>.001*	*None*	*p<.05*	*p>.001*
Big Five Personality	*Neuroticism*		✓		✓		
	Extraversion	✓			✓		
	Openness		✓		✓		
	Agreeableness	✓			✓		
	Conscientiousness	✓			✓		
Study Process	*Surface*	✓				✓	
	Strategic	✓				✓	
	Deep	✓			✓		
Artistic Practice	*Drawing*			✓		✓	
	Painting		✓		✓		
Drawing Devices	*Geometry*		✓			✓	
	Perceptual	✓			✓		
	Outline	✓			✓		
	Usage			✓		✓	
Masculinity	*Sex*			✓	✓		
	Masculinity			✓	✓		
	Instrumentality			✓	✓		
	Expressiveness		✓		✓		
	Schizotypy	✓			✓		
Education	*GCSE*		✓				✓
	AS-Level	✓				✓	
	A-Level	✓			✓		
	Age	✓				✓	
Parents and the arts	*Sympathetic*	✓			✓		
	Practice	✓			✓		

3.4.1 Observational Drawing Interacts with other Artistic Abilities

It can be seen from the results of this survey study that drawing ability interacts with a number of other artistic activities and abilities. Firstly, self-perceived drawing skill correlates significantly with the accuracy scores given by external raters of the drawings made by the participants in this study. This finding is of practical importance to the methodologies presented in Chapters 5, 6, 7 and 8, as self-perceived drawing skill scores are used to stratify experimental samples in terms of drawing skill. This finding also suggests that art students see drawing accuracy as an important component of the quality of their drawings despite interview data from Chapter 2 suggesting that artists see observational drawing as a heterogeneous artistic activity which is not exclusively concerned with achieving photo-realistic representations. Furthermore, and vindicating assertions as to the importance of drawing made in the aforementioned interview study, the vast majority of the sample reported that improving their observational drawing whilst studying at art school was very important to them. These data suggest that observational drawing still serves an important purpose in art education and in the perception of talent in artists themselves. This finding vindicates a longer term aim of the project outlined within this thesis; to provide a psychological account of an artistic activity that can be applied in the setting of art and design education to enable aspiring artists to develop their technical skills. Artists appear to be acquiescent to the notion of ongoing observational drawing training as a crucial element of their artistic development.

The use of drawing devices was significantly correlated with externally rated drawing ability. Whilst each of the drawing devices presented in the questionnaire was reportedly used by the sample of art students, only a quarter of the sample used any of the devices frequently in their drawing practice. The most commonly used devices were producing quick sketches to eliminate detail and plotting out pivotal points on the image at the beginning of the drawing to record the fundamental global proportions of the figure. Whilst the latter device helps in guiding the drawing process, it is unclear how individuals faithfully represent proportion in the first place. The role of proportional perception and global/local approaches to perceptual processing are explored in the experimental investigations in Chapters 5 and 7. The sporadic use of a wide range of drawing devices reflects the apparent heterogeneity of the drawing process within the discussion with artists in Chapter 2. However despite the apparent heterogeneity of the sample in terms of their use of drawing devices it was found that the tendency to use one drawing device predicted the tendency to use another. This could be due to the fact that the range of drawing devices produces similar effects on perception and production within the drawing process. In the later experimental chapters (Chapters 5 & 6) in the thesis I seek to find perceptual

processing enhancements that are common to all proficient draughtsmen. Evidence for the particular perceptual processes involved in observational drawing arises when looking in more depth at participants' perceived observational drawing abilities. Whilst perceptual factors were referred to a number of times within the interview study, it appears from the survey data that proficiency in these areas is not predictive of externally rated drawing skill, whereas an understanding and proficiency at representing geometrical relationships is related to proficiency in drawing. This notion is explored further in studies of angular and proportional relations in Chapter 5.

The survey data show that art students perceived there to be a link between proficiency in drawing and proficiency in other artistic media, such as the use of colour and three-dimensional and mechanical materials. This finding supports the idea of drawing as a ubiquitous medium which underpins other artistic activities, such as design, sculpture and painting, as suggested in the conclusions of Chapter 2. However, when externally rated drawing ability was taken into account, there was only a relationship between proficiency with 3D subject matter and drawing accuracy. The role of manipulation of 3D objects in drawing makes intuitive sense; a fundamental task of drawing is to convert the 3D to the 2D, and previous studies have shown abilities at mental rotation to be related to drawing ability (Kozbelt, 2001). It can be suggested that if an individual can envisage an object from multiple viewpoints, they will be better at correctly rendering any particular viewpoint into a 2D representation. In support of the link between mental rotation and drawing, an interest in areas of design was related to self-perceived drawing skill in the survey study, again highlighting the link between 2D and 3D manipulative capacities and drawing.

3.4.2   Visual Imagery has an Imagined link with Drawing Ability

Research previously suggested that there is a link between visual imagery capacities and drawing ability (Perez-Fabello & Campos, 2007; Rosenberg, 1987). In the current study two different questionnaires were employed to measure self-assessed imagery capacity. Scores on the VVIQ and the object component of the OSIQ appeared to represent the capacity for object imagery (imagery for the detailed visual properties of individual objects). Imagery for spatial relations appeared to be independent of object imagery, corroborating the notion of the object and spatial pathways in higher level vision (Haxby et al., 1991; Kosslyn & Koenig, 1992; Ungerleider & Mishkin, 1982). An interesting dissociation arose in the current data set when exploring the relationship between the two measures of drawing ability (self-perceived and externally-rated) and object and spatial visual imagery capacity. Whilst scores on the VVIQ and both components of the OSIQ correlated moderately with

self-perceived drawing ability (r~.28), this relationship disappeared when correlations with externally rated drawing ability were conducted.

This result suggests that either some individuals consistently highly rate their abilities across all measures, or that artists believe there to be link between visual imaging capacities and drawing ability. Whichever explanation holds true, it does not appear to be the case that imagery as measured by self report relates to drawing ability when external raters judge the accuracy of drawings. It could be the case that visual imagery is implicated in situations in which individuals need to manipulate visual representations or create new ones, and therefore could be linked to creative drawing or caricature. Furthermore, there has been some criticism of the use of questionnaire methodologies to elicit individual differences in visual imaging capacity, and the advocation of objective measures of visual imagery have been propounded (Borst & Kosslyn, 2010). However, in terms of the current study it appears that visual imagery can be excluded from an explanation of individual differences in drawing ability

3.4.3 Handedness and Learning Difficulties

The role of handedness in artistic ability is still of debate (Edwards, 1989; Lanthony, 1995; Lanthony, 2005; Mebert & Michel, 1980; Magnus & Laeng, 2006). In the context of the current study left and right handed individuals showed no differences in either self-perceived or externally-rated drawing ability. The data from the survey study runs contrary to the conclusions of Magnus and Laeng (2006) that drawings produced by the left hand are superior. In their study only one ambidextrous individual was used and it may be the case that within ambidextrous individuals there is evidence for superiority in the left hand. The current data suggest however that this is not the case for those that are ambisinistrous. However, the finding that handedness does not correlate with drawing ability does not constitute a refutation of the laterality of brain structures involved in the drawing process (Edwards, 1989) as these differences are not necessarily manifest in differences in handedness. Lateralization of the brain regions recruited during observational drawing is more explicitly examined in the voxel based morphometry (VBM) analysis outlined in Chapter 8 which correlates grey matter density in the cerebral and cerebellar cortices with drawing accuracy, and finds lateralisation of grey and white matter density increase in relation to drawing ability. In a similar pattern to findings for handedness, there was no evidence that confusion between left and right underpinned poor drawing ability as assessed by external raters, although those that experienced problems distinguishing left and right did report poorer drawing skills, perhaps reflecting a response bias to all items on the questionnaire rather than a meaningful correlation.

Previous evidence has suggested that dyslexia may underpin some drawing difficulties (Winner, von Karolyi, & Malinksy, 2000) although a later study found no link between dyslexia and drawing accuracy (McManus et al, 2010). In the current study again no evidence was found for poorer drawing performance in dyslexic individuals. However in this instance a positive correlation between spelling ability and externally-rated drawing ability was found. This correlation was weak (r=.20) but significant, and perhaps is representative of the tendency for those who perform better academically to show superior drawing ability, rather than a direct link between spelling and drawing ability. It is unlikely that this finding supports the notion that perceptual deficits due to dyslexia are directly responsible for poorer performance at observational drawing tasks.

The pattern for mathematical abilities and difficulties shows a similar pattern to those of the spelling and dyslexia measures. Those that enjoyed and found maths useful had higher drawing ratings and perceived themselves to be better at drawing. Mathematical attainment at school was also related to externally-rated drawing ability, providing further support that academically achieving individuals are also more likely to have superior drawing ability. In a similar vein to the results of the spelling, it could be the case that the relationship between mathematical attainment and drawing ability is driven by individual differences in academic ability. The same trend is reflected in the relationship between overall GCSE, AS-Level and A-Level grades discussed in the exploration of demographic factors. However, specific learning difficulties associated with maths were not related to problems with drawing, much as dyslexia diagnosis was unrelated to drawing ability.

3.4.4 Practice does not always make Perfect

As outlined in the introduction to this chapter, it has been suggested that extensive and prolonged practice is the key to achieving expertise in a number of domains (Ericsson, Krampe, & Tesch-Römer, 1993; Hayes, 1981; Sosniak, 1985; Gustin, 1985; Kalinowski, 1985; Wallingford, 1975; Monsaas, 1985) and it is likely that developing expertise in drawing is no exception. In an initial regression analysis the amount of time that participants spent drawing in the last two years predicted accuracy scores given by independent raters, when time spent painting in the last two years was taken into account. This finding supports studies into the effects of drawing experience on other perceptual abilities directly or indirectly relating to drawing (Carson & Allard, 2013; Zhou et al., 2012). However in a path analysis, it appeared that time spent drawing only indirectly predicted drawing ability, through time spent engaging with techniques for drawing, which itself was a strong predictor of drawing ability. This finding suggests that not all time spent practicing drawing is time well spent, particularly for those with a surface approach to learning who show lower

drawing ability than those who take a deep or achieving approach to studying. It is evident from this analysis that time spent practising must be used to engage fully with the drawing process, to discover and develop new techniques, in order to progress as a draughtsman.

A contingent hypothesis for the current survey study was that there would be a link between conscientiousness and drawing ability as those that were more conscientious would be willing to practise more and thus develop their skills at a faster pace than their peers. However, no correlation was found between conscientiousness and externally-rated drawing ability in the survey data, nor did conscientiousness predict time spent drawing in the last two years. Instead conscientiousness was positively associated with achieving approaches to learning on the basis of the path model (Figure 3.10). Therefore, in this instance it can be proposed that conscientious individuals are more likely to strive for successful understanding of the skills necessary to develop good drawing skills, rather than purely a drive to practice.

The hypothesis that certain learning styles would relate to drawing ability was supported. It was the case that those who took only a surface approach to learning were worse at drawing. It can be seen then that a surface approach to drawing, whilst encouraging practice due to fear of failure, does not result in engagement with the drawing process, therefore is less likely than the other two approaches to learning to be productive. However, contrary to the experimental hypothesis an achieving rather than a deep style of learning was associated with higher drawing accuracy scores. Individuals who take an achieving style to learning may be more focused on the quality of the end product, and do not muse too deeply over the processes. On the other hand a deep approach will encourage individuals to try lots of drawing techniques, in an attempt to understand the process better, which may incidentally lead to better drawing overall, but this approach may be time consuming and result in many unfruitful experiments, again leading to a lack in proficiency, at least in the shorter-term. Intuitively it would seem that if drawing is *over* intellectualised then it may be difficult to progress. It is also probably the case that those who take a deep approach to learning are less involved with superficially 'accurate' drawings and perhaps desire more expressive and aesthetic outcomes.

A potential methodological problem with the current learning style scale being used that should be highlighted here is that the scale was developed for medical students, for whom these styles of working are relevant and familiar. Art students may encounter different learning contexts to medical students and therefore may have felt that the questions from the SPQ did not pertain to their learning processes, rendering the SPQ less applicable to their experiences of developing as artists. It may be fruitful in the future to develop a range of study process questionnaires, adapted for particular vocations.

3.4.5 Neither Masculinity nor Gender Predicts Differences in Drawing Ability

When males and females were compared in the current study, men were found to rate themselves more highly in terms of drawing skill but there were no differences when externally-rated drawing ability was analysed. This finding suggests that there are no differences in drawing ability due to sex, merely that males believe themselves to be more proficient than females. Also it appears that case that sex differences in relation to factors underling drawing ability cancel the role of sex over all out. Females perform better academically, which is correlated with drawing ability, but show reduced achieving approaches to learning, which is also correlated positively with drawing ability. In the case of masculine traits there were found to be associations between male-identified behaviours and self-perceived drawing skill. Those that perceived themselves to be less expressive and more instrumental were more likely to rate themselves as more proficient at drawing. When external drawing ratings were analysed however, it was found that neither masculinity nor its subscales related to externally rated drawing ability. Finally, contrary to the conclusions made in Glazek's (2012) paper we found no association between schizoptypal traits and drawing ability either as a whole or in relation to the three schizotypic subscales.

3.4.6 Educational Attainment Supports Drawing Ability

As alluded to in the discussion of reading, writing and numerical abilities in individuals who show superior drawing skills, overall academic attainment predicted drawing ability, however the influence of academic attainment on drawing decreased over time, with correlations being higher at GCSE level than A-Level, perhaps due to the heterogeneity of educational experience at higher educational levels. In the path analysis it was shown that GCSE grades predict drawing ability independently of all other background variables. Surprisingly though, the fact that participants' parents engaged in or were sympathetic towards the arts did not influence self-perceived or externally-rated drawing scores, suggesting that an individual's drive to pursue drawing is more important that parental involvement.

3.5 Interim Conclusions

The survey data presented characterises drawing as one of many manifestations of artistic abilities which are interconnected and dependent on one another. Drawing seems to be particularly related to design and the manipulation of 3D visual input. Art students appear to approach the process of observational drawing in highly heterogeneous ways. However, there is a substantial degree of overlap between art students' assessments of their own

drawing ability and external raters' assessments of accuracy suggesting that the two measures relate to one construct, thus both measures can prove useful in pinpointing the psychological processes that underpin observational drawing. There is evidence from the current data to suggest that the etiology of drawing ability differs depending on the type of dependent variable under consideration, as some predictors of self-perceived drawing ability did not predict externally-rated drawing scores, most notably in the case of visual imagery. This finding raises an interesting question about the validity of the various methods employed to measure artistic ability and more importantly raises the question of which measure is the most valid to use in experimental investigations of this nature. In an academic arena in which ecological validity must reach a compromise with experimental rigour, it is crucial to produce findings that are reliable yet applicable to the artistic community, and therefore the method of measurement of the phenomenon under question is paramount. The next chapter in this thesis approaches this question directly by reviewing the relative merits of using external ratings, self-perception and objective shape analysis techniques to assess drawing ability. With a firmer methodological foundation in place it will be possible to introduce the later experimental studies (Chapters 5-8) with an understanding of the methods needed to quantify complex and nuanced dependent variables such as artistic ability and with a decision as to which kind of dependent variable will prove most fruitful in these investigations.

The current findings concerning the relationship between visual imagery and drawing ability are the most compelling examples of where self-perceived and externally-rated measures of drawing ability depart from one another. The non significant relationship found between externally-rated drawing ability and imagery measures appears to suggest that the link found with self-perceived drawing ability is epiphenomenal upon participants' general assessments of their ability across the scales in the questionnaire (those that rated themselves positively in one scale were likely to do so in other unrelated scales), or more specifically it may reflect lay intuitions concerning the link between internal and external imaging abilities. Thus, it is valid to conclude from the current data that visual imagery can be eliminated from the range of psychological processes that underpin drawing ability. With visual imagery excluded from this exploration, it becomes more critical to further investigate the role of other internal representations that may play a role in drawing, such as those stored in long and short-term visual memory. It was beyond the scope of the current survey study to explore visual memory as there are few subjective measures with which to quantify memory abilities. Therefore the role of visual memory in drawing is experimentally investigated in Chapter 7, in which a series of long and short-term visual memory tasks were employed in order to further characterise the interaction between stored and online visual

representations during the drawing process. Established and novel visual memory paradigms were used to connect existing theories of the functions and characteristics of visual representations with current perceptual theories relating to observational drawing.

Both the qualitative and quantitative data presented in Chapters 2 and 3 highlight the heterogeneity of the devices and abilities associated with observational drawing, posing a challenge to researchers attempting to identify common areas of perceptual processing that might characterise the many and various instances of observational drawing. Despite the disparate range of responses however, a focus on geometry and local and global detail in relation to drawing has arisen from the literature review of perceptual functioning in ASD and expert artists, which has been supported by the conclusions of the interview and survey study. Therefore these two components form the focus of a substantive part of the rest of the thesis (Chapters 5 & 6) in which local detail focus and ability to represent angular and proportional spatial relationships are examined experimentally. The conclusions of these studies, alongside the study concerning visual memory (Chapter 7) feed into the final empirical chapter that explores the neural basis of observational drawing (Chapter 8), by associating both drawing ability and perceptual abilities that directly relate to drawing ability with the development of neural structures as a function of expertise. The neuroimaging investigation also serves to corroborate the conclusions from the survey study that lateralization in handedness does not contribute to drawing proficiency, by exploring the lateralisation of neural structures that are associated with drawing ability.

It has become clear from the findings of the survey study that academic attainment predicts drawing ability. This could be due to one or both of two independent factors. It could be the case that underlying differences in IQ which predict differences in spatial ability could also predict performance in a task like drawing, which has a strong spatial component. To test this prediction in the later empirical work presented in this thesis individual differences in IQ will be tested for to ascertain if they are correlated with the ability to draw. If this is the case then IQ could be the mediating link between many spatial abilities and drawing. Therefore it will be important to factor IQ into the experimental design wherever links are seen between IQ and the independent variables under question. Previous research has suggested that graphical competency and IQ are not related, such that general low intelligence does not prevent the development of drawing ability (O'Connor & Hermelin, 1987b). An alternative linking factor between academic attainment and drawing ability could be the role of engagement in learning. It has been found that a strategic approach to learning correlates significantly with drawing ability as well as GCSE grades. Drawing ability is higher in those that practiced drawing more within in the past two years, but this did not appear to be influenced substantially by individual differences in personality

traits. Furthermore, individual differences in approaches to learning appear to drive the link between masculine personality traits and drawing ability. An inclination to be competitive and assertive may drive the desire to achieve when drawing, and persevere in the face of failure. Masculinity may also be related to improved spatial skill as suggested in the introduction to this chapter (Berfield et al., 1986; Krasnoff et al., 1989). As spatial skills were not tested explicitly in the survey sample, it is unclear whether masculinity relates to spatial ability in the current study, but this prediction can be tested in the later empirical studies in which tests of spatial ability like the block design task are used. Sex effects on drawing were cancelled out by their relationship with academic success and achieving approaches to learning.

The next chapter takes a brief deviation from the current theoretical questions concerning the psychological underpinnings of drawing ability to consider the way in which drawing ability is measured. As mentioned previously, it is crucial to use both valid and reliable methods of obtaining a dependent variable in the experimental studies that follow. Therefore, a full investigation of quantification of drawing ability was conducted, and the most appropriate method for measuring drawing accuracy was used in the subsequent empirical investigations of perception, visual memory and neural processing.

Chapter 4.   Quantifying Drawing Accuracy

'Pictures and sculptures of any style possess properties that cannot be explained as mere modifications of the perceptual raw material received through the senses'

Rudolf Arnheim

(Arnheim, 1956, p.163)

4.1 Introduction

Before presenting behavioural and neuroscientific investigations into the perceptual and memorial foundations of observational drawing, it is necessary to take a deviation and consider one of the most challenging methodological aspects of research into the visual arts; that of quantifying the quality of visual artworks. This is of critical import to the current thesis as dependent measures in each of the following experimental chapters utilise subjective judgements of drawing accuracy as a key dependent variable. In this chapter I argue that subjective aesthetic preferences permeate evaluation of the accuracy of art works, often preventing the reliable measurement of accuracy for comparison across studies. In the context of scientific study of the visual arts it is desirable to develop paradigms that measure artistic skill (or perceptual sensitivities) independently from subjective aesthetic experience. The current chapter demonstrates alternative modes of assessing the accuracy of drawings, with a view to providing a more reliable and valid dependent measure of drawing ability as a foundation for the remaining empirical components of the thesis.

Advances in the analysis of paintings shed light on how artistic output can be effectively quantified and have proved effective in demonstrating where paintings mimic, and where they depart from, real visual scenes. (Graham et al., 2009; Graham, Hughes, Leder, & Rockmore, 2012; Juricevic, Land, Wilkins, & Webster, 2010). Whilst there appears to be a relationship between how artists represent statistical regularities in natural scenes and in their art, work by Daniel Graham and colleagues has revealed that luminance spectra in natural scenes and paintings differ. Differences in luminance scaling (termed the artists look-up table; ALUT) could characterise artistic style (Graham et al., 2012). It is argued that by strategically enhancing and reducing luminance gradients in particular parts of the image, artists can achieve a greater communicative effect. The same can be said for drawing in which representations are greatly simplified (especially in caricatures) and in doing so may communicate object identities more effectively than photographs (Graham et al., 2009). The aforementioned research demonstrates that qualities of artworks can be effectively quantified to answer meaningful questions about the nature of artistic ability and visual perception.

As painting has been analysed using a quantitative approach, it can be argued that observational drawing is also viable for quantification. Quantitative analyses of drawings could shed light on the nature of effective representation in the same way as analyses of luminance spectra in painting. Like painting, drawing is bound by a two-dimensional surface, and is often focused upon an object or scene that can be compared from the same perspective as the resultant image. This makes it possible to make direct comparisons

between the artwork and its subject relatively easily. However, unlike the analysis of painting, drawing may not introduce aesthetic considerations about colour and is more linear in nature, lending itself to shape analysis rather than the analysis of other image statistics such as luminance spectra (Graham & Field, 2007).

In the past psychologists have made attempts to quantify drawing ability in a variety of ways. These projects have typically sought to evaluate drawing as a means of measuring other cognitive skills, such as intelligence in the Goodenough-Harris draw-a-man test (Scott, 1981) or general artistic ability in Clark's drawing abilities test (Clark, 1989). Whipple (1919) presented 7 separate tests of drawing ability, including the Steacy Drawing Constructions Tests, the Manual Perceptual Learning Test, the Esthetic Appreciation Test and Drawing a Toy Wagon from Observation Test. This extensive list of tests pertaining to drawing ability represented a surge of research that took place at the turn of the 20th century. Such tests fell out of fashion (only one of the tests that Whipple cited remains in use today; as part of the Stanford-Binet intelligence scale) when it was later argued that none provided an adequate assessment of ability or aptitude in the visual arts (Buros, 1972; Eisner, 1972; Khatena, 1982).

The quantification of drawing ability is of importance to the growing body of research that explores the relationship between perceptual processes and observational drawing skill (Cohen & Jones, 2008; Cohen & Earls, 2010; Kozbelt, 2001; Kozbelt et al., 2010; McManus et al., 2010; McManus et al., 2011; Ostrofsky et al., 2012). These studies tend to use a subjective rating method for assessment of drawing accuracy, which typically entails asking novice or expert raters to estimate the accuracy of each drawing compared with its subject (see 3.3.1. Drawing Rating Procedure for Hand and Block Drawings). Inter-rater reliability for this method has been shown to be high, with Cronbach's alpha values of up to 0.9 presented in previous studies (Cohen & Bennett, 1997; McManus et al., 2010; Ostrofsky et al., 2012). Despite reliability of the rater method being high, appraisals of the attractiveness of a piece of work can skew appreciations of likeness, which presents a problem for researchers attempting to reliably quantify aspects of drawing ability.

Cohen and Bennett (1997) clarify the problem of defining accuracy in one of the first papers to investigate the source of drawing errors,

> Our use of the term *visual accuracy* suggests that an objective description of accuracy can be made. This description, however, is both culturally determined and difficult to describe (see Gombrich, 1984). We operationally defined a visually accurate representation as one that can be recognized as a particular object at a particular time and in a particular space, rendered with little addition of visual detail that cannot be seen in the object represented or with little deletion of visual detail.......... Because this definition relies on a viewer's judgment, however, the visual accuracy of any specific work of art is ultimately a subjective decision.
> (p.609)

The authors suggest that because accuracy is reliant upon the viewer's perception, it is inherently a subjective judgement. Therefore it can be suggested that those measures of accuracy that seek to reduce or eliminate viewer based judgements may be argued to be more 'objective' methods of establishing visual accuracy. Aaron Kozbelt, who also conducted an extensive study of perceptual abilities of artists, highlighted the problem of settling upon an adequate definition of drawing accuracy,

> Determining the accuracy or realism of depictions turns out to be surprisingly tricky. Because no meaningful objective measure of accuracy exists, one must rely on the consensual assessment of raters.

> (Kozbelt et al, 2010, p. 95)

Kozbelt argues that no meaningful objective measure of accuracy exists. It is the intention of the current chapter to assess this claim by investigating the potential role of shape analysis in the assessment of drawing accuracy, with a view to providing a 'meaningful' objective measure of accuracy.

4.1.1 Theron Cain and the Quantification of Drawing Ability

An early attempt to quantify drawing accuracy as a means of assessing artistic ability for entrance to art school, which has a bearing on more recent work into drawing accuracy was conducted by Theron Cain in 1943. In Cain's study art students drew irregular hexagons (described as the cross-sections of houses) from observation (Figure 4.1).
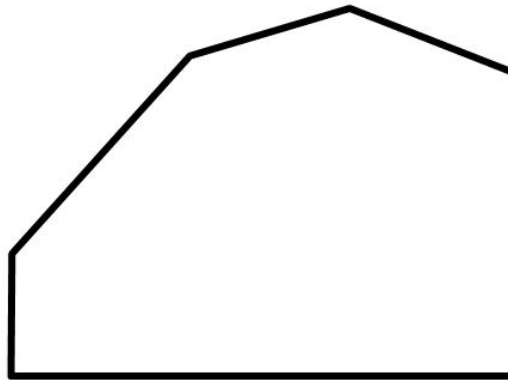
Figure 4.1. An example of the Cain house task stimuli used in the current study

Cain began by assessing a series of methods by which to measure the accuracy of the drawings of the houses; including measurement of the area and the difference in length between the contours of a model and a copy. He finally employed a protractor methodology to measure angular accuracy which he found to be the best indicator of shape error. Angular accuracy on the house task was compared with scores from art school drawing examinations. It was found that angular accuracy in the house drawing task predicted drawing ability at examination in art school. Cain suggests that accuracy in the house task may be a product of innate perceptual ability, as correlations with drawing test scores measured earlier in the academic year were higher than those with scores taken later in the year. He suggests that such a method could be used to assess innate talent for drawing as opposed to previous training, and also as a non-subjective means of measuring drawing ability. Cain celebrates a quantitative approach to drawing assessment. In the opening remarks of his paper he stated that,

> The implication is evident that aesthetic considerations become less and less possible with each gain in objectivity [in methods used for measuring drawing accuracy]. This seems to be unavoidable and inherent in the essentially subjective nature of aesthetic experience. However, we need not deplore this fact. Both aesthetic and perceptual sensitivities are important but distinct elements in art talent and, if they are measured separately as independent variables, we will doubtless obtain a more complete and useful profile of an individuals' artistic powers than if they were measured together as one vague mixture (1943, p.36)

In this statement Cain makes an important claim about the way empirical studies into the visual arts should conceptualise skill. He suggests that in order to fully understand the nature of artistic ability, perceptual and aesthetic elements must be studied and explained independently.

The analysis of drawing accuracy has moved on technologically and theoretically since Cain's early study in which angles of simple six-sided geometric shapes were analysed, from now on referred to as Cain's house task as the stimuli resemble the cross sections of houses. However, it is still of interest to assess whether Cain's simple technique of judging drawing accuracy can be brought to bear on higher level drawing ability. McManus et al (2010) successfully replicated Cain's original finding that angular accuracy in the house task predicted drawing ability, suggesting that there is some validity in the technique and that it is worth probing further.

The key to establishing objective methods for analysing drawing accuracy in the current context most likely lies within shape analysis. Rudolf Arnheim comments on the analysis of shape in relation to art in his seminal work '*Art and Perception: A Psychology of the Creative Eye'* (1956). He argued that the most accurate way to describe the spatial features that represent shapes is to determine the location of the points on an image that make up these spatial features. He draws on Alberti's recommendations in *'On Sculpture'* (1972) that by utilising a ruler, protractor and plumbline all spatial relationships expressed by angles and distances between points can be defined. Arnheim likens this approach to that which occurs in analytic geometry, in which shape is determined through the definition of spatial location of the shape's points, relative to a vertical and horizontal Cartesian coordinate. Whilst this is primarily an instruction for how artists can successfully represent shape more generally, this approach can also be harnessed to analyse the accuracy of drawings. Indeed, this is the approach that studies in this field have adopted (Carson & Allard, 2013; Hayes & Milne, 2011). By employing digital analogues to Alberti's ruler, protractor and plumbline they can capture some or all of the spatial features that represent shape and use these digital analogues to compare a drawing and the drawn object or scene.

As previously stated, in recent years interest has increased in using quantitative methods for measuring drawing accuracy in order to increase experimental validity and reduce variance due to subjective noise or bias. Angular accuracy was set at the heart of the drawing, both as a method for quantifying accuracy, and as a measure of perceptual performance in relation to expert ability in a study by Carson and Allard (2013). The authors piloted a method in which they selected particular un-occluded acute and obtuse angles in a still life composition and measured the accuracy of the drawings of these angles by expert and non-expert artists. They used this measure to assess which parts of a visual scene were drawn accurately and which were not. They suggest that angular accuracy in positive spaces was greater than angular accuracy in negative spaces (that is the shapes created by the relations between objects, rather than the shapes of the objects or their parts; illustrated in Figure 2.1).

Some researchers harness shape analysis techniques from other academic fields to produce objective measures of drawing accuracy (Costa & Corazza, 2006; Hayes & Milne, 2011). Shape analysis methods have been used in the biological sciences for some time. D'Arcy Thompson used a 'theory of transformations' to explain how the differences between biological species can be represented by differences in geometrical properties after one object is warped into another (Thompson, 1917). The techniques of most relevance to the analysis of observational drawing are landmark-based geometric methods which use sets of biological landmarks or coordinates and shape analysis procedures such as Kendall's shape space (Kendall, 1989) or Procrustes distance (Goodall, 1991). After the effects of non-shape variations such as translations, scaling, shearing and rotation have been filtered out analysis of the remaining shape information can be used to determine the degree of relation of one set of coordinates to another. In evolutionary biology shape analysis can be used to determine the extent to which two species are related. In much the same way shape analysis can be employed to compare the accuracy of drawings with their subjects.

Hayes and Milne (2011) used geometric morphometric information in faces to investigate drawing accuracy in portraiture. Morphometrics refers to the study of shape variation and its covariation with other variables (Adams, Rohlf, & Slice, 2004). Drawing on anthropometric theory the authors analysed three methods for portrait drawing evaluation: visual assessment, anthropometric measures and geometric morphometric analysis. Visual assessors were required to rate each portrait's likeness to a photograph of the sitter in the same position, and to also assess various elements of the photograph and portrait such as featural configuration and pitch, cant and turn of the head. For each assessor two dependent variables were derived: likeness ratings and assessments of properties of the shape and position of the head. In relation to the drawing studies already discussed, the former assessment is probably most akin to subjective accuracy ratings given by expert or non-expert judges in these studies. With reference to likeness the authors stated that,

> There is a fairly good level of agreement within the theoretical literature con-
> cerned with portraiture as to what makes an effective likeness, though this tends
> to be largely anecdotal (Brilliant, 1991; Brophy, 1963; Gage, 1997; Gombrich,
> 1977, 1982; Speed, 1917; Sturgis, 1998). Although linked to a slavish copying of
> life, a portrait that is perceived to be too precise a recording of an individual's
> facial features, is generally thought to result in a poor representation.

(Hayes & Milne, 2011, p. 150)

Whilst Hayes and Milne argue that actual mimesis is not conducive to 'likeness' on the basis of aforementioned anecdotal evidence, they also highlight that portraiture manuals (Edwards, 1989; Maughan, 2004) often argue that a deviation from the visual stimulus inevitably leads to inaccuracies in the appearance of the portrait, suggesting that shape analysis measures should capture perceived accuracy or likeness. Furthermore they make an interesting prediction about the relationship between scale and shape in reference to portrait likeness. Whilst shape analysis measures may be impervious to scale changes (these are transformed) they will still be sensitive to shape changes.

> While both exaggeration and generalization do not constitute a mimetic rendering of an individual's facial appearance, they are not entirely inaccurate either. The more tangible transformations that occur in the translation of a living person into a traditional 2D portrait tend to be somewhat less than desirable; that is, largely unintentional manipulations of the sitter's facial shapes which more often than not are unintended side-effects of the processes involved in visual perception.

(Hayes & Milne, 2011, p.151)

This statement suggests that shape analysis techniques are particularly suited to the assessment of the accuracy of drawings, as they disregard scale and orientation differences to focus purely on shape deviation. In Hayes and Milne's (2011) study they found that visual assessment did not coincide with anthropometric morphometric evaluations of pitch and cant of the head. This finding suggests that subjective perceptions of the actual visual features of the portraits were inaccurate; participants were not perceiving the photographic stimuli correctly. Furthermore, assessments of likeness did not relate to Procrustes distance, an estimation of the deviation of set of predefined landmarks on the portrait with corresponding landmarks on the photograph of the face. This finding suggests that perceived accuracy or likeness of a drawing with its subject does not correlate with objective likeness derived from shape analysis techniques. However, the authors were unable to say what kind of distortions lead to increased likeness ratings of portraits. Furthermore, the results suggest that, contrary to their proposal, deviation from the actual shape of the subject *does* affect likeness ratings, as Procrustes gives an overall impression of shape deviation rather than scale.

The discrepancy between perceived accuracy and objective accuracy has been explained as resulting from the tendency of artists to use bias in their representations, to create heightened aesthetic effects which are misconstrued as increased likeness (Hayes & Milne, 2011). Ernst Gombrich (1960) suggested that artists emphasise features unique to an

individual viewpoint, whilst omitting certain visual details, encouraging the viewer to 'fill-in' the gaps. The tendency of artists to systematically emphasise or downplay elements of the face was highlighted by Costa and Corrazza (2006) in a study of feature portrayal in artistic portraits. Over seven hundred portraits were compared with a large control sample of photographic portraits. It was found that certain facial features were consistently enhanced including eye roundness, lip roundness and eye height resulting in a face that is less wide and more vertical with a more pointed chin. These findings were later confirmed in a study in which art students were required to construct self-portraits which were then compared with original photographs. The authors argue that systematic biases in representation are evidence of the formation of 'supernormal stimuli' which encourage an aesthetic response in the viewer. It could be the case that aesthetic responses could bias subjective ratings of 'likeness', resulting in the mismatch between objective and subjective measures of accuracy found in Hayes and Milne's (2011) study.

A tension appears to exist between different shape analysis approaches to the evaluation of drawing ability. On the one hand Cain's (1943) and Carson and Allard's (2013) studies suggest that higher-level drawing accuracy can be predicted by simple objective attributes such as angles between lines on the drawn image, such that pure accuracy seems to be the determinant of higher-level drawing accuracy. On the other hand, research into the accuracy of portraiture seems to suggest that artists deliberately skew their drawings to create an illusion of likeness that is unrelated to objective measures of accuracy, as there was no correlation between anthropometric measures and estimates of likeness (Hayes & Milne, 2011). Therefore, it remains unclear whether objective measurements of accuracy predict whether a drawing will resemble its subject. Stimuli in the studies of Cain (1943), Carson and Allard (2013) and Hayes and Milne (2011) differ in their semantic content. It can be argued that faces are a special form of visual stimulus and may be subject to their own rules of representation which are independent from other visual objects. Therefore, likeness judgements in the instance of faces may be more subjective than objects with less emotional and semantic content. It is important to assess the relationship between objective measures of shape and different complex visual stimuli other than faces and across a range of simple and complex images. An assessment of the relationship between advanced shape analysis methods like Procrustes analysis (see data preparation section 4.3.1. for a description of Procrustes analysis) and more simplified methods such as the protractor method used by Cain (1943) and Carson and Allard (2013) has yet to be undertaken and would shed light on the relationship between perceived and objective accuracy with regard to drawing ability.

The primary aim of this study was to explore the relationship between subjective measures (likeness of accuracy judgements by viewers) and objective measures of drawing accuracy (shape analysis and angular/proportional measurements). Without an estimate of objective accuracy it is not possible to say how a third person impression of an image differs from its real life subject. Furthermore, it is not possible to establish to what extent subjective estimates of accuracy deviate from objective measures, if indeed they do at all. Research into the accuracy of portraiture seems to suggest that artists deliberately skew their drawings to create an illusion of likeness that is unrelated to objective measures of accuracy produced by shape analysis techniques. As there is no research assessing likeness and objective measures of accuracy in representations other than those of faces, an investigation into varying kinds of visual stimuli is necessary. Costa and Corrazza (2006) suggest that manipulation of the shape of local features changes the appreciation of likeness. To that end the current study aimed to assess the relationship between objective measures of both local and global accuracy with subjective ratings. It was hypothesised that global objective accuracy must remain intact to promote likeness measures, whereas local measures of accuracy may deviate from subjective measures of accuracy. On the basis of Hayes and Milne's (2011) findings it was hypothesised that shape analyses of drawing accuracy would not correlate with subjective ratings of drawing accuracy. However, if a correlation was to be found between objective and subjective measures of drawing accuracy, it was hypothesised that the correlation would be on a global rather than a local level as local deviations could be in line with emphasis of features whereas global inaccuracies would be more likely to be misjudgements of shape and result in unconvincing drawings.

4.2   Method

4.2.1   Participants

The sample consisted of an aggregation of the samples of three studies conducted for different purposes:

1. *Sample 1.* Art students (N=44, 24 female, Mean Age = 21.0, SD= 4.2) studying for a foundation degree at Swansea Metropolitan University (SMU).

2. *Sample 2.* Art students (N=105, 84 female, Mean Age=21.6, SD=8.1) studying for a foundation degree at Swansea Metropolitan University (SMU).

3. *Sample 3.* This sample consisted of university students attending undergraduate and post-graduate art and design degrees at Camberwell College of Art (CAM) and The Royal College of Art (RCA) respectively (N=20, 16 female, Mean Age = 23.3, SD= 6.2). The remaining participants within the third sample studied a variety of non

visual arts degrees at UCL and served as controls (N=25, 16 female, Mean Age=24.4, SD=8.5).

4.2.2   Apparatus and Stimuli

All tasks were performed individually within one testing session lasting between 1-1.5 hours at SMU, the RCA or UCL. Tasks were conducted in the order presented in the procedure.

4.2.3   Procedure

Task completion by sample.

1. *Sample 1.* Completed hand, block and Cain drawing tasks

2. *Sample 2.* Completed Malevich drawing task

3. *Sample 3.* Completed hand, block and Cain drawing tasks

4.2.3.1 Observational Drawing Tasks

Drawing tasks were completed on A4 (297 × 210 mm) heavy-weight art paper (130 g.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 60Hz refresh rate (Figure 4.2).

Cain House Task. Participants were instructed to make an accurate drawing of five irregular hexagonal shapes based on those of Cain (1943) described as representing the cross-sections of different houses. Each shape was presented for one minute. Participants were instructed to focus upon replicating the angles and proportions of the shapes as accurately as they could.

Hand, Block and Malevich Photographs. Participants were instructed to make an accurate drawing of a photograph of a hand holding a pencil, a block construction and a painting by Kasimir Malevich (5 min per image).
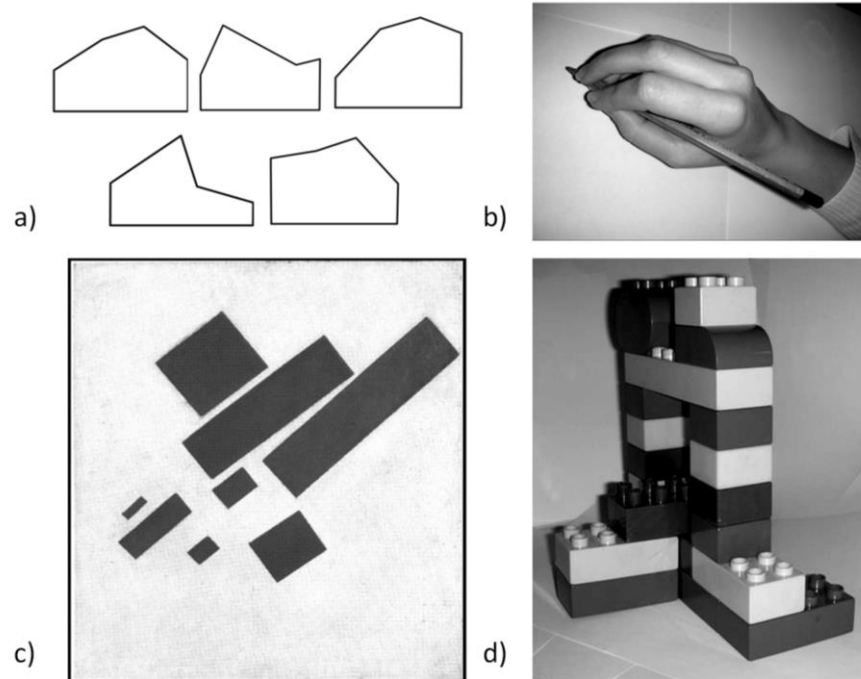
Figure 4.2. Drawing Stimuli - Cain Houses, Hand and Block Photographs, and Kasimir Malevich 'Suprematism with eight red rectangles' (1915)

Ethics

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

4.3   Results

4.3.1   Data Preparation

4.3.1.1 Drawing Rating Procedure for Hand, Block and Malevich Drawings.

See 3.3. Data Preparation, for a full description of the procedure for rating the accuracy of participants' drawings.

4.3.1.2 Angle and Proportion Measurement in the Cain House Task.

Digitised images of the Cain house drawings were entered into an analysis program on MATLAB 7.10 which recorded 6 key points on the image in a coordinate frame. Angular error on the Cain house task was calculated by deriving angular measurements from the six angles enclosed by the six sides of each house, and subtracting these from the true angular values in the original stimulus. Proportional error was calculated by dividing the five non-

horizontal sides by the base length of the stimulus and comparing these proportions with the proportions of the original stimulus. All errors were transformed into absolute errors.

4.3.1.3 Procrustes Analysis for House, Block, Hand and Malevich Images

In the same way as the Cain house drawings, a series of coordinate points were taken from both the hand, block and Malevich images for entry into shape analysis packages (Figure 4.3). In the case of the block images, major intersections between orthogonal lines were chosen as key landmarks, amounting to 34 points in total. For the hand image, major anatomical landmarks were chosen, so each knuckle and the inclination where the hand meets the wrist formed the pivotal landmarks in this image, amounting to 18 points in total. For the Malevich, points were marked at the corner of each of the eight rectangles, totalling 32 points.
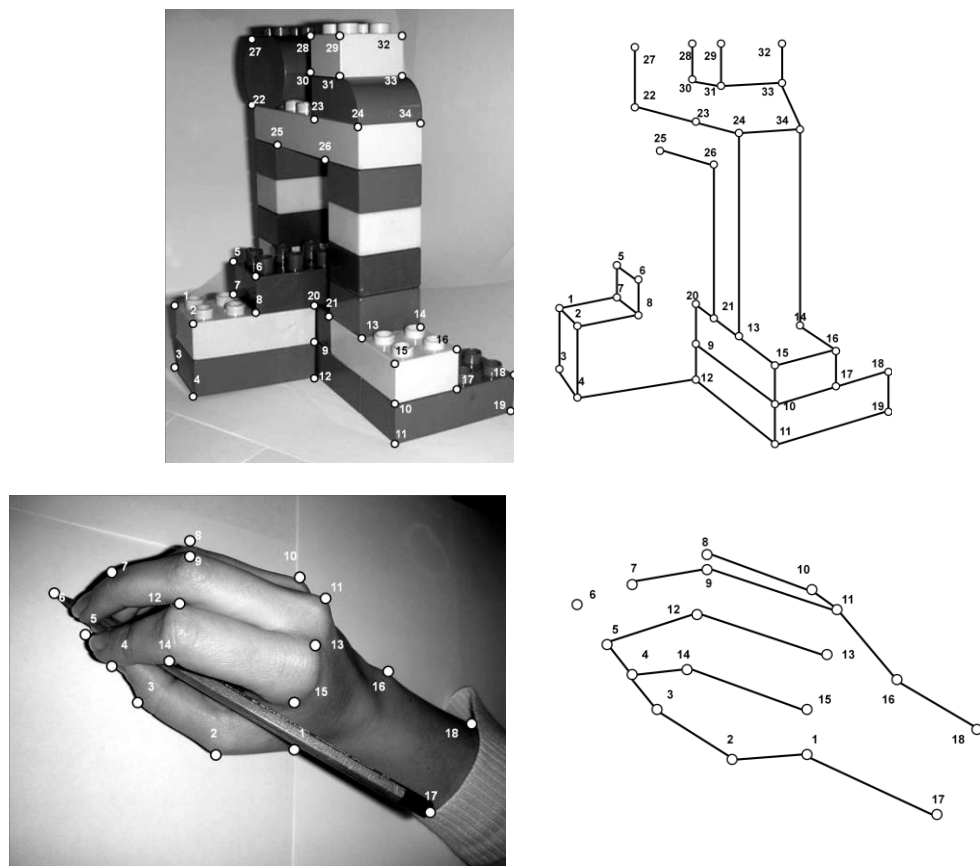
Figure 4.3. The coordinate entry system for block construction and hand stimulus, with and without baseline photographic images

Procrustes analysis technique was employed in MATLAB 7.10 using Statistics Toolbox 8.0 to determine the similarity between participants' copies of the Cain houses, the block construction, the hand photograph and the original images. Procrustes analysis is a technique used to establish the best commonality of shape between two images, each of

which has been marked with a set of mathematical landmarks. Euclidean transformations are performed, namely scaling, orthogonal rotation, reflection and translation. Translation is applied first, then scaling, rotation and reflection (if required). The final transformation is that which results in the least sum of squares distance between the input coordinates and the target coordinates. After transformation, the transformed set of coordinate points can be superimposed onto the target set of coordinate points (Figure 4.4). A least sum of squares goodness of fit measure between 0 and 1 is then produced that describes the similarity between the target and the transformed image; 0 denotes a perfect fit between target and transformed image. For more information on Procrustes shape analysis see Bookstein (1991), Goodall (1991) and Gower and Dijksterhuis (2004).
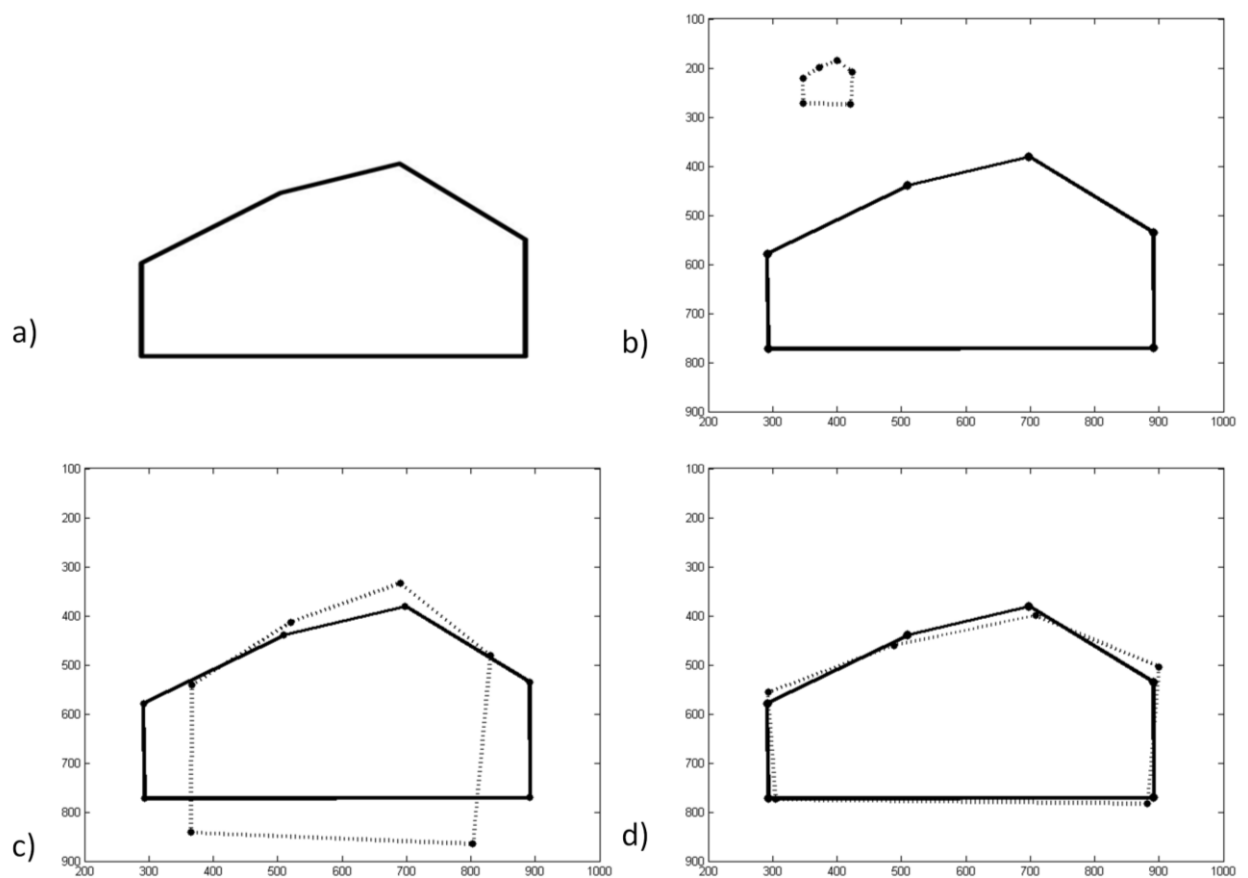
Figure 4.4. Examples of Procrustes and Affine Transformations using the Cain House Task stimuli. a) The original Cain house that was copied, b) Coordinate points of a participant's drawn image of Cain house 1(dotted line) alongside baseline coordinate points of original Cain House 1 (solid line), c) Procrustes transformed coordinate points of participant's drawn image (dotted line) alongside baseline coordinate points of original Cain House 1 (solid line), d) Affine transformed coordinate points of participant's drawn image (dotted line) alongside baseline coordinate points of original Cain House 1 (solid line).

4.3.1.4 Affine Transformation for House, Block and Hand Images

An affine transformation works in much the same way as generalised Procrustes analysis. However affine transformations also include vertical and horizontal shearing which can overcome stretching on the horizontal and vertical axes. Although angles and lengths do not remain the same, parallel lines do remain parallel and straight lines remain straight, preserving the shape characteristics necessary to evaluate deviations in accuracy between the copies and the original images (for more information on affine transformation and it's application to shape analysis in Matlab see Solomon & Breckon, 2011). Affine transformation was performed in Matlab 7.10 using the *cp2tform* function in the Image Processing Toolbox 8.0. The *cpt2tform* function infers a spatial transformation on the basis of a set of control landmarks and returns a structure which describes the transformations necessary to fit a new set of landmarks to the control set. After deriving the affine transformation matrices from the *cpt2tform* function, a transformation was applied to each set of input coordinates, and an affine distance score was calculated by comparing the sum of squared deviations of the affine transformed coordinates with the sum of squared deviations of the target coordinates. This again produced a value between 0 and 1 to describe the fit between the input coordinates and the target coordinates.

4.3.1.5 The Relationship between Procrustes and Affine Transformation

Whilst Procrustes and affine are presented as two methods of shape analysis, the transformations made by the two techniques show a high degree of overlap. Both transform in terms of translation, scaling and rotation. In addition affine analysis performs shearing to eliminate the skew parameter. Affine analysis is of interest to the current analysis, as some participants may make errors of shape but not overall proportion, whereas others may stretch the image horizontally or vertically but preserve all other shape characteristics. The effect of skew on subjective judgements was therefore assessed by comparing the independent contribution of Procrustes and affine analysis on subjective accuracy ratings.

4.3.2   Data Analysis

4.3.2.1 Observational Drawing Ratings

Participants' scores for the hand and block drawings were averaged across the ten non-expert raters. Inter-rater reliability was high, with Cronbach's alphas of .92 for hand drawing ratings and .93 for block drawing ratings. Figure 4.5 shows the range of participants drawings. Participants were rated as slightly more accurate in the hand drawing task (M=4.58, SD=1.37) compared with the block drawing task (M=4.50, SD=1.23). Hand drawing ratings significantly positively correlated with block drawing ratings, r (76) =.59,

p<.001, and therefore a composite drawing rating was produced by averaging drawing ratings for the hand and blocks for each participant. Drawing ratings were also taken for the Malevich drawings (M=3.53, SD=1.44). In this instance there were no exemplars against which to compare quality so raters ranked drawings in categories from best to worst (best=1, worst=7). Four raters judged the accuracy of the Malevich task yielding a Cronbach's alpha of .72.

Lowest (1.88)   Median (4.00)   Highest (7.00)

Lowest (1.75)   Median (4.30)   Highest (7.20)
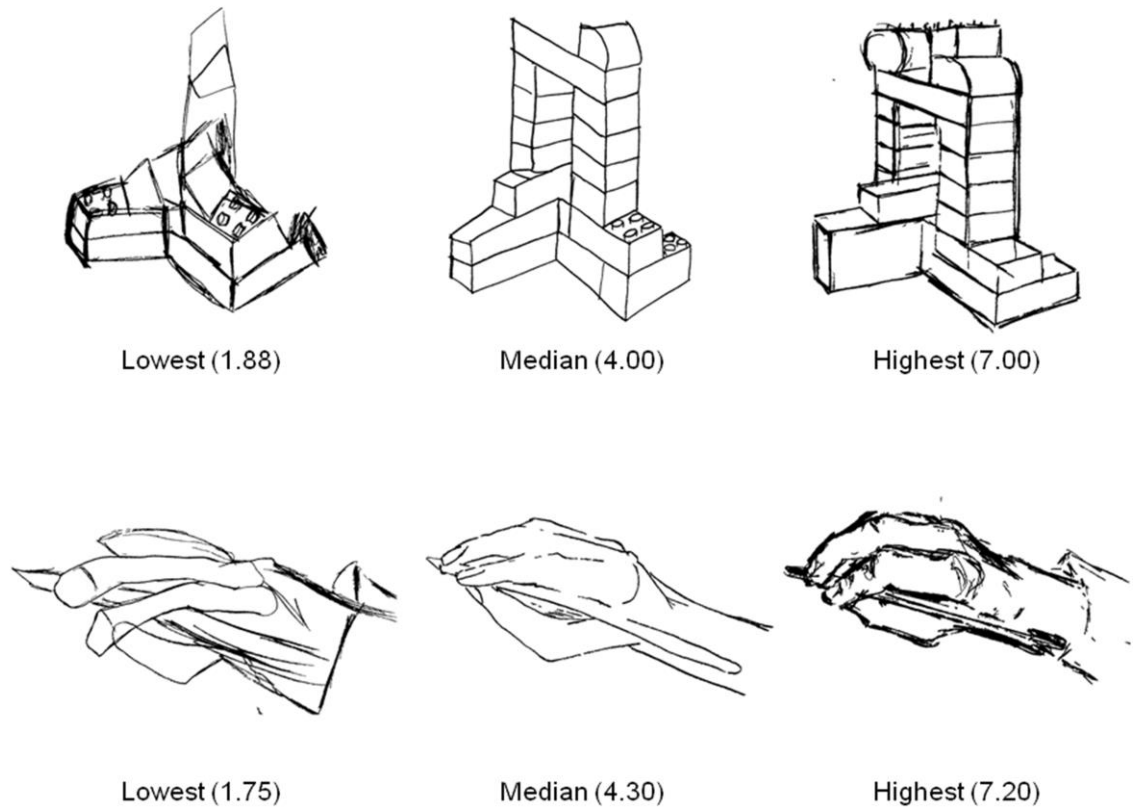
Figure 4.5. High, median and low drawing ratings for hand and block stimuli

4.3.2.2 Procrustes and Affine Transformation

Procrustes and affine distance scores were calculated for drawings of the block construction, hand photograph and the Malevich painting by calculating the least sum squares distance from the Procrustes/affine transformed coordinates to the baseline shape coordinates. Distance scores were multiplied by 1000 and are displayed in Figure 4.6. Outlying scores more than 3 times the interquartile range were excluded from further analysis.

4.3.2.3 Relationship between Procrustes and Affine Analysis

As can be seen from Figure 4.6 participants were most accurate in the Malevich task and least accurate in the hand task.
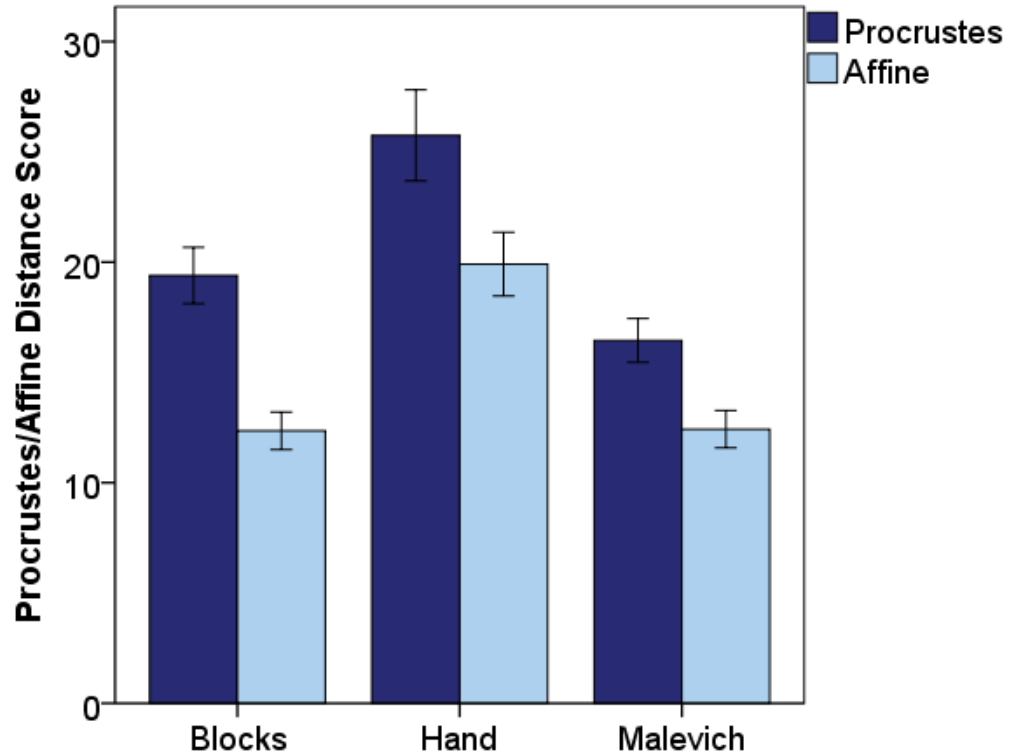
Figure 4.6. Mean Procrustes and Affine distances for the blocks, hand and Malevich drawing tasks. Higher distance scores indicate lower drawing accuracy. Error bars represent +/- 1 standard error of the mean (SEM).

In a 2×2 ANOVA with Procrustes and affine distance scores for both the hand and the block tasks as the dependent variables, there was a main effect of shape analysis method (Procrustes distance scores were significantly higher than affine distance scores for both the hand and blocks tasks, F (1, 52) =75.45, p<.001), and a main effect of stimulus type (the hand stimulus produced higher distance scores than the block stimulus, F (1, 52) = 15.09, p<.001). There was also an interaction between shape analysis method and stimulus type, F (1, 52) =4.06, p<.05, as there was a greater reduction in accuracy between the hand and block drawings with affine analysis compared with Procrustes analysis, suggesting that removing the skew from drawings had a greater effect on subjective accuracy ratings of the block task. Within-subjects analysis for the Malevich task could not be conducted as this task was performed by a separate sample, however a paired samples t-test in this instance revealed that affine scores were significantly higher than Procrustes scores for this task, t (104) =2.71, p<.01.

Correlation matrices were produced to assess the degree of agreement between the two objective measures of accuracy, to assess how distinct the affine and Procrustes approaches were:

1. Affine distance for the hand/block/Malevich drawings

2. Procrustes distance for the hand/block/Malevich drawings

From the correlation matrix (Table 4.1) it can be seen that Procrustes and affine distance scores in the hands, blocks and Malevich tasks correlated extremely highly with each other, suggesting that shearing images during transformation did not greatly affect the resulting estimates of drawing accuracy. This was particularly salient in the affine analysis of the hand task. However, it remained of interest as to whether one form of objective drawing accuracy measurement was more predictive of subjective accuracy ratings by taking account of the skew of the drawings, therefore the analysis proceeded using both affine and Procrustes scores as independent variables.

Table 4.1. Correlation matrix for affine and Procrustes scores of drawing accuracy for hand, block and Malevich drawings (n range=53-81).

	Procrustes Transformation		
	Hand	Block	Malevich
Affine Transformation	.93**	.79**	.99**

Notes: p<.01**

4.3.2.4 Analysis of the Cain House Task in Relation to Shape Analysis Scores and Subjective Accuracy Ratings

Angular and proportional accuracy in the Cain house correlated significantly with one another, r (65) =.35, p<.01. Angular and proportional accuracy in the Cain task was compared with shape analysis measures of the hand and blocks task combined. Angular accuracy correlated significantly with both affine and Procrustes analysis of the drawing tasks (Table 4.2). Proportional accuracy showed the same pattern as angular accuracy in relation to the affine and Procrustes analysis of the hand task.

Table 4.2. Correlation matrix for objective measures of drawing accuracy in the Cain house task and affine and Procrustes distance scores for the hands/blocks tasks (n range=49-65)

	Cain House Task	
	Angle	Proportion
Hand/Blocks Affine	.46**	.38**
Hand/Blocks Procrustes	.43**	.43**
Hand/Blocks Rating	-.36**	-.16

Notes: p<.01**

This suggests that both angular and proportional accuracy contribute to the estimates of accuracy derived from shape analysis techniques, and that the lower level protractor/ruler technique is an adequate reflection of more complex methods of assessing drawing accuracy. In the instance of the drawing ratings however there was a dissociation between angular and proportional accuracy in the Cain house task. While angular accuracy correlated with subjective drawing ratings for the hands and the blocks, proportional accuracy was not significantly correlated with drawing ratings. This suggests that angular accuracy is more important to subjective ratings than proportional accuracy is. The relationship between angular accuracy and drawing performance is more extensively studied using the Cain house task in the next chapter.

4.3.2.5 Procrustes and Affine Analysis for Hands, Blocks and Malevich Drawings and Subjective Drawing Accuracy Measures

A correlation matrix was produced to assess the relationship between global Procrustes and affine distance scores for the hand, block and Malevich drawing tasks and ratings of the accuracy of drawings of the same stimuli (Table 4.3).

Table 4.3. Correlation matrix for affine and Procrustes shape analysis with subjective judgements of accuracy on the hands and blocks drawing tasks (n range 50-105).

		Hand Rating	Block Rating	Malevich Rating
Affine	Local	-.19	-.57**	-.45**
	Global	-.47**	-.64**	-.16
Procrustes	Local	-.36**	-.69**	-.17
	Global	-.45**	-.59**	-.14

Notes: p<.01**

It can be seen that there are high and significant negative correlations between affine/Procrustes scores and hands and blocks ratings. Correlations between Procrustes/affine distance and rating judgements of accuracy were higher for the block stimulus than the hand stimulus. Affine analysis accounted for 39.5% of the variance in block accuracy ratings, where Procrustes analysis accounted for 33.4% of the variance. Similarly, affine analysis accounted for 20.2% of the variance in subjective accuracy ratings in the hand drawing task, where Procrustes analysis accounted for 18.1% of the variance. However, in the case of the Malevich there were no significant correlations between accuracy ratings and Procrustes/affine analysis. Across the tasks, affine analysis was more predictive of subjective accuracy ratings, suggesting that skewing did not affect subjective accuracy ratings, as the objective measures of accuracy were more sensitive to subjective accuracy judgements after shearing.

4.3.2.6 Local and Global Shape Analysis for Hands and Blocks

Having established an association between the objective shape analysis measures and subjective ratings of accuracy in the hand and block drawing tasks, a further series of local accuracy measures were taken for each of the drawing tasks using the shape analysis methods. To conduct the global-local analysis, the hand and block coordinate maps were split into quadrants (Figure 4.7). Procrustes and affine analyses were then rerun for coordinate point groupings in each quadrant. The Procrustes and affine distances for each quadrant were averaged to produce local measures of accuracy for each image.
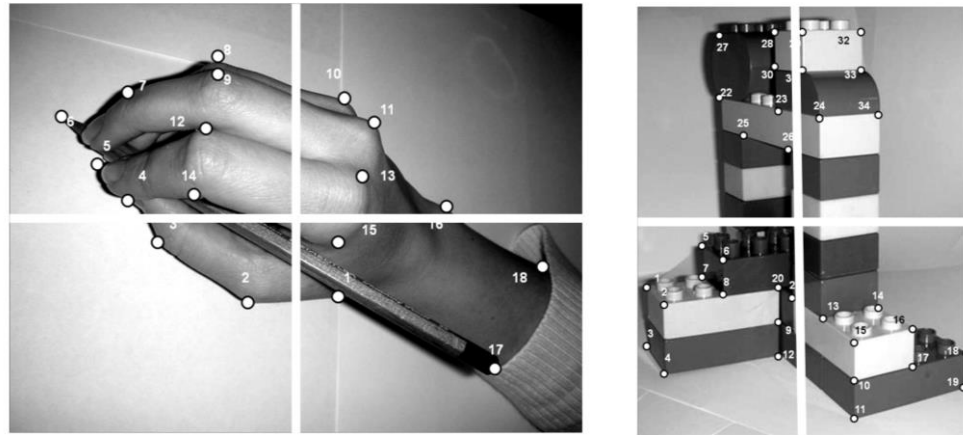
Figure 4.7. Coordinate entry for Procrustes and affine analysis and divisions made for local shape accuracy analysis.

Table 4.3 shows the correlation matrix for local features of the hand and block tasks and subjective accuracy ratings. It shows that in analysis of the blocks tasks, subjective accuracy measures relate to all local measures as well as global measures. However in the case of the hand task it appears that subjective accuracy ratings relate to a lesser extent to local estimates of objective accuracy, especially in the instance of affine analysis. To test whether the difference between correlations between local and global affine scores and hand ratings was significant, a Meng's Z-test for correlated correlations was conducted (Meng, Rosenthal, & Rubin, 1992). This test was applied as it takes into account the fact that local and global affine scores for these tasks are correlated (hand task, r (51) =.49, p<.001; blocks, r (69) =.71, p<.001). There was a significant difference in the correlations between hand accuracy ratings and global and local affine scores for the hand, z (51) =-2.07, p<.05, but not for the block task. This finding suggests that raters analyse the hand task in a more global manner than the blocks task. The same analysis was conducted for testing the difference between correlations between global and local Procrustes scores and drawing ratings. However, in this instance there were no significant differences in the correlation for the hand or block task.

4.3.2.7 Local and Global Shape Analysis for Malevich

For the Malevich an accuracy score for each individual rectangle was taken for affine and Procrustes analysis. These scores were then averaged to produce a local accuracy score for each analysis method. Local Procrustes accuracy scores reflected the findings for global accuracy and were not significantly correlated with drawing ratings for the Malevich painting (Table 4.3). However, whilst global accuracy scores were not correlated with subjective drawing ratings, local accuracy scores were significantly correlated with drawing ratings for the affine analysis, suggesting that subjective ratings were driven by local accuracy, without consideration of

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proportional distortion for local elements evidenced by no significant correlations with any of the Procrustes distance scores. This finding was confirmed with Meng's Z-test which revealed a significant difference between correlations between global and local affine distance scores and drawing ratings for the Malevich, z (105) =-2.88, p<.01, but no significant difference in the case of Procrustes local and global analysis.

4.4   Discussion

The aim of the current study was to evaluate the relative merits of differing approaches to measuring drawing accuracy. The analysis has revealed commonalities and differences between subjective and objective measures of higher-level and lower-level drawing ability using shape analysis, simple angular and proportional analysis and rating data. I will first address what shape attributes the Procrustes and affine analyses appear to be driven by and the limitations of such methods, and then discuss their validity in comparison with subjective drawing ratings. To reiterate, the initial hypotheses were that there would be a relationship between angular and proportional accuracy in the Cain house task and drawing ratings, but no relationship between shape analysis measures of more complex stimuli (hand/blocks/Malevich) and subjective ratings. The first hypothesis was supported in the case of angular accuracy, replicating previous findings, however the second hypothesis must be rejected as robust correlations between objective and subjective measures of accuracy were found when comparing Procrustes and affine distance scores with ratings of higher-level drawing tasks. Furthermore, the subjective judgement of accuracy was found to differ on the basis of global and local accuracy dependent upon the particular visual stimulus being judged.

4.4.1   The Relationship between Objective and Subjective Measures of Drawing Accuracy

Angular and proportional accuracy in the Cain task highly correlated with higher level shape analysis measures, validating Cain's technique for assessing drawing accuracy. Furthermore, in a replication of an earlier study (McManus et al., 2010), angular error but not proportional error in the Cain house task predicted subjective drawing ratings, suggesting that simple reproduction of angles can predict higher level drawing ability, and also that angular measurements could effectively predict drawing accuracy in more complex stimuli. This result is supported by the findings of Carson and Allard (2013) who measured angular accuracy in complex visual scenes and found it to be related to drawing experience. However in the current study drawing experience was not related to angular or proportional accuracy in the Cain house task. The relationship between drawing ability, angular and

proportional perception, and drawing experience is the subject of inquiry in the next chapter, where the Cain house task is again put to use.

Contrasting with the findings of Hayes and Milne (2011), and contrary to the experimental hypothesis, in the current study there was a relationship between subjective accuracy ratings (termed 'likeness' ratings in the former study) and objective shape analysis of the accuracy of participants' drawings. Affine and Procrustes distance scores both correlated with subjective accuracy ratings in the current study. The reason for a discrepancy between the current findings and those of Hayes and Milne (2011) could be that 'likeness' was interpreted more flexibly in the context of Hayes and Milne's study and thus likeness ratings could have reflected the rater's subjective impressions of whether a portrait 'captured' a particular individual in a more aesthetic, emotional manner than was intended, whereas in the study reported here participants were explicitly told only to judge how much the drawing looked like the original image, and to actively ignore aesthetic judgements. Of the two shape analysis methods employed to quantify drawing accuracy, affine transformation seems to be the more appropriate approach to characterising subjective perceptions of drawing accuracy. Regression analyses revealed that whilst both affine and Procrustes distance scores correlate with observational drawing ratings, the affine distance scores for the block drawing task accounted for more variance in subjective drawing ratings. In the case of the hand task both affine and Procrustes analyses were significant predictors, and did not contribute independent variance to the subjective drawing ratings. This finding suggests that the shearing transformation is of greater value when assessing the accuracy of more geometric stimuli, where perspective itself can result in transformations similar to affine transforms. It may be the case that subjective raters automatically perform some kind of shearing when looking at the blocks but not the hand task, due to an enhanced awareness of potential perspective tricks used to create the illusion of depth. Participants also seemed less likely to stretch the hand image than they did the block construction as evidenced by higher correlations between affine and Procrustes distance scores for the hand task than the block task. Therefore affine transformations were less useful in this context. The results were less conclusive when considering the Malevich task. There were no significant correlations between global and local Procrustes scores, global affine scores and ratings of the drawings of this stimulus. This finding suggests that rating of this stimulus is not being conducted on the basis of gross shape deviation, and that only when proportional skewing is taken into account can subjective accuracy rating be characterised. This could be due to the fact that although the Malevich was easier to define in terms of landmark coordinate points, rating drawings of this stimulus was more difficult, as the painting represented an arrangement of many different shapes whereas the hand and block tasks were

representations of single objects. In this way participants may have been focusing on local shape accuracy as this was easier to perform than assessing the whole configuration for holistic inaccuracies.

4.4.2   The Role of Global and Local Detail in Accuracy Assessment

When local deviations in shape were assessed using affine analysis, there were significant correlations between ratings of the Malevich and affine distance scores. This finding provides information as to the way in which participants are approaching the accuracy rating task in geometric contexts. Differences in objective measures of local and global accuracy were also found in relation to the hand and block tasks. Whilst the hand drawings appeared to be assessed for global accuracy by the subjective raters, both local and global components were as important for subjective evaluations of accuracy in the block task. The finding that local accuracy in shape in the hand task was not significantly correlated with subjective drawing accuracy ratings can be related to Costa and Corrazza's (2006) study in which manipulation of individual facial features was found to be related to likeness ratings. It would seem that drawings can violate local accuracy constraints but must appear holistically accurate in order to be perceived to be a good likeness. In sum, it appears that more geometric stimuli are assessed for accuracy in a more local, detail oriented manner, whilst more organic life-like stimuli are assessed for accuracy more holistically. Analysis of the objective accuracy of local and global features suggests that in some contexts local deviations in shape do not affect subjective measures of accuracy, suggesting that omitting some local landmarks may not necessarily result in a perception of inaccuracy. This finding supports the contentions of Ernst Gombrich (1960) that artists emphasise features unique to an individual viewpoint whilst omitting certain visual details. This however does not appear to be the case for more geometric stimuli like the block and Malevich task. There is preliminary evidence for deliberate emphasis or manipulation of key local elements of the image whilst preserving global shape features of a subject in the representation of organic stimuli.

It can be suggested that the minimal landmarks chosen for shape analysis (Figure 4.8) are based on those points in the image that are fundamental to object identification (Biederman, 1987; Marr & Nishihara, 1978) and are fundamental visual details in the image that an artist cannot omit for fear of rendering their drawing unrecognisable.
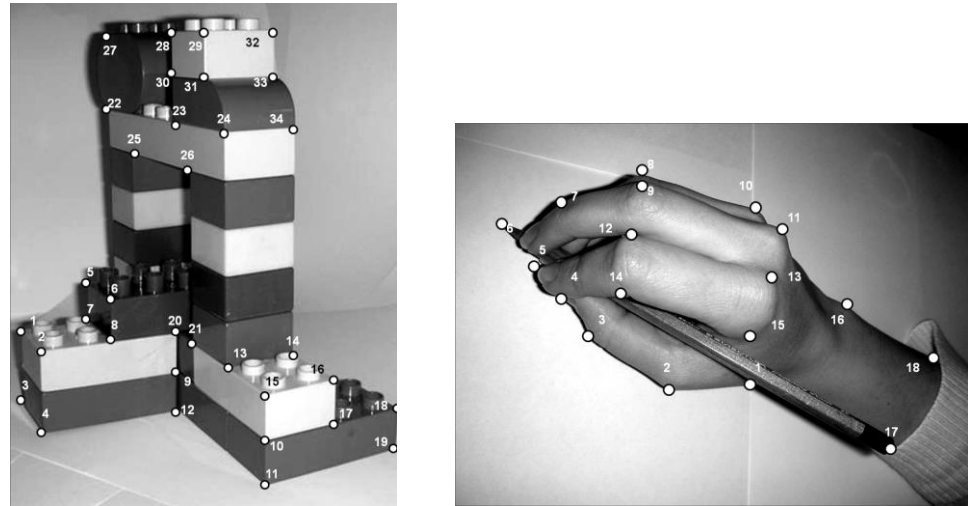
Figure 4.8. The coordinate entry system for block construction and hand stimulus

It is not possible to test Gombrich's prediction of omitted visual detail in the context of the current data, as it is unlikely that the artists chose to omit any of the landmarks chosen for analysis here. However, analysis of the objective accuracy of local and global features does suggest that in some contexts local deviations in shape do not affect subjective measures of accuracy, suggesting that omitting some local landmarks may not necessarily result in a perception of inaccuracy. It could also be the case that a proportion of the difference between objective and subjective ratings can be accounted for by the artists' deliberate *emphasis* of features defined by key landmarks. In order to investigate this it would be necessary to conduct a piece-by-piece analysis of certain aspects of the image, rather than a cumulative measure of overall accuracy as affine and Procrustes distance scores provide. In future it may be possible to use shape analysis methods to analyse parts of an image separately to asses where in the image artists and non-artists tend to make errors. Carson and Allard (2013) suggest that accuracy may differ in positive vs. negative space in a given image. It would be possible to test such a hypothesis using localised shape analysis. Therefore, whilst the current shape analysis methods remain a rather blunt tool for measuring accuracy in drawing, they have the potential to answer a number of experimental questions concerning the role of perceptual error in representational drawing.

Non-shape judgements for subjective accuracy could be further explored using digital image manipulation techniques to 'skew' the shape of drawn images to fit the landmark coordinate points of an original photographic stimulus. In this way a vast proportion of shape errors would be accounted for so that non-shape variables such as quality of line and non-shape-based depth cues which may enhance the feeling of accuracy could be more effectively isolated and studied.

I piloted this technique in a series of images created by the participants in the current study.
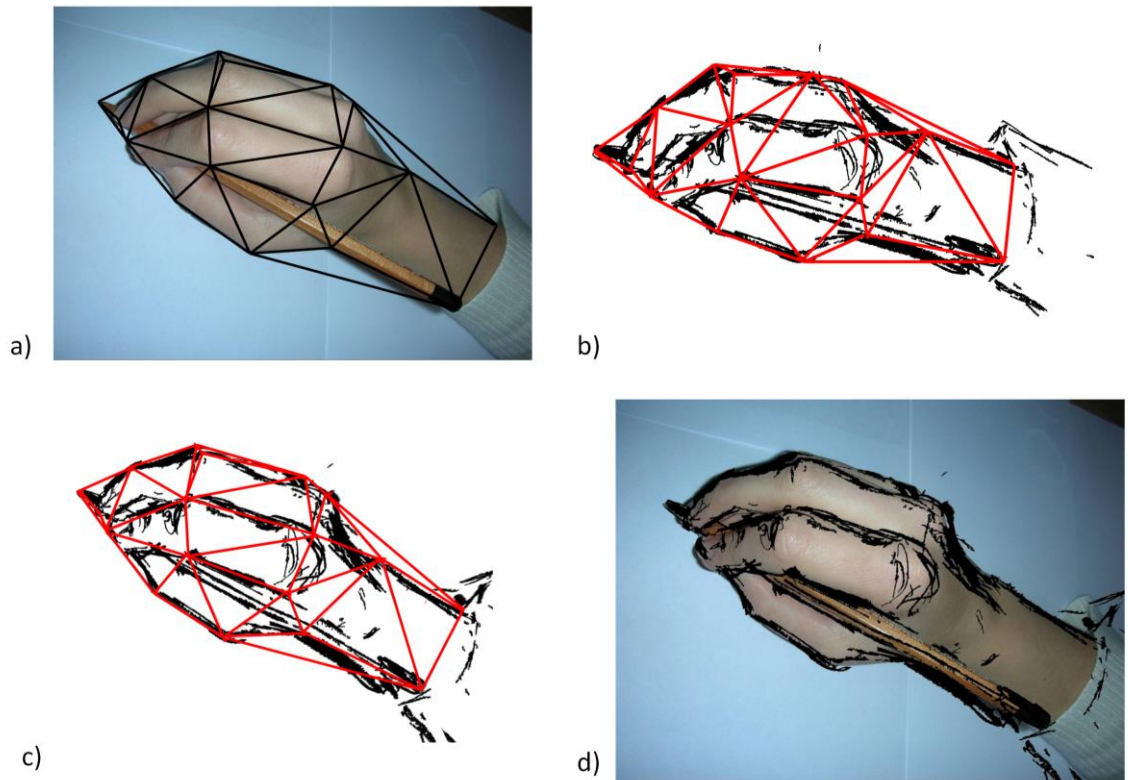
Figure 4.9. Step-by-step demonstration of piecewise linear image warping: a) Delauney triangulation of the original stimulus image, b) Delauney triangulation of input drawing, c) piecewise linear transformation and Delauney triangulation of warped drawing, d) warped drawing superimposed on original stimulus image

Warping was achieved by applying piecewise linear (affine) transformation using the aforementioned *cpt2tform* function. First Delauney triangulation was applied to the baseline points (Figure 4.9. Image a), and then to the input points (Figure 4.9, Image b) before mapping the corresponding input points onto the baseline point map (Figure 4.9, Image c). The mapping was performed by affine transformation for each Delauney triangle in the image. The best fitting set of triangular transformations is then applied to the drawn image to produce a best match to the photographic image (Figure 4.9, Image d).

Examples of this technique applied to a range of images in the image set are shown in Figure 4.10. Here a series of images are warped to fit the shape parameters of the original images. The six images of each stimulus are chosen as they represent different regions of the affine/rating space outlined in this study (i.e. high and low affine scores, and high, medium and low drawing rating scores). The drawings that reflect medium drawing ratings and either high or low affine distance scores were those that lay on the regression line between drawing accuracy ratings and affine scores.
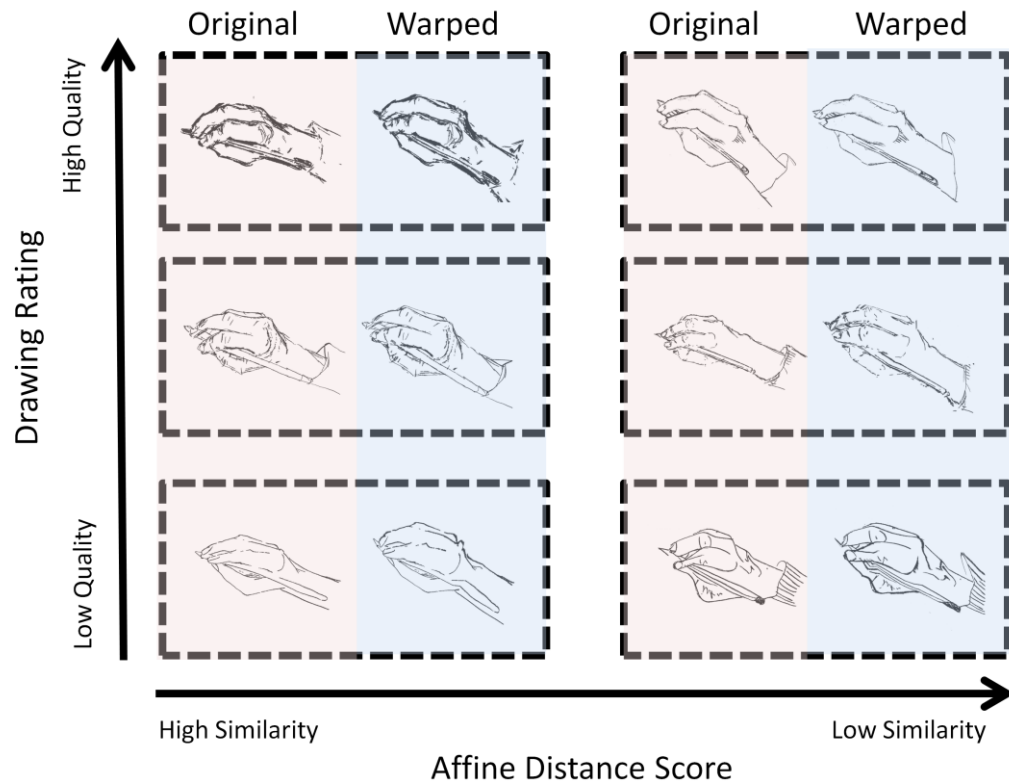
Figure 4.10. Piecewise linear warping of participants' drawings to fit as closely as possible to the original image

4.4.3   Limitations of Objective Measures of Drawing Accuracy

The shape analysis techniques used reveal subtle differences in participants' approach to the range of drawing tasks used here. However, there is a disadvantage to using shape analysis techniques to assess drawing accuracy, and that is that they take no account of the accurate drawing of curves. In the current study curved surfaces were present in some aspects of the block construction, and to a much greater extent for the hand stimulus. As can be seen in the analysis of the relationship between subjective ratings and Procrustes and affine distance scores for the hand and block drawings, the variance accounted for dropped from 26% for the block drawing to 15% for the hand drawing. It can be argued that this discrepancy in the predictive power of shape analysis for the hand drawing is because the hand has more nuances of line, whereas the block drawing is predominantly a task of correct geometry, where lines rarely deviate between two landmark coordinates. The same critique can be made of Carson and Allard's (2013) study, in which a highly geometrical still life was chosen specifically for the purpose of the measurement of angles. If researchers in the field are to provide ecologically valid measures of drawing accuracy, they must address the issue of how one effectively analyses the properties of drawn curves. As has been noted by researchers elsewhere, the

analysis of curves using computerised methods poses particular logistical problems (Schmidt, Khan, Kurtenbach, & Singh, 2009) and Cain submitted that the protractor method was inappropriate for measuring curvature (Cain, 1943). The challenges of analysing the drawing of curves have been the subject of an undergraduate research project at UCL (Lee, 2011). In this research Michael Leyton's analysis of curves in his *Symmetry, Causality, Mind* (1992), which was initially used to analyse paintings and drawings, is employed in order to characterise curved lines by parsing them according to their M+, M-, m+ and m- maxima and minima. M+ and M- represent where curves extend outward as a product of internal forces (either through protrusion or resistance) and m+ and m- represent where curves extend inward as a product of external forces (either through squashing or indentation). By establishing the greatest extent of these four curve modalities the characteristics of a curved shape can be determined and then differing curves compared with one another.

4.5   Interim Conclusions

The emphasis of key features rather than true mimesis may create the most convincing representational drawings (Gombrich, 1960). There does appear to be some overlap between individuals' impressions and quantified measures of accuracy; although the two are by no means collinear. Subjective raters are using features over and above absolute shape inaccuracy to define performance, perhaps some kind of holistic likeness measurement that encompasses line accuracy, but also quality, tone and expression. It could be the case that there are extra-shape attributes that cannot be captured by the objective measures employed here, but nevertheless inform subjective accuracy judgements. For example, the quality of the lines that the participants produced could not be captured by landmark based shape analysis, but nevertheless may have permeated subjective appraisals of accuracy. Shading was eliminated from the current drawings by converting shades of grey to monochrome during the digitization process so this quality can be excluded as an element of participants' judgements. As suggested previously, curve drawing accuracy may also have been incorporated into the subjective ratings where it could not in the shape analysis techniques. Despite the success of the current objective techniques, it must be argued that the most important element for an artist in achieving communicative effect is to convince the viewer that their work is realistic or meaningful. Therefore, and in light of the fact that subjective notions of accuracy do relate to objective measures in many respects, I would advocate the continued use of subjective raters for studies into perceptual underpinnings of drawing ability, particularly for stimuli which contain subtle nuances of line which as yet cannot be adequately characterised by the shape analysis methods outlined here. Therefore in the remaining chapters the subjective rating method is used as a dependent variable measuring

drawing accuracy; however where relevant, objective measures of drawing accuracy are also included.

In the following chapter the findings from the current study are built upon in a more extensive analysis of the relationship between low-level perception of angles and proportions in the Cain house task and higher-level drawing ability. I move on from the question of measuring drawing accuracy, to the main focus of this thesis; whether perceptual enhancements are related to drawing accuracy. The theme of the next chapter is perceptual enhancement for geometric properties of visual stimuli. Geometric in this context refers to the precision of perceptual representations of both angular and proportional relationships in visual input. To explore this theme, the Cain house task is again utilised, alongside a novel task that requires participants to replicate angular and proportional relationships between lines in a non-rendering context. The ability to match shape stimuli is also investigated under the umbrella of understanding and perception of simple shape properties.

Chapter 5.   Perception of Simple Shape Properties.

'A great draughtsman can, as far as I have observed, draw every line *but* a straight one'

John Ruskin

(Ruskin, 1856, p.38)

5.1 Introduction

This chapter summarises evidence that individuals who can draw more accurately also perceive the world more accurately in terms of its geometrical structure. From previous evidence provided by Cain (1943) it is suggested that individuals who can perceive and represent angles more veridically are able to draw more accurately. However Cain's study was confounded by individual differences in motor control as the shapes had to be drawn by hand, and both angle and proportion were inherently dependent in Cain's stimuli, making it difficult to study the independent effects of angular and proportional perception on drawing accuracy. Therefore, the current study sought to investigate the independent effects of angular and proportional perception on drawing accuracy and also to test whether this is the case in a task which is not confounded by non-perceptual factors relating to drawing. Precision for 2D geometric angles may support the perception of orientations of planes in the 3D world (Snippe & Koenderink, 1994), and therefore could be an important component of the transfer of 3D to 2D information during the drawing process. Proportional accuracy is also a vital component of drawing, as evidenced by its prominence in instructional drawing manuals. It is also a particularly salient feature of global accuracy in drawn forms as demonstrated by Procrustes analysis of geometric forms and more complex visual stimuli in the previous chapter, which showed that global shape inaccuracies in proportion were correlated with subjective ratings of drawing accuracy.

5.1.1 Perception of Angles

The perception and encoding of angles from real-world visual representations is a complex computation. Howe and Purves (2004) found that the perception of both angles and oriented lines is in part determined by the statistical relationship between geometrical stimuli and their physical sources in typical visual environments. Cognition surrounding the geometric structure of the world can therefore skew our representations of naturalistic stimuli, as Wertheimer (1923) made clear,

> Right angles surround us from childhood (table, cupboard, window, comers of rooms, houses).At first this seems quite self-evident. But does the child's environment consist of nothing but man-made objects? Are there not in nature (e.g. the branches of trees) fully as many obtuse and acute angles? But far more important than these is the following consideration. Is it *true* that cupboards, tables, etc., actually present right angles to the child's eye? If we consider the literal reception of stimuli upon the retina, how often are *right angles* as such involved? (p.223).

Wertheimer (1923) highlights the intuitive cognitive distinction between acute, right and obtuse angles, the impact that this has upon the visual system and the subsequent impact this has upon the way we represent the external world. For example, an angle of 93 degrees tends to be perceived as an inadequate right angle rather than an obtuse angle. This is termed the Goldmeier Effect (Goldmeier, 1972) and entails that obliquely projected right angles are inaccurately perceived. Right angles achieve some kind of special status, that entails that they are processed in an orientation dependent manner (Appelle, 1971). Angular processing, which is suggested to have a low-level neural basis connected with orientation selective brain regions (Regan, Grey & Hamstra, 1996), appears to be affected by our understanding of the visual environment and is dependent on global shape properties (Kennedy, Orbach, & Loffler, 2006; Kennedy, Orbach, & Loffler, 2008), which could result in perceptual effects such as shape constancy (Mitchell et al., 2005). This makes angular perception a critical faculty with respect to observational drawing. Previous studies on angular discrimination have typically focused on constant error or bias (e.g. Howard, 1982) or precision (Hakiel, 1978; Chen & Levi, 1996; Snippe & Koenderink, 1994; Regan et al, 1996), both of which could have a bearing on drawing accuracy. Bias would result in certain angles being consistently over or underestimated whereas lack of precision would result in a more random fluctuation of angular error and would probably result in more noticeable deviations from the drawn object or scene.

Snippe and Koenderink (1994) found that perception of 2D fronto-parallel angles have average thresholds of 5 degrees. This threshold is subject to individual difference; thus it is possible that individual differences in angular precision could underpin differences in drawing ability. Investigations into angular perception have also investigated whether angles are processed as holistic entities (a global strategy) or whether they are processed by comparing the orientation of two boundary lines (a local strategy) and conclude that angles are processed in a global manner:

> Our results, that angle discrimination depends primarily on angle size rather than line orientation, are in accord with the Gestalt psychologists' famous phrase "The whole is more than the sum of its parts" (Chen & Levi, 1996, p.1732)

The perception of an angle appears to be an emergent whole property of the two boundary lines that represent it. Therefore, the perceptual representation of an angle is more than the sum of representation of its parts, and angular perception appears to be more akin to shape perception than orientation perception. This proposition is supported by the evidence of Chen and Levi (1996) who showed that angle discrimination depends foremost on angular size rather than the orientation of the boundary lines, except in those angle around 90

degrees. This notion has consequences for later analyses in this thesis, in which local and global visual processing is explored in relation to drawing ability and angular and proportional perception. If angles are considered to be holistic entities, it can be assumed that enhanced local processing may help to eliminate bias based on holistic properties, whereas if they are already processed locally it can be assumed that enhanced local processing would not be related to angular perception. The effect of precision, bias, and holistic/part processing with respect to angular relationships are all of interest in the investigation of perceptual enhancements in expert draughtsmen; the effects of precision are the particular focus of the current chapter. In addition, at the conclusion of Chapter 6 the relationship between angular perception and local processing will be assessed to establish whether differences in local processing could have an impact on angular and proportional processing in this context.

5.1.2   Perception of Proportion

Proportion is a critical factor in the appraisal of visual works of art. The role of proportion has a long history in the study of visual aesthetics of art works, but the ability to perceive and represent proportion has not been studied formally with respect to observational drawing. An interest in the aesthetics of proportion of rectangles stems from Fechner's (1876) early investigations and aesthetic psychologists have long strived to uncover the 'Golden Section' (a ratio of 1:1.62, Figure 5.1) within famous works of art.
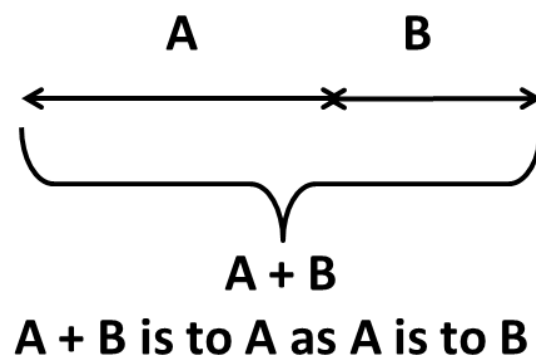
Figure 5.1. The Golden Section, the length of line A relates in the same way to the length of lines A+B as the line B's length does to the length of line A

It has been found that individuals show weak but reliable preferences for rectangles of differing ratios, but these do not appear to follow the Golden Section, and the role of this ratio in great works of art is of some doubt (Boselie, 1992; McManus, 1980; McManus, Cook, & Hunt, 2010). However, the aforementioned studies do suggest that individuals express preferences for different ratios in aesthetic studies.

Whilst there has been much investigation into aesthetic preference for proportion, few studies have explored the ability to *perceive* proportion and whether this differs between individuals. Apelle and Goodnow (1970) used a comparison paradigm to investigate proportional perception in the same manner that they analysed angular perception in a later study (Appelle, 1971). They argued that proportion is a complex property requiring the integration of two distinct perceptual elements into a single ratio. They aligned with Gibson (1966) in thinking that this ratio is independent of modality. Accuracy in judging proportion, like angular perception, also appears to obey Weber's Law and decreases from the standard form of a square (representing a 1:1 ratio) which seems to hold a special status in the same way that right angles do in relation to angular perception. Furthermore, accuracy in judging length does not impact upon proportion perception performance, reinforcing the notion that proportion is an emergent holistic property, rather than a comparison of independent elements of a visual object (Appelle, Gravetter, & Davidson, 1980).

Proportion is a critical element of drawing, which when represented incorrectly, inevitably leads to inaccurate depictions. Early drawing manuals emphasised the importance of basic proportion by reducing descriptions to simple line drawings (Kozbelt & Seeley, 2007). Schemata arguably provide artists with knowledge of proportions of visual objects and their parts (Gombrich, 1960; Kozbelt & Seeley, 2007). Therefore, expertise in representing proportion could result from top-down or bottom-up perceptual processing or indeed a combination of the two as explored in the introduction (1.4.3. Top-down and Bottom-up: A Unified Account). However, internal proportional frameworks (primary geometry that represents the main 'axes' of the drawing but aren't visible in the environment) are probably more likely to result from drawing knowledge rather than perceptual skill as they are not directly apparent from visual perception. Skill at representing simple proportions that are not entrenched in real world visual scenes or objects is most likely to be independent of the influence of schemata. Hence proficiency at a task that elicits basic proportional perception taken out of a contextual setting may provide evidence for bottom-up perceptual enhancements in expert draughtsmen.

5.1.3   Aims of the Current Study

Angle and proportion appear to be emergent, holistic properties that are perceived independently of the extent of their component parts. The ability to perceive these coherent wholes varies amongst individuals and according to perceptual laws depending on their extent. Angular and proportional perception is susceptible to cognitive penetration, and as such may fall prey to biases and perceptual constancy effects. Therefore, it is to be expected that those individuals who can avoid contextual effects on angles and proportion would

perceive and draw them more accurately. The current study sought to explore the role of low-level perception of angles and proportions on drawing accuracy. In a study of our research group, McManus et al (2010) successfully replicated Cain's (1943), finding that angular and proportional accuracy in a simple shape drawing task correlated with ratings of accuracy on two more complex drawing tasks (as was demonstrated in Chapter 4). However, proportional error was not a predictor of drawing ability when angular accuracy was taken into account in McManus et al (2010). Angular and proportional error in a higher level drawing task that required participants to copy a geometric painting by Kasimir Malevich did not correlate with drawing ability on other tasks. Cain's (1943) study suggests that higher level drawing accuracy can be predicted by simple objective attributes such as angles between lines. Demonstration that low-level perception of angles and proportions in a non-rendering context would provide support for an innocent eye conception of perceptual enhancements associated with drawing ability. Accordingly, it is not expected that cognitive strategies applied in the drawing context will be applied in a non-rendering situation and therefore if enhanced perception is present in the latter case, it can be assumed to be reflective of bottom up processing. It was predicted that precision in perception of angles and proportions as measured by the Cain House task and the line task would be correlated with drawing accuracy.

5.2   Method

5.2.1   Participants

4. *Sample 1.* Art students (N=44, 24 female, Mean Age = 21.0, SD= 4.2) studying for a foundation degree at Swansea Metropolitan University (SMU).

5. *Sample 2.* This sample consisted of university students attending undergraduate and post-graduate art and design degrees at Camberwell College of Art (CAM) and The Royal College of Art (RCA) respectively (N=20, 16 female, Mean Age = 23.3, SD= 6.2). The remaining participants within the third sample studied a variety of non visual arts degrees at UCL and served as controls (N=25, 16 female, Mean Age=24.4, SD=8.5).

5.2.2   Apparatus and Stimuli

All tasks were performed individually within one testing session lasting between 1-1.5 hours at SMU, the RCA or UCL. Tasks were conducted in the order presented in the procedure.

5.2.3   Procedure

Task completion by sample.

1. *Sample 1.* Completed Cain drawing tasks

2. *Sample 2.* Completed Cain drawing and Line Matching Tasks

5.2.3.1 Questionnaire

Art students were asked how much time they spent drawing and painting currently and over the past two years on an 11-point scale ranging from *'most days for 4+ hours'* to *'never'*. 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'*.

5.2.3.2 Observational Drawing Tasks

Drawing tasks were completed on A4 (297 × 210 mm) heavy-weight art paper (130 g.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 60Hz refresh rate.

5.2.3.3 Cain House Task

Participants were instructed to make an accurate drawing of five irregular hexagonal shapes based on those of Cain (1943) described as representing the cross-sections of different houses. Each shape was presented for one minute. Participants were instructed to focus upon replicating the angles and proportions of the shapes as accurately as they could (see Figure 4.2 for Cain house stimuli).

5.2.3.4 Line Matching Task

Stimulus presentation and data collection were controlled using the Psychophysical Toolbox (Brainard, 1997; Pelli, 1997) for Matlab 7.10. Participants were instructed to match two pairs of lines presented simultaneously on a computer screen. Stimuli were presented as white lines on a black background on a 13 inch liquid crystal computer screen with a 60Hz refresh rate. Participants sat 60cm away from the screen; at this distance each pair of lines subtended a maximum visual angle of 9.8 × 10.0 degrees and the whole display subtended a visual angle of 20.1× 16.6 degrees.

One pair of lines was located in the top left hand quadrant of the screen and the other in the bottom right hand quadrant of the screen. Both pairs of lines were centred about a point equidistant from the centre and edges of the screen. The upper stimulus line pair remained static at a fixed angle or proportion.

In each trial a method of adjustment procedure was used to make the lower (test) pair of lines match the upper (stimulus) pair of lines. Participants completed 8 trials of both angle and proportional matching. One of the two lines in the lower line pair was manipulated by the participant in a rotational motion (angle condition) or in an upwards/downwards motion (proportional condition) using a computer mouse (Figure 5.2).
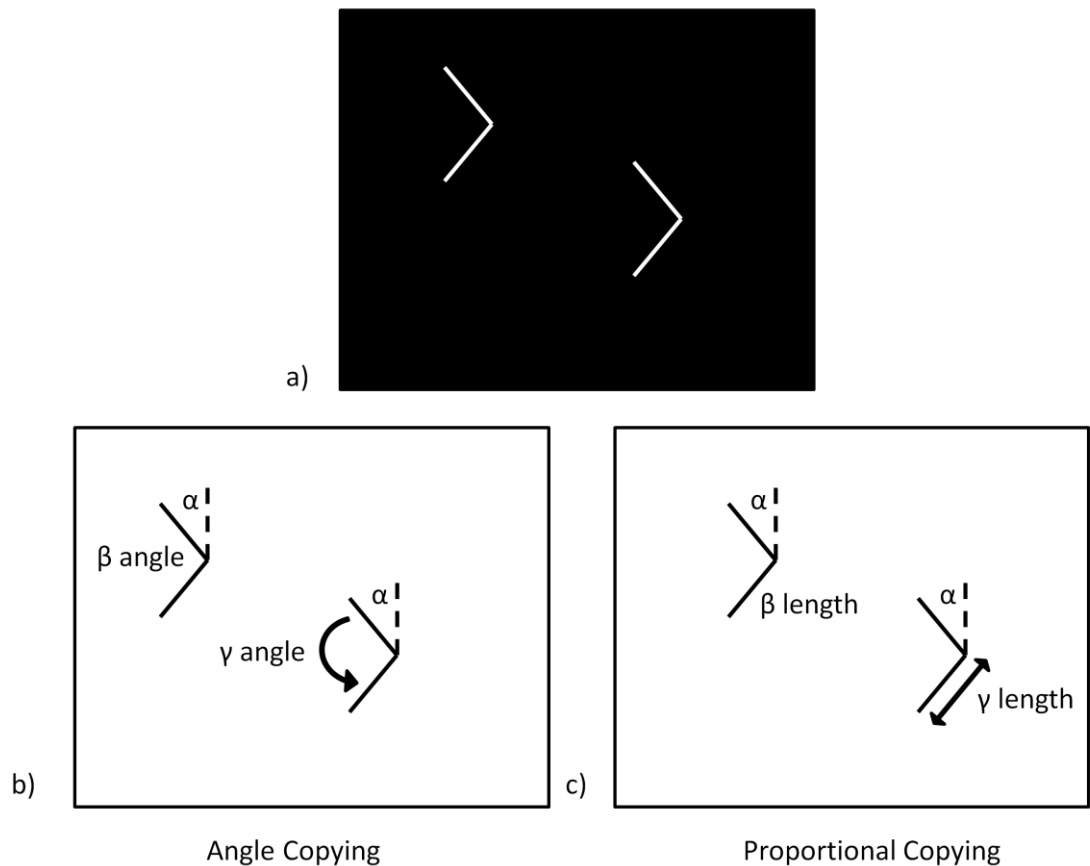
Figure 5.2. The Line Task. a) Screen shot of line angle/proportion task trial, b) Angle condition of the line task where β represents the stimulus angle, α represents the orientation of the stimulus line pair (from possible 0-90^0) and γ represents the angle to be manipulated by the participants, c) Proportion condition of the line task where β represents the stimulus line length, α represents the orientation of the stimulus line pair (from possible 0-90^0) and γ represents the line length to be manipulated by the participants.

Angle Condition. Baseline angles between the stimulus lines were 20, 40, 60, 80, 100, 120, 140 and 160°, each of which appeared once. A random angle of jitter was added to

these, to avoid practice effects across multiple viewing conditions, adding up to +/- 5° to the baseline angle. The orientation of the stimulus line pair was also varied randomly from 0° (horizontal) to 90° (vertical). The orientation of the test line pair matched that of the stimulus line pairs, such that both pairs of lines were parallel.

Proportion Condition. Baseline proportions between the stimulus lines were 1.1, 1, 0.9, 0.8, 0.7, 0.6, 0.5 and 0.4. A random level of proportional jitter was added to these to avoid practice effects, adding up to +/- 0.025 to the baseline proportion. The orientation of the stimulus line pair was also varied from 0° (horizontal) to 90° (vertical). The orientation of the test line pair matched that of the stimulus line pairs, such that both pairs of lines were parallel.

Ethics

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

5.2.4   Drawing Rating Procedure for Hand and Block Drawings.

See data preparation section 3.3 for a full description of the procedure for rating the accuracy of participants' drawings.

5.3   Results

5.3.1   Observational Drawing Ratings

Participants' scores for the hand and block drawings were averaged across the ten non-expert raters. Inter-rater reliability was high, with Cronbach's alphas of .92 for hand drawing ratings and .93 for block drawing ratings. Participants were rated as slightly more accurate in the hand drawing task (M=4.58, SD=1.37) compared with the block drawing task (M=4.50, SD=1.23). Hand drawing ratings significantly positively correlated with block drawing ratings, r (76) =.59, p<.001, and therefore a composite drawing rating was produced by averaging drawing ratings for the hand and blocks for each participant.

5.3.2   Line Task Performance

Precision (standard deviation of absolute error) was high in the angle (M=2.93°, SD=1.25) and proportion (M=3.70%, SD=1.61) conditions of the line copying task. Bias was not significantly different from zero in either the angle, t (38) =.38, p=.24, or proportion, t (38) =.32, p=.24, conditions. A correlation matrix was calculated to assess the relationship

between precision on the line copying task and the Cain house, hand and block drawing tasks.

Table 5.1. Correlations between drawing tasks and the line copying tasks (n range= 37-76)

		Cain Drawing		Line Matching	
		Angle	Proportion	Angle	Proportion
Cain Drawing	Angle	-	.35**	.40*	.08
	Proportion	-	-	.05	.43**
Line Matching	Angle	-	-	-	.31
	Proportion	-	-	-	-

Notes: p<.05*, p<.01**.

Mean drawing ratings were found to be significantly correlated with angle error in the Cain house task and with angular and proportional precision in the line copying task. Angular precision in the line copying task predicted angular error in the Cain drawing task and proportional precision predicted proportional error, but there were no cross-over correlations, suggesting that angular and proportional accuracy contributed independently to drawing ability (Table 5.1). Furthermore angular accuracy did not correlate with proportional accuracy in the line task, although this trend was approaching significance (p=.06).

5.3.3 Independence of Angular/Proportional Accuracy in Relation to Drawing Ratings

The independence of angular and proportional contributions to drawing accuracy in the hands and blocks was explored in two linear regressions. In the first the regression model was significant, $F (2, 36) =6.64$, p<.01, and both angular, $t (34) =-2.16$, p<.05, and proportional, $t (34) =-2.13$, p<.05, precision in the line matching task independently predicted drawing accuracy on the hands and blocks tasks. In the second regression, the model was again significant, $F(2, 62) =4.53$, p<.05, but only angular precision in the Cain house task was a significant predictor of drawing ratings, $t (62) =-2.68$, p<.01, suggesting that when angles and proportions are to some extent dependent on one another, angular accuracy overrides the importance of proportional accuracy.

5.3.4 Drawing Experience and Angular and Proportional Accuracy.

Correlations between time spent drawing in the last two years and drawing ratings were conducted. In a replication of the result found in the survey study (Chapter 3) there was a significant correlation between subjective drawing ratings and time spent drawing, r (21)=.54, p<.05. A linear regression was conducted with angular and proportional accuracy in the Cain house task as the independent variable and time spent drawing in the last two years as a dependent variable. The regression model was non-significant, F (2, 18) =.89, p=.43, suggesting that practice does not impact the relationship between the rendering of simple angles and proportions and drawing accuracy for more complex tasks. A second linear regression was conducted with angular and proportional accuracy in the line matching task as predictors and time spent drawing in the last two years as a dependent variable. The regression model was also non-significant, F (2, 17) =.29, p=.75, and neither of the regressors were significant predictors.

5.4 Discussion

The aim of the current study was to assess art students' ability to process geometrical relationships and to link this with processes involved in observational drawing. It has already been shown in the previous chapter that the ability to draw angular and proportional relationships within simple shapes is associated with higher level drawing ability. In an extension of this finding in the current study, it was found that performance in a non-rendering line replication task predicted drawing accuracy, both in angular and proportional conditions, and that angular and proportional accuracy seemed to contribute independently to drawing accuracy.

5.4.1 Angular and Proportional Perception Predicts Drawing Accuracy

It appears that geometric perceptual abilities contribute to observational drawing in a hierarchical manner, with simple angular and proportional relationships between pairs of lines serving as a foundation for more complex proportional and angular relationships inherent in complex, real-world stimuli (Figure 5.3). It can be speculated that if a student of drawing is inaccurate at the fundamental level – that is at the level of simple angles and proportions – their drawing will appear inaccurate at greater levels of complexity, as these errors translate into larger and larger errors at higher levels of the hierarchy. Therefore, representing objects or scenes accurately at the local level is just as important as knowing how to represent them accurately at a global level. Evidence also points toward separate hierarchical systems for angular and proportional accuracy, which contribute to drawing

ability in a parallel manner, as angular and proportional accuracy in the line task independently predicted accuracy in the higher level drawing tasks. However, once angles and proportions become intrinsically linked, angular accuracy takes precedence over proportional accuracy. The hierarchical perceptual structure will feature in the perceptual module of the toolbox of drawing ability presented in the concluding chapter of this thesis.
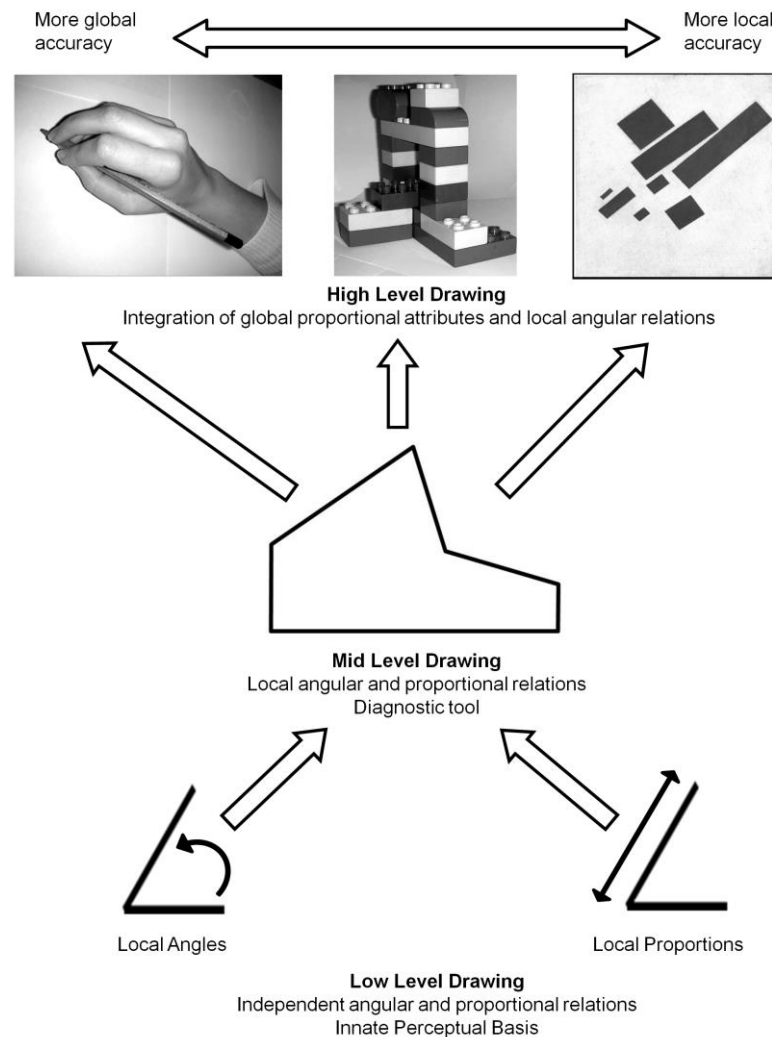
Figure 5.3. Hierarchy of Drawing Ability

Simple angular and proportional perception could be used as a diagnostic tool for higher-level drawing ability and for exposing innate talents in children (Cain, 1943). Support for this proposal was found in the current study, as performance in a line copying task that did not require drawing predicted higher level subjective ratings of drawing accuracy and proportional and angle drawing in a simple shape drawing task. This ability appears to function independently of drawing training, as there appeared to be no significant relationship between time spent drawing in the last two years and performance on the line task, suggesting that indeed this perceptual ability is not mediated by short- term practice. This measure therefore

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could be, as Cain (1943) initially suggested, a diagnostic marker for proficient drawing. The fact that the better draughtsmen performed more precisely in a task that did not require any drawing suggests that artists witness a general perceptual heightening (either as a cause or effect of superior representational drawing) that is independent of the context in which they are creating art. Domain-general perceptual enhancement has also been shown in a study in which expert artists exhibited superior visual encoding both in rendering and non-rendering contexts (Glazek & Weisberg, 2010). A domain-general approach contrasts with the data from some interviewees in the interview study (Chapter 2) in which some artists commented that drawing 'switched on' a particular mode of perception. The relationship between performance on non-rendering and rendering tasks suggests that perception is enhanced in general for expert draughtsmen. On the other hand, it could be the case that perceptual accuracy developed under drawing contexts extends to other non-artistic tasks, but that this ability is heightened to an even greater degree when an individual is in the process of drawing. In the current study artists performed the line task within the same session as the drawing tasks and a little time after they were conducted. Therefore it is a possibility that there were some perceptual 'spill-over' effects from the drawing tasks to the tasks that followed, such that enhanced angular and proportional perception may have indeed been 'switched-on' during this time.

The finding that angular perception performance in the line task correlates with drawing ability contrasts with the results of Carson and Allard's (2013) study. They reported no correlation between the estimation of planar and projected angles and drawing experience (for examples of each type of angle see Figure 5.4), despite finding a relationship between perception of slanted angles (i.e. angles as they truly are in the visual environment) and drawing experience.
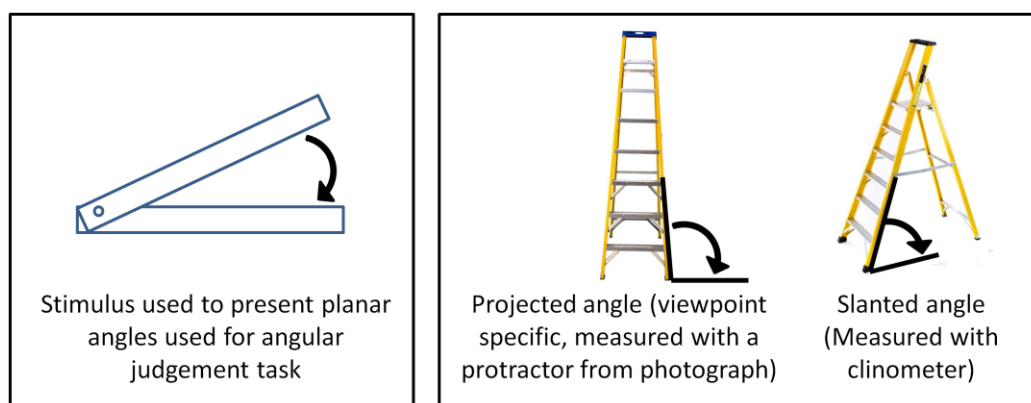
Figure 5.4. Planar, slanted and projected angles as used in Carson and Allard (2013)

The angles presented in the line task in the current study were most like the planar angles used in Carson's study as they required participants to estimate and angle presented in 2D

on a vertical plane. However verbal report of angles/proportions was avoided in the current study and instead participants were asked to use a visual adjustment procedure with minimal motor demands. As the current experimental task is arguably a more valid representation of the visual task artists have to perform when they are drawing (i.e. trial and error reproduction rather than a single verbal estimate), this could explain why a link between angular perception and drawing ability was found where Carson and Allard (2013) did not. Additionally, in the current study drawing accuracy was measured as a dependent variable, whereas Carson and Allard (2013) used drawing experience, which may not always correlate with actual ability, and perhaps is an independent theoretical question.

As mentioned previously, drawing experience in the current study was not predicted by angular or proportional error in the line task, suggesting that this ability is independent of experience. This finding supports Theron Cain's contention that angular accuracy in the house task may predict innate artistic ability, at least for representational drawing.

> It is reasonable to believe that the test did not measure the effect of training so much as it measured innate perceptual ability (Cain, 1943, p.49)

However, the measure of drawing experience in the current study only extended to the previous two years that the artists had been working and therefore may not adequately reflect the amount of drawing practice some artists may have accumulated over many years. As Carson and Allard (2013) conducted a much more thorough analysis of drawing experience (number of years spent drawing in total) and failed to find a link between experience and perceptual ability, we can still suggest that the link between planar angular perception and drawing ability may be experience independent. An interventional study that specifically trains students to perform a task like the line task and then measures the improvement in drawing accuracy would help to explicate the causal link between angular perception and drawing ability. Similarly, if a group of novices completed an intensive drawing course and there was little improvement in the ability to judge planar angles it could be concluded that this is perhaps a more innate faculty pertaining to drawing.

Despite the putative link demonstrated here between simple angular and proportional perception and drawing ability, there exist many more factors that influence the drawing of more complex real-world stimuli that are not accounted for by this simple task. The line task presents angles and proportions without any contextual cues, whilst in real-world drawing tasks angles and proportions are distorted by framing and constancy effects, which have been shown to have significant impact on drawing accuracy (Mitchell et al., 2005; Ostrofsky et al., 2012). A more naturalistic assessment of angular perception in

context was conducted in Carson and Allard's (2013) study. The relationship between angular perception in a superficial context and angular perception in ecologically valid tasks remains to be investigated, as this was only measured using drawing paradigms in the current task. It is unclear whether veridical perception at the lower level may reduce constancy effects at a higher level in the drawing hierarchy, or whether the two effects work additively to contribute to drawing ability.

5.5 Interim Conclusions from Perceptual Studies.

The last two chapters have highlighted the importance of geometry in drawing research, both in the process of assessment and production of artworks. Considering the evidence reported in the literature review as well as the current studies, these are good examples of the strong relationship between aesthetics and production within the arts. This was implied in the discussion of Graham's work on analysis of painting using luminance spectra and has been highlighted by aesthetic psychologists who suggest that aesthetic appraisal is a mirror-image of artistic production, with the latter stages of production reflecting the early stages of appreciation (Tinio, 2013).

The assessment of objective shape analysis methods for establishing drawing accuracy has provided a firm methodological framework for later studies concerning visual perception and visual memory, the first of which was the subject of this chapter. It was found that affine shape transformations appear to be the most appropriate shape analysis technique for objective approaches. Furthermore, objective assessments of drawings relate to subjective ratings of the same drawings by non-expert raters. This finding provides support for both approaches; they are both measuring the accuracy of participants' drawings but in slightly different ways. However, there are limitations to both approaches. Shape analysis cannot account for all properties of images that pertain to accuracy. As yet it is not possible to explicitly measure accuracy of curvature, and the quality of mark-making is overlooked by landmark-based shape-analysis techniques. On the other hand subjective raters might be biased by certain properties of an image, and the use of emphasis to caricature the visual image (Gombrich, 1960). However, considering these limitations it has been concluded that the subjective rating process is valid and reliable enough to be a continuing and appropriate approach to the analysis of drawing accuracy.

With a firmer empirical foundation for the assessment of drawing accuracy, the relationship between angular and proportional perception and drawing ability was investigated as a result of discovering a relationship between angular accuracy on the Cain house task and externally rated drawing ability in the study in Chapter 3. The results of the study in the current chapter highlight the importance of both angular and proportional

accuracy on higher level drawing ability and for the drawing of simple geometrical shapes. Thus a perceptual hierarchy in relation to drawing was proposed, with simple global angular and proportional relationships forming the basis for more complex combinations of elements as the drawing task increases in complexity. This hierarchy will form a substantive part of the perceptual element of the drawing toolbox presented in the discussion at the conclusion of this thesis (Chapter 9). The lower levels of the hierarchy (simple shape drawing such as the Cain house and perception of individual angles and proportions) appear to function independent of drawing experience, suggesting that these abilities may have more of an innate basis than high level drawing ability, which is more likely to be related to the amount of time artists spend practicing drawing.

In the next chapter I remain with the topic of visual perceptual enhancement and drawing accuracy, moving on to an in-depth investigation of the role of local and global visual processing within the drawing process. As outlined in the introduction, there has been evidence to suggest that local processing biases most notably demonstrated in individuals with ASD may be linked to drawing accuracy. Primarily it is the aim of the following chapter to establish a specific link between enhanced local processing and drawing accuracy independent of artistic ability. There is also a posited link between performance on the angle and proportion line task in the current chapter and performance on local processing tasks in the following chapter, as the perception of angles and proportions could be biased by global processing. If there is found to be a link between local processing ability, drawing ability and angular and proportional perception, it can be argued to be the case that enhanced local processing underpins drawing ability from the bottom of the perceptual hierarchy upwards.

Chapter 6. Local and Global Visual Processing

'Drawing is not the form; it is the way of seeing the form.'

Edgar Degas

(Valéry & Paul, 1989, p.82)

6.1   Introduction

Processing of objects or scenes in the visual world involve distinct analyses of segmenting the visual array into its component parts, local visual processing, or grouping parts together to construct a coherent whole, global visual processing.   As summarised in Chapter 1, evidence from the ASD literature suggests that a bias toward local processing of perceptual stimuli may underpin some savant talents in Autism Spectrum Disorder (ASD), such as prodigious talent for music or drawing. Individuals with ASD who show a precocious talent for drawing demonstrate local progression in their drawing behaviour, and also manifest visual processing behaviours that are suggestive of a locally oriented approach. For example, they perform in a superior manner to controls in tasks such as the Block Design Task (BDT; Caron et al., 2006; Shah & Frith, 1993), the Embedded Figures Task (EFT; Jolliffe & Baron-Cohen, 1997; Ryder et al., 2002), and show less susceptibility to visual illusions (Happé, 1996). It has been suggested that this perceptual processing profile supports enhanced drawing ability, both in the ASD and non-ASD population (Drake et al., 2010; Drake & Winner, 2011). In the last two years, Drake and colleagues have demonstrated that superior drawing ability in children and non-artistic adults is related to local processing ability (Drake et al., 2010; Drake & Winner, 2011). However, a study by Pring et al (2010) showed few differences in local processing between artists and non-artists. Cumulatively this research suggests that local processing biases could be specific correlates of realistic drawing rather than artistic ability more generally. However, drawing ability was not included as a dependent variable in a study of local processing in non-ASD artists and controls (Pring et al., 2010) and artistic ability was not measured in Drake's studies. As the talent of artistic savants almost invariably manifests itself as realistic drawing skill, the ASD sample in Pring's study may have shown a difference in local processing performance as a result of their graphical abilities rather than general artistic skill. No study has yet included both artistic ability and drawing ability as independent variables, and thus it remains unclear whether local processing relates to artistic ability in general or drawing ability more specifically, which is one of the motivating aims for the current chapter.

The nature of the link between local processing and drawing realism has also yet to be explored. A pertinent question in this domain is whether local processing associated with superior drawing is a function of weak central coherence (WCC), a reduced ability to cohere local parts into a whole (Happé & Frith, 2006), or enhanced perceptual functioning (EPF), intact coherence coupled with a reduction in global interference which is characteristic of typical visual processing (Happé & Booth, 2008; Mottron et al., 2006; Plaisted et al., 2003). The dichotomy between these two explanations of local processing enhancements has been

assessed in children with ASD using the Navon task of hierarchical stimuli (Navon, 1977). Variants of this task have been produced, such that the degree of global advantage (or precedence) and global interference can be measured independently, thereby distinguishing local processing in the presence or absences of deficits in global processing (Plaisted, Swettenham, & Rees, 1999). Global advantage is the extent to which one responds to global forms more quickly than local forms, while global interference refers to the extent to which global forms interfere with the successful processing of local stimuli. Global interference and global advantage can act independently; the former reflecting an individual's ability to cohere local stimuli and the latter reflecting an ability to ignore global and focus on local forms when necessary. By measuring response rates and reaction times to local and global levels of Navon stimuli and partitioning global interference and advantage effects, it is possible to deduce whether EPF or WCC accounts are responsible for local processing performance in individuals with and without ASD.

Previous research suggests that enhanced local processing in ASD is not a corollary of reduced global processing (Plaisted et al., 1999; Plaisted et al., 2003). In a Navon task using letter stimuli (Plaisted et al., 1999) it was found that children with ASD showed local advantage and interference effects in a divided attention condition of the task. In a selective attention condition they performed in the same pattern as controls, replicating a previous study (Ozonoff, Strayer, McMahon, & Filloux, 1994). The former result is consistent with a WCC interpretation of local processing benefits in children with ASD, as this group showed reduction in both global advantage and interference. However conflicting results from the selective attention condition suggest that local processing benefits are only manifest in certain attentional circumstances. Furthermore, Drake and Winner (2012) assessed the degree of weak central coherence in a precocious realist with ASD. They found that local processing was enhanced but in conjunction with a reduction in global processing evidenced by poor performance in an impossible-possible figures task. This finding suggests that in the ASD population, drawing accuracy could be a result of enhanced local processing with an associated deficit in cohering local stimuli into a global form. It is unclear what the pattern of local-global enhancements and deficits is in proficient draughtsmen without ASD. Therefore, in the current study both the divided and selective attention conditions of the Navon task were employed to assess whether artistic and non-artistic individuals demonstrated the same patterns in perceptual processing.

6.1.1   Aims of the Current Study

Exploration of WCC and EPF in relation to drawing ability in individuals without ASD can help to establish whether expertise for particular types of visual media arise at the price of

efficient visual processing in non-drawing contexts. It is unclear whether similar patterns of hierarchical visual processing would be found in a non-ASD population who were proficient draughtsmen, as qualitative differences between ASD and non-ASD processing have been found in the past (Mottron, Belleville, & Menard, 1999; Pring et al., 2010).

On the basis of the limitations of Drake et al (2010; 2011) and Pring et al's (2010) studies the current study sought to establish whether individual differences in drawing ability in non-ASD artistic and non-artistic adults could be explained by a bias toward local perceptual processing, and whether such a bias was a result of the WCC or the EPF accounts of perceptual processing in ASD. Both artistic and non-artistic individuals were included to assess whether differences in local processing strategy were related to drawing ability, artistic ability, or a combination of the two. It was also of interest to note whether non verbal IQ (NVIQ) mediated any link between local processing and realistic drawing ability. As scores on the block design task (Shah & Frith, 1993) contribute to assessment of intelligence in the Wechsler Adult Intelligence Scale and scores on the GEFT are known to correlate with IQ (Milne & Szczerbinski, 2009; Riding & Pearson, 1994), it was necessary to explore this potential confound to establish a direct link between local processing and drawing ability. Also in the survey study Chapter 3 it was found that academic attainment predicted drawing ability (see Chapter 3, Section 3.4.6), suggesting that there may be a link between IQ and drawing ability which is manifested in a link between academic grades and drawing accuracy ratings, providing further support for the inclusion of NVIQ as an independent variable of interest in the current study.

The BDT, EFT and the Adult Autism Spectrum Quotient (AQ) were employed to explore local visual processing. In addition, a Navon task (Navon, 1977; Plaisted et al., 1999) modified to exclude verbal processing was included to measure global advantage and global interference effects in a divided and selective attention condition. In Plaisted et al's (1999) study, global advantage in a selective attention paradigm was derived by measuring the difference in error rates and reaction times between trials in which the attended stimulus was global and trials in which the attended stimulus was local. Global interference was calculated by measuring the difference between trials in which local and global levels were compatible and trials in which the local and global levels were incompatible in local target trials (where global perception 'interferes' with the local percept). In the divided attention condition global advantage was evidenced by faster responding and fewer errors in target present trials in which the global and local levels were compatible, compared with trials in which the two levels were incompatible. Global interference was derived by comparing the two incompatible conditions; if responses were more accurate and faster in the global target

condition compared with the local target condition, this would suggest that there was effect of global interference on the local target trials.

In the current study, if global advantage in the Navon Task was found to be negatively correlated with drawing ability alongside a positive correlation with global interference, this would suggest that drawing ability is associated with a reduced ability to cohere local stimuli into a global form, supporting WCC theory. On the other hand if global interference was found to be negatively correlated with drawing ability with no correlation with global advantage, this would suggest that drawing ability is associated with enhanced perceptual functioning without a corresponding deficit in coherence, supporting EPF theory. Previous studies have not been able to tease apart reduction in coherence vs. enhanced perception as explanations of local processing advantages in gifted draughtsmen. In the current study it is expected that a deficit in global coherence would be detrimental to drawing performance, as an appreciation of global proportional relationships is fundamental to successful drawing. Therefore on the basis of previous studies and intuitive conceptions of perceptual enhancements associated with drawing, it was hypothesised that realistic drawing ability would correlate with:

1. Higher scores on the attention to detail subscale of the AQ

2. Superior performance on the group EFT

3. Reduced segmentation facilitation in the BDT

4. Decreased global interference coupled with an intact global advantage effect in a Navon shape task.

A final aim of the current study was to assess how local processing facilitates perceptual processing in drawing. As even simple angles and proportions are arguably perceived in a global manner (Appelle & Goodnow, 1970; Appelle et al., 1980; Chen & Levi, 1996) it can be proposed that enhanced local processing may facilitate the perception and reproduction of angles and proportions. In the previous chapter (5.4.1. Angular and Proportional Perception Predict Drawing Accuracy) the relationship between angular and proportional drawing and perception was discussed. This discussion is brought into the current chapter in which the relationship between performance on local processing tasks such as the Navon task, the EFT and the BDT will be analysed with respect to angular and proportional accuracy in the Cain house and the line matching task. It is predicted that enhanced local processing will support performance for angular and proportional accuracy in the Cain house task. It is unclear whether this relationship will translate to a non-rendering context and therefore no directional hypothesis is made with regard to the potential relationship between local processing ability and angular and proportional accuracy in the line matching task. If

associations are found between local processing and simple representation of angles and proportions they would provide some insight into how local processing facilitates drawing accuracy, indicating that local processing reduces contextual effects on angles and proportions. There is neuroimaging evidence to suggest that superior performance on the BDT has a low-level basis in individuals with ASD (Bölte, Hubl, Dierks, Holtmann, & Poustka, 2008). In this study individuals with ASD showed lower hemodynamic responses to the BDT in the V2 region of the visual cortex, an area responsible for the representation of angles, junctions and grating stimuli and critical for shape perception. In an fMRI study of the EFT, it was found that individuals with ASD showed higher levels of cortical activation in regions associated with regions related to the encoding of spatial relations and the allocation of visual attention (Ring et al., 1999). This finding suggests that performance in tasks like the BDT and the EFT could be linked to lower level shape representation, and thus facilitate drawing performance through enhancing accurate perception of local angular and proportional relationships. If a link between local processing performance and the perception of lower-level angular and proportional relationships is shown, this will help to integrate the various perceptual components of drawing ability into a coherent element of the drawing toolbox presented in the final chapter of this thesis (9.3. A Toolbox for Drawing Ability).

6.2   Method

6.2.1   Participants

6.2.1.1 Art Students

Participants consisted of a sample stratified according to drawing skill (n=40; 26 female; mean age =23.8 (SD = 6.0) years) recruited from respondents of a larger questionnaire based study (N=132) conducted in September 2011. The sample included students attending foundation (n=44), undergraduate (n=14) and post-graduate (n=74) art and design courses at Swansea Metropolitan University (SMU), Camberwell College of Art (CAM) and The Royal College of Art (RCA) respectively.

6.2.1.2 Controls

Control participants (n=33; 22 female; mean age =24.9 (SD = 6.2) years) were recruited from the undergraduate and postgraduate student population at University College London (UCL). Participants studied a range of non visual arts degrees and did not differ significantly in age, t (71) =-.71, p=.48, to the art student sample.

6.2.2   Procedure

Participants were tested individually on all tasks within one testing session lasting between 1-1.5 hours at SMU, the RCA or the psychology department at UCL. Tasks were administered in the order presented in the experimental procedure.

6.2.2.1 Questionnaire Measures

Participants completed a questionnaire consisting of a single folded sheet of A3 paper (for more questionnaire information see the methods section of the survey study 3.2.2). 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'*.

Adult Autism Spectrum Quotient (AQ). ASD traits (Baron-Cohen et al., 2001) including social skills, attention switching, attention to detail, communication and imagination were measured by responses to statements on a 5-point scale, ranging from '*definitely agree*' to '*definitely disagree*'. AQ data were only collected from art students due to time constraints.

6.2.2.2 NVIQ: Shortened Form of Ravens Advanced Progressive Matrices

A shortened form of Ravens Advanced Progressive Matrices (RAPM) was administered (Arthur & Day, 1994). This form has been validated and normalised (Arthur, Tubre, Paul, & Sanchez-Ku, 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 minutes (for stimuli examples see Appendix C). Stimuli were presented on paper and participants gave their responses verbally. All participants completed the task in the allotted time.

6.2.2.3 Group Embedded Figures Test

This task consisted of identifying the outline of a simple figure within a more complex figure (Figure 6.1; for more stimuli examples see Appendix D). Participants were instructed

to trace or shade in the outline of the corresponding simple figure within each complex figure. Participants were given an unlimited amount of time to complete five practice trials and subsequently a five minute time limit to complete as many out of eight test trials as possible. Participants were instructed that the simple figures would appear in the same orientation and with the same proportions in the simple figures as in the complex figures.
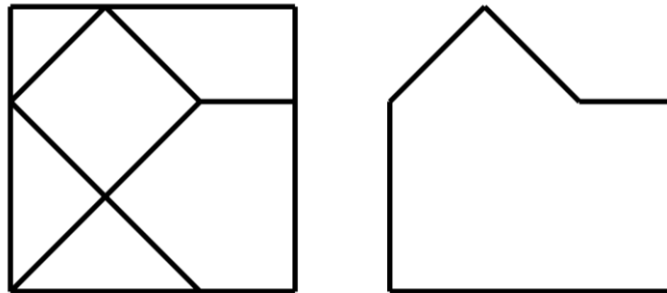
Figure 6.1. Example stimuli from the GEFT originally developed by Witkin (1971). The complex shape is on the left and the target shape is on the right.

6.2.2.4 Block Design Task

The task was administered, modified for adult administration from the methodology used by Drake et al (2010) by reducing the time limits for pattern construction. Participants were instructed to copy a pattern presented on a computer screen as quickly as possible using either four or nine cubes with four differently patterned sides (Figure 6.2 ; for more stimuli examples see Appendix E). Patterns were initially presented in an un-segmented format, beginning with a practice trial followed by two test trials with four blocks and two test trials with nine blocks. The second stage consisted of segmented patterns, again beginning with two practice trials and then two test trials with four blocks followed by two test trials with nine blocks. The un-segmented version was always presented first to avoid learning effects as in previous studies (Caron et al., 2006; Drake et al., 2010; Drake & Winner, 2011; Shah & Frith, 1993). After pilot testing, a 60 second time limit per trial was used. The time taken to complete each pattern was recorded, if participants failed to complete the pattern a maximum time of 60 seconds was recorded.
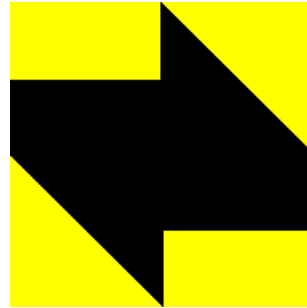
Unsegmented 4 Block Trial   Segmented 4 Block Trial
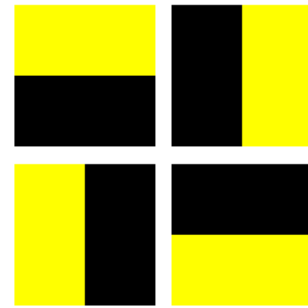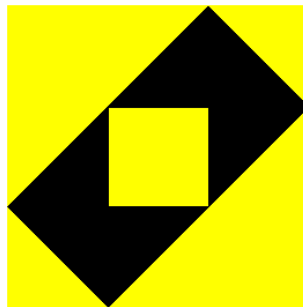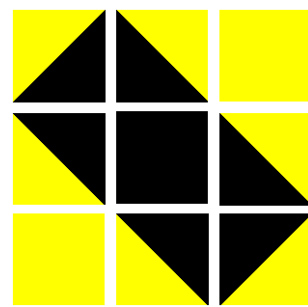
Unsegmented 9 Block Trial   Segmented 9 Block Trial

Figure 6.2. Example stimuli for the BDT

6.2.2.5 *Navon Shape Task*

A modified Navon task taken from Plaisted et al (1999) was administered, using shape stimuli instead of letters in order to avoid confounds with verbal ability.

Stimulus presentation and data collection were controlled using the Psychophysical Toolbox (Brainard, 1997; Pelli, 1997) for Matlab 7.10. Stimuli were presented as black shapes on a white background on a 13-inch liquid crystal computer screen with a 60Hz refresh rate. Each large shape was comprised of approximately 30 smaller shapes. Participants sat 140cm away from the screen; at this distance large shapes subtended a visual angle of $6.2° \times 6.1°$; small shapes subtended a visual angle of $0.2° \times 0.2°$ degrees. All stimuli appeared on screen for 1000 ms per trial with an inter-trial interval of 500 ms.

Selective Attention Condition. Participants were required to attend either only to the large global shape or to the smaller local shapes for a whole block of trials. The level (global/local) to be attended to was randomised across blocks, with 50% of the blocks being global and 50% local. The level to which participants were to attend was indicated at the beginning of each experimental block. Within each trial participants were instructed to press one response key if the target shape was a square and another response key if the target shape was a circle. Trials were separated into compatible/incompatible and global/local

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types depending on the attended level of the experimental block (Figure 6.3). Reaction times and correct/incorrect responses were collected for each trial. Participants completed two practice blocks followed by 14 experimental blocks and were free to rest between blocks. There were 12 trials per block, in which each stimulus image appeared twice in a randomised order. There were 192 trials in total.

Compatible – Global/Local Target
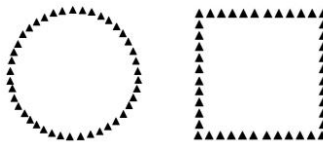
Incompatible –Global Target, Neutral Distracter
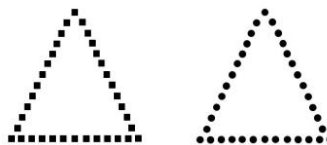
Incompatible – Local Target, Neutral Distracter

Incompatible – Global/Local Target, Global/Local Distracter

Figure 6.3. Navon Shape Task Stimuli - Selective Attention Condition

Divided Attention Task Condition. Only a subset of the total sample of participants completed the divided attention condition of the Navon Task due to time constraints (artists, N=25; controls, N=19). Participants were required only to state whether a square was present or absent, either at the local or global level. The square was present on 50% of the trials. Within each trial participants were instructed to press one response key if the square was present and another response key if the square was absent. Trials were

separated into positive/negative, compatible/incompatible and local/global depending on the presence or absence of the target and the attended level of each trial (Figure 6.4). Reaction times and correct/incorrect responses were collected for each trial. Participants completed two practice blocks followed by six experimental blocks. There were 24 trials per block, in which each stimulus image appeared four times. There were 192 trials in total.

Compatible Positive (target present) and Negative (target absent)
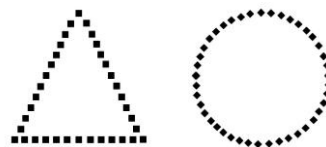
Incompatible Local Positive (target present) and Negative (target absent)
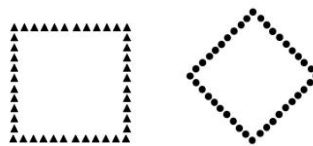
Incompatible Global Positive (target present) and Negative (target absent)

Figure 6.4. Navon Shape Task Stimuli - Divided Attention Condition

6.2.2.6 Observational Drawing Tasks

Drawing tasks were completed on A4 (297 × 210 mm) heavy-weight art paper (130 g.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 60Hz refresh rate.

Hand and Block Photographs. 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; Figure 4.2).

Ethics

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

6.3   Results

6.3.1   Drawing Rating Procedure for Hand and Block Drawings

See methods Chapter 3 (3.3. Data Preparation) for a full description of the rating procedure.

6.3.2   Observational Drawing Ratings

Participants' scores for the hand and block drawings were averaged across the ten non-expert raters. Inter-rater reliability was good with a Cronbach's alpha of .92 for hand drawing ratings and .93 for block drawing ratings, which are comparable with alpha reliability of expert judges in a previous study conducted by our research team (McManus et al., 2010).

Hand drawing ratings were highly positively correlated with block drawing ratings, r (70) =.72, p<.001, therefore a composite drawing rating was produced by averaging drawing ratings for the hand and blocks for each participant. Self-perceived drawing ability correlated significantly with art students' mean drawing ratings, r (37) =.46, p<.01, validating the method of sample stratification.

Figure 6.5 shows the drawing ratings given to the control participants and the art students. A t-test confirmed that the art students' drawing performance was significantly better than that of the control group, t (70) =3.09, p<.01.
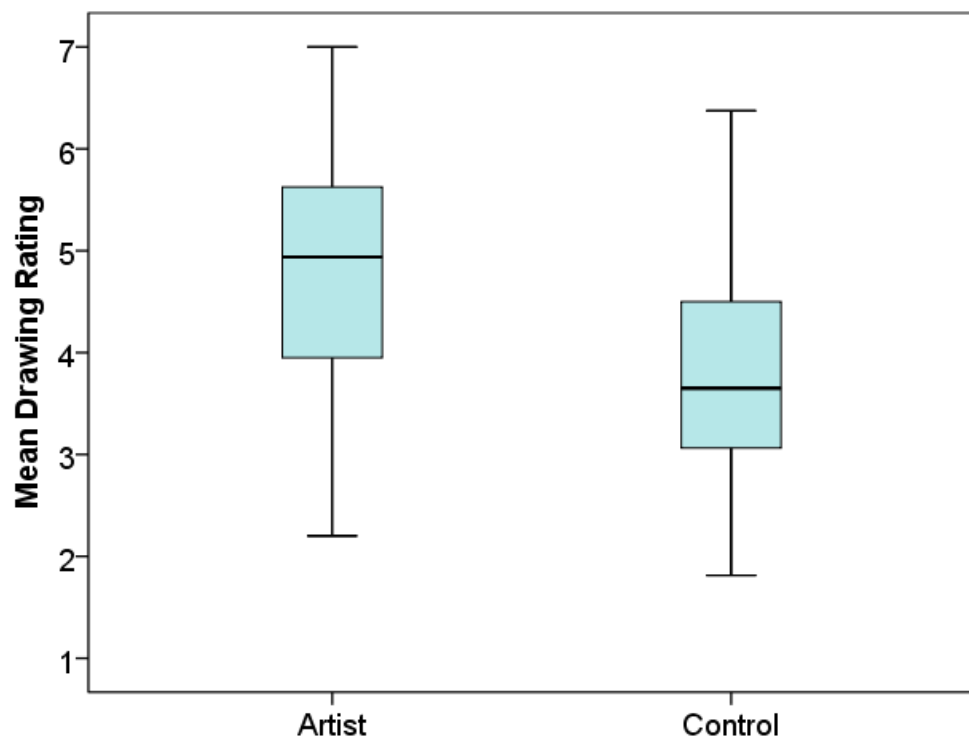
Figure 6.5. Drawing ratings for art student and control participants

6.3.3 Differences between art students and controls

Table 6.1 shows the mean performance on each task for the control and art student subsamples. On observation of the group means for art students and controls, it appeared that there were few group differences in the NVIQ and local processing tasks.

Table 6.1. Summary Statistics for Drawing Ratings, RAPM, GEFT and BDT Scores and independent samples t-tests comparing performance across groups.

	Controls (N=33)		Artists (N=40)		
	Mean	SD	Mean	SD	T-Test
RAPM Score /12	7.70	2.66	6.64	2.07	$t(70)$ =-1.89, p=.06
RAPM Completion Time (mins)	11.11	2.64	11.41	2.96	$t(70)$ =-.99, p=.33
GEFT Score/8	4.94	2.02	5.21	2.15	$t(70)$ =.54, p=.59
BDT Completion Time (secs)					
4 Blocks Unsegmented	21.83	12.80	22.82	11.81	$t(69)$ =.03, p=.97
9 Blocks Unsegmented	37.52	13.16	37.62	11.56	$t(69)$ =.35, p=.73
4 Block Segmented	10.04	2.24	9.92	2.04	$t(69)$ =1.34, p=.18
9 Blocks Segmented	20.29	5.70	21.99	4.96	$t(69)$ =-.23, p=.82

Independent samples t-tests were conducted to test for differences in performance between art students and controls. There were no significant differences in performance between the control and art student populations on the NVIQ, GEFT or BDT, although there was a marginally significant difference in NVIQ between the two groups.

6.3.4 Background Variables

It was of interest to ascertain whether any variables extraneous to those being currently tested were involved in the prediction of drawing ability. Therefore, a multiple regression was conducted on the data for both art student and controls with drawing ability as a dependent variable and age, artistic experience (controls only), time spent drawing (art students only) and NVIQ as independent variables.

In a linear regression the model was not significant for the art-student group, F (3, 37) =1.68, p=.19, or the control group, F (3, 32) =1.89, p=.15. Age, NVIQ and artistic experience were not significant predictors of drawing ability.

6.3.5 Local Processing Ability

Local processing ability was then analysed with respect to drawing accuracy. First analyses were conducted on the sample as a whole. Then the relationship between local processing and drawing ability was explored separately in the control and art-student subsamples.

6.3.5.1 Autism Spectrum Quotient

AQ responses were split into five subscales: social skill, attention switching, attention to detail, communication and imagination. Scores for each subscale (max=5) were derived by summing positive responses to questions pertaining to each type of processing after reverse coding for negatively phrased questions. Highest scores were found for the attention to detail subscale (M=3.20, SD=1.24), followed by attention switching (M=2.82, SD=1.28), communication (M=2.15, SD=1.22) and imagination (M=2.11, SD=1.01). Scores were lowest for the social skill subscale (M=1.76, SD=1.35). A total AQ score was also calculated by summing responses to all areas of processing (M=10.26, SD=3.61). No participant scored in the extremely high range on the questionnaire (32+) suggestive of autism spectrum disorder (Baron-Cohen et al., 2001).

A multiple regression analysis was run on the five categories of the AQ. The regression model was not significant, F (5, 4) =2.20, p=.23 and none of the five subscales predicted drawing ability.

6.3.5.2 The Group Embedded Figures Task

Performance on the GEFT was calculated by summing correct responses in the test phase to derive a score out of 8. In a linear regression, F (2, 70) =26.85, p<.001, both NVIQ scores, t (70) =3.02, p<.01, and drawing ratings, t (70) =6.72, p<.001, independently predicted GEFT scores.

6.3.5.3 Block Design Task

Due to high completion rates in the BDT (93% of participants completed the four block conditions and 77% completed the nine block conditions in under 60s) only construction times were analysed with respect to drawing ability. Segmentation facilitation for the four and nine block conditions was calculated by averaging performance on four and nine block

trials in unsegmented and segmented conditions and then subtracting the mean unsegmented completion time from the mean segmented completion time. Relative segmentation was then computed by dividing the mean segmentation facilitation for four and nine block conditions by the mean time for un-segmented trials for the four and nine block conditions. Relative segmentation facilitation was slightly less for the control group in the four block trials (M=-.48, SD=.21) than the art student group (M=-.44, SD=.22). However this difference was not statistically significant, t (69) =-79, p=.43. In the nine block trials art students showed less benefit of segmentation (M=-.38, SD=.18) than the control group (M=-.43, SD=.13), however again this difference was not statistically significant, t (69) =1.25, p=.22.

The four and nine block conditions of the BDT were analysed separately with respect to drawing ability. It was found that NVIQ scores, t (69) =2.32, p<.05, and drawing ratings, t (69) =2.07, p=<0.05, predicted BDT four block condition difference scores, F (2, 69) =5.48, p<.01. However only drawing rating, t (69) =4.91, p<.001, and not NVIQ predicted nine block segmentation difference scores, F (2, 69) =17.21, p<.001.

6.3.5.4 Navon Shape Task

Both total error rates and mean reaction times (RTs) were calculated for the selective and divided attention conditions of the Navon shape task. NVIQ was not found to be correlated with any measures of local processing performance in the selective or divided attention Navon tasks (all p>.05) and therefore was excluded from subsequent analyses.

6.3.5.5 Selective Attention Navon Shape Task

Error Data. Error rates were lower in the global condition for compatible and neutral trials (Figure 6.6), compared to the local condition suggestive of a global advantage effect on error, however the main effect of perceptual level (global/local) on error rates was not significant, F (1,63) =.38, p=.54. The main effect of trial type (compatible/incompatible/neutral) was significant, F (2,124) =12.96, p<.001, with fewer errors made in compatible trials compared with incompatible and neutral trials. There was no significant interaction between perceptual level and trial type, F (2, 126) =1.51, p=.23. In a planned comparison it was found that error rates were lower for compatible trials in which the target was local compared to incompatible trials in which the target was local, demonstrating a global interference effect on error, t (64) =-2.30, p<.05, in line with Plaisted et al (1999).
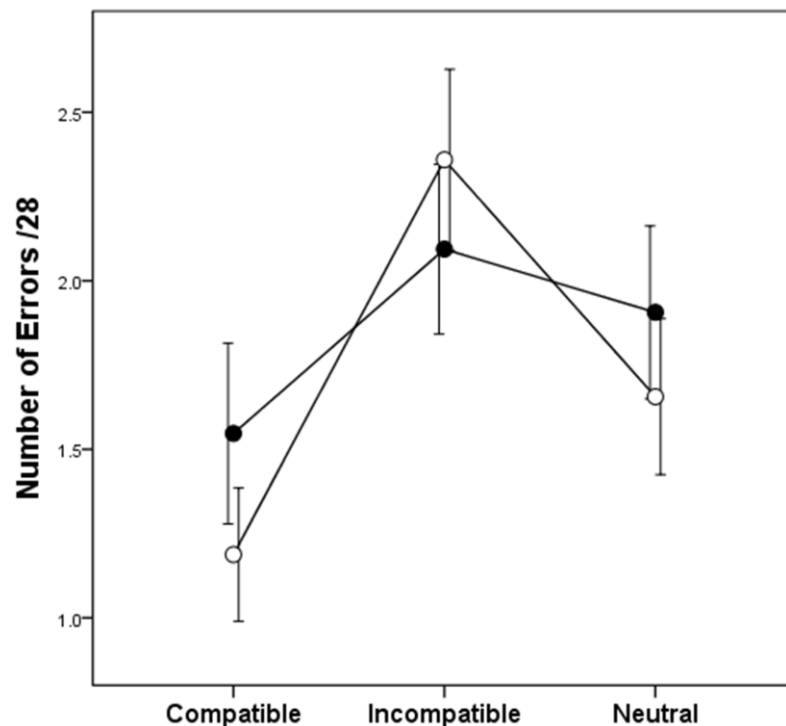
Figure 6.6. Mean error rates for compatible, incompatible and neutral local (●) and global (○) trials in the Selective Attention Navon Shape Task (N=73). Error bars represent +/- 1 standard error of the mean (SEM).

A global advantage error score was calculated for each participant by first producing a mean error score for all local target trials and all global target trials. The mean local trial error scores were then subtracted from mean global error scores. A smaller difference between the two is indicative of a larger global advantage effect, as participants respond more accurately to global trials than to local trials. There was no significant difference in global advantage on error rates between the control and art student groups, t (62) =-.15, p=.89. There was no significant correlation between global advantage score and realistic drawing ability, r (63) =.100, p=.55.

A global interference effect was calculated by subtracting mean error rates for compatible trials in which the target was local, from mean error rates for incompatible trials in which the target was local. Worse performance on incompatible local target trials when compared with compatible local target trials is suggestive of increased global interference. Larger negative scores indicate a greater amount of global interference on error scores for incompatible local target trials. There was no significant difference in global interference on error rates between the control and art student groups, t (62) =.32, p=.75. There was no

significant correlation between global interference on error scores and drawing ratings, *r* (63) =-.13, p=.32.

RT Data. RTs were shorter in the global condition for compatible, incompatible and neutral trials, reflecting the global advantage effect (Figure 6.7). The main effect of perceptual level (global/local) on reaction time was significant, $F (1, 62) =24.71$, p<.001. There was also a main effect of trial type (compatible/incompatible/neutral) on reaction time, $F (2,124) =59.80$, p<.001, but no significant interaction between trial type and perceptual level, $F (2, 124) =1.31$, p=.27. In a planned comparison reaction times were also shorter for compatible trials in which the target was local compared to incompatible trials in which the target was local, replicating the global interference effect $t (62)=-6.49$, p<.001, in line with Plaisted et al (1999).
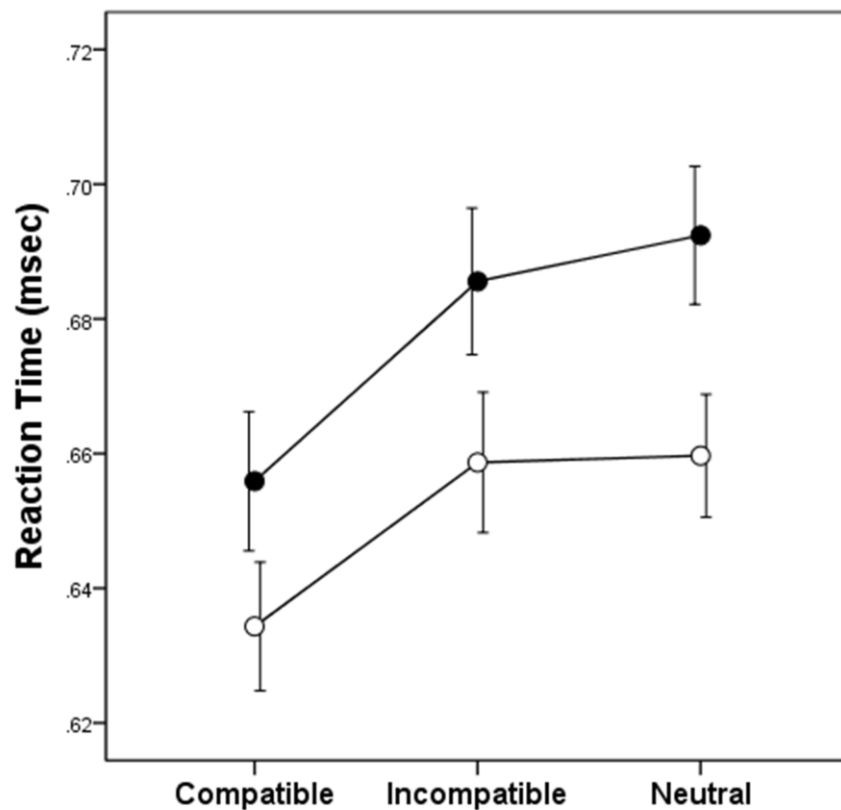
Figure 6.7. Mean RTs for compatible, incompatible and neutral local (●) and global (○) trials in the Selective Attention Navon Shape Task (N=73). Error bars represent +/- 1 SEM.

Global advantage scores for the RT data were calculated in the same way as global advantage error rates. There was no significant difference in global advantage on RTs between the control and art student groups, $t (61) =.76$, p=.45. There was no significant correlation between global advantage RTs and realistic drawing ability, $r (62) =.05$, p=.73.

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Global interference on RTs for incompatible local target trials was calculated in the same manner as global interference on error rates. There was no significant difference in global interference on RTs between the control and art student groups, t (61) =-1.15, p=.25. There was a significant negative correlation between global interference score and drawing rating, r (62) =-.28, p<.05. This finding indicates that individuals who showed more global interference on reaction times (i.e. a larger positive difference between local incompatible and local compatible trial types) had poorer drawing accuracy (Figure 6.8). A Fisher r to z transformation was conducted to compare the extent of the correlations between drawing ratings and global advantage in the first instance, and global interference in the second instance. The difference between the two correlations was marginally significant, z(62)=1.85, p=.06 (one-tailed test. As the hypothesis was made a priori a one-tailed test produces a statistically significant difference at p<.05).
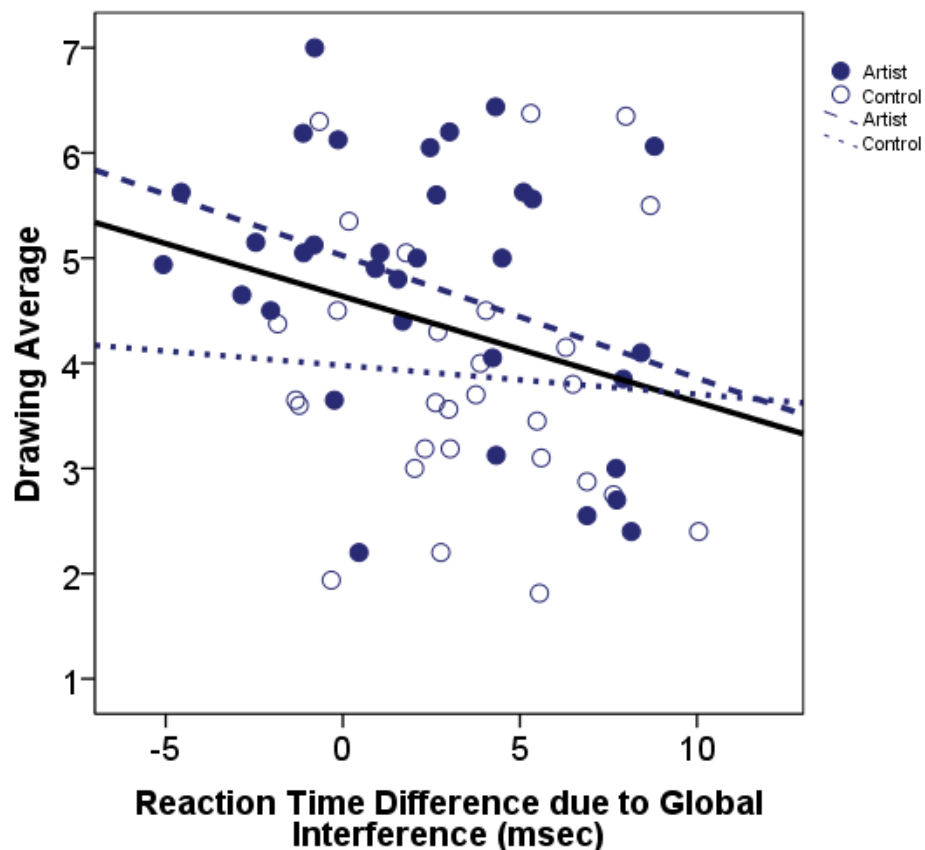
Figure 6.8. Selective attention global interference in the Navon shape task in relation to mean drawing rating for artist and control groups.

6.3.5.6 Divided Attention Navon Shape Task

Error Data. Error rates were lower in the compatible condition in both negative and positive trials relative to the incompatible global and local conditions, suggestive of a global

advantage effect (Figure 6.9). There was no effect of presence or absence of the target in trials, $F (1, 40) =.21$, p=.65. There was a main effect of trial type (compatible/incompatible global/incompatible local), $F (2, 80) =16.63$, p<.001; participants committed fewest errors in the compatible condition, followed by the incompatible local target condition and then the incompatible global target condition. This finding diverges from Plaisted's (1999) findings for typically developing subjects, who committed the fewest errors in the incompatible global target and compatible conditions. There was no interaction between presence/absence of the target shape and trial type, $F (2, 80) =1.26$, p=.29. In planned comparisons it was found that errors made for the incompatible global condition were more numerous than errors made in the incompatible local target condition for both positive, $t (40)=-2.64$, p<.05, and negative , $t (40)=-2.81$, p<.01, trials, suggesting more local than global interference on error rates.
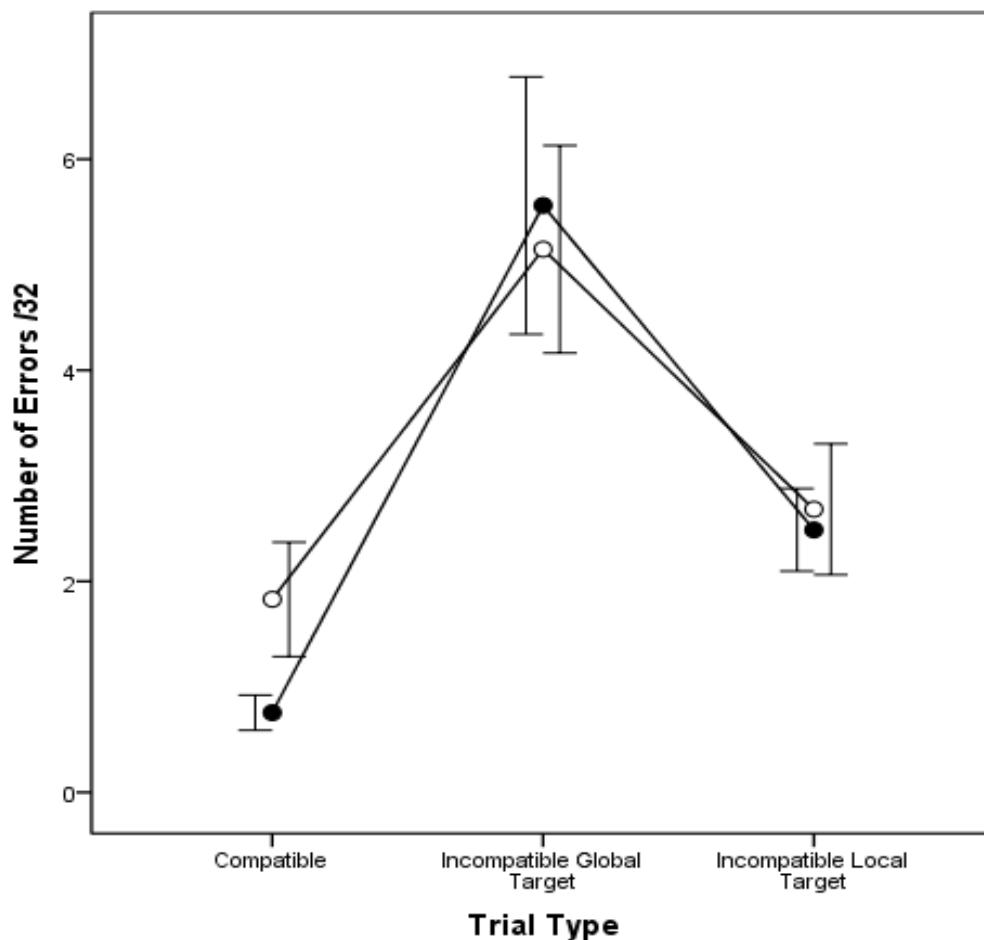
Figure 6.9. Mean RTs for compatible, incompatible global and incompatible local positive (square present○) and negative (square absent●) trials. Error bars represent SEM.

Only positive trial types were analysed with respect to global advantage and interference, in accordance with Plaisted et al (1999). Global advantage error scores were

calculated by subtracting mean error scores in the positive incompatible conditions from mean error scores in the positive compatible condition. A greater difference would suggest greater global advantage as response to a form that had global as well as local indicators of form would be more efficiently responded to than local or global forms alone. There was no significant correlation between the global advantage effect and realistic drawing ability, r (40) =-.11, p=.51.

To calculate global interference scores the total number of correct responses in positive incompatible trials in which the target was present at the global level was subtracted from incompatible trials in which the target was present at the local level. A larger positive difference would indicate that response to conflicting local target trials is worse than on conflicting global target trials, suggesting a greater impact of global form in local trials, than local form in global trials. There was no significant correlation between the global interference effect and realistic drawing ability, r (40) =-.05, p=.78.

RT Data. There was a significant main effect of presence of the target shape (positive/negative) on RTs in the divided attention condition of the Navon task, F (1, 40) =61.42, p<.001, RTs were longer for target absent compared with target present trials. There was also a significant main effect of trial type (compatible/incompatible global/incompatible local) on RTs, F (2, 80) =220.46, p<.001; RTs were shorter in the compatible condition compared with the incompatible local and global conditions (Figure 6.10). There was also a significant interaction between presence/absence of the target shape and trial type, F (2, 80)= 34.45, p<.001; in negative trials RTs were longer in the incompatible global condition compared with the incompatible local condition, where there was no difference between these two conditions for positive trials. Again these results are inconsistent with the findings of Plaisted (1999), as they suggest both local interference effects in negative trials, and no sign of global interference in positive trials.
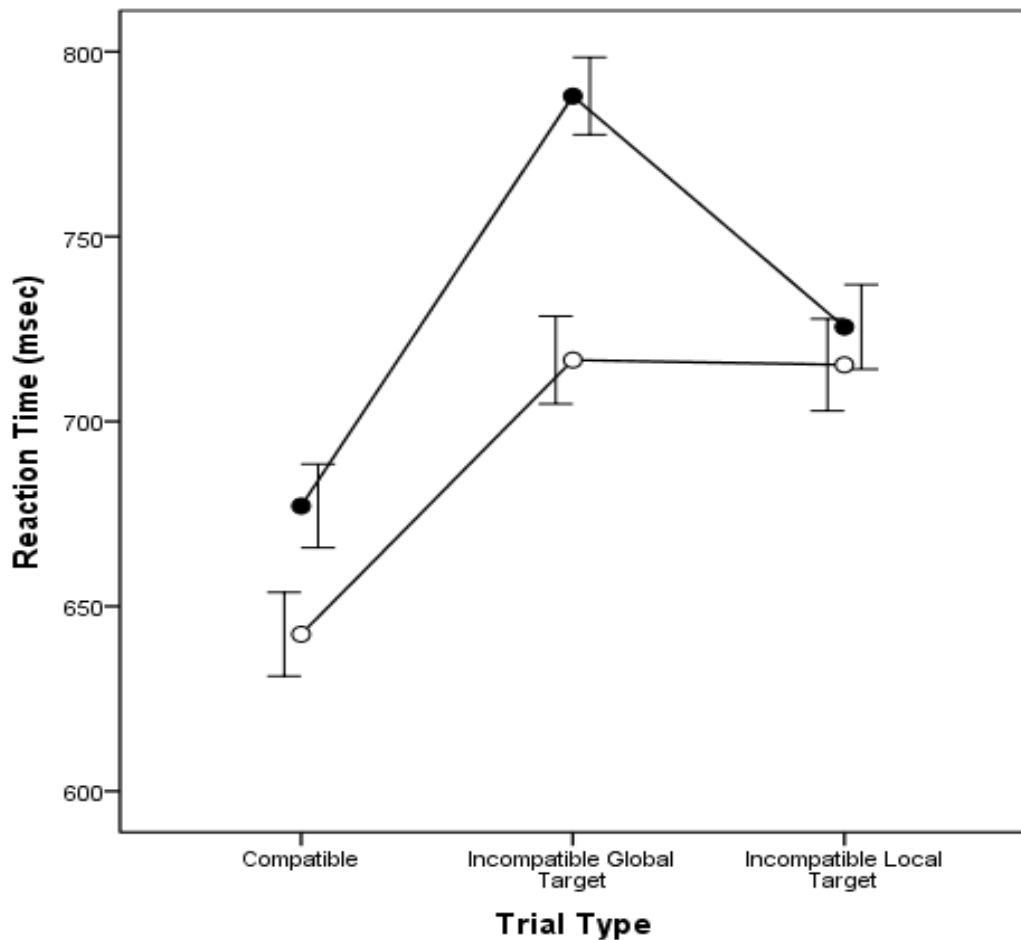
Figure 6.10. Mean RTs for compatible, incompatible global and incompatible local positive (square present ○) and negative (square absent ●) trials. Error bars represent SEM.

Global advantage RT scores were calculated by subtracting mean RT in the positive incompatible conditions from mean RT in the positive compatible condition. There was no significant correlation between the global advantage effect and realistic drawing ability, r (40)=.10, p=.52.

To calculate global interference scores mean RTs for positive incompatible trials in which the target was present at the global level were subtracted from mean RTs for incompatible trials in which the target was present at the local level. There was a significant correlation between the effect of global interference on RTs and realistic drawing ability, r (40) =-.38, p<.05. This finding again indicates that individuals who showed more global interference in this task had lower drawing ratings (Figure 6.11). A Fisher r to z transformation was conducted to compare the extent of the correlations between drawing ratings and global advantage in the first instance, and global interference in the second instance. The difference between the two correlations was significant, z(40)=2.18, p<.05.
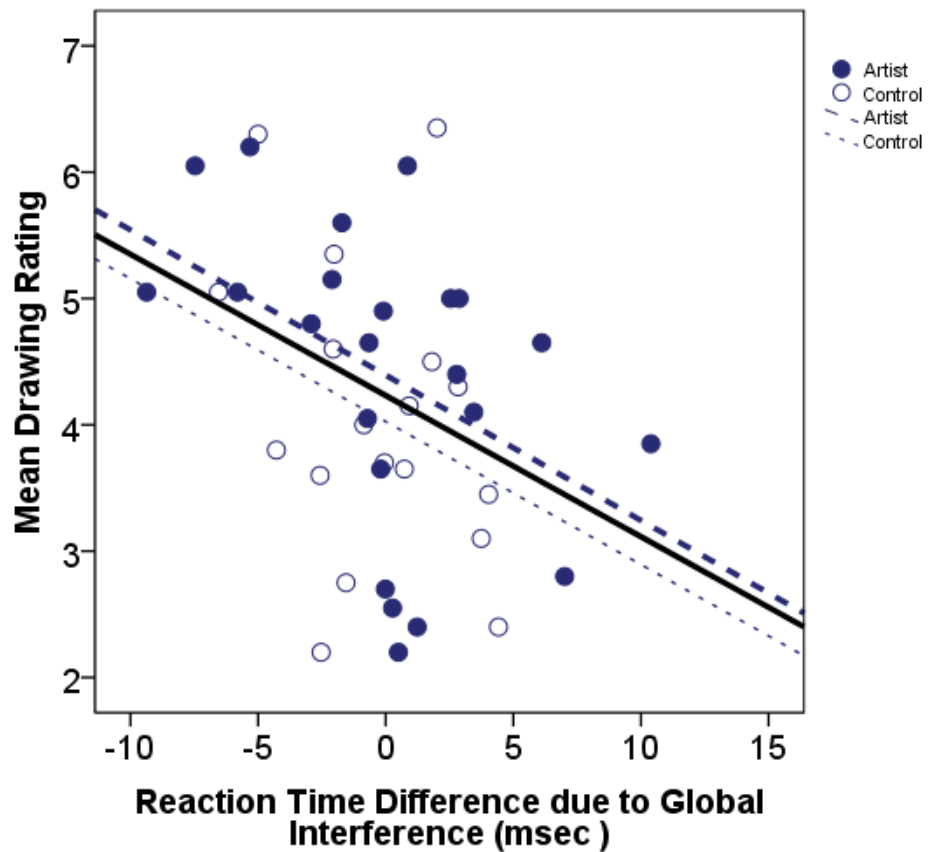
Figure 6.11. Divided attention global interference in the Navon shape task in relation to mean drawing rating for artist and control groups.

6.3.6 Heterogeneity in Drawing and Local Processing in Art Students

Analyses were conducted to establish whether there were differences in drawing ability, in relation to time spent drawing and to artistic experience (foundation/undergraduate/post-graduate level qualification). An independent groups ANOVA revealed there were no significant differences in drawing ability between the participants from SMU, CAM and RCA although the trend for increasing drawing ability with increasing artistic experience was approaching significance $F_{(2, 36)} = 3.204$, p=.05. Drawing ability was not significantly correlated with time spent drawing over the past two years, $r_{(39)} = .26$, p=.12.

The same analyses were conducted in relation to performance on the three local processing tasks that had been found to be associated with drawing ability (for descriptive statistics see Table 6.2). There were no significant differences in performance on the GEFT, $F_{(2, 36)} = 1.46$, p=.25, the four block, $F_{(2, 35)} = .15$, p=.86, nine block, $F_{(2, 35)} = 2.70$, p=.08, conditions of the BDT, or global interference on RTs in the selective attention, $F_{(2, 31)} = .26$, p=.77 or divided attention, $F_{(2, 20)} = .45$, p=.64, conditions of the Navon shape

task, between levels of artistic experience. There were also no significant correlations between time spent drawing and any of the local processing tasks.

Table 6.2. Descriptive statistics for three artistic groups for drawing ratings and local processing tasks

	SMU (N=14)		CAM (N=8)		RCA (N=18)	
	Mean	SD	Mean	SD	Mean	SD
Mean Drawing Rating	4.07	1.34	4.87	.67	5.13	1.20
GEFT Score	4.69	2.50	4.63	2.13	5.83	1.82
4 Blocks Segmentation	-.51	.26	-.46	.15	-.47	.20
9 Blocks Segmentation	-.46	.16	-.28	.22	-.37	.16
Selective Attention Global Interference	.032	.033	.018	.045	.024	.042
	SMU (N=12)		CAM (N=6)		RCA (N=5)	
Divided Attention Global Interference	-.007	.041	.016	.063	.000	.035

6.3.7 Relations between local processing tasks

Table 6.3 shows correlations between scores on each of the local processing tasks, which show the extent to which local processing is a unitary function. Scores on the GEFT and BDT correlated highly, and there was some degree of correlation between interference on RTs in the selective attention condition of the Navon shape task and BDT and EFT, although these correlations were not significant.

Table 6.3. Correlations between the different local processing tasks (n range=61-71)

| | 1. GEFT Accuracy | 2. BDT Accuracy | Navon Selective Attention | | Navon Divided Attention | |
			3. Error	4. Reaction Time	5. Error	6. Reaction Time
1	-	.46**	-.07	-.20	-.10	-.26
2	-	-	-.01	-.22	.25	-.19
3	-	-	-	.21	.03	-.09
4	-	-	-	-	.12	.36*
5	-	-	-	-	-	-.07

Note: GEFT=group embedded figures task, BDT=block design task, NTS=Navon task selective attention global interference, NTD = Navon task divided attention global interference *p<.05, **p<.01.

To explore the relationship between the local processing measures further, a principal components analysis (PCA) was conducted on the local processing scores, excluding errors on the Navon shape task as they were not predictive of local processing or drawing ability. The PCA confirmed that there was one underlying factor (total eigenvalue=1.90) for local processing, upon which the BDT segmentation scores and global interference in the divided attention condition of Navon task loaded lowest (Table 6.4).

Table 6.4. Factor loadings for the local processing factor

Factor	Loading
GEFT	.69
BDT	.78
NTS Reaction Time	-.71
NTD Reaction Time	-.57

Factor scores were created to assess the relationship between the local processing factor and realistic drawing ability; there was a significant correlation between the local processing factor and drawing ability, r (36) =.64, p<.001 (Figure 6.12).
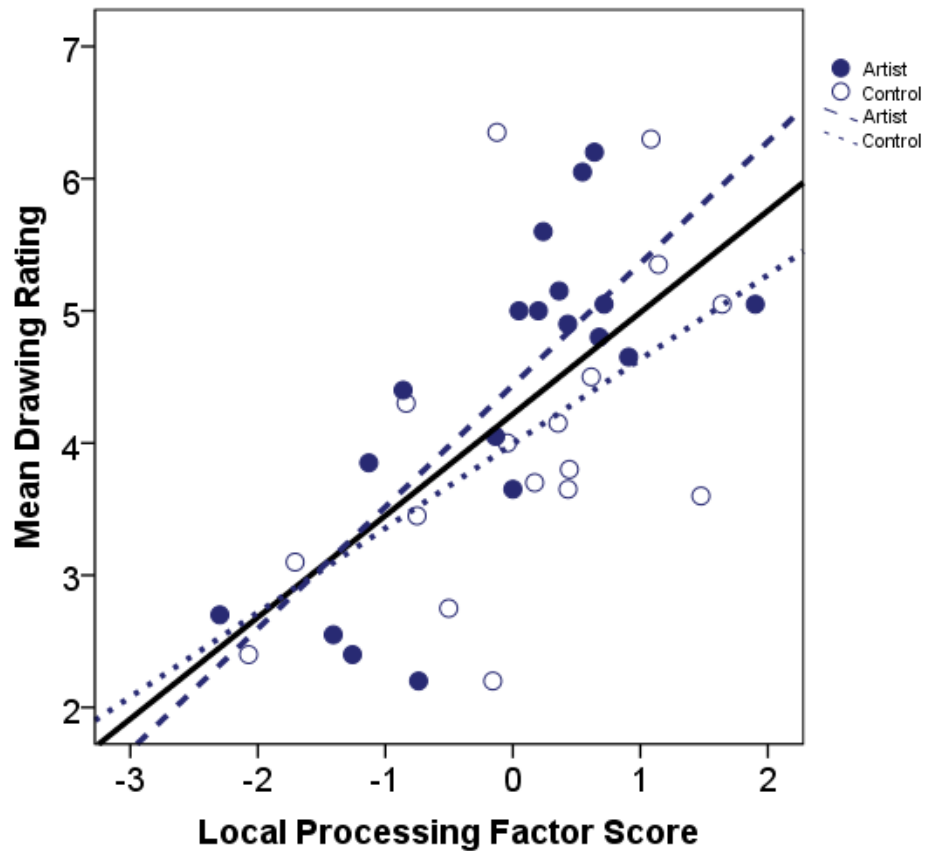
Figure 6.12. Relationship between drawing ratings and local processing factor scores for participant subgroups

6.3.8 Group differences in local processing link

It was of interest to assess the relative contributions of local processing to realistic drawing ability in the control group and the art student groups, to pull apart the influence of artistic ability and drawing ability for local processing, and also to assess the effect of immersion in art related activity on the development of local processing. On review of the correlation matrix (Table 6.5) it would appear that local processing is a more reliable predictor for drawing ability in the art students compared to the controls.

Table 6.5. Correlation coefficients between local processing tasks and drawing accuracy for artists and controls (n range=29-38)

Local Processing Tasks	Artists	Controls
GEFT	.67**	.55**
BDT	.59**	.50*
NTS Global Interference (RT)	-.36*	-.07
NTD Global Interference (RT)	-.43*	-.31
PCA Local Processing Factor Score	.76**	.55*

Notes: GEFT=group embedded figures task, BDT=block design task, NTS=Navon task selective attention, NTD = Navon task divided attention, $*p<.05$, $**p<.01$.

An exploration of local processing in the art students and controls suggests that local processing predicts drawing ability to a greater extent in the artistic sample. However, there was no statistically significant difference in the slopes of the regression lines of the two subgroups in individual local processing tasks or the local processing factor (Figure 6.12).

6.3.9   Local Processing Measures and Perception of Angles and Proportions

The role of local processing in simple geometric drawing tasks was assessed. Primarily it was necessary to assess to what extent the difference subtasks of the local processing battery correlated with the different angle and proportional perception tasks, and more broadly with the local processing factor scores (Table 6.6).

Table 6.6. Correlations between local processing tasks and angular and proportional error on the Cain house and line tasks (n range=32-37)

	Cain Angle Error	Cain Proportion Error	Line Angle Error	Line Proportion Error
GEFT	-.38*	-.41**	-.28	-.22
BDT	-.55**	-.20	-.26	-.41**
NTS	.09	.28	.47**	.25
NTD	.21	.09	.24	.15
LPF	-.37*	-.51**	-.45**	-.38*

Notes: GEFT=group embedded figures task, BDT=block design task, NTS=Navon task selective attention, NTD = Navon task divided attention, LPF=Local Processing Factor *p<.05, **p<.01.

The GEFT showed consistent negative relationship with angular and proportional errors in the Cain House task, suggesting that local processing is related to greater precision of angular and proportional perception, but to a greater extent with the Cain house task. The BDT also showed negative correlations with the angle and proportion perceptual tasks, but the pattern of results was less clear in this instance, favouring angular accuracy in the Cain house task and proportional accuracy in the line task. The two Navon shape tasks showed less robust correlation with either the Cain house or the line tasks, apart from a strong positive correlation between performance on the angular condition of the line task and length of RTs in the selective attention condition of the Navon shape task. It appears that there is a dichotomy between the way the GEFT and the BDT tasks relate to angular and proportional processing compared with the Navon shape task.

Overall it would seem that local processing ability is more predictive of angular and proportional processing in the rendering context of the Cain House task. In order to test this assertion the Cain house task and line task error scores were standardised into z-scores and then mean scores were derived for both tasks, neglecting differences in angular and proportional accuracy. They were then entered as independent variables in a regression in which local processing factor was the dependent variable. The regression model was significant, $F (2, 29) =6.82$, p<.01, but both predictors were only marginally significant (Line performance, $t (29) =-1.86$, p=.07; Cain performance, $t (29) =-2.00$, p=.055). This outcome suggests multicollinearity, most probably due to correlations between angular accuracy between the line and Cain task, and proportional accuracy between the line and

Cain task (see Table 5.1). However, in spite of this it appears that local processing enhancements can be see in rendering and non-rendering contexts.

6.4 Discussion

Realistic drawing ability correlated positively with enhanced local processing in the current study, which supports previous research in non-ASD individuals (Drake et al., 2010; Drake & Winner, 2011). This correlation was found to be independent of artistic ability, supporting Pring et al's (2010) conclusion that there was no difference in local processing ability between artists and non-artists, and was also found in the current study to be independent of NVIQ. Accuracy on the GEFT, completion times in the BDT and global interference on reaction times in a Navon shape task predicted differences in realistic drawing ability in both art students and controls. Therefore it can be concluded that drawing ability in part results from enhanced perceptual functioning, evidenced by reduced global interference but intact global advantage effects in hierarchical visual processing, and superior disembedding of local features from global patterns. Furthermore, local processing enhancements were shown to relate to rendering and reproduction of angles and proportions, suggesting that local processing acts at low-levels of the perceptual hierarchy during drawing.

6.4.1 Differences in Local Processing between Art Students and Controls

The artistic group was significantly better at the drawing task than the controls, but no difference in performance was revealed between art students and controls in the GEFT, BDT or global interference in the Navon task. This finding replicates the results of Pring et al (2010), in which no differences were found between art students and non-art students on local processing task performance. Art students and non-art students who performed better at the local processing tasks were more likely to be rated highly in drawing accuracy. This finding suggests that local processing confers a specific advantage to realistic drawing rather than artistic ability in general, which is a novel conclusion of the current study. In this way, this study has teased apart contributions of local processing to drawing and artistic ability respectively. It is unclear why local processing is specifically advantageous to drawing rather than alternate artistic media, on the basis of which many of the art students in the current study gained entry to art school. It could be suggested that an enhanced appreciation of local features is less useful in more abstract art forms in which global percepts may be more pertinent to the artwork. Studies targeted at the assessment of perceptual expertise across different artistic disciplines in the future would help to establish when and where local processing is advantageous in the visual arts.

From the results of the current study it can be seen that local processing is enhanced in proficient draughtsmen from both artistic and non-artistic backgrounds, extending the findings of Drake and Winner (2011) who found that local processing predicted drawing ability in non-artistically gifted adults. However, there are some discrepancies between the results of their study and the current findings. The current study found a link between BDT completion times and drawing accuracy, whereas Drake and Winner (2011) report a link only between BDT accuracy and realistic drawing. The discrepancy in these results could be due to methodological differences between the two studies. Participants were given shorter time limits to complete the block design patterns in the current study. A speeded element to the task may have resulted in completion rates being a more valid predictor of drawing ability as opposed to accuracy, which was found to be high across all participants in the current study. Participants were also given relatively shorter periods of time in which to complete their drawings, compared to the drawings made in Drake and Winner's (2011) study.

These two different aspects of performance in the BDT may relate to different styles of drawing; that of quick rough sketches intended to capture the essence of subject, and more detailed and precise drawings. Speeded perceptual analysis may be superior in those who are proficient at capturing the essence of visual stimuli in a matter of seconds, whilst more sustained and detailed analysis may be enhanced in those who are accustomed to producing drawings over a longer period of time. This could be linked with enhancements in procedural memory, which are evident in a previous model of artists' perceptual advantages (Seeley & Kozbelt, 2008), and are implicated in the findings of the voxel-based morphometry study in Chapter 8. A distinction is made in the ASD literature between speeded and unspeeded local-global tasks, with performance in short and long exposure hierarchical tasks contributing independently to local processing ability (Mottron et al., 2006). It could be the case that the current study and the studies of Drake et al (2010; 2011) are eliciting different components of local processing in their behavioural measures. In the future it would be of interest to explore the relative roles of speeded and unspeeded local processing in realistic drawing. This distinction is also one that may prove pertinent in the study of the visual enhancements associated with artistic processing in general. Glazek (2012) found that artists demonstrate superior visual encoding at short exposure periods, suggesting that artists' perceptual advantages may be particularly noticeable in time-constrained conditions.

6.4.2   Enhanced Perceptual Functioning

In the current study global interference on reaction time in the Navon task correlated with drawing ability, but the effect of a global advantage on reaction time did not. Error scores in the Navon task were not predictive of drawing ability, but also did not replicate the global advantage effect shown in a previous study suggesting that error scores in this context are not as informative as in the study upon which the methodology was based (Plaisted et al., 1999). As mean error rates were also very low (<2.5 out of a possible 28 across conditions) it is possible that a lack of variation in performance affected the results. The RT data of the Navon task suggest that global processing is not compromised in those who are able to draw well, but that their ability to ignore the holistic properties of an image is enhanced when necessary. It is therefore possible to rule out weak central coherence as a mechanism for enhanced local processing in realistic drawing and likely that enhanced perceptual functioning underpins local processing in this context. This conclusion is supported by findings in a study of children with realistic drawing talent, who showed less benefit of segmentation in the block design task but who still showed a global advantage in a visual memory task (Drake & Winner, 2009).

The current findings also fall in line with contentions that an ASD-related local bias is a positive processing style, rather than a deficit of global processing and that enhanced local processing need not go hand in hand with a reduction in global perceptual functioning (Happé & Frith, 2006; Happé & Booth, 2008; Milne & Szczerbinski, 2009; Plaisted et al., 2003). However, research suggests that the artistically talented ASD population may yet have difficulty cohering local stimuli into a global form (Drake & Winner, 2012), therefore it remains unclear whether individuals with ASD are proficient at drawing as a result of weak coherence. Within the non-ASD population it appears that artists require intact global perception as well as enhanced local processing to render stimuli successfully. Future studies directly comparing local processing in individuals with and without ASD will establish whether there are qualitative differences in the relationship between local processing and drawing ability in these two populations.

6.4.3   Flexibility of Visual Processing

None of the subscales of the AQ correlated with drawing ratings in the current study. This finding supports Drake and Winner's (2011) finding that scores on the attention to detail subscale did not correlate with realistic drawing ability, suggesting that a self reported local bias is not indicative of superior drawing. In reference to detail focus in individuals with ASD, Caron et al (2006) suggest that rather than demonstrating a *bias* toward local processing, individuals with ASD are more flexible than non-ASD populations in terms of

local and global processing. This suggestion could provide an explanation for why gifted draughtsmen may not be more detail-focused than their peers. They may instead be more skilled at adapting to the demands of local and global processing at each stage of a drawing task, rather than possessing a bias for one or the other.

At some stage in the drawing process the draughtsmen must analyse proportions and interrelations of components of the drawing as a whole, to check for overall accuracy, which requires an enhanced appreciation of global rather than local form. Evidence of preserved global precedence effects in skilled drawers in the Navon task supports this claim. Furthermore, evidence that local progression is not implicated in superior drawing in non-ASD individuals (Drake & Winner, 2011) would suggest that starting off from a local point of view may not be a successful strategy, with an initial assessment of holistic properties of an image perhaps being more appropriate. Tasks that explicitly focus on the ability to switch between global and local levels of visual stimuli will serve to test this hypothesis. There is potential to manipulate local-global focus within gaze-contingent eye movement paradigms by controlling the size of the aperture through which the artist must look. By experimenting with different sizes of aperture and the timing at which they are deployed it may be possible to uncover when and how local and global strategies are most advantageous during drawing. The future exploration of global-local switching is discussed in more depth in the final chapter (9.2.2.2. Top-down Perceptual Contributions to Representational Drawing).

6.4.4   Independence of Drawing Ability from NVIQ

The current study revealed that the relationship between local processing and realistic drawing is not mediated by NVIQ. This finding contrasts with the results of Drake *et al* (2010) who found a strong correlation between performance on the non verbal segment of the Kaufman Intelligence Test-II and drawing ability in children. The reason for this discrepancy may be that NVIQ reduces in predictive power over drawing ability across the life span. As individuals develop and engage in more deliberate practice in drawing and its associated perceptual faculties, drawing ability may become more a function of expertise in specific perceptual modules, rather than general intellectual ability. Despite this putative relationship between drawing practice and local processing ability, the causative link between local processing ability and realistic drawing ability is purely speculative at present and requires further investigation. There is some suggestion that enhanced local processing can be induced through drawing training as Zhou, Cheng, Zhang and Wong (2011) found a correlation between years of portrait drawing practice and reduced holistic processing of faces. The sample size of art students in the study reported in this chapter was not sufficient to make any concrete claims concerning the effect of time spent drawing on the extent of

local processing, but it appears that there may be improvement in some local processing abilities with increasing artistic experience and drawing training, especially in the BDT. Training studies that explore either the effect of perceptual training on drawing ability, or artistic training on perceptual processing will establish the direction of causation between enhanced perceptual processing and drawing ability, and is the focus of discussion in 9.4.1. Methodology: Longitudinal and Training Studies.

6.4.5   A Unitary Concept for Local Processing

A strength of the current research is that drawing has been shown to be associated with a disparate range of local processing tasks with both long and short exposure durations. Passive perceptual, active constructional and speeded measures of local processing all relate to realistic drawing. However, there remains much debate as to how tasks such as the GEFT and BDT relate to local and global visual processing, and whether there is one unified local processing construct. It is possible that there may be a number of different perceptual factors that support local processing task performance, including disembedding and visual integration, which may be developed independently of one another (for a full review of unification of local processing and figure-ground independency see Milne & Szczerbinski, 2009). Local processing in the Navon shape task was only mildly correlated with scores on the BDT and EFT in the current study, which falls in line with research suggesting some heterogeneity of local processing task performance (Booth, 2006; Milne & Szczerbinski, 2009). The BDT appears to be the strongest and most ubiquitous measure of local processing ability, as it correlated highly with scores on the GEFT and loaded most highly onto the local processing factor. However the GEFT was the best predictor of drawing ability in both art students and controls. This could be because it most closely represents visual processing for drawing in real-world situations, as stimuli often project a feeling of depth that the Navon task and BDT fail to encapsulate. Furthermore, alternative perceptual modalities through which local processing can be explored were not included in the current study due to time constraints. Incorporating other modalities in future research would help to determine whether differences in local processing arise at the visual perceptual level, or at higher executive levels.

6.4.6   Local Processing and Perception of Angles and Proportions

Whilst there appears to be a relationship between local processing ability and higher-level drawing of complex subjects, this relationship also appears to permeate further down the drawing hierarchy that was presented in Chapter 5 (Figure 5.3). Correlations were found between local processing factor scores and precision of angular and proportional

representations in both the Cain house and the line reproduction task. These findings suggest that local processing does indeed facilitate the perception of angles and proportions at a fundamental level, probably in addition to facilitating the break-down of complex visual scenes for rendering. It can be conjectured that local processing facilitates angular and proportional perception because angles and proportions are perceived in a holistic manner, even at their most basic representation (as in the line task). Therefore, local processing helps to convert holistic processing of the line pairs into more focused processing of the subparts of angles and proportions. Processing of angles is reduced to the processing of the orientation of one line, and proportion is reduced to the processing of the length of a line when processed locally rather than globally, rather than a combined representation of two orientations and two lengths that are subject to context effects. Local processing in this context is related to both rendering and non-rendering contexts, implying that it has an impact on domain-general rather than domain-specific processing for drawing.

6.4.7 Local Processing and Drawing Strategies

Why does reduced global interference underpin realistic drawing ability in individuals regardless of their artistic ability? It is likely that the ability to disembed certain elements of an image from their context may aid drawing in a number of ways. Focusing in on local details encourages individuals to avoid taking a gist-like representation of an image, which may in turn lead to a reduction in both perceptual constancy effects (Cohen & Jones, 2008; Ostrofsky et al., 2012) and canonical biases (Mitchell et al., 2005; Ropar & Mitchell, 2002) which arise from insufficient appreciation of the distinctiveness of the current object and viewpoint. This biasing of visual processing could happen at any stage of the visual hierarchy (Figure 5.3). This appears to be what happens in the case of individuals with ASD, as they appear to avoid attending to conceptual and perceptual context information when processing visual stimuli. Happé (1997) argued that a deficit in central coherence will impede appreciation of meaning in context, making the salience of certain aspects of the display differ for savant artists, which may underpin proficiency for representing perspective in particular. Ropar and Mitchel (2002) showed that individuals with autism neglected knowledge that a shape was a slanted circle when perspective cues were eliminated, demonstrating how local processing may relate to the reduction of conceptual knowledge that biases drawn representations. This drive to avoid perceptual closure and conceptual biases upon visual representations seems to favour bottom-up conceptions of drawing ability that defer to the innocent eye (Rosenberg, 1963) as a means of extracting accurate information from the environment onto the sketch pad.

However, top-down control over attentional processes could modulate the ability to focus upon global or local aspects of a visual image, as has been shown in studies exploring the role of visual selection in drawing ability (Kozbelt et al., 2010; Ostrofsky et al., 2012). The interplay between bottom-up and top-down processes in drawing is more fully discussed in the final chapter (9.2.2. The Perceptual Core). Mottron, Dawson and Soulieres (2009) contend that top-down processing is mandatory in the non-ASD population but is optional for individuals with ASD. It is very likely that cognitive control over the avoidance of inappropriate visual schemata and conceptual knowledge is a fundamental component of drawing expertise, and that this can only arise as a function of extensive practice and engagement with the visual world in a drawing-specific manner. This may be one way in which artistic experts are qualitatively different to individuals with ASD. Whilst artistic experts can exert cognitive influence over their attendance to global or local elements of the scene, the visual processing of individuals with ASD is more automatic and under less cognitive control. In support, Chatterjee (2004, p.1581) argues that individuals require, "considerable practice and training to minimize this automatic visual hypothesis testing in order to better "see" the world". Engagement with training and practice by artistic experts will be better able to harness local and global processing abilities in order to engage in a drawing process that is maximally efficient. It is probably the case that autistic savants possess an innate predisposition toward local processing, which initially facilitates artistic production at a young age, but like any talent in the non-ASD population, requires engagement with training and practice to fully develop. This potentially explains that whilst there appear to be local processing biases prevalent in all individuals with ASD, only a few go on to develop savant-like abilities during development.

6.5   Interim Conclusions: Angles, Proportions and Local/Global Processing

The previous two chapters have highlighted the importance of visual processing in the production of visually realistic drawing. The ability to render simple shapes translates to the ability to render more complex visual scenes and objects, such that there may be a hierarchy of perceptual processing for drawing ability (Figure 5.3). Furthermore, the ability to precisely perceive and reproduce angles and proportions in a non-rendering context supports accurate depiction. These findings highlight the importance of lower level visual processing in a toolbox for drawing ability, which has not received attention in previous research on drawing.

Where research on global-local processing demonstrates the importance of attending away from the general context of an image to enhance accuracy, the translation of local elements is also dependent on precise appreciation of local angular and proportional

relationships that are absolutely rather than relationally determined. Local processing appears to enhance perception, associated with drawing at low levels of the perceptual hierarchy. This contention is supported by the finding that local processing ability relates to the rendering and reproduction of angles and proportions in simple tasks. It can be hypothesised at this stage that the accurate rendering of angles and proportions is underpinned by enhanced local processing, enabling angles to be processed at the level of orientation of the component lines, rather than a global component. A similar mechanism may be at work for local proportions, in which the absolute length of the component lines is apprehended rather than the proportional relationship as a whole. This contention could be tested by assessing whether proficient draughtsmen show more susceptibility to the orientation of the boundary lines of an angular stimulus.

The next chapter follows the drawing process from online representations, to the fidelity and longevity of visual stimuli held in visual short and long-term memory. Anecdotally any to-be-drawn image must first pass through some kind of temporarily held internal representation. However, research and theory on the involvement of visual memory in drawing is mixed and often contradictory (see 1.5. The Role of Visual Representations). A systematic investigation of the role of short and long term representations has yet to be conducted and is the focus of the following chapter of this thesis. With a more comprehensive picture of the perceptual and memorial processes involved in drawing it will be possible to bring forward reliable behavioural measures that can be used in the investigation of the neural underpinnings of drawing ability in the voxel based morphometry (VBM) study reported in Chapter 8. From the empirical foundation built up from Chapters 2-8 a toolbox of drawing ability will be presented (section 9.3. A Toolbox for Drawing Ability).

Chapter 7.   Visual Memory

'Drawing depends on seeing. Seeing depends on knowing. Knowing comes from a constant effort to encompass reality with all your senses, all this is you.'

Kimon Nicolaides

(Nicolaides, 1941, p.221)

7.1   Introduction

Having established some aspects of the relationship between visual perceptual processing and representational drawing, this exploration moves from perceptual processing (the investigation of angular and proportional perception in Chapter 5 and local-global visual processing in Chapter 6) to the role of stored visual representations which are the subject of investigation in the current chapter. This investigation assesses the role of both long and short-term memory representations in the drawing process, using a range of memory paradigms adapted from current memory research (Bays, Gorgoraptis, Wee, Marshall, & Husain, 2011; Heyes, Zokaei, van der Staaj, Bays, & Husain, 2012; Xu & Chun, 2005; Xu, 2007) and perceptual tasks (Cain, 1943) previously used to assess the role of online perceptual representations in drawing. The relative roles of object and spatial visual working memory are tested to establish which types of representation are most useful to the drawing process. With reference to the survey data in Chapter 3, the role of visual imagery will be discussed as visual imagery findings have relevance for the role of internal representations in existing models of drawing ability and for the contents of the toolbox presented at the conclusion of this thesis. Existing literature addressing the role of visual memory in representational drawing, which received a more extended discussion in the introductory chapter will then be briefly summarised, before I go on to outline the more general aims and predictions for the current studies.

7.1.1   Visual Imagery

Nicolaides (1941) argues in his seminal book on drawing instruction that the drawing process necessarily entails the translation of visual perceptual representations into internal visual representations before action plans can be made. In a similar vein, Van Sommers,' (1989) model includes a visual buffer (Figure 1.2), which functions as the means by which long term representations are brought into conscious visual awareness. The visual buffer is also used during depictive decisions, during which time a number of different representations must be held internally for consideration. This facet of van Sommers' model is supported by a later model proposed by Guerin et al (1999), in which they suggest that due to its close connection with visual perception, visual imagery is associated with the drawing process as it shares the same components with perceptual analysis. Guerin et al (1999) take their inspiration from Kosslyn and Koenig's (1992) model of visuo-spatial cognition (Figure 7.1). In this model the visual imagery system (visual buffer) feeds into processes concerning associative memory, categorical and coordinate property search and pattern activation. Guerin et al (1999) argue that this conception of the perceptual system is ideal for dealing with the kinds of processes underlying copying drawing.

Figure 7.1. A depiction of Kosslyn and Koenig's (1992) model of visuo-spatial cognition with visual buffer highlighted. Adapted from Kosslyn, Flynn, Amsterdam and Wang (1990).

However, the role of visual imagery and thus the importance of the visual buffer in a model of drawing has been called into question from the data presented in the initial survey study (Chapter 3). It is apparent that there is no relationship between self-report imaging capacities and drawing accuracy measured by subjective ratings, contrary to the suggestions of previous research (Perez-Fabello & Campos, 2007; Rosenberg, 1987) and to the predictions of early drawing models. However, it is clear that artists intuitively believe there to be a connection between imagery and drawing, as there was a significant correlation between self-report imagery and self-report drawing ability in the survey study. This finding could explain why visual imagery has featured so prominently in artists' models of the drawing process. It still remains possible that visual imagery is utilised in situations in which individuals need to manipulate visual representations or create new ones, and therefore this faculty could be linked to creative drawing or caricature rather than representational approaches. It could also be the case that visual imagery is used when drawing from short or long-term memory, but investigations into these kinds of drawing acts lie outside of the remit of this thesis. However, there is substantial evidence from this thesis to suggest that the vividness of visual imagery and the ability to image spatial relations internally does not support realistic drawing processes in which the subject is present during the drawing act. This downplays the role of a visual imagery in an explanation of drawing ability (see 3.4.3. Visual Imagery and 3.5.2.Visual Imagery has an Imagined Link with Drawing Ability).

It remains unclear whether the finding that visual imagery ability is uncorrelated with drawing ability, can be extrapolated to the kinds of internal representations that manifest from short term retention in working memory in the visuo-spatial sketchpad (Baddeley & Hitch, 1994), or long term retention. Previously it has been reported that measures of visual imagery do not relate to performance measures of visual working memory (Dean & Morris, 2003; McKelvie, 1995), therefore it is not possible to disregard VSTM from the drawing process on the basis of the previous elimination of visual imagery. As is clear from the discussion of evidence pertaining to the role of VSTM and VLTM in drawing in Chapter 1, the question remains open as to whether other visual representations are excluded from the drawing process. Evidence for and against the role of varying kinds of internal visual representations in the drawing process will now be summarised briefly.

7.1.2   Long Term Memory and Premotor Planning

In all likelihood the role of visual memory in drawing is intimately connected with the role of the motor system, as visual memory helps to frame action plans on the basis of previous expectations and schemata. Those that argue the prominence of visual memory in a model of drawing tend to agree that motor processes mediate the involvement of memory, by interacting with motor plans (Glazek, 2012). Tchalenko and colleagues extended this notion by proposing that the role of working memory is precluded by premotor planning; visual representations in perceptual pathways translate directly to visuo-motor transformation without the need for a visual buffer in between (Miall & Tchalenko, 2001; Tchalenko, 2009; Tchalenko & Miall, 2009). Whilst this account appears to downplay the role of visual working memory in drawing, it leaves open the possibility of enhanced structures in VLTM that interact with the drawing process in place of temporarily stored representations in VSTM. Research suggests that LTM may be implicated in the drawing process by underpinning the interaction between existing representations and incoming visual information that required interpretation and segmentation for an accurate depiction. VLTM representations may aid online visual perceptual processing through guiding visual attention during the drawing process, as they do in other natural tasks (Stokes et al., 2012; Summerfield et al., 2006; Summerfield et al., 2011).

Expertise accounts of chess players suggest that structures in VLTM may aid the interpretation and structuring of incoming visual information, shedding light on the interaction between long term representations and perceptual processing (Charness, Reingold, Pomplun, & Stampe, 2001; Chase & Simon, 1973; Reingold, Charness, Pomplun, & Stampe, 2001). A similar kind of model could be applied to the development of expertise in representational drawing, using enhanced structures in VLTM to guide more efficient

encoding and consequently more efficient rendering. Aaron Kozbelt's work on visual selection may link representations in VLTM with drawing accuracy. In his studies artists performing a minimal line tracing task were better able to depict visual stimuli using output (Kozbelt, 2001; Ostrofsky et al, 2012 – see 1.4.1. The Role of Schema). It can be suggested here that representations in VLTM help artists to select the most appropriate elements of the visual scene, based on prior experience. There is evidence to suggest that structures in VLTM may result in more efficient encoding, as Glazek and colleagues' research into the visual memory capacities of artists has shown. They found that artists have superior short-term recognition memory for simple and complex stimuli (Glazek & Weisberg, 2010). It was also found that encoding strategies change less in artists in response to familiarity, suggesting that internal representations may be more veridical as they are less susceptible to bias associated with semantic knowledge. Thus representations in VLTM acquired by years of experience with particular visual subjects may change the way in which those subjects are then perceived and encoded, reducing visual bias during the translation from perception to WM and VLTM. In addition to evidence for enhanced representations in VSTM in artists, there is experimental evidence to suggest that fidelity in VLTM is related to artistic ability. Previous studies by Winner and colleagues appeared to demonstrate that superior representations in VLTM and artistic ability are related (Casey et al., 1990; Rosenblatt & Winner, 1988; Sullivan & Winner, 1989; Winner & Casey, 1992). Furthermore, in a previous study, memory for two-dimensional subjects was specifically related to drawing ability (Rosenblatt & Winner, 1988). The link between VLTM and drawing ability was also investigated in a more recent study (McManus et al, 2010), which provided the direct impetus for the VLTM aspect of the current study. The methodology used in the previous study will now be discussed in more detail.

7.1.3　The Rey Osterrieth Complex Figure

The Rey Osterrieth Complex Figure Test (ROCFT) was initially formulated in 1941 by Andre Rey as a test of visuo-spatial memory (Meyers & Meyers, 1995; Rey & Osterrieth, 1993). The copy condition of the task was developed in order to measure, 'the perceptual analytic process or strategy an individual used to complete the copy. The recall trial drawing was scored for accuracy as an index of visual memory' (Corwin & Bylsma, 1993, p. 15–16). Participants can be tested in an immediate recall (as soon as the copy condition is finished) and delayed recall condition (up to 30 minutes after the immediate recall condition is completed). The immediate recall condition tests capacity and encoding efficiency, whilst the delayed recall condition tests longer term storage (Gallagher & Burke, 2007). In this way it is possible to measure both perceptual and memorial processing using the ROCFT. Later

the test gained popular usage in the identification of certain types of neuropsychological damage, such as damage to executive function, visual neglect and declarative memory (see Shin, Park, Park, Seol, & Kwon, 2006 for a review of applications of the ROCFT). Gallagher and Burke (2007) conducted an extensive analysis of age, gender and IQ correlates of the ROCFT. Performance in the task deteriorates with age, males performed better than women and those with higher IQ scored higher in the task. These were eliminated when delayed recall was expressed as a proportion of copy and immediate recall performance. They conclude that the maximally useful ROCFT scores are raw scores for the copy condition, immediate recall as a proportion of the copy score and delayed recall as a proportion of the immediate recall score. In the current study both raw and percent retained recall scores were used to analyse scores on the ROCFT.

Robust positive correlations between performance on the ROCFT and drawing ability, found in a previous study, suggests a link between VLTM and drawing (McManus et al, 2010). This link is independent of the relationship between angular and proportional perception and drawing as scores on the Rey Osterrieth memory condition did not correlate with errors in the Cain house task in the same study. Therefore VLTM appears to contribute independently to drawing ability over and above the role of perceptual processing; it is not merely the case that individuals who have enhanced perceptual processing in turn possess more faithful internal representations. The aim of the current chapter is in part to further segregate the Rey Osterrieth and the Cain angle and proportion perception task in order to isolate components of visual memory with and without the need to draw. This will elaborate on the preliminary finding of McManus et al (2010).

7.1.4   Object and Spatial Visual Short-Term Memory

With the findings relating to VLTM in the ROCFT (McManus et al., 2010) serving as a foundation for the current study, it is necessary to develop memory tasks that do not require the participant to draw as previous research has found differences in visual recognition memory attributed to artistic competence only when graphic depiction is involved (O'Connor & Hermelin, 1987b). Furthermore it is necessary to investigate VSTM representations as well as the role of long term representations of the kind needed to facilitate performance in the ROCFT. The line task presented in Chapter 5 can be easily modified to include a visual memory component. Research suggests that there are individual differences in the precision of orientation representations in VSTM (Heyes et al., 2012), and that these can be measured in reproduction paradigms akin to the task employed to assess online precision of angular and proportional relationships. In addition VSTM conditions of the line task can be created that best emulate the kind of internal visual storage that an artist

has to perform during drawing. In a similar manner to the eye movement study of Cohen (2005), it is possible to restrict when the participant sees the 'to-be-drawn' image and when they see the copy in a visual memory paradigm. It is possible to allow the participant to control when they see the stimulus image and when they see their copy, much in the way that an artist is in control of when she is looking at the stimulus or the drawing. It was the aim of the current VSTM studies to provide as much ecological validity for the artist participants as possible, by using modified VSTM paradigms that emulate the drawing process, alongside more classic tests of VSTM capacity that are established in the experimental literature.

A distinction in the visual imagery literature that is also pertinent to the current discussion of the relationship between visual memory and drawing ability, is between object and spatial representations in VSTM (Logie, 2003). Evidence for this dissociation has been shown in interference tasks, in which the features of an object have to be remembered whilst an interfering task is performed; either a spatial tapping task or viewing irrelevant line drawings. Interfering tasks that are spatial in nature interfere with spatial memory, whilst featural (colour/shape) tasks interfere with object memory (Darling, della Salla, & Logie, 2009). The two forms of memory also have difference developmental trajectories (Logie & Pearson, 1997). It is argued that object memory has a basis in the visual cache of Baddeley's visuo-spatial sketchpad within working memory (Baddeley, 1986; Baddeley & Hitch, 1994), whilst spatial location and movement is located within the inner scribe in the same system, and therefore the two forms of memory are to some extent distinct in the working memory architecture (Logie, 2003). It is of interest to determine whether object or spatial or both components of VSTM are involved in the drawing process.

In the survey chapter it was predicted that spatial rather than object representations in visual imagery would predict individual differences in drawing accuracy. In the same way the current chapter seeks to identify whether different types of visual memory might be more strongly associated with the ability to draw. Paradigms that measure object memory, spatial memory or a combination of the two, may produce conflicting evidence concerning the role of visual memory in the drawing process, explaining the lack of agreement in the experimental literature to date. Along the same lines as predictions concerning visual imagery in which spatial imagery was hypothesised to be more closely related to the drawing process than object imagery, it can be hypothesised that spatial VSTM will account for more variance in drawing accuracy than memory for detail. To test this contention, an experiment that measures object and spatial memory simultaneously within the same paradigm is reported in the current chapter. Object memory for angles and proportions is also tested in a modified version of the line task reported previously in Chapter 5 with

reference to perceptual processing. This experiment also provides the opportunity to test whether there is a relationship between perceptual and memorial ability within the same paradigms; more specifically whether more accurate perception leads to more accurate visual memory. It could be the case that enhanced encoding, facilitated by superior perceptual processing, could in turn facilitate the formation of representations in memory without an individual possessing superior memory, over and above any perceptual advantages they may have.

7.1.5   Aims of the Current Study

The current investigations sought to assess the relative contributions of both long and short-term visual memory to drawing accuracy, and the relative contributions of spatial and object based representations in the VSTM system. This was achieved by using paradigms employed in both previous research conducted by our research group (McManus et al, 2010) and in the investigation of perceptual processing in previous chapters in this thesis. Previous findings have suggested that the contribution of visual memory and visual perception to drawing ability are independent (McManus et al., 2010). These findings are investigated further in the current studies, by employing an STM version of the line reproduction task which can be compared with its perceptual counterpart (5.2 Methods. Understanding and Perception of Angles and Proportions). Exploration of the ROCFT is also extended by comparing correlations between drawing accuracy and copy, immediate, delayed recall and recognition versions of this task. In line with previous results, it is expected that there will be significant correlations between copying, immediate recall and delayed recall performance on the Rey Osterrieth task. It is also predicted that this superiority of VLTM will transfer to a non-rendering scenario in the case of the recognition version of the Rey-Osterrieth task on the basis of previous findings using non-rendering paradigms which found a link between visual memory fidelity and artistic ability (Glazek & Weisberg, 2010).

It is unclear whether the fidelity and capacity of STM representations relates to drawing ability. Work by Glazek and colleagues (Glazek & Weisberg, 2010) suggests that artists encode visual stimuli more efficiently and without familiarity bias effects, but it remains in doubt whether this ability relates to artistic ability more generally or specifically drawing ability. Therefore, no directional hypothesis was made concerning the relationship between performance on short- term memory tasks (orientation and proportion memory, object and spatial VSTM) and drawing accuracy in the current studies. However, it can be tentatively hypothesised that accuracy in spatial conditions of a VSTM icon task will correlate with drawing accuracy. This prediction mirrors the hypotheses made in Chapter 3 concerning the relationship between drawing accuracy and representations in visual

imagery. Table 7.1 provides a brief summary of each of the tasks used in the current studies, the type of visual memory (short-term/long-term) and the nature of the representation (object/spatial) for each condition of each task.

Table 7.1. Summary of VLTM and VSTM tasks employed in the current studies

Task	Condition	Long/Short Term	Object/Spatial
ROCFT	Copy	Perception	Both
	Immediate Recall	VLTM	Both
	Delayed Recall	VLTM	Both
	Recognition	VLTM	Both
Line Task	Copying	Perception	Object
	Single Exposure	VSTM	Object
	Flipping	VSTM	Object
	Dual-Monitor	VSTM	Object
VSTM Icon Task	Object Shape	VSTM	Object
	Object Shape, Location Irrelevant	VSTM	Object
	Object Shape and Location	VSTM	Both
	Object Location, Shape Irrelevant	VSTM	Spatial

7.2   Method

7.2.1   Participants.

As the data for this chapter were collected over the time period 2007-2012 different groups of participants completed different visual memory tasks at different points in time. The participant demographics for each specific memory task are given below in Figure 7.2 and Table 7.2.
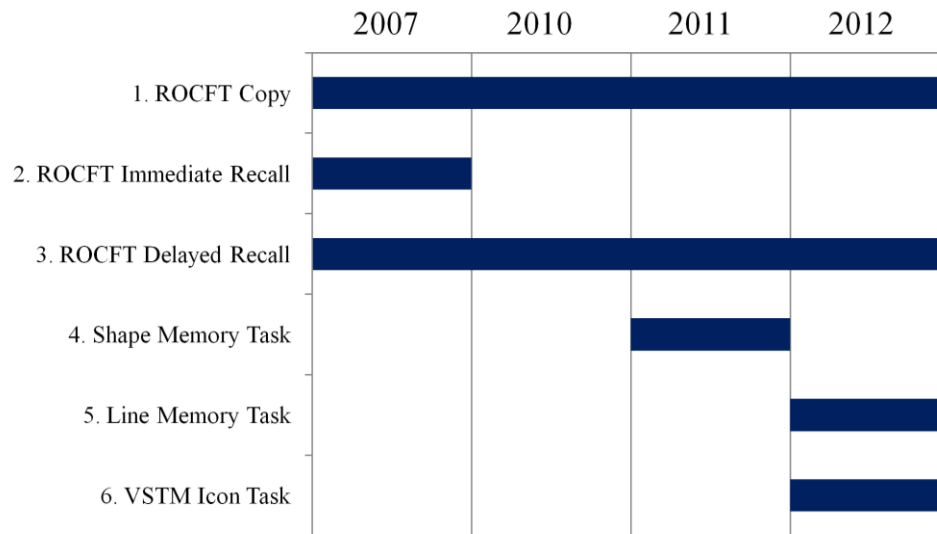
Figure 7.2. Visual memory task in terms of number of years administered. (N.B – visual memory data was not collected in the years 2008 & 2009)

Table 7.2 Sample sizes and demographic details for participant samples for each memory task

Task		N	Mean Age	SD
	Copy	234	24.8	8.76
	Immediate	68	24.8	8.76
ROCFT	*Delayed*	206	24.8	8.76
	Recognition	97	22.30	10.45.
Line Memory Task		39	22.5	3.47
VSTM Icon Task		24	25.9	5.90

7.2.2   Procedure

All participants completed a questionnaire (see 3.2. Method and Appendix B) and the drawing tasks, in addition to the memory tasks described below.

7.2.2.1 Observational Drawing Tasks

Drawing tasks were completed on A4 (297 × 210 mm) heavy-weight art paper (130 g.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 60Hz refresh rate.

7.2.2.2 Rey Osterrieth Memory Tasks
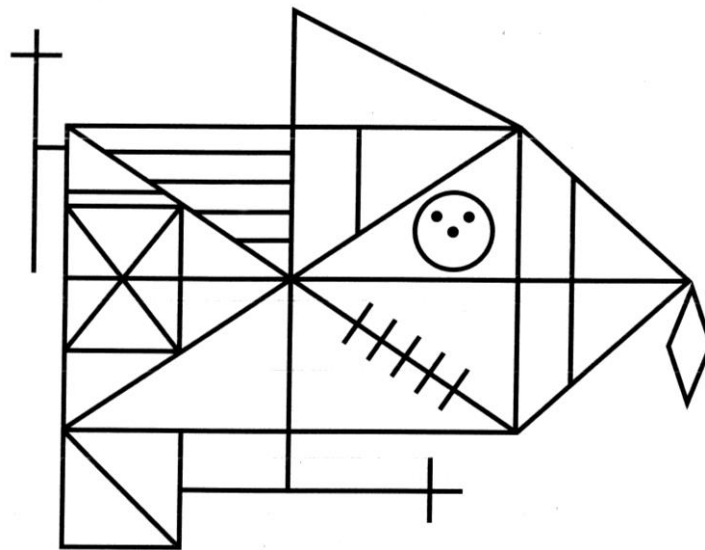
Figure 7.3. The Rey Osterrieth Complex Figure (ROCF)

Copying Condition. Participants made a copy of the ROCF (4 minute time limit). They are not informed that they will have to remember the figure later.

Immediate Recall Condition. Participants were unexpectedly asked to draw the ROCF immediately after they have copied it, without looking back at the original ROCF or their copy (3 minute time limit).

Delayed Recall Condition. Participants are unexpectedly asked to draw the ROCF approximately 30 minutes after they initially copied it, without looking back at the original ROCF or their copy (3 minute time limit).

Recognition Condition. Participants are given 3 minutes to study the ROCF without drawing it in order to memorise it for a later test. After a 30 minute delay they are presented with a number of items which either appear in the original ROCF figure or appear in a similar figure (the Taylor Complex Figure; Taylor, 1969). They are asked to indicate for each item whether it appeared in the original ROCF they studied at the beginning of the testing session (See Appendix F for full recognition task stimuli).

7.2.2.3 Line Memory Task

For stimuli and procedure of the baseline line copying task upon which the following memory conditions were based, see Chapter 5.2.3.5. Line Matching Task.

Line Task Memory Conditions.

Single Exposure Condition (Figure 7.4). The single exposure condition of this task was designed in the manner of traditional VSTM tasks in that the stimulus appears once and then disappears before a response is requested. In the single exposure condition participants viewed the pair of lines in the upper left quadrant of the screen for 2 seconds. This pair of lines then disappeared and after a delay of 4 seconds the pair of lines in the lower quadrant appeared. The participants then had an unlimited period of time in which to reproduce the pair of lines they had just seen.
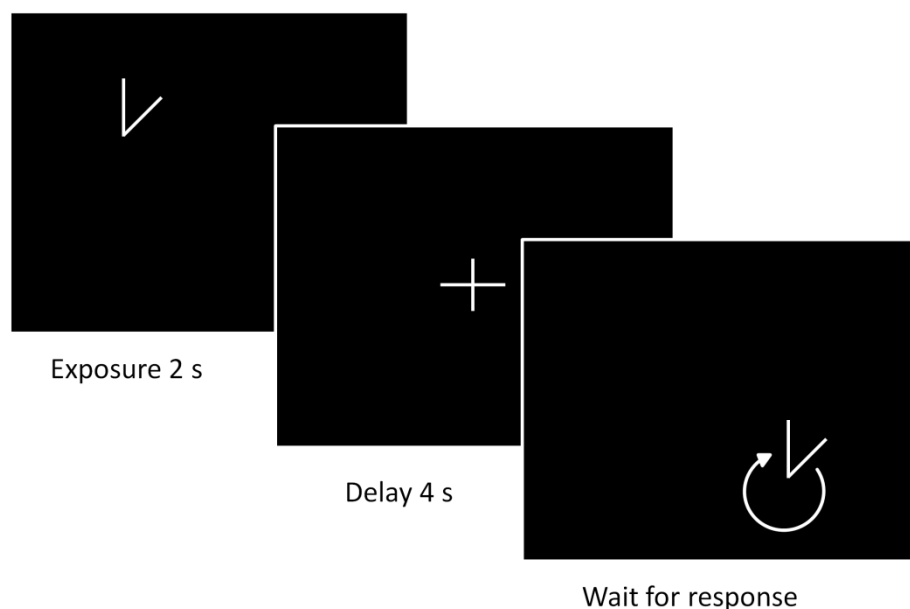
Figure 7.4. Single exposure condition for the line matching task

Flipping Condition (Figure 7.5). The flipping condition was designed to emulate the process by which an artist looks from stimulus to drawing and back again. Crucially in this task the participant can decide how many times they want to refer back to the reference stimulus before making their response. In the flipping condition participants first viewed the pair of lines in the upper left quadrant of the screen. By then pressing the 'F' key on the computer keyboard they could 'flip' between the upper and lower pair of lines so that one pair was available on the screen at any one time. They could continue to adjust the lower pair of lines and flip between the two pairs for as long as they required. When they were

satisfied that the lower pair of lines matched the upper pair of lines they could proceed to the next trial.
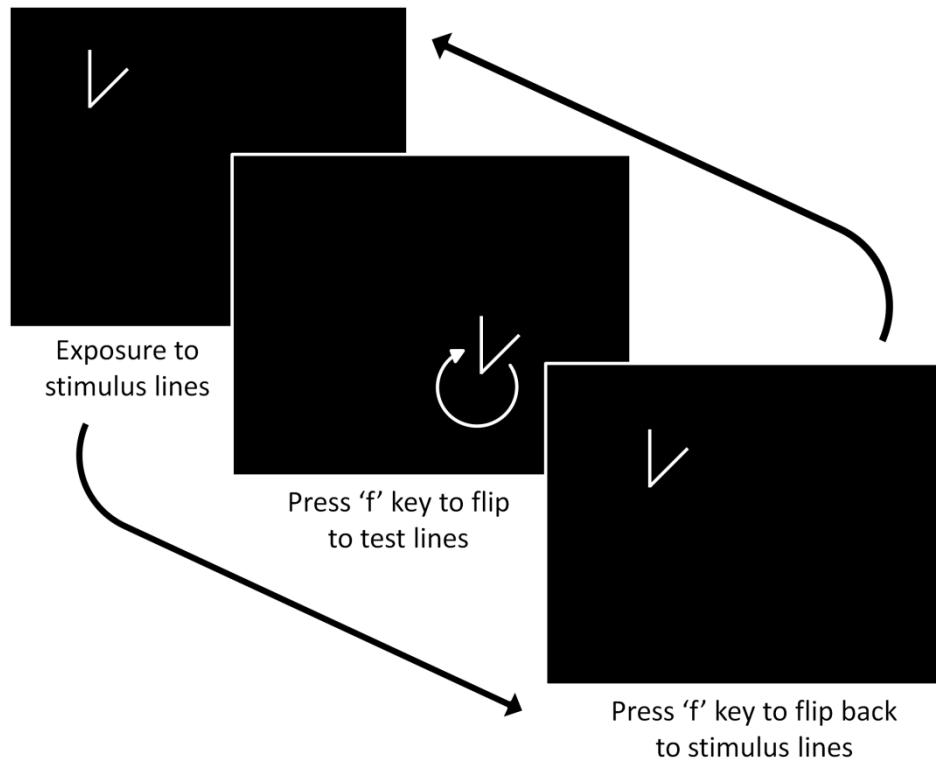
Figure 7.5. Flipping condition for the line matching task

Dual-monitor Condition (Figure 7.6). The dual-monitor task was again designed to emulate the drawing process, by placing the stimulus and response regions physically apart. In this way the condition functions as a representation of the process by which the draughtsman shifts their gaze from the stimulus to the drawing and back again. In the dual-monitor condition participants were sat equidistant from two computer monitors. On the left hand monitor the stimulus lines were presented in the upper left quadrant of the screen in exactly the same position as in the other two memory conditions. The matched pair of lines were presented on the other monitor in the lower right quadrant of the screen. Again, participants were instructed to adjust the response line pair until they were satisfied that the two pair of lines matched. Importantly, it was impossible for the participants to view both computer monitor screens at the same time, due to the limited degree of visual angle afforded to them by their seating position.
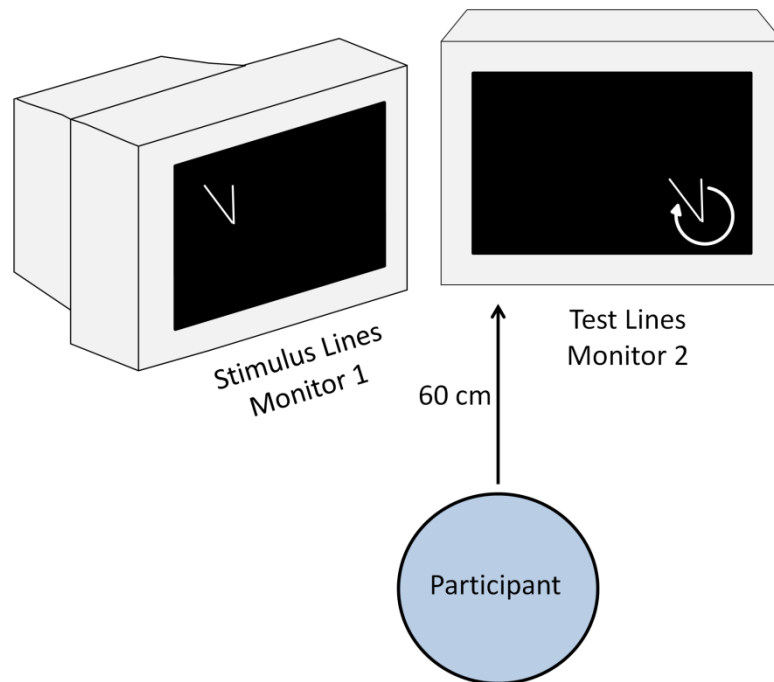
Figure 7.6. Dual-monitor condition for the line matching task

7.2.2.4 *Visual Short-term Memory (VSTM) Icon Task.*

Stimulus presentation and data collection were controlled using Cogent Graphics Toolbox for Matlab 7.10. Participants were instructed to remember one or more objects which appeared sequentially on the screen at fixation or at the periphery (for full stimuli set see Appendix H). Stimuli were presented as black 2D line drawings on a grey background on a 13-inch liquid crystal computer screen with a 60Hz refresh rate. Participants sat 60cm away from the screen.

Each item appeared onscreen for 100 milliseconds before a 1 second delay. After the second delay an object appeared on the screen (the memory probe) for 3 seconds and participants were instructed to respond as to whether this object was seen during the current experimental trial. If the object was present in the current trial, participants pressed the numerical key '1' and if the object was not present they pressed the numerical key '2'.

The number of items presented on any trial varied according to a staircase procedure up to a maximum of 10 reversals. A block of trials would begin with 2 items to remember and then after 3 consecutive correct responses, the number of items in the set would increase by one in the following trial. After each incorrect response, the number of items in the set would decrease by one in the following trial. Participants received feedback after each trial and were also told how many items would be in the following set at the start of each trial.

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Participants completed the four blocks of trials (one for each condition) in a randomised order after successfully completing a practice of 12 trials before each block. Figure 7.7 demonstrates how each trial proceeded. There were four experimental conditions:

Condition 1. Object Shape. All memory set items appear at fixation. The memory probe also appears at fixation. The task is to remember the object's shape only (Figure 7.7).
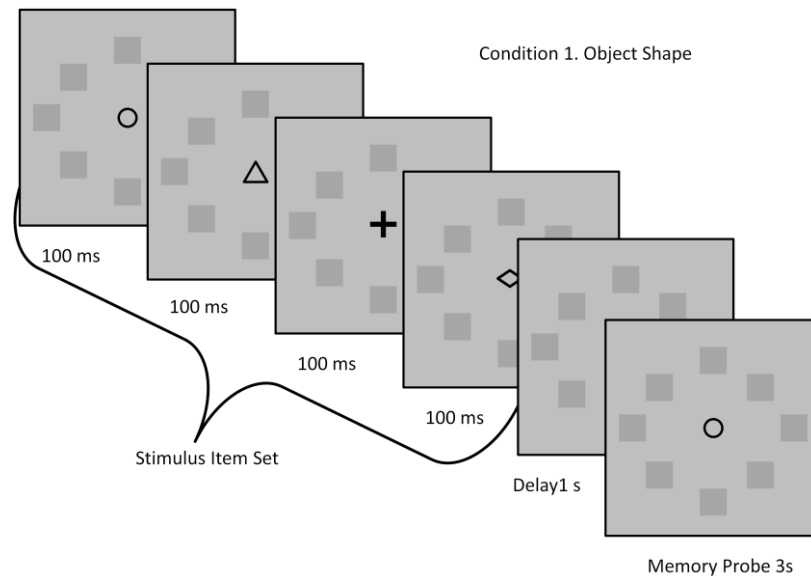
Figure 7.7. Example of a trial in Condition 1 of the VSTM Icon Task

Condition 2. Object Shape, Location Irrelevant. The memory set items appear at different locations around fixation but the location is irrelevant. The task is to remember the object's shape only. The memory probe appears at fixation (Figure 7.8).
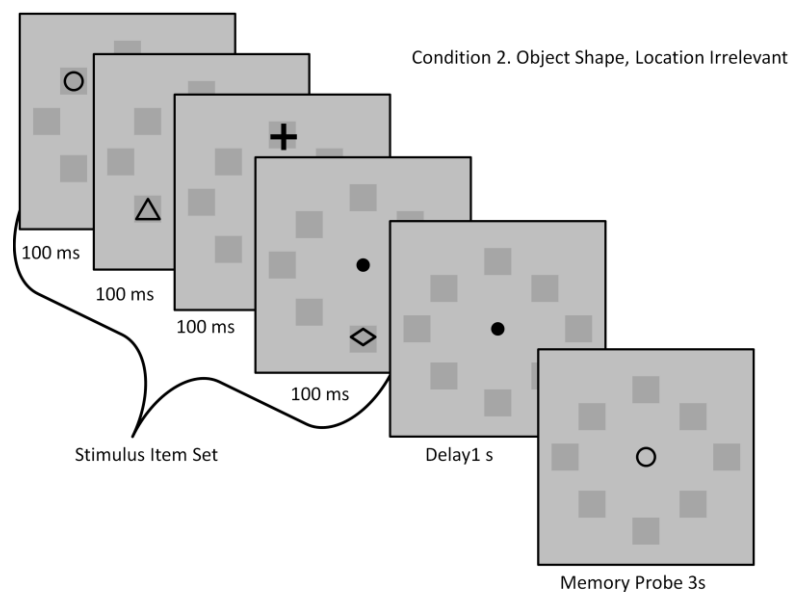
Figure 7.8. Example of a trial in Condition 2 of the VSTM Icon Task

Condition 3. Object Shape and Location. The memory set items appear at different locations around fixation. They now need to remember both location and shape. The memory probe always appears in one of the occupied locations of the memory set items. But they respond "same" only if it's the same shape in the same location (Figure 7.9).
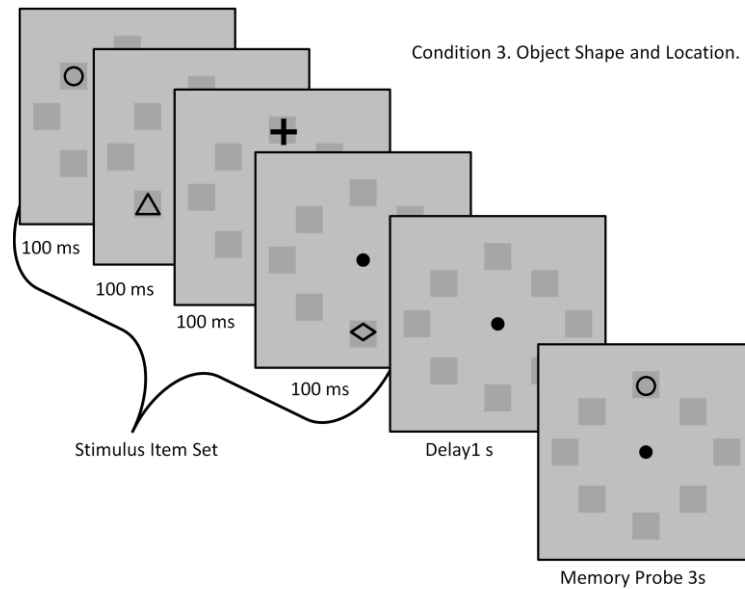
Figure 7.9. Example of a trial in Condition 3 of the VSTM Icon Task

Condition 4. Object Location, Shape Irrelevant. The memory set contains only one shape that appears in a different location every time. The shape is irrelevant and they only need to remember the location (Figure 7.10). The memory probe appears either in one of the memory set locations ("same") or in a new location ("different").
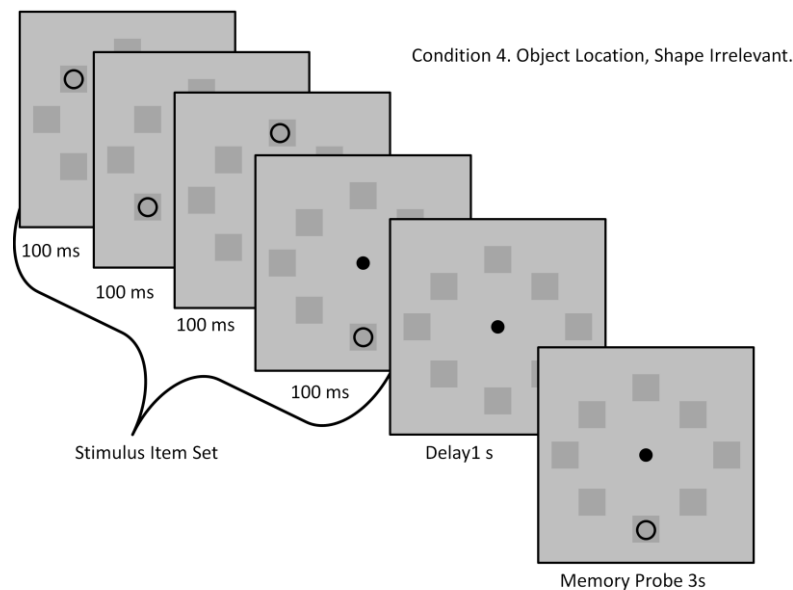
Figure 7.10. Example of a trial in Condition 4 of the VSTM Icon Task

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Ethics

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

7.3 Results

7.3.1 Drawing Rating Procedure for Hand and Block Drawings

See data preparation section 3.3 for a full description of the procedure for rating the accuracy of participants' drawings.

7.3.2 Observational Drawing Ratings

Participants' scores for the hand and block drawings were averaged across the ten non-expert raters. Inter-rater reliability was good with a Cronbach's alpha of .86 for hand drawing ratings and .86 for block drawing ratings across the four samples of drawings for each memory task, which are comparable with alpha reliability of expert judges in a previous study conducted by our research team (McManus et al., 2010). Average scores of accuracy for the hand task was 4.62 (SD=1.62) and for the blocks task was 4.38 (SD=1.88). Hand drawing ratings were highly positively correlated with block drawing ratings, r (211) =.61, p<.001, therefore a composite drawing rating was produced by averaging drawing ratings for the hand and blocks for each participant.

7.3.3 Rey Osterrieth Complex Figure

Data Preparation. All Rey Osterrieth copies and memorised drawings were scored according to the Rey-Osterrieth Scoring Manual (Meyers & Meyers, 1995; Rey & Osterrieth, 1993). Scores are derived from accuracy of both positioning and detail of each element of the ROCFT (see Appendix G for the full ROCFT scoring scheme and examples of copied and memorised figures by participants in the current study). Scores are then summed to derive total scores out of a possible 36 (2 points per element). Both total and percent retention scores (recall score/copy score x 100; taken from Boone, Lesser, Hill-Gutierrez, Berman & D'elia, 1993) were derived for the immediate and delayed recall condition. Percent retained scores take into account the copy performance in order to isolate VLTM. The ROCFT recognition test scores were derived by summing the number of elements participants correctly identified as occurring and missing from the figure. The maximum points that could be scored for this task was 24. The descriptive statistics for each condition are presented in Table 7.3.

Table 7.3. Descriptive statistics for the ROCFTs

		Mean Score	SD
ROCFT Copy		31.95	4.18
ROCFT Immediate	Total	22.84	6.10
	Percent Retention (%)	70.09	18.48
ROCFT Delayed	Total	21.62	5.96
	Percent Retention (%)	67.93	17.0
ROCFT Delayed Recognition		19.14	2.82

Scores on the three conditions of the ROCFT correlated with one another. Copy scores correlated significantly positively with total, r (68) =.34, p<.01, but not percent retained scores, r (68) = -.18, p=.14, for the immediate recall condition. A similar pattern emerged for the delayed recall condition, in which copy scores correlated significantly with total, r (205) =.45, p<.01, but not percent retained scores, r (205) = -.07, p=.33.

Correlations between performance on the ROCFT and measures of observational drawing ability are shown in Table 7.4 below.

Table 7.4. Correlations between externally rated drawing ability, angular and proportional accuracy and Rey Osterrieth Copy, Immediate and Delayed Recall Scores (n range=68-203)

		Externally rated drawing ability	Cain House Task Angle Error	Cain House Task Proportion Error
ROCFT Copy		.28**	.09	-.05
ROCFT Immediate Recall	Total	.41**	-	-
	% Retained	.33**	-	-
ROCFT Recall	Total	.32**	.02	-.02
	% Retained	.20**	-.00	-.08
ROCFT Recognition		.14	-	-

Notes: ** p<.01

Copying Condition. The copying condition of the ROFT correlated significantly positively with externally rated drawing ability, but there was no correlation between copy scores and angular and proportional error in the Cain house task (Table 7.4).

Immediate Recall. The immediate recall condition of the ROFT correlated positively with externally rated drawing ability both for total scores and percent retained. There was no data available for the Cain house task for this condition, as participants who completed the immediate recall condition did not complete the Cain task in this experimental session.

Delayed Recall. The delayed recall condition of the ROFT correlated positively with externally rated drawing ability both for total scores and percent retained, but there was no correlation between delayed recall scores and angular and proportional accuracy in Cain House task.

Delayed Recognition. There were no data available for the Cain house task for this condition, as participants who completed the delayed recognition condition did not complete the Cain task in this experimental session. There was no significant correlation between delayed recognition performance and drawing accuracy ratings.

Global and Local Features of the Rey Osterrieth. In line with investigations of global-local visual processing, it was of interest to assess whether memory and copying performance for local and global features of the ROFT were correlated with externally rated drawing ability. In a previous study researchers made global/local scoring modifications for the ROCF and this scoring system was used to divide elements of the ROCF representing global and local features in the current study (McConley, Martin, Baños, Blanton, & Faught, 2006). The scoring system only included 10 elements of the ROCF as some elements could not be categorised as either global or local and is shown below in Figure 7.11.
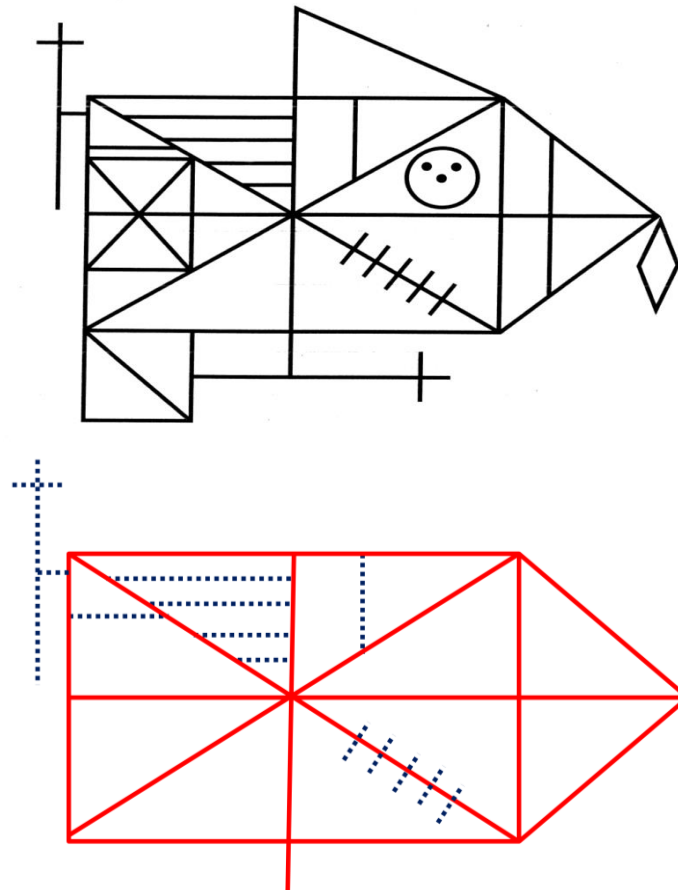
Figure 7.11. The original ROCF (above) alongside local (blue, spotted) and global (red, solid) elements of the ROCF (below)

In the immediate recall condition locally copied features were not significantly correlated with drawing ratings, r (58) =.25, p=.06, but globally copied features were, r (58) =.31, p<.05. In the delayed recall condition, both locally, r (160) =.23, p<.05, and globally, r (160) =.16, p<.05, copied features correlated positively with externally rated drawing ability.

7.3.4 Line Memory Task

Angular and proportional precision and bias was calculated for each condition of the line memory task. The descriptive data are shown in Table 7.5. It can be seen that performance was most accurate in the dual-monitor condition, followed by the copying condition then the flipping condition. Participants performed worst in the single exposure condition in which their accuracy was 4.56° lower than in the flipping condition.

Single Exposure Condition. In a one-sample t-test mean angular and proportional errors were not significantly different from zero, indicating that there was no systematic bias (angular error, t (18) =-1.18, p=.25; proportional error, t (18) =.59, p=.56).

Flipping Condition. Mean angular and proportional errors were not significantly different from zero, indicating that there was no systematic bias (angular error, t (18) =-.51, p=.61; proportional error, t (18) =-.82, p=.42).

Dual-Monitor Condition. Mean angular errors were not significantly different from zero, indicating that there was no systematic bias (angular error, t (34) =1.94, p=.06). However, there was a consistent underestimation in the proportion condition, t (34) =-8.64, p<.01.

Table 7.5. Descriptive Statistics for the Line Memory Task

	Angle Condition (º)		Proportion Condition (%)	
Line Memory Task Condition	Mean	SD	Mean	SD
Copying	2.93	1.25	3.70	2.61
Single Exposure	8.19	3.42	10.1	5.00
Flipping	3.63	1.47	5.34	3.74
Dual-Monitor	2.54	.93	4.94	2.17

A correlation matrix was calculated to assess the relationship between precision (standard deviation of the mean error scores) on the line copying task (explored in Chapter 5), the remaining three conditions of the line task and externally rated drawing ability.

Table 7.6 shows the correlations between the four conditions of the line task. Angular and proportional accuracy seem to be independent in the single exposure and flipping conditions, but were significantly correlated in the copying and dual-monitor condition. There were no significant correlations between performance on different conditions of the line task. However, a trend for positive correlation between angular accuracy in the copy condition and the single exposure, flipping and dual-monitor conditions was evident (r range=.24-.30). This trend was to some degree evident for proportional precision in the copy condition but correlations were weak to moderate (r range=.11-.29).

Table 7.6. Correlations between conditions of the line copying task and drawing accuracy ratings (n range=28-40)

		Line Matching Task Conditions								Drawing Ratings
		Angle				Proportion				
		C	S-E	F	D-M	C	S-E	F	D-M	
Angle	C	-	.30	.24	.24	.32*	.03	.01	.06	-.46**
	S-E	-	-	.01	.24	-.09	.19	.14	-.01	.02
	F	-	-	-	.14	.27	.21	.12	.17	.01
	D-M	-	-	-	-	-.02	-.10	.04	.46**	-.22
Proportion	C	-	-	-	-	-	.11	.29	.21	-.43**
	S-E	-	-	-	-	-	-	.10	.04	-.16
	F	-	-	-	-	-	-	-	.03	.01
	D-M	-	-	-	-	-	-	-	-	-.13

Notes: *p<.05, **p<.01, C=Copying Condition, S-E=Single Exposure Condition, F=Flipping Condition, D-M=Dual-monitor Condition.

As reported previously, there were significant negative correlations between angular and proportional precision and drawing accuracy ratings in the copying condition of the line task. However, these correlations were not replicated in any of the other conditions of the line memory task (see correlations in Table 7.6). There was little statistical relationship between angular and proportional precision and drawing accuracy ratings for the single exposure and flipping conditions of the line task. There appeared to be a trend for negative correlations between angular and proportional precision and drawing accuracy in the dual-monitor condition, in the same direction as for the copying condition, but these correlations were weaker than those of the copy condition and did not reach significance. There was a significant difference in the correlation coefficients between the angle copying and drawing rating on the one hand, and both the single-exposure and flipping conditions and drawing rating on the other (single-exposure vs. copying z(39)=-2.23, p<.05; flipping vs. copying z(39)=-2.18, p<.05). There was no significant difference between the correlation coefficients with line copying and drawing ratings, and multi-monitor line reproduction and drawing ratings. Finally, there was a significant positive correlation between the flip rates (number of flips/total trial time) in the angle condition and drawing accuracy ratings, r (16) =.62, p<.01,

but not between flip rate and drawing accuracy in the proportion condition, r (17) =-.33, p=.20.

7.3.5 VSTM Icon Task

For the VSTM icon task a staircase paradigm was used. For each condition the mean number of items retained in short-term memory was derived for 8 and 10 reversals. To remind the reader in Condition 1 participants were only required to remember the object's shape at fixation. In Condition 2 participants had to remember the shape of the object but its location also changed during the trial. In Condition 3 participants had to remember both the object's shape and location. Finally in Condition 4 the shape of the object was irrelevant and participants were only required to remember its location.

Descriptive statistics for each of the four conditions are shown in Table 7.7. Participants memorised the largest set of items in condition 4 (location only) and remembered the fewest items in condition 2 (shape only, location varied). Participants showed equivocal set sizes after both 8 and 10 reversals in the first three conditions, but retained significantly higher set sizes for 8 reversals compared with 10 reversals in condition 4, t (22)=4.68, p<.01.

Table 7.7. Descriptive statistics for the VSTM icon task (N=24).

		Mean Accuracy	SD
1. Object Shape	8 reversals	2.81	.95
	10 reversals	2.72	.77
2. Object Shape, Location Irrelevant	8 reversals	2.46	.42
	10 reversals	2.45	.38
3. Object Shape and Location	8 reversals	2.79	.77
	10 reversals	2.75	.69
4. Object Location, Shape Irrelevant	8 reversals	4.34	1.00
	10 reversals	4.01	.83

The relationship between performance on the different conditions of the VSTM task and their association with drawing ability was assessed (Table 7.7). There was little correlation in performance across the four conditions of the VSTM task, apart from between performance on the object shape condition and the object shape and location condition.

However the significant positive correlation between these conditions would not withstand Bonferroni correction. All correlations were positive apart from the relationship between conditions 2 and 3, suggesting some association between levels of performance in the various conditions.

Table 7.8. Correlations between different conditions of the VSTM task (N=24)

		1. Object Shape	2. Object Shape, Location Irrelevant	3. Object Shape and Location	4. Object Location, Shape Irrelevant	Drawing Rating
1. Object Shape	8 reversals	-	.15	.39	.17	-.19
	10 reversals	-	.20	.49*	.17	-.33
2. Object Shape, Location Irrelevant	8 reversals	-	-	-.02	.17	.07
	10 reversals	-	-	.07	.21	-.07
3. Object Shape and Location	8 reversals	-	-	-	.17	-.43*
	10 reversals	-	-	-	.30	-.37
4. Object Location, Shape Irrelevant	8 reversals	-	-	-	-	.17
	10 reversals	-	-	-	-	.13

Notes: *p<.05.

The number of items retained in VSTM was weakly negatively correlated with drawing ratings in Condition 1 (shape only) but these correlations did not reach significance. There appeared to be no relationship between performance in Condition 2 (location change, shape relevant only). There was some evidence of a negative relationship between performance in Condition 3 (shape and location), but this relationship was only statistically significant after 8 reversals, and constitutes a moderate correlation (Dancey & Reidy, 2004). Finally and contrasting with the other three conditions, there was a weak positive relationship between number of items retained in Condition 4 (location only) but this correlation did not reach significance. However, there were no significant differences between the correlation coefficients between the various iconic memory conditions and drawing ratings.

7.4   Discussion

In this chapter a series of long and short-term visual memory tasks were employed to assess the relationship between visual memory precision, spatial content and drawing accuracy. In summary, consistent relationships were found between drawing conditions of the ROCFT and drawing accuracy, including when copying accuracy was taken into account, suggesting that both accuracy of visual perception and VLTM contribute to drawing in this context. This finding can be explained by the notion that that representations in VLTM help to guide visual perception in expert draughtsmen. However there appeared to be little relationship between VLTM and drawing accuracy, as evidenced by participants' performance in a modified version of the ROCFT that measured recognition memory without the need to copy or reproduce the ROCF. Furthermore, there is some evidence that memory for global features of an image is more important for drawing over shorter time periods, but that memory for both local and global features is necessary for drawing accuracy over longer time spans. The global-local processing finding will shortly be discussed in relation to the findings of Chapter 6 on local-global perceptual processing in drawing. In two VSTM tasks (line/icon) there appeared to be little relationship between object or spatial VSTM and drawing accuracy. Thus there appears to be a dichotomy between the role of rendering and non-rendering and short and long term representations, in terms of the role of visual memory in accurate observational drawing, which will now be explored in more detail.

7.4.1   Encoding when rendering is necessary for accuracy

The act of drawing appears to be a key condition for the interaction of visual representations with drawing accuracy, in contrast to the findings concerning perception outlined in Chapters 5 and 6, in which perceptual performance in rendering and non-rendering tasks both predicted drawing accuracy equally. Firstly, accuracy in copying the ROCF during the encoding phase predicted accuracy for the hand and block drawing tasks. Scores in the copying condition were unrelated to angular and proportional accuracy in the Cain house task, excluding the precision of perceptual representations as a mediator for the link between scores in the copying condition and drawing accuracy. Instead this correlation could reflect the role of efficient encoding and planning in drawing as participants only had 4 minutes to copy the entire figure. There was also a significant link between total ROCF immediate and delayed recall scores, in which participants were required to make a drawn copy of the ROCF in the initial encoding stage and then reproduce it through rendering after a short or long delay. It is conceivable that this relationship may have been dependent upon the amount of information taken in during the encoding phase. However, a link between the percentage of items retained in memory from the ROCFT and the accuracy of participants'

drawing was seen in the immediate and delayed recall conditions, suggesting that regardless of copying ability, visual memory in this context was associated with drawing accuracy. Performance in the rendering conditions of the ROCFT correlates with drawing accuracy, in contrast with the finding that performance in the recognition condition of the ROCFT did not correlate with drawing accuracy. This finding also contrasts with earlier research which suggests that visual LTM, as measured by change detection performance, is related to drawing ability (Casey et al., 1990; Rosenblatt & Winner, 1988; Sullivan & Winner, 1989; Winner & Casey, 1992). Furthermore, Glazek's (2012) findings suggest that in rendering *and* non-rendering contexts encoding in visual memory supports superior drawing in artists. The finding that recognition VLTM in a non-rendering task does not correlate with drawing ability could be a product of the task itself. It can be suggested that drawing a stimulus is more engaging than viewing a stimulus with the goal of memorising it. This could be especially true for those that are gifted at drawing. A more extensive investigation of the role of visual memory in rendering and non-rendering contexts is necessary to make firm conclusions regarding the context of superior visual representations in proficient draughtsmen. In this instance it appears that drawing *during* the process of encoding is of fundamental importance to the subsequent recognition of those items for proficient draughtsmen.

7.4.2 Weak Associations between Quality of Representations in VSTM and Observational Drawing Accuracy

From the current data there is stronger evidence to suggest that VLTM plays a role in drawing than VSTM. Both the immediate and the delayed recall conditions of the ROCFT constitute VLTM tasks, as both required participants to remember the stimulus for more than 4s, which is beyond the duration of visual working memory (Baddeley, 1986). Performance on these tasks shows a clear and positive relationship with drawing accuracy. However, performance on the VSTM tasks presented in this chapter did not consistently and significantly correlate with drawing accuracy. This finding suggests that the precision, spatial accuracy and capacity of representations in visual working memory are weak predictors for individual differences in drawing accuracy. This result follows on from previous findings reported in this thesis that demonstrate little correlation between representations in visual imagery and drawing accuracy (3.4.3. Visual Imagery).

It was predicted that spatial VSTM would be related to drawing accuracy ratings in the current study, but no directional hypothesis concerning the link between object VSTM and drawing accuracy was made. The line matching task can be construed as an object VSTM task as it requires precise, detailed representations of the visual stimulus for superior

performance. Whilst perceptual accuracy in the line matching task showed a positive relationship with drawing accuracy in the copying condition, this association appeared to break down in instances in which participants had to hold the visual stimuli in working memory for up to four seconds. There was tentative evidence for performance on the dual-monitor condition of the line task to be correlated with drawing accuracy. This condition appears to be the most similar to the activity artists perform when they are drawing and perhaps represents a situation in which there was least reliance on maintenance of working memory associations. Instead, performance could have been driven by the speed at which participants could shift their gaze from one pair of lines to the other. This finding highlights the importance of ecological validity in tasks that attempt to associate memorial abilities with complex cognitive tasks such as drawing.

In the icon task object and spatial VSTM were directly compared in a series of conditions that required participants to recall either the location, shape or location and shape of icons. There was some evidence of a negative relationship between performance and drawing accuracy in tasks requiring only the memorisation of shape (Condition 1, VSTM Icon Task), or of a combination of shape and location (Condition 3, VSTM Icon Task). This finding suggests that object VSTM may even be detrimental to the accuracy of drawings. This could be due to the fact that if visual representations are too detailed and do not communicate the necessary and sufficient information they will not result in a proficient rendering. On the other hand, it was expected that enhanced spatial relations in short-term memory would support drawing. However, from the current data it is not possible to state conclusively that spatial VSTM is related to drawing accuracy. If there is an association, it is only weak at best and therefore VSTM is not included as a prominent feature in the toolbox for drawing ability presented in the concluding chapter of this thesis. It must be noted that in the context of the current visual memory studies, drawing was not required for responses, as it was desirable for the memory conditions of the line matching task to resemble the copy condition (which was designed specifically not to include rendering) as closely as possible. Furthermore, as Glazek (2012) found a non domain-specific encoding advantage for artists in his studies, it was predicted that in the same way superior draughtsmen in the current memory studies would show an advantage in the line matching task even though they were not required to draw the stimuli. As the non domain-specific hypothesis has not been borne out in the current studies, and rendering appears to be a condition for increased performance in the VLTM tasks, it would be advisable to conduct future studies of VSTM and drawing with rendering and non-rendering conditions. This would eliminate the possibility that artists must be drawing in order to demonstrate a VSTM advantage.

The findings for the VSTM tasks do appear to ameliorate the role of working memory in an explanation of individual differences in observational drawing ability. This conclusion is supported by the empirical and theoretical propositions of Tchalenko and colleagues (Tchalenko, 2009; Tchalenko & Miall, 2009), who suggest that the need for enhanced working memory representations is precluded by premotor planning in expert draughtsmen. Therefore, individual differences in the premotor domain may be more predictive of individual differences in the drawing domain. Visuo-motor transformations made during the drawing process may act directly, rather than via internal visual representations, explaining the lack of a robust correlation between both the quality of spatial relationships and detail within visual memory and drawing accuracy in this study. Furthermore, evidence from the flip rate in the line task suggests that those participants who flipped more quickly from one stimulus to the other showed superior drawing accuracy, showing an understanding of how to reduce WM load. This finding is supported by eye movement findings of Cohen (2005), who found that increased gaze frequency predicted higher drawing accuracy scores and that by manipulating the gaze frequency to be lower, drawing accuracy could be artificially lowered in turn. Therefore, it appears that those who decreased their dependence on working memory representations were more likely to create more accurate drawings of the hand and the block stimuli.

7.4.3   The role of VLTM in drawing: Visual Encoding and Motor Planning

The findings from the current tasks together suggest that VSTM and VLTM in non-rendering contexts are not strongly related to individual differences in observational drawing. However, there appears to be a positive role for VLTM when drawing is required which needs further elaboration. In the introductory chapter research was cited which suggested that LTM may interact with the drawing process, by facilitating efficient visual analysis and encoding via spatial schemata (Glazek, 2012; Kozbelt, 2001; Kozbelt et al., 2010; Seeley & Kozbelt, 2008). Spatial schemata represent sets of stimulus features sufficient for accurate depiction (Gombrich, 1960; Seeley & Kozbelt, 2008). VLTM representations, such as those required for the ROCFT, may aid online visual perceptual processing through attentional guidance (Stokes et al., 2012; Summerfield et al., 2006; Summerfield et al., 2011). However on the basis of the contrasting results of the rendering and non-rendering conditions in the ROCFT, it can be argued that superior attentional guidance only occurs in cases in which artists are encoding in the context of rendering. Seeley and Kozbelt (2008) argue that endogenous shifts of visual attention enhance encoding of expected features in the visual fields and inhibit the perception of distracters. Therefore, artists can be said to have better endogenous shifts of attention and better

developed expectations, which enables them to inhibit biasing distracters. Spatial attention could also be underpinned by the procedural memory, which is discussed further in the following VBM chapter on drawing, in which it is shown that brain regions associated with procedural memory are related to expertise in drawing. The notion of the interaction between long-term memory, motor planning and perceptual attention coincides with Glazek's (2012) model for LT-WM in drawing, in which he argues that long term representations interact with motor plans for more efficient drawing behaviour.

The notion of encoding of 'expected' features in the visual world directly relates to research on expertise. Expertise in chess impacts upon representations in LTM, by enhancing evaluation of visual stimuli and procedural structures during drawing which leads to more effective perceptual processing. Expertise in drawing could function in the same way. The discussion of LTM here points toward a coupling of perception and memory, such that enhanced encoding and premotor planning leads to better recall performance in drawing. A benefit of efficient encoding as highlighted by Glazek (2012) is the time afforded to creative processes. Additionally, I propose that time afforded to planning is also a benefit of faster, more efficient visual processing into LTM. The ROCFT has been used in the past as a measure of executive function (Stern et al., 1994). Therefore, relationships between the copying and recall conditions of the task could also be reflective of superior planning in drawing accuracy as a result of faster encoding. This contention has yet to be tested explicitly and is a potential avenue for future research.

7.4.4 Perceptual Processing and Global and Local Memory

One of the supplementary aims of this study was to assess whether performance in perceptual tasks related to performance in memorial tasks and how the two may interact to facilitate drawing ability. As mentioned previously, visual LTM may be associated with drawing accuracy through enhanced encoding of visual stimuli in rendering contexts. If this were the case then we would expect to see a relationship between perception and memory performance in these tasks. Indeed, in the case of the ROCFT copying performance predicted both total and percent retained immediate and delayed recall, suggesting that the initial ability to perceive and render the stimulus was related to the ability to remember it. However, in the analysis of the line matching task there was little evidence of correlations between perceptual and memory performance. Performance on the copying condition of the line task did not robustly predict subsequent retention of the same stimuli, the average correlation between the copying condition and the other memory conditions being .24. This finding suggests that the two faculties are to some extent independent of one another in this context. Therefore, it can be concluded that in the case of the VSTM tasks, accurate

perception is not a necessary corollary of accurate encoding and subsequent accurate recall, as was the case in the ROCFT.

The short-term memorisation of global features in the ROCFT was more predictive of drawing ability than local features. This finding may seem to contrast with the local focus that was demonstrated in Chapter 6, however it does provide support for the notion that global processing is as important as local processing for expertise in drawing. When memorising stimuli for longer periods of time it appeared that both local and global memory were related to drawing ability, suggesting that effective processing and encoding of both local and global features is necessary for proficient drawing. It could be the case that the order in which global and local features are copied in the ROCFT also effects retention and recall. The order of construction of the ROCFT has been previously used to assess local-global processing (Booth et al., 2003; Mottron et al., 1999). This assessment has not yet been conducted in the non-ASD population and is a fruitful avenue of investigation. Encouraging participants to use either a local or global initial framework for their drawing may affect drawing accuracy and its relation to visual memory; again there is no evidence to support this hypothesis, but it would be a valuable further study, especially as it would help to establish *causative* links between global-local processing and drawing accuracy.

7.5   Interim Summary of Perceptual and Memorial Contributions to Drawing

Before proceeding to the final experimental chapter of this thesis it is necessary to summarise the body of evidence pertaining to perception and memory in order to consolidate the various lines of enquiry presented thus far. Findings from the interview study presented at the beginning of this thesis (Chapter 2), highlighted the importance of accurate perception to students of drawing, with artists citing the use of restricted productive and perceptual techniques in order to extract certain features from the visual environment. The survey study confirmed the importance of observational drawing and the use of drawing techniques for students, as well as highlighting which drawing devices were most commonly used. Those devices that were cited as being used most frequently were those that isolated global features of visual objects or scenes such as blurring vision or marking the pivotal points on an object (3.4.2. Observational Drawing Ability, Devices and Practice). The interview and survey studies were followed up in a series of experimental investigations of the role of perception in drawing to provide quantitative support for the interview data that represented a small subsample of practicing artists.

Chapters 5-7 have demonstrated that enhanced perceptual processing is associated with drawing accuracy, whilst it appears from the current studies that VLTM representations play a role in drawing ability, but VSTM representations are less likely to underpin individuals

differences in drawing. On the basis of the visual memory findings it can be concluded that retention of the material is less important for the drawing process than perception facilitated by LTM. The cumulative empirical findings presented here support research conducted in artistic savants, who showed enhanced perceptual processing in picture matching and copying tasks and in local processing, but not in recall and recognition tests of VSTM (Hermelin & O'Connor, 1990; O'Connor & Hermelin, 1987b; O'Connor & Hermelin, 1990). Together these findings put perception at the centre of the drawing process, echoing Cohen and Bennett's (1997) early findings that perceptual errors form the foundation of most drawing errors. The toolbox in the concluding chapter of this thesis will take these data along with data from the survey study in Chapter 3 into account and provide a framework that focuses upon visual perceptual processes as the core element for explaining individual differences in drawing ability.

Previously some attempts have been made to place a framework for drawing within neural mechanisms in the brain. Complementary research from the behavioural and neuroimaging domain will help to cement the claims made here. The final empirical chapter of this thesis tests the contention that perceptual processing is enhanced in proficient drawing by assessing correlations with artistic ability, drawing ability and grey and white neural matter in a voxel based morphometry (VBM) study. A selection of the tasks developed in the behavioural studies outlined here was used in the VBM study in order to assess the neural roles of perceptual and memorial processing in the drawing process. Structural neuroimaging data was analysed for overlap of areas associated with local-global processing and drawing accuracy, to assess whether long term structural changes occur as a result of enhanced perception in relation to drawing. This study provides information concerning the mechanisms underpinning the links between behavioural measures and drawing accuracy. It may also highlight the roles of other modules of the drawing process that hitherto have been neglected in the behavioural components of this thesis.

Chapter 8.   Drawing on the Right Side of the Brain

'As each new skill is learned, you will merge it with those previously learned until, one day, you are simply drawing - just as, one day, you found yourself simply driving without thinking about how to do it.'

Betty Edwards

(Edwards, 1989, p.XIX)

8.1 Introduction

Thus far this thesis has presented a number of behavioural studies investigating the underlying correlates of representational drawing ability, including personality and demographic factors and individual differences in visual perception, imagery and memory. In this final empirical chapter, I link the behavioural manifestations of expertise in drawing with its underlying neural substrate. Literature concerning the neural structures associated with drawing is summarized in the introductory chapter of this thesis (1.7. Drawing and the Brain).

To recap briefly, early studies drew on the neurological patient literature, particularly from patients with hemispheric damage (Chatterjee, 2004), visual agnosia (Trojano & Grossi, 1992) and various forms of dementia (Miller et al., 1998), whilst functional neuroimaging studies have started to accumulate in the last decade (Bhattacharya & Petsche, 2005; Ferber et al., 2007; Makuuchi et al., 2003; Miall et al., 2009; Solso, 2001). Neuropsychological research implicates brain regions that underpin the integration of multimodal perceptual data, largely involving the parietal cortices. The study of constructional apraxia supports the contention that the parietal lobes appear to be critical in drawing (Makuuchi et al., 2003), whilst differing drawing pathologies are manifested in right-brain damaged compared to left-brain damaged patients (Chatterjee, 2004). Corroboratively, a study of a patient who demonstrated increased grey matter in parietal regions, as a result of progressive aphasia, produced drawings that increased in realism as her condition progressed (Seeley et al., 2008). The authors of the aforementioned study argue that structural and functional enhancements in parietal regions give rise to specific forms of visual creativity that are liberated by the deterioration of the frontal cortex in this disease. Neuroimaging data have supported the findings of neuropsychological studies, by demonstrating higher relative activation in the parietal cortices during drawing. In addition, they have found activity in the motor regions and the cerebellum to be relatively higher during drawing (Makuuchi et al., 2003; Miall et al., 2009; Solso, 2001). Ferber et al (2007) failed to replicate these findings, instead finding increased activation in the anterior cingulate and medial frontal gyrus when drawing or copying was compared with tracing. Finally, Schlegel et al (2012) found that novices who had undergone an intensive drawing and painting course showed functional changes in the cerebellum during gestural drawing, and structural changes to right inferior frontal regions revealed by fractional anisotropy (FA). A summary of the brain regions implicated in each study of drawing is shown below in Table 8.1. Cumulatively these data suggest that drawing encompasses a wide range of neural processes and regions, and that some of these are structurally or functionally altered

by expertise. I will now explain the role of brain regions that have been previously shown to be related to drawing in cognitive and motor functioning more generally, in order to build a picture of how they may functionally interact to enable the drawing process.

Table 8.1 Studies investigating the neural correlates of drawing with behavioural tasks, neuroimaging methodology and brain regions associated with behavioural measures

Authors	Behavioural Measure	Technique	Brain Region(s)
Bhattacharya & Petsche (2005)	Free drawing	EEG	i. Right Cerebral Hemisphere
Ferber et al (2007)	Free drawing Copying Tracing	fMRI	i. Right Anterior Cingulate ii. Left Medial Frontal Gyrus iii. Left Middle Occiptial Gyrus iv. Left Cuneus v. Left Lingual Gyrus
Makuuchi et al (2003)	Gestural drawing	fMRI	i. Left/Right SPL ii. Left/Right IPS iii. Left Precentral Gyrus iv. Left/Right Dorsal and Ventral PMC v. Left/Right Pre-SMA vi. Left/Right SMA vii. Left/Right Cingulate Gyrus viii. Inferior temporal sulcus ix. Left/Right cerebellum
Miall et al (2009)	Copying	fMRI	i. Left SMA ii. Right Cerebellum iii. Left PMC iv. Left Parietal Cortex
Schlegel et al (2012)	Gestural drawing	VBM	i. Right Cerebellum ii. Right inferior frontal cortex
Seeley et al (2008)	Free drawing	VBM	i. IPS ii. Right SPL iii. Right STS
Solso (2001)	Copying	fMRI	i. Right PPL ii. Right middle frontal areas

8.1.1 The Parietal Cortex, Cerebellum and Motor Cortices

Existing research strongly implicates the role of the parietal cortices, motor regions and the cerebellum in representational drawing (Makuuchi et al., 2003; Miall et al., 2009; Schlegel et al., 2012; Solso, 2001). The following section will outline what is generally construed to be the main functions of each of these brain regions, in order to provide a framework of the neural underpinnings of drawing and to advance a directional hypothesis for regions associated with drawing in the current VBM study.

The Parietal Lobes. The parietal lobes serve a broad array of cognitive and perceptual processes. They have been associated with a disparate range of functions including attention (Corbetta, 1998; Corbetta & Shulman, 2002), mathematical and magnitude processing (Chochon, Cohen, van de Moortele, & Dehaene, 1999; Pinel, Piazza, Le Bihan, & Dehaene, 2004), reading (Turkeltaub, Gareau, Flowers, Zeffiro, & Eden, 2003) and more recently with memory (Wagner, Shannon, Kahn, & Buckner, 2005). There is increasing evidence for parcellation of the parietal lobes, with as many as ten distinct regions present, each serving a different and diverse function (Mars et al., 2011).

Makuuchi et al (2003) pinpoint posterior regions of the parietal cortex, Brodmann's areas 7 and 40, as being specifically involved in drawing. Brodmann's area 7 encompasses a large region of the parietal lobe including the intraparietal and the superior parietal lobule, and is predominantly linked with coding of space for goal oriented behaviour. Damage to BA7 impairs reaching movements for objects in the contralesional hand in monkeys and results in a complex pattern of spatial neglect with respect to movement in humans (Karnath, 2001). Brodmann's area 40 covers a region of the inferior parietal lobule, which has been associated with grasping, effecting strategy and response changes, attentional shifts and memory retrieval, suggesting a role in longer-term coding of space for goal oriented behaviour (Karnath, 2001; Mars et al, 2011). Other posterior regions of the parietal cortex may be associated with more specific task demands in drawing; Solso's studies implicated increase in efficiency in parietal areas involved in face processing in an expert portrait artist (Solso, 2000; Solso, 2001). Parietal regions associated with drawing may therefore be related to the specific visual stimulus being drawn, or to more general strategies for pairing incoming visual information with attentive and motor processes.
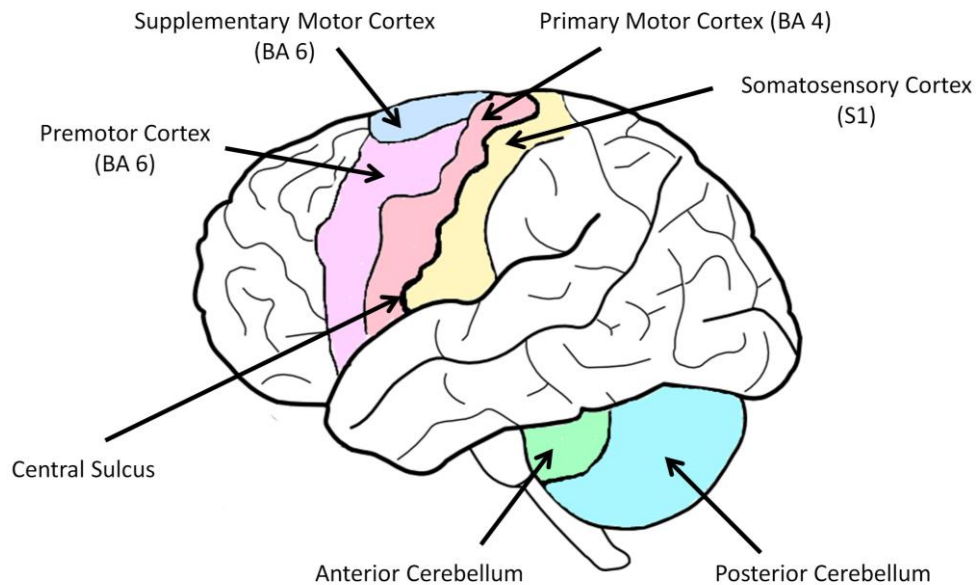
Figure 8.1. The somatosensory, primary motor, supplementary motor and premotor regions of the human neocortex and the cerebellum.

Sensorimotor Cortices. The sensorimotor cortices have also been associated with neural activity in drawing tasks (Makuuchi et al., 2003; Miall et al., 2009; Figure 8.1). In particular Brodmann's areas 1-4 have been implicated in the neural network underpinning drawing. Brodmann's areas 1-3 encompass the primary somatosensory cortex which represents sense of touch across the body, whilst Brodmann's area 4 represents the primary motor cortex (M1) which executes action plans (Lee, Chang, & Roh, 1999). Both areas are somatotopically arranged, such that more ventral areas are associated with facial and upper body areas moving dorsally to lower body representations (Penfield & Boldrey, 1937). In terms of drawing behaviour it is most likely that regions of sensorimotor cortex pertaining to representations of the hand will show higher activation, as is also likely to be the case in the somatotopically organised regions in the cerebellum which will be described in the following section.

The primary somatosensory and motor cortices are supported by adjacent motor regions; the supplementary and premotor areas (Figure 8.1), which have also been shown to be active during drawing (Miall et al., 2009). The supplementary motor area (SMA; M2), which is also organised somatotopically and is associated with Brodmann's area 6, is argued to contribute to the preparation, as well as the feedback monitoring, of action plans (Lee et al., 1999; Passingham, 1996; Wiesendanger, 1993). The premotor area (PMA) which is also encompassed by Brodmann's area 6 lies dorsally to the SMA. This region contains representations of body parts that tend to overlap to a greater extent (Graziano & Aflalo,

2007) than representations in M1 and is thought to be dissociated into up to six different regions (Rizzolati & Luppino, 2001). The PMA represents movements of greater complexity than M1, although these two regions are thought to work in parallel rather than in a hierarchical manner (Graziano & Aflalo, 2007). Previous findings that implicate Brodmann areas 1-4 and 6 in the drawing process, place the sense of touch and action at the heart of the neural basis for drawing, with primary and secondary motor areas most probably working in concert with the refined inhibitory mechanisms of the cerebellum, the structure and function of which will be discussed in the following section.

The Cerebellum. The studies of Makuuchi et al (2003), Miall et al (2009) and in Schlegel et al (2012) found that the cerebellum plays a role in drawing. Historically, the function of the cerebellum has been found to be predominantly motor; classic symptoms of cerebellar damage feature difficulties with the control and automaticity of fine-grained movement (Holmes, 1939). However more recently it has become apparent that the cerebellum is involved in a much wider range of more cognitive functions including sensorimotor control, language, spatial processing and executive control (Stoodley & Schmahmann, 2009) which can be disrupted in cerebellar cognitive affective syndrome (Schmahmann & Sherman, 1998).

The distinct functions of the cerebellum follow its anatomy; motor processing occurs in the anterior lobe, whereas the vermis and posterior regions are involved in more cognitive and affective processing, as revealed by a meta-analysis of non-motor functioning in the cerebellum (Stoodley & Schmahmann, 2009). The authors of this study also found that language and spatial associations in the cerebellum show a complementary pattern to the neocortex where language and verbal working memory appears to be right-lateralized, whereas on the other hand spatial processing appears to be left-lateralized. It is possible that either cognitive or motor functions of the cerebellum could contribute to drawing behaviour, but it is most likely that representations of the hand are functionally or structurally altered and interact with neocortical representations to produce finely tuned and highly efficient motor behaviour when drawing.

Whilst other cortical areas relating to motor control function contra-laterally to the side of the body being moved, each cerebellar hemisphere functions ipsilaterally, such that somatotopic maps in the left hemisphere of the cerebellum control the left side of the body (see Manni & Petrosini, 2004 for a review of the motor functions and topography of the cerebellum). Existing studies provide conflicting data regarding the lateralisation of cerebellar activation for proficient drawing. While Makuuchi et al (2003) showed bilateral cerebellar hemispheric involvement, Miall et al (2009) found right cerebellar activation

during drawing, suggesting that either ipsilateral or some kind of bilateral interactivity is responsible for action monitoring while drawing.

In summary, previous evidence suggests drawing employs a constellation of brain regions, encompassing the parietal, motor cortices and the cerebellum. There is little suggestion of involvement of occipital visual regions, apart from some association with lingual gyrus in a functional neuroimaging study (Ferber et al., 2007). Therefore, despite behavioural evidence supporting enhancement of perceptual processing as a result of drawing expertise (Cohen & Bennett, 1997; Kozbelt, 2001; Ostrofsky et al., 2012), this appears to be manifested in brain regions that are directly involved with visuomotor processing, rather than brain regions afforded to visual perception alone. It is only through the transformation of visuo-spatial information into action sequences, that we appear to see a tangible difference in neural function and architecture in proficient draughtsmen. The locus of these visuomotor transformations appears to be the parietal lobes. However, the prominent role of sensorimotor cortices and the cerebellum in previous studies suggest that refined motor planning, execution, monitoring and procedural knowledge is also developed in expert draughtsmen.

Previous research into neural correlates of drawing ability has predominantly relied upon functional studies, which look at transient changes in brain activation whilst individuals participate in real or simulated drawing tasks. However, in the expertise and skill literature, whilst functional studies are also used to explore the neural correlates of talent, researchers are also interested in the long-term structural changes that take place as a result of prolonged and effortful practice in a particular medium of expertise. They explore these structural changes using voxel based morphometry (VBM) techniques, which assess the relative volume and density of cortical and subcortical grey and white matter associated either with a group of experts or with the extent of performance at a particular expert task. I will now consider expertise studies using VBM more generally, in order to assess what kind of relationships between behavioural performance and neural structures can be determined using this particular methodology.

8.1.2   Expertise Studies using Voxel Based Morphometry

Over the past decade researchers have sought to establish the basis of a variety of domains of expertise and giftedness by studying the development of neural structures either longitudinally or cross-sectionally through the recruitment of specific expert populations. Maguire and colleagues (Maguire et al., 2000) conducted a seminal study using this approach, which showed that London taxi drivers have greater grey matter volume in their posterior hippocampus than controls. This study indicated that expertise confers specific

changes on its supporting neural structures; in this case the locus of spatial memory. Furthermore, in this study it was shown that the number of years spent working as a taxi driver correlated with the extent of hippocampal grey matter volume. Later it was shown that this structure developed during the course of taxi driver training, demonstrating a causal link between domain-specific training and increase in cortical grey matter volume (Woollett & Maguire, 2011). More recently, Gilaie-Dotan and colleagues conducted the first study of neuroanatomical correlates of expertise external to spatial, motor or visuo-spatial domains by looking at structural brain changes in association with visual expertise for car models (Gilaie-Dotan, Harel, Bentin, Kanai, & Rees, 2012). Visual car experts performed within-category discriminations for both their category of choice and a similar but non-expert visual object category. It was found that expert performance was associated with grey matter volume in the prefrontal cortex and upper insula, but not with ventral occipito-temporal cortex, which was a region of interest for the study on the basis of previous functional imaging evidence pertaining to visual expertise. The results of this study suggest that perceptual enhancement (which is seen in relation to drawing expertise) may elicit structural changes in the brain, but not necessarily in strictly visual areas, instead conferring changes in regions in which visual information interacts with cognition and action.

Research into neural correlates of ability in the creative arts has also progressed over the past decade. There have been a number of VBM studies involving musical expertise (Gaser & Schlaug, 2003; Hutchinson, Hui-Lin Lee, Gaab, & Schlaug, 2003; Münte, Altenmuller, & Jäncke, 2002; Sluming et al., 2002), but virtually none that target expertise in the production of *visual* art as a dependent variable, most probably because musical expertise is easier to define and quantify than visual artistic expertise. The aforementioned VBM studies on musical expertise and brain structure often show a direct relationship between musical proficiency, attainment and practice intensity and increased grey matter in cortical/sub-cortical regions, suggesting that neural changes occur as a result of long-term skill acquisition rather than innate propensities, corroborating findings from the spatial navigation domain (Woollett & Maguire, 2011). Considering musical expertise studies in conjunction with the more restrictive quantification of artistic abilities such as those propounded in this thesis in the previous experimental chapters, it is likely that the same kind of approaches can be conducted with expert visual artists to ascertain whether proficiency in the visual arts relates to innate differences in brain structure, or whether it reflects a change over time.

Whilst the studies summarised thus far took advantage of a subpopulation that pursued expertise in a particular field independently of the research study and over a number of years, researchers have also measured the short-term impact of training on brain structure

by recruiting novices to a particular expert field. In perhaps the most famous of these training studies, Draganski et al (2004) taught participants to juggle over a three month training course. The juggling group showed an increase in grey matter volume in mid-temporal regions (hMT/V5) and the left posterior intraparietal sulcus, which are commonly thought to pertain to the perception of visual motion (Grefkes & Fink, 2005; Dubner & Zeki, 1971). To the authors' surprise, no differences were found in motor areas that are involved in the planning and execution of coordinated movement (SMA/PMC, cerebellum, basal ganglia). This study by Draganski et al (2004) provides evidence that the brain flexibly changes over very short time periods to accommodate new skills. This finding tends to imply that innate neural substrates of talent are somewhat overemphasised and that intense practice can have a real short-term impact on brain structure. Schlegel et al's (2012) study used a similar training method for drawing and painting but witnessed no structural changes in grey matter. However, they did demonstrate a reduction in fractional anistropy in the inferior frontal lobe as a result of training, which the authors argue represents neural changes as a result of development of creativity (Jung et al., 2010). As a painting and drawing course is likely to be less restricted and focused than juggling training, it is perhaps not surprising that no short-term grey matter changes are seen in Schlegel et al's (2012) study. Evidence of functional changes in the cerebellum in this study however suggest that over longer periods of time structural brain changes could be seen in response to training in the visual arts.

Cumulatively these studies show that short and long-term development of visuo-motor and perceptual expertise confers functional and structural changes to brain regions. Findings from such studies can provide insight into the nature of talent in these domains, by demonstrating which regions are show increased/reduced grey and white matter density in response to expertise. Of particular pertinence to the justification for the current study is the dissociation between functional and structural evidence in previous studies, and for the lack of evidence of motor areas in some areas, and visual in others contrary to pre-experimental expectations. It cannot be assumed that those regions functionally or theoretically related to drawing ability will be those that undergo structural changes as expertise develops. Furthermore, it is clear from some studies that expertise does not always confer changes at a structural level (Memory expertise, Maguire et al, 2003; Medical expertise, Woollett et al, 2008), and therefore information from both fMRI and structural MRI studies is necessary to obtain a sophisticated and nuanced picture of how the brain achieves a high-level and complex activity like drawing.

8.1.3   Aims of the current study

On the basis of previous neuroimaging evidence, drawing appears to activate a large network of brain regions which corresponds to the wide range of behaviours that are encompassed in a drawing act, including perceiving the visual stimulus, recalling previous experiences of similar stimuli and maintaining tight hand-eye interactions. However the question remains as to where and to what extent the brain changes in response to prolonged activation through training and practice in drawing. While there appear to be short-term changes in FA in frontal regions in response to drawing practice (Schlegel et al., 2012) it is unclear whether other brain regions are implicated in longer term skill development, and whether these pertain specifically to drawing or to creative processes more generally.

There are also shortcomings of the current neuroimaging data. Tasks previously used have been conducted in the scanner, and may lack ecological validity (Ferber et al., 2007). Therefore, a more extensive voxel based morphometry study of drawing abilities in expert and novice artists is presented in the current chapter, which investigates long-term expertise associated changes in grey and white matter density in the brain regions highlighted by the functional and structural studies previously discussed. This approach enables the use of ecologically valid tasks that are performed outside of the MRI scanner. Both novices and trained artists were recruited, in order to test for neural differences specific to drawing ability that could be dissociated from artistic ability more generally. The opportunity also arose to explore other facets of perceptual processing, which correlated with drawing ability, such that it was possible to investigate whether there are overlapping brain regions employed during local processing tasks and drawing (previously shown to be correlated, see 6.3). This approach, of observing the neural correlates of both drawing and perceptual abilities associated with drawing, elucidated the nature of connections between visual perceptual abilities and the drawing process, providing a more meaningful analysis of neuroimaging findings beyond localisation of the process to a particular region/s of the brain.

Data from functional studies suggest that the parietal and motor regions are specifically active during drawing. On this basis, it was hypothesised that expert representational draughtsmen will show increased cortical grey and white matter bilaterally in parietal regions, and more specifically the superior parietal lobule and intraparietal sulcus (Makuuchi et al., 2003). Functional studies also point toward involvement of frontal regions, particularly the supplementary motor area (Ferber et al., 2007; Makuuchi et al., 2003; Miall et al., 2009) as well as subcortical regions, in particular the cerebellum (Makuuchi et al., 2003; Schlegel et al., 2012). However, structural studies have not always elicited

correlations in the same brain regions as functional studies (see Gilaie-Dotan et al, 2012's VBM findings in contrast to fMRI findings concerning visual car expertise). Therefore a whole-brain analysis is needed in order to reduce the likelihood of excluding areas that may be involved in long-term brain development in expert draughtsmen but are not previously implicated by fMRI studies. In order to assess the effect of training on the extent of grey matter volume in areas shown to be associated with drawing, these volumes are compared with measures of how much time the artists in the current study have spent drawing. Further, potential overlap between brain regions associated with local processing and drawing were assessed in order to illuminate the mechanisms by which the development of specific brain regions facilitates drawing behaviour. In a previous study investigating neural correlates of the embedded figures task (EFT) in controls and individuals with ASD (Ring et al., 1999) it was found that the EFT mediated activation in middle and inferior temporal gyri (BA 21, 37), the supramarginal gyrus (BA 40), precuneus (BA 7), inferior frontal gyrus and middle occipital gyrus (BA 18, 19). On the basis of functional studies in drawing and the EFT considered together, it is hypothesised that there may be overlap in parietal regions with structures pertaining to both drawing and local processing, particularly in the region of Brodmann's area 40 and 7, which have been shown to be activated during drawing (Makuuchi et al., 2003).

8.2 Method

8.2.1 Participants

8.2.1.1 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. The questionnaire sample included undergraduate (*n*=14) and post-graduate (*n*=74) students attending art and design courses at Camberwell College of Art (CAM) and The Royal College of Art (RCA) respectively. There were 6 undergraduate students in their second year of a drawing BA from CAM and 15 postgraduate students studying a range of artistic disciplines from RCA in the neuroimaging sample. Within this sample there were 17 right handed individuals.

8.2.1.2 Controls

Control participants (*n*=23; 16 female; mean age =25.8 (*SD* = 7.1) years) were recruited from the undergraduate and postgraduate 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 this sample there were 22 right handed individuals.

8.2.2 Procedure

Participants were tested individually on all tasks within one testing session lasting between 1-1.5 hours at CAM, the RCA or the psychology department at UCL. Tasks were administered in the order presented in the experimental procedure.

8.2.2.1 Questionnaire Measures.

Participants completed a questionnaire consisting of a single folded sheet of A3 paper described more fully in the method section of the survey study 3.2.2 (for additional questionnaire questions see Appendix B). Questions of interest to the current study were:

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'*.

8.2.2.2 Observational Drawing Tasks.

Drawing tasks were completed on A4 (297 × 210 mm) heavy-weight art paper (130 g.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 60Hz refresh rate. 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).

8.2.2.3 Group Embedded Figures Test and Block Design Task.

For details of local processing task administration see methods section 6.2.2.

8.2.3 Image Acquisition and Analyses

MR images were acquired on a 1.5 Tesla Siemens Avanto MRI scanner (Siemens Medical, Erlangen, Germany) with a 32-channel head coil. High-resolution whole-brain MR images were obtained using a T1-weighted three-dimensional magnetization-prepared rapid

acquisition gradient-echo sequence (MPRAGE; repetition time=2.73s; echo time=3.57 ms; voxel size=1.0×1.0×1.0 mm).

8.2.3.1 *Voxel-Based Morphometry Protocol and Data Pre-processing*

White and Grey Matter Analysis. The MR images were first segmented for grey matter (GM) and white matter (WM) using the segmentation tools in SPM8 (http://www.fil.ion.ucl.ac.uk/spm). Subsequently, a Diffeomorphic Anatomical Registration Through Exponentiated Lie Algebra (DARTEL) (34) in SPM8 was performed for inter-subject registration of the GM images (Ashburner, 2007; Ashburner and Friston, 2000). In this co-registration pre-processing, local GM volumes were conserved by modulating the image intensity of each voxel by the Jacobian determinants of the deformation fields computed by DARTEL. The registered images were smoothed with a Gaussian kernel (FWHM = 8 mm) and were then transformed to MNI stereotactic space using affine and nonlinear spatial normalisation implemented in SPM8 for multiple regression and factorial ANOVA analysis.

The pre-processed images were entered into a series of multiple regression models in SPM5 to identify cortical regions that showed correlations with:

a. Drawing ability

b. Artistic ability

c. Local processing performance

The first regression included drawing and artistic ability as covariates of interest, as artistic and drawing ability may be conflated in this study, and it was of interest to assess the independent relationship of each factor to its neural substrate. Age, gender and total grey matter volume (following ANCOVA normalisation) were included as covariates of no interest in the model. In the second regression model local processing was included as the covariate of interest and the same covariates of no interest were added to the model.

A statistical threshold of $p<0.05$ corrected for the whole-brain volume at a cluster level using the 'Non-Stationary Cluster Extent Correction for SPM5 toolbox (http://fmri.wfubmc.edu/cms/NS-General (Hayasaka, Phan, Liberzon, Worsley, & Nichols, 2004)) was used as an indicator of regions of significant correlation between the behavioural variables and grey matter density.

Ethics

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

8.3   Results

8.3.1   Drawing Rating Procedure

See data preparation section 3.3 for a full description of the procedure for rating the accuracy of participants' drawings. Participants' scores for the hand and block drawings were averaged across the ten non-expert raters. Inter-rater reliability was high with a Cronbach's alpha of .92 for hand drawing ratings and .93 for block drawing ratings. Hand drawing ratings were highly positively correlated with block drawing ratings, r (44) =.83, p<.001, therefore a composite drawing rating was produced by averaging drawing ratings for the hand and blocks for each participant.

8.3.2   Behavioural Data

Table 8.2 shows the performance of the two participant groups on the behavioural tasks of the VBM study. A series of paired samples t-tests were conducted to identify significant differences in performance between the two groups. There were significant differences in performance on the drawing tasks. Artists' drawing ratings were on average 1.42 points higher than non-artists, t (42) =3.51, p<.01, which supports a regression model that includes both artistic and drawing ability as covariates, as differences in grey matter could be attributed to either drawing or artistic ability given that the two participant groups differ in both respects. Average points on a logarithmic scale for time spent drawing in the artist sample was 25.62 (SD=11.53), which corresponds to two hours per week on total spent drawing over the last two years.

Performance on the local processing tasks was not significantly different between artists and non-artists, although artists' performance was marginally significantly better at the BDT, t (42) =1.92, p=.06. Performance on the two local processing tasks was significantly correlated, r (44) = .36, p<.05, therefore a composite local processing score was calculated by computing standardised scores for the GEFT and BDT and the computing the average of the two scores. This 'local processing score' was then input as a covariate in the VBM analysis.

Table 8.2. Descriptive statistics for artists' and non-artists' performance on behavioural tasks

	Artists		Non-Artists		
	Mean	SD	Mean	SD	Correlation with Drawing Rating
Drawing Rating/8	5.17	1.33	3.75	1.35	-
GEFT Score/8	5.48	1.81	5.04	1.94	.58**
BDT 9 Block Segmentation Difference Score	-12.57	7.72	-17.53	9.24	51**

Notes: **p<.01

A series of correlations were conducted to assess the relationship between drawing accuracy and local processing ability in the context of the current study, in order to verify that the results could be replicated from the local processing study in Chapter 6. From Table 8.2 it can be seen that drawing accuracy scores correlate significantly with performance on the BDT, GEFT and combined standardised scores for both (Table 8.2). When GEFT and BDT scores were standardised and combined, the correlation between local processing ability and drawing rating rose to r (44)=.66, p<.001.

8.3.3 Whole Brain Analysis Grey Matter

Regression analyses were conducted on GM segregated scans across the whole brain. First artistic ability and drawing accuracy were explored in a multiple regression, followed by an exploration of GM differences in association with local processing ability with a view to identifying regions of overlap between the two behavioural measures.

Drawing and Artistic Expertise. VBM analysis was used to explore the correlations between local grey matter density and drawing and artistic expertise. Regions showing significant correlations between neural structure and drawing and artistic expertise (artists versus non-artists) at a statistical threshold of p<.05, uncorrected for multiple comparisons across the whole brain are reported in Table 8.3. At a more rigorous statistical threshold of p<.05 corrected for multiple comparisons across the whole brain volume significant correlations between grey matter density and drawing accuracy were found in the left anterior cerebellar cortex (T(44)=4.74, P =.036 FWE-corrected for the whole brain; peak MNI coordinate x=-44, y=-51, z=-28; Figure 8.2). No significant correlations were found

between regions of decreased cortical or subcortical grey matter and drawing ability or artistic expertise.

Table 8.3. Brain regions in which grey matter density significantly positively correlated with drawing and artistic expertise (p<.05 uncorrected).

	Anatomy (Brodmann Area)	MNI coordinates			Cluster Size	Z	P_{uncorr}	P_{corr}
		X	Y	Z				
Drawing	**Left Anterior Cerebellum**	**-44**	**-51**	**-28**	**935**	**3.99**	**.00**	**.04**
	Right Medial Frontal Gyrus (BA 6)	8	-25	56	288	4.17	.02	.27
Artist	Right Precuneus (BA 31)	9	-55	33	187	3.70	.05	.42

Notes: Artist= Artist/Non-artist, Drawing=Drawing rating, brains regions correlated at p<.05 corrected are shown in bold.
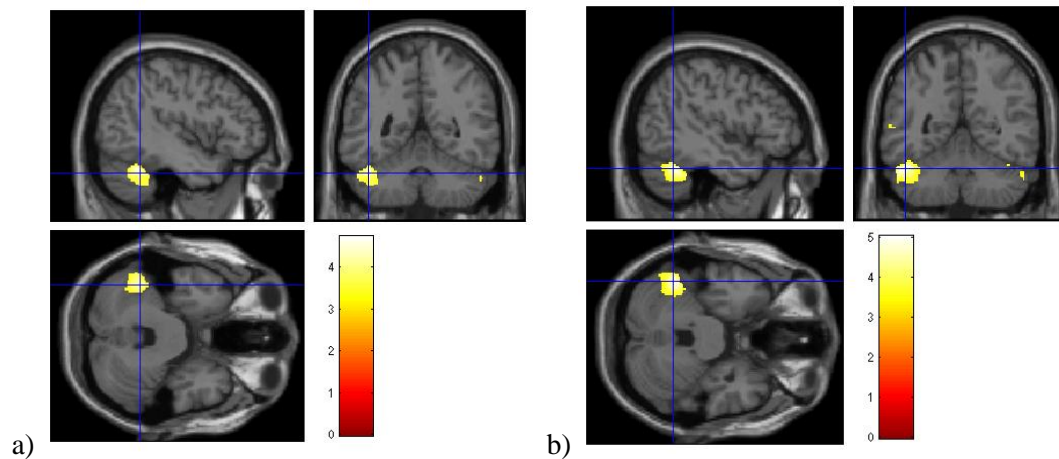
Figure 8.2. a) Grey matter volume significantly positively correlated with drawing accuracy at cluster level with whole brain analysis correction for multiple comparisons (p<.05) b) Grey matter volume significantly positively correlated with drawing accuracy at cluster level with whole brain analysis correction for multiple comparisons for right handed participants (N=39; p<.05).

Analysis in Left and Right Handers. Due to the fact that correlations between drawing ability and grey matter volume were found in the left cerebellar hemisphere (corresponding to control of the ipsilateral hand) the GM analysis was repeated just for right handed participants in order to ascertain whether this finding was dependent on handedness.

This analysis was conducted to rule out the possibility that correlations between grey matter density and drawing were driven by the larger proportion of left-handed participants in the artist group who were also statistically better at drawing than the non-artist group. The two groups could not be directly compared as the sample size for the left-handed group was too small, therefore this analysis permits the identification of the pattern of results as being qualitatively different between left and right-handers.

Table 8.4. Brain regions in which grey matter density significantly positively correlated with drawing and artistic expertise in right handers (p<.05 uncorrected).

	Anatomy (Brodmann Area)	MNI coordinates			Cluster Size	Z	P_{uncorr}	P_{corr}
		X	Y	Z				
Drawing	**Left Anterior Cerebellum**	**-47**	**-52**	**-28**	**1482**	**4.32**	**.00**	**.01**
	Right Medial Frontal Gyrus (BA 6)	8	-24	56	397	3.77	.04	.15

Notes: Artist= Artist/Non-artist, Drawing=Drawing rating, brains regions correlated at p<.05 corrected are shown in bold.

In this instance it can be seen that correlations between drawing and grey matter volume remain in same regions for the right handed participants as for the participant group as a whole (Table 8.4). However, correlations between grey matter and artistic ability are no longer present in this analysis. At a more rigorous statistical threshold of p<.05 corrected for multiple comparisons across the whole brain volume significant correlations between grey matter density and drawing ratings was found in the left anterior cerebellar cortex as in the previous analysis (T(39)=5.03, P =.010 FWE-corrected for the whole brain; peak MNI coordinate x=-47, y=-52, z=-28).

Local Processing. Two regions of grey matter significantly increased in volume in association with local processing ability (Table 8.5; Figure 8.3). The first region was located in the right medial frontal gyrus and was significant at a statistical threshold of p<.05 corrected for multiple comparisons across the whole brain volume (T(44)=5.16, P =.016 FWE-corrected for the whole brain; peak MNI coordinate x=6, y=-22, z=-57). The latter region was located in the left middle temporal gyrus (T(44)=4.76, P =.041 FWE-corrected for the whole brain; peak MNI coordinate x=-59, y=-43, z=3).

Table 8.5. Brain regions in which grey matter density significantly positively correlated with local processing scores

	Anatomy (Brodmann Area)	MNI coordinates			Cluster Size	Z	P_{uncorr}	P_{corr}
		X	Y	Z				
Local Processing	**Right Medial Frontal Gyrus (BA 6)**	**6**	**-22**	**57**	**688**	**4.48**	**.00**	**.02**
	Left Middle Temporal Gyrus (BA 22)	**-59**	**-43**	**3**	**571**	**4.20**	**.01**	**.04**

Notes: brains regions correlated at p<.05 corrected are shown in bold.
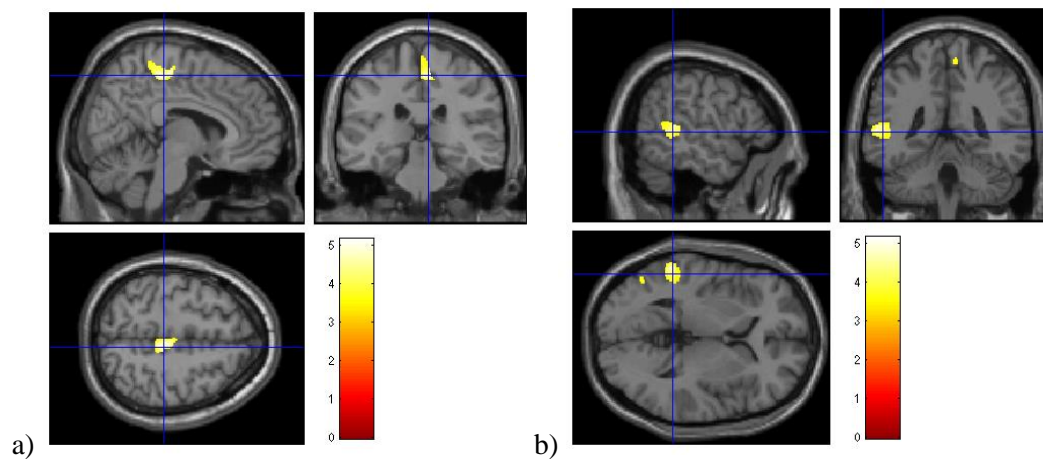
Figure 8.3. Grey matter volume in the a) right medial frontal gyrus, b) left middle temporal gyrus significantly positively correlated with local processing scores at cluster level with whole brain analysis correction for multiple comparisons (N=44; p<.05).

Overlap of Local Processing and Drawing Ability. GM volume in the medial frontal gyrus was found to be correlated with both drawing and local processing. Therefore, it was of interest to see whether GM volume in peak voxels in the VBM analysis of drawing and local processing correlated with behavioural measures of drawing/local processing. In order to test whether there was a significant relationship between these two correlations, grey matter volume in the region associated with local processing was extracted for each participant and then the GM values were correlated with drawing accuracy scores. There was found to be a significant correlation between GM volume in the right medial frontal gyrus associated with local processing ability and drawing accuracy scores (*r* (44) =.32, p<.05; Figure 8.4).
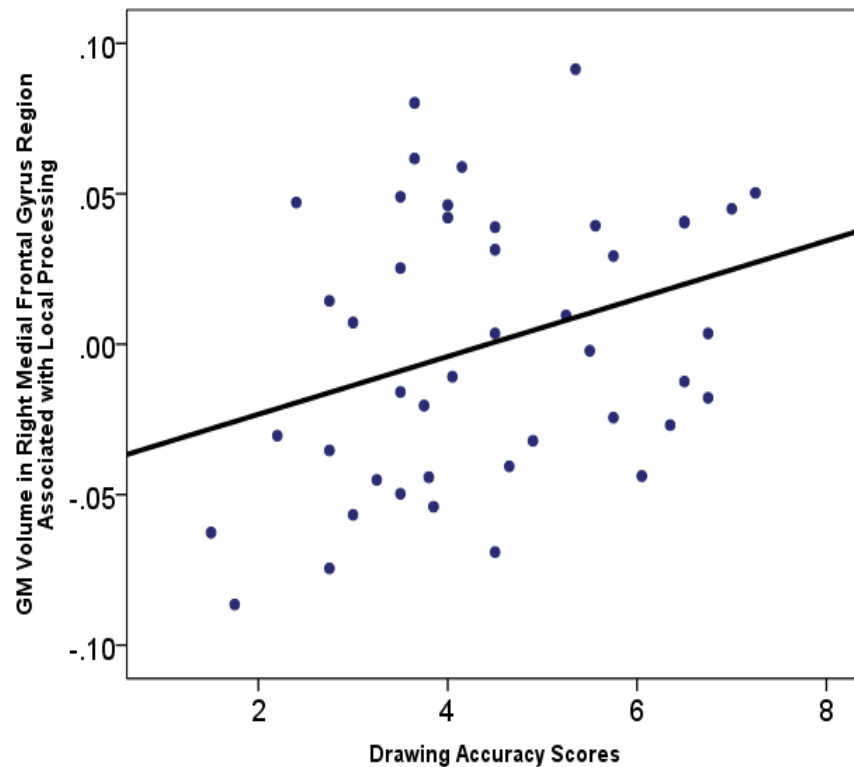
Figure 8.4. The association between GM volume in the region of right medial frontal gyrus significantly positively correlated with local processing scores, and drawing accuracy scores in the drawing task

8.3.4   Whole Brain Analysis White Matter Density

The same regression analyses that were conducted on GM volumes across the whole brain were conducted for the WM segregated scans. First artistic ability and drawing accuracy were explored in a multiple regression, followed by an exploration of WM differences in association with local processing ability, with a view to identifying regions of overlap between the two behavioural measures.

Drawing and Artistic Expertise. The results of the WM density analysis to some extent support the findings from the GM analysis. In this instance there was found to be increased WM density in the left cerebellar lobe, but in a region more posterior to that found in the GM analysis (Table 8.6). This region was not found to be significant when a corrected p<.05 threshold due to multiple comparisons was taken into account. There were no regions of increased WM density that significantly correlated with artistic expertise.

Table 8.6. Brain regions in which white matter density significantly positively correlated with drawing and artistic expertise (p<.05 uncorrected).

	Anatomy (Brodmann Area)	MNI coordinates			Cluster Size	Z	P_{uncorr}	P_{corr}
		X	Y	Z				
Drawing	Left posterior cerebellar lobe	-26	-46	-45	748	3.91	.01	.18

There was found to be a region of the left precentral gyrus in which WM density correlated negatively with artistic expertise (Table 8.7). However, this contrast was not significant at the corrected p-value for multiple comparisons across the whole brain.

Table 8.7. Brain regions in which white matter density significantly negatively correlated with drawing and artistic expertise (p<.05 uncorrected).

	Anatomy (Brodmann Area)	MNI coordinates			Cluster Size	Z	P_{uncorr}	P_{corr}
		X	Y	Z				
Artist	Left precentral gyrus (BA 6)	-41	-12	63	285	-4.16	.04	.55

Local Processing. A significant correlation between WM volume and local processing was found in a region covering the right paracentral lobule and medial frontal gyrus (T (44) =4.91, P=.017 FWE-corrected for the whole brain; peak MNI coordinate x=8, y=-30, z=60; Figure 8.5). This region corresponds with the same region found in the grey matter analysis (Table 8.8). There were no regions of white matter that were significantly negatively correlated with local processing ability.

Table 8.8. Brain regions in which white matter density significantly positively correlated with local processing ability (p<.05 uncorrected).

Anatomy (Brodmann Area)	MNI coordinates			Cluster Size	Z	P$_{uncorr}$	P$_{corr}$
	X	Y	Z				
Local Processing	**Right Paracentral Lobule/Medial Frontal Gyrus (BA 6)**						
	8	**-30**	**60**	**601**	**4.31**	**.00**	**.02**

Notes: brains regions correlated at p<.05 corrected are shown in bold.
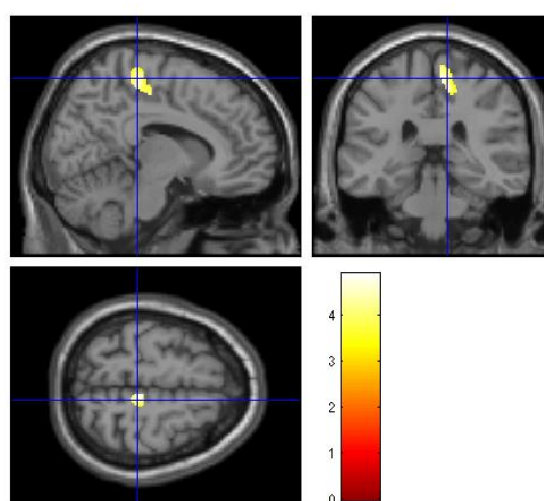
Figure 8.5. White matter volume in the right paracentral lobule/medial frontal gyrus significantly positively correlated with local processing scores at cluster level with whole brain analysis correction for multiple comparisons (N=44; p<.05).

8.3.5 Relationship between time spent drawing and neural structures.

Extracted GM and WM volumes from peak voxels associated with drawing ability were assessed in relation to amount of time in the last two years spent drawing by the artistic proportion of the sample (N=19). There were no significant correlations between time spent drawing and GM volume in the left anterior cerebellar region or in the medial frontal lobe (both p>.20). There was also no significant correlation between time spent drawing and WM volume in the left posterior cerebellar region (p=.70).

8.4 Discussion

The current study sought to establish regions of the brain that were associated with the development of long-term drawing skill through structural analysis of grey and white matter, and dissociate these regions from brain regions associated with artistic ability in general. It was hypothesised that regions of the brain associated with visuo-spatial and motor processing would be shown to be structurally different in proficient draughtsmen compared with novices. Therefore, on the basis of previous functional and structural neuroimaging research, it was predicted that drawing expertise would be correlated with increased GM volume in the cerebellum and the parietal and motor cortices. These hypotheses were partially supported, in that increased GM and WM were related to drawing ability in the right anterior cerebellum and the right medial frontal lobe, corresponding to the supplementary motor area (SMA). A summary of the results of this VBM study are shown below in Table 8.9.

Table 8.9 Results of the VBM analysis of structural grey and white matter with drawing ratings, artistic ability and local visual processing ability

Behavioural Measure	White/Grey Matter	Region	P_{uncorr}	P_{corr}
Drawing	GM	Left Anterior Cerebellum		✓
		Right Medial Frontal Gyrus	✓	
	WM	Left Posterior Cerebellum	✓	
Artistic Ability	GM	Right Precuneus	✓	
	WM	Left Precentral Gyrus	✓	
Local Processing	GM	Right Medial Frontal Gyrus		✓
		Left Middle Temporal Gyrus		✓
	WM	Right Paracentral Lobule/ Medial Frontal Gyrus		✓

8.4.1 VBM reveals visuo-motor processing underpins drawing.

To some extent the current structural findings corroborate the findings of previous functional studies (Ferber et al., 2007; Makuuchi et al., 2003; Miall et al., 2009; Schlegel et al., 2012; Solso, 2000; Solso, 2001). The most significant finding was the significant positive correlation between drawing accuracy and left anterior cerebellar volume. The cerebellar region was found to be functionally more active in the studies of Makuuchi et al (2003), Miall et al (2009) and Schlegel et al (2012) in relation to drawing. However, in the current study GM volume in the left cerebellar hemisphere was correlated with drawing rating, whereas the right cerebellar hemisphere was more heavily implicated in the aforementioned studies of drawing. In Makuuchi et al (2003) the left cerebellar region (peak voxel x=-30, y=-58, z=-28) roughly corresponds to the region found in the current study, suggesting that the cerebellum witnesses both functional and structural changes in response to training in drawing. Whilst Schlegel et al (2012) did not find structural changes to the cerebellum in their drawing and painting training study, they did find functional changes when participants performed a gestural drawing task, suggesting that functional differences in this region during task performance may give rise to structural changes over longer periods of training. It could be the case that the period of training in Schlegel et al's (2012) study was not long enough to confer lasting structural changes in the cerebellum, whereas in the current study all art students had at least three years' post-high school artistic training and an average of two hours of drawing practice per week over the last two years, suggesting a more long-term involvement in drawing practice.

Positive correlations with GM in the right medial frontal gyrus (BA 6) and drawing ability are also in line with previous research (Makuuchi et al, 2003; Solso, 2001) but again in a contrasting hemisphere to previous studies (see Table 8.1), as the authors found increased activation in the left rather than the right medial frontal gyrus on these occasions (Miall et al, 2009; Ferber et al, 2007). The region of the right medial frontal gyrus highlighted here most probably corresponds to the SMA, whose bounds are described in a meta-analysis and fit the coordinates of the peak voxel this study (Mayka, Corcos, Leurgans, & Vaillancourt, 2006) and which was identified as an active region in previous research (Ferber et al., 2007; Makuuchi et al., 2003; Miall et al., 2009). As mentioned in the introduction, the SMA contributes to the preparation and feedback monitoring of action plans (Wiesendanger, 1993; Lee et al, 1999; Passingham, 1996), and in this way appears to serve a similar function to the cerebellum, albeit at a more gross motoric level. In a review of the structure and function of the SMA, its role in inhibiting inappropriate behaviour toward objects was emphasised (Nachev, Kennard, & Husain, 2008), which suggests that the SMA is critical for pairing external (visual cues) and internal states (memory) with action.

This finding can provide a rational explanation for the increased size of the SMA in the current study; it appears to be involved in integrating current visual information (the stimulus image) with hand movements necessary to replicate a specific aspect of the visual stimulus on the basis of previous experience. The SMA has also been previously associated with procedural knowledge (Ackermann, Daum, Schugens, & Grodd, 1996; Grafton et al., 1992), as has the cerebellum (Molinari et al., 1997; Torriero et al., 2007). Therefore, procedural memory could underpin the involvement of both the cerebellum and the SMA in long term drawing expertise acquisition. The role of procedural memory has been highlighted in a previous model of drawing ability. Kozbelt and Seeley's (2007) Visuomotor model conceptualises the underlying basis for perceptual advantages in artists and suggests how procedural knowledge can impact upon incoming visual information (Figure 8.6). It demonstrates that procedural knowledge in the rostral SMA and the PMC influences the interpretation of visual information and interacts with representations in VSTM, on the basis that activity in the SMA and PMC is correlated with selective attention for locations, features and objects (Awh & Jonides, 2001; Schubotz & von Cramon, 2003).
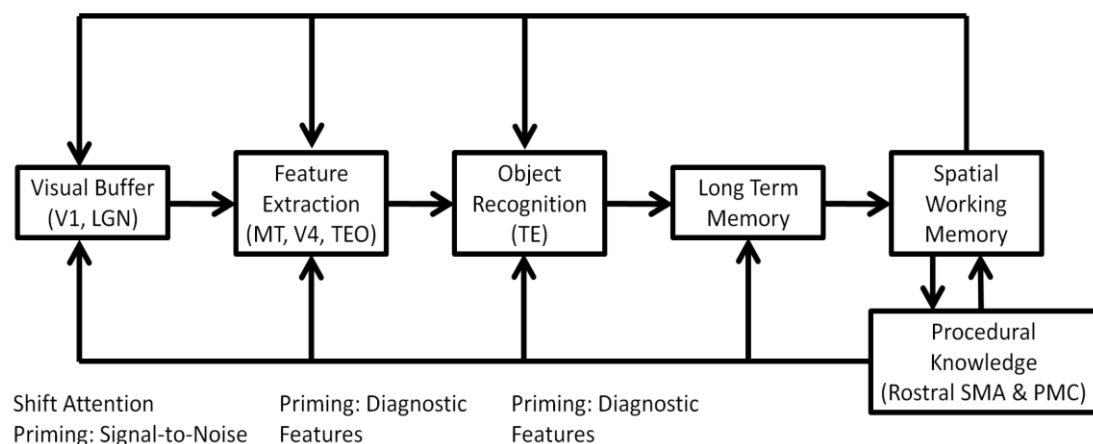
Figure 8.6. A simplified version of Kozbelt & Seeley's (2007) Visuomotor Model for Artists' Perceptual Advantages

However, the finding that the *right* SMA is involved in drawing is (like the localisation of increased GM volume in the cerebellum reported previously) somewhat counter-intuitive as it would be expected that the left SMA, contralateral to the dominant hand of the majority of participants (n=40), would be implicated in drawing. It has been shown in a lesion study that apraxia can result from a right cortical lesion that encroached upon the SMA (Marchetti & della Salla, 2007). Therefore it is still possible that activation in the right SMA is related to monitoring of action plans for the dominant hand in right-handed subjects. If the role of the SMA is more cognitively determined in this context, it could be

the case that it is responsible for top-down control of action plans and not responsible for the movement of the hand per se, therefore reducing the significance of lateralisation of the implicated brain region, and supporting previous contentions of right neocortical lateralisation of drawing ability (Edwards, 1989). Literature on different forms of apraxia suggests that ideomotor apraxia is more often associated with left cerebral lesions (Basso, Faglioni, & Luzzatti, 1985; Della Salla, Lucchelli, & Spinnler, 1987), whereas constructional apraxia, which is conceptually closest to drawing, is more often associated with right cerebral lesions (Arrigoni & De Renzi, 1964; Benowitz, Moya, & Levine, 1990). The motor associations found here also support behavioural work by Glazek (2012), which suggests that proficient draughtsmen show more efficient motor output during drawing. The current findings support and extend Makuuchi et al's (2003) contentions for the neural basis of drawing, by finding evidence for the involvement of the SMA and PMA (visualised in Figure 8.7).

One of the most striking findings from the current study is that there is no evidence of long-term changes to the parietal lobes in response to prolonged training in drawing. This finding suggests that, there is little structural change as a result of prolonged functional involvement, perhaps because these regions are applied to particular visual stimuli rather than drawing behaviour more generally. As can be seen from the extended version of Makuuchi et al's (2003) model of neural correlates of drawing, the extent to which the early areas (BA 7, 40 & 37) are involved in the drawing behaviour is very much dependent on the kind of visual information entering through the dorsal or ventral visual pathways. Further downstream the neural processes involved are less likely to be stimulus-specific, and therefore, the structural changes may be more generalised and more noticeable. In future research it would be advantageous to target participant groups on the basis of artistic expertise, in order to assess whether stimulus-specific structural changes occur according to specialisation; for example portrait artists may show changes over time in the fusiform face area (FFA) of the parietal lobe as seen in Solso's (2001) functional MRI study.
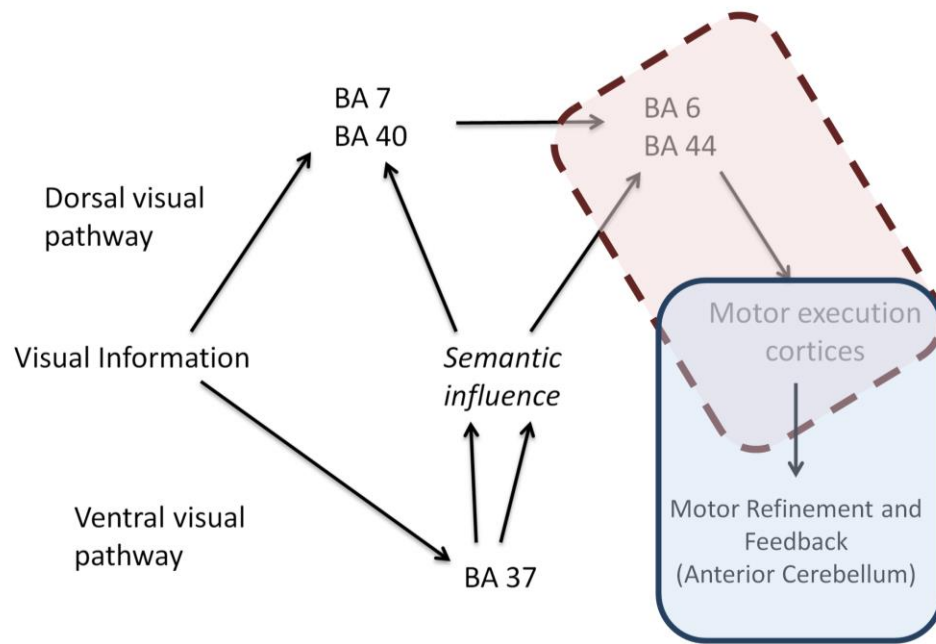
Figure 8.7. Adapted diagram of brain regions associated with drawing in Makuuchi et al's (2003) study. Regions highlighted in red (dotted outline) were found to be associated with drawing in the current study, whilst the blue highlighted region (solid outline) represents novel evidence for brain regions found in the current study.

Due to the emphasis on visual perceptual processing shown in the behavioural studies in the previous chapters presented in this thesis, it was expected that GM volume differences in occipital regions associated with perceptual processing would be correlated with drawing accuracy in the current study. However, in much the same manner as has been found in a previous study of visual expertise, in which a directional hypothesis focused upon occipital regions as the likely neural locus of expertise (Gilaie-Dotan et al., 2012), GM and WM volume in typically 'pure' visual brain regions were not found to be correlated with drawing. Miall et al (2009) suggested that activation of visual areas during drawing was not prolonged and ceased during a retention interval, after which a remembered stimulus was to be drawn. They posit that,

> 'visual information is not retained as continued activation within these visual
> face-processing areas, but is instead converted into more refined visuo-motor or
> spatial signals in order to guide the subsequent drawing actions' (p.402).

The emphasis on motor regions in Miall et al's (2009) study supports this conclusion, although the lack of parietal cortical grey matter implicated in the VBM analysis is still somewhat of a surprise given previous neuroimaging evidence.

8.4.2 The Centrality of the Cerebellum.

As previously mentioned, the most significant finding in the current study was the relationship between cerebellar GM volume and drawing ability. Grey, but not white matter, in the left anterior lobe of the cerebellum was found to be significantly correlated with drawing accuracy at the more restrictive p value correction for whole brain analysis. The anterior lobe of the cerebellum is associated with motor coordination of parts of the body, and it appears that the region found in the current study is associated with a representation of the hand in the cerebellar somatotopic map (Jäncke, Specht, Mirzazade, & Peters, 1999; although see Mottolese et al., 2013 for a review of disorganised somatopy of the cerebellum; Nitschke, Kleinschmidt, Wessel, & Frahm, 1996; Rijntjes, Buechel, Kiebel, & Weiller, 1999). As previously stated, the region of increased GM volume in this context was in the left hemisphere, which functions ipsilaterally to control the body in most human subjects (Mottolese et al., 2013; Nitschke et al., 1996). It is unclear at present why the contralateral cerebellar hemisphere to the dominant hand of participants is structurally affected in this way. One possibility was that left-handed artists who were also better at drawing than non-artists were driving this correlation. This confound was tested by conducting a supplementary analysis which was only applied to right-handed participants (N=40). The same results were obtained in this analysis with statistically more robust findings, suggesting that this finding is not an artefact of an increased proportion of left-handed participants in the artistic group. It must be noted that this region of the cerebellum is contralateral to the region of the medial frontal gyrus that was also found to be associated with drawing ability, and therefore fits the conception that drawing utlises processes on the right side of the brain.

8.4.3 Neural Structures Supporting Drawing and Local Processing.

Correlations between regional grey and white matter volumes and local processing performance were assessed, in order to determine whether there was some degree of overlap between brain regions responsible for drawing and those for local processing. Local processing was focused upon in the context of the current study, as robust behavioural evidence suggests that enhanced local processing is positively related to drawing ability (see 6.3 Results). Significant positive correlations with GM volume in the left middle temporal gyrus (BA 22) and the right medial frontal gyrus (BA 6) were found in relation to combined performance on the GEFT and the BST. BA22 and BA6 correspond to relatively more active brain regions when the EFT (Ring et al., 1999). In this study, regions of the bilateral temporal gyri and premotor cortices were found in association with performing the EFT vs. performing a similar visual task without embedded figures (Ring et al., 1999). The latter

brain region found to be correlated with local processing also corresponds with VBM differences in autistics vs. controls, in which individuals with ASD showed decreased white matter in the right medial frontal gyrus (Ke et al., 2009).

The anterior temporal lobes are associated with semantic processing and memory; semantic dementia produces specific atrophy upon the anterior temporal lobes (Mummery et al., 1999). Semantic dementia has also been mimicked in healthy participants by stimulating the anterior temporal lobes using repetitive transcranial magnetic stimulation (Pobric, Jefferies, & Lambon Ralph, 2007). This provides further evidence that the anterior temporal lobes are critical for the formation and maintenance of semantic representations. On the basis of this evidence the increased GM volume found in BA 22 in this study most probably reflects semantic associations with the current local processing tasks and the use of semantic memory to aid performance.

Data from the current study revealed an overlap of brain regions that show structural GM differences related to both drawing and local processing performance. When GM volumes were extracted from the region of the medial frontal gyrus associated with local processing, volumetric grey matter was found to be significantly positively correlated with drawing accuracy scores. The reason for this overlap could be due to the role of the PMA and the SMA in action selection, corresponding with the right medial frontal gyrus. Increased GM volume in these regions could result in better monitoring of motor processing on the basis of visual information from the occipital and parietal cortices. Again, this finding may represent a more efficient coupling of perception with action that is critical in both drawing and local processing task performance. However, overlap in parietal regions for both drawing and local processing may have been anticipated to a greater extent, especially in the case of the EFT in which the motor component of the task is not fundamental to task performance.

8.4.4 Neural Correlates of Artistic Expertise.

Contrasts for artists versus non-artists in the current sample revealed increased GM volume in the right precuneus (BA 31)/posterior cingulate cortex, which is located in the medial parietal lobe, in relation to artistic expertise. This region arguably subserves a number of functions, including introspection (Johnson et al., 2002; Northoff et al., 2006; van der Meer, Costafreda, Aleman, & David, 2010), empathy (Farrow et al., 2001; Völlm et al., 2006) and emotion (Maddock, Garrett, & Buonocore, 2003; Murphy, Nimmo-Smith, & Lawrence, 2003) all of which could be critical to successful artistic practice, but represent the non-technical, creative and emotive side of artistic functioning (see Cavanna & Trimble, 2006 for a review of function and anatomy of the precuneus). In a VBM study of divergent

thinking as a measure of creative thinking, Takeuchi et al (2010) found increased GM volume bilaterally in the precuneus for individuals with higher divergent thinking scores and Jung et al (2010) found GM volume in a region of the right posterior cingulate correlated positively with a composite creativity index of creative achievements, design fluency and creative uses of objects. The authors suggest that the precuneus may be responsible for facets underlying creativity, particularly mental imagery which has also been previously shown to be underpinned by the precunues (Cavanna & Trimble, 2006). At this stage it is only possible to speculate on the role of the precuneus in artistic functioning. In future research it will be necessary to quantify artistic ability beyond the level of academic attainment and to derive measures of creativity and imagery in order to dissociate artists from non-artists before successfully making concrete conclusions concerning the link between the precuneus, imagery, creativity and artistic ability.

8.4.5   Conclusions from the VBM Study

This VBM study has reoriented the basis of drawing ability to visuomotor processing and procedural memory in contrast to perception alone. There do not appear to be long-term structural changes in visual regions in the occipital cortices and in visuo-spatial higher level representations in the parietal cortices as a result of enhanced drawing ability. Considered in conjunction with the functional neuroimaging studies discussed in this chapter these findings suggests that drawing is underpinned by a complex network of brain regions, beginning with occipital efferents which progress through the parietal lobes to the sensorimotor cortices with interactions with cerebellar representations of the hands. Experience with drawing confers particular structural changes to the cerebellum and SMA and is independent of neural difference associated with artistic ability. Instead this appears to be related to increased GM volume in regions of the precuneus, possibly relating to creative ability and the ability to create internal visual imagery. Whilst these data are tentative and represent a modest sample size, they suggest that prolonged practice and experience fundamentally alters the neural structures underpinning drawing, aiding efficiency of drawing behaviour in future episodes.

This chapter has shifted focus from perception to motor processing. However, there is no reason to suggest that these findings cannot sit in collaboration with one another. The key to a successful characterisation of drawing ability is the ability to explain and support both behavioural and neuroimaging findings within a single model. In summary, the interview and survey studies demonstrated the importance of perception and practice in drawing. The experimental chapters then reinforced the critical role of perception in drawing, whilst finding weak evidence for the roles of both visual imagery and visual short-term memory.

Finally, the structural neuroimaging data provided evidence that structures involved with motor control, monitoring and planning are developed in those that have enhanced drawing skill, suggesting that interaction between perceptual and motor processes may be fundamental to successful drawing.

In the final chapter a more extensive overview of the behavioural evidence provided in this thesis will be presented, in conjunction with the neuroimaging evidence discussed herein. This will provide the framework for the development of a comprehensive toolbox for drawing ability that is informed both by past and present neuroimaging and behavioural findings. It will provide predictions and avenues for future research in the field.

Chapter 9.   General Discussion

'The first step toward creation is to see everything as it really is, and that demands a
constant effort'

Henri Matisse

(Flam, 1995, p.218)

9.1 Introduction

Representational drawing is an ancient medium of human expression, which is as vital for artistic communication today as it was 75,000 years ago. However, drawing has received relatively little attention from a psychological perspective. In response to the relative poverty and scarcity of experimental research in this domain, this exploratory thesis aimed to characterise the perceptual, memorial, cognitive and motoric underpinnings of representational drawing. A series of studies collected data that spanned from the attitudes and observations of artists themselves, to the structural changes in the brain that arise from expertise in drawing. The investigations provided evidence for associations between observational drawing ability and perceptual processing, visual memory, personality and demographic factors. These data are amalgamated into a novel toolbox for drawing, presented and explained in section 9.3, which also takes into account existing behavioural and neuroimaging work in the field as well as previous models of the drawing process (Guerin, Ska, & Belleville, 1999; Makuuchi et al., 2003; Seeley & Kozbelt, 2008; van Sommers, 1989). The thesis also takes the first steps to establish the role of innate and practise-based talent in representational drawing skill; focus upon which should be one of the critical aims of the research project in the future. It will become evident that the results of this investigation could have a significant impact on the way in which art schools employ artistic training, and could provide early diagnostic tools for identifying talent in the visual arts (see 9.4.3. Drawing Training in Art and Design).

9.1.1 The Primacy of Drawing Reaffirmed

This is a pertinent point at which to remind the reader of the initial impetus for the current thesis, and to show in what respect the findings from the studies have validated this impetus. In the opening comments (1.1.1. Drawing in Society), I argued that drawing practice was witnessing a resurgence in the UK and cited a number of examples that demonstrate a renewed interest in representational art forms, including the development of new higher educational courses in drawing, drawing on the national curriculum and public initiatives to encourage the adoption of drawing. The interview data presented in Chapter 2 and survey data in Chapter 3 both served to corroborate this argument, as students expressed a desire to draw and to be taught observational drawing. Furthermore, and more pertinently to the aims of this thesis, drawing was cited as a tool for perceptual enhancement.

> I think it's a basis for seeing, you see more of the world if you draw

> [female, 35, painter]

These comments by an artist in the interview study echo the quotes of prolific artists throughout the centuries, framing drawing as a critical tool for seeing, and thus a fundamental process for any artist engaging with visual media. The theme of perceptual enhancement was carried throughout the thesis, upon the basis of the aforementioned evidence and substantial amounts of literature concerning the association between perception and representational drawing (Cohen & Bennett, 1997; Kozbelt, 2001).

Regardless of their specialism, artists in the current studies advocated increased focus on drawing within art education. This reflects wider trends in the current UK education system, as more undergraduate and postgraduate institutions establish drawing courses and the Conservative-Liberal Democrat coalition government places more emphasis on representational media (painting, drawing) in their revision of the national curriculum to be implemented in 2014.

> I just don't think people are given that grounding, I don't think they are in school and then in university, from what I can see the trend of universities now are even more against a taught solid ground, so it felt like jumping off a cliff into nothing

[Female, 28, Mixed Media]

There arises a strong feeling that representational drawing is critical for success across artistic media and that art education is not providing enough grounding in these fundamental skills, before development of more abstract and creative components of the process are nurtured. The data from the interview study informed a section of the subsequent survey study, which elicited attitudes toward drawing in the 603 art students surveyed. An overwhelming proportion of foundation, undergraduate and postgraduate students expressed the belief that learning observational drawing whilst studying at art school was very important to them. Thus it can be of little doubt that observational drawing is of importance to artists and art students alike, and that the development of representational drawing is a key aim of art students entering higher education. This finding provides a compelling motivation for the current thesis, and one that was evident from the inception of the current research programme in 2005 when Chris McManus from UCL and Qona Rankin from the RCA first discussed the relationship between learning difficulties and acquisition of drawing skills. As the majority of art students studied in the present thesis believe observational drawing to be crucial to their work and express a desire to improve, there is a motivation for psychologists to characterise the process of observational drawing with a view to enlightening artists on their process and also to inform pedagogical practice. The way in which such research can inform teaching strategies is approached in the latter stages of this

discussion, and recent pilot work has suggested that pedagogical application is a fruitful avenue to pursue (see 9.4. Future Directions for Drawing Research and Application of Research in the Visual Arts). In order for research of the kind presented in the present thesis to flourish, it is critical that an interactive and bidirectional relationship is maintained between art practitioners and psychologists, so that theory can be successfully translated into practice.

9.1.2   Framework of the Thesis

Before presenting an overview of the critical findings from the present thesis, I will summarise the thesis framework, to remind the reader of the aims and conclusions of each chapter. The present thesis began with an interview study, with the intention of exploring the importance of representational drawing for artists, recording their impressions on the phenomenology of the drawing experience, as well as eliciting general approaches to the enhancement of their own practice. The interview data provided a foundation for a series of survey studies. These studies investigated demographic and personality factors that could potentially mediate the link between more fundamental (perceptual/memorial/motoric) aspects and expertise development. The survey study revealed that predictors for success related to approaches to studying, personality, practice and the uptake of techniques for drawing, as well as skill in alternative artistic domains to drawing. Subsequently to the survey study, an assessment of accuracy in representational drawing revealed a strong relationship between objective and subjective methods of accuracy and demonstrated a novel technique (shape analysis of global and local properties of drawings) with which to characterise the subjective perception of accuracy in representational drawing. Having established a firm foundation for more in-depth experimental work, the interview, survey and drawing accuracy data provided avenues of exploration for perceptual and memorial relations to drawing, alongside previous work in the field of perception, autism, visual memory and motor processing.

The first experimental study (Chapter 5, Understanding and perception of simple shape properties) assessed the importance of perception and production of angles and proportions on higher level drawing ability using a novel paradigm, which was primarily motivated by research investigating lower-level perceptual abilities and drawing (Cain, 1943; McManus et al, 2010). The study implicated the presence of a hierarchical system of perception upon which representational drawing might rest. Having set up an agenda of exploring the perceptual basis of drawing accuracy, an analysis of global and local visual processing contributions to representational drawing was conducted, in which for the first time the relative contributions of artistic and drawing ability to local processing were tested

in one paradigm. This investigation was also the first to tease apart two theoretical explanations of local processing from the ASD literature and apply them to local processing in gifted draughtsmen.

Having focused upon visual perceptual contributions to drawing, the role of short and long-term representations held in visual memory was then explored, the result of which revealed associations between drawing and long-term memory structures. There was less robust evidence of a relationship between the fidelity and capacity of presentations in VSTM and drawing ability, favouring the preclusion of visual memory by premotor planning. This finding concerning visual memory plugs a gap in the literature which contains few explorations of the relationship between fidelity, capacity and duration of representations in visual memory and drawing ability.

The final empirical study in the present thesis (Chapter 8), used behavioural paradigms employed in the former three chapters to investigate the neural basis of representational drawing, in a VBM study of structural white and grey matter differences associated with artistic ability and drawing accuracy. This is the first study, to my knowledge, to test structural brain differences in artists versus non-artists. The VBM study revealed changes in grey matter and white matter in motor structures in relation to drawing ability, and in the precuneus in relation to artistic ability. Cumulatively these investigations have built up a rich picture of the foundations of representational drawing. It should be emphasised here that the null findings regarding aspects of perceptual and memorial processing are as important as the positive findings, as they all help to determine the contents of the drawing toolbox presented in section 9.3.

9.2   Summary of Research Findings

In the following section I will summarise the critical findings from each section of the thesis to provide a reminder of the main themes of the results, before progressing into a more in-depth discussion of the implications of such findings for a toolbox for drawing ability (Section 9.3). I will first summarise the findings pertaining to cognitive characteristics of drawing expertise that were elicited from the large-scale survey study (Chapter 3), with a particular focus on the mediation of engagement in practice on demographic and academic factors associated with drawing. Then, in a manner that mirrors the introductory literature review in the first chapter of the thesis, I will discuss the four lines of experimental enquiry that were followed up from Van Sommers' (1989) early model of drawing: visual perceptual processing, visual imagery, memory and motor processes, in relation to the current research findings.

To briefly summarise the results as a whole, survey studies revealed the interplay between personality, approaches to learning, drawing practice and technique usage. The experimental studies provided evidence that individual differences in perceptual processing (particularly perception and focus upon local elements of the visual stimulus) correlate with differences in observational drawing ability, variance in visual imagery and visual memory appear to play less of a role in individual differences in drawing skill. Findings pertaining to neural structures that support the drawing process highlight the importance of motor mechanisms in the drawing process.

9.2.1   An Educational Model of Drawing Ability

The survey study (Chapter 3) sought to characterise the interplay between underlying demographic and personality factors that may drive the expression of talent in gifted draughtsmen, in order to provide a framework of cognitive influences on drawing expertise. Firstly, it became clear that the vividness of representations in visual imagery was unrelated to drawing ability. A similar null result was found for problems related to handedness and motor coordination. This result corroborated earlier findings that the predominant reason for poor drawing practice was perceptual, rather than a problem of internal imaging or motor coordination (Cohen & Bennett, 1997). From the data it was clear that observational drawing ability interacts with other artistic faculties and that success at drawing is reliant on a commitment to practice and developing techniques for drawing, that are mediated by a number of factors.
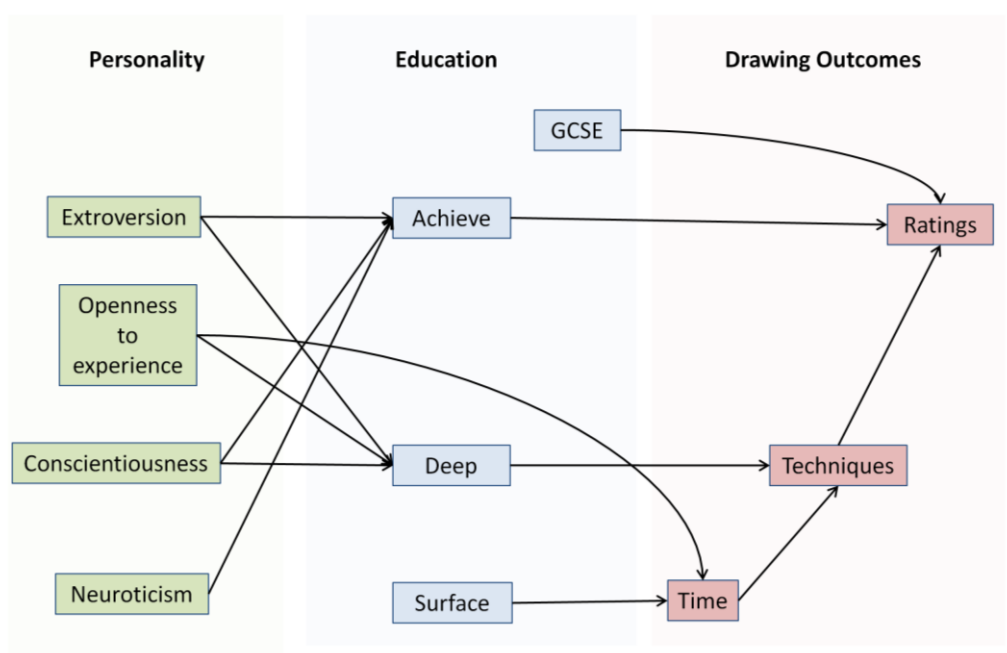
Figure 9.1. An Educational Model of Individual Differences in Drawing Ability

Figure 9.1 presents a simplified model of personality and demographic factors underpinning drawing, motivated by the results of the survey study and the subsequent path analysis (Figure 3.11), but without the negative predictor relationships included. The educational model of individual differences in drawing demonstrates the pathway from elements of personality, through to approaches to studying and then to drawing outcomes which influence the development of observational drawing accuracy. Arrows indicate direct connections between the predictors and the dependent variable of drawing ability. A prominent predictor of drawing ratings is practice, which in turn is influenced by the uptake of techniques for drawing. This artist from the interview study reflects upon the importance of practice for developing perceptual abilities employed during drawing,

> You're drawing ten hours a day five days a week. It's a job practically, but umm, you find your eyes working much harder because you're focusing close and then far away, and just practice makes you work harder and want to get more out of it

> [Female, 26, Illustrator]

This quote highlights two mechanisms by which practice translates into superior performance further along down the line; practice enhances perception by making the eyes work harder, but it also provides a motivation to work harder and to derive something more meaningful from the experience. In the context of the educational model, practice and technique usage are argued to be influenced by individual differences in personality and approaches to learning. More conscientious, extroverted and neurotic individuals will tend to take a more achieving approach to drawing which results in success. Surface approaches only increase the time spent practicing but result in decreased drawing ability. Deep approaches to learning promote the uptake of techniques for drawing, potentially because students want to learn as much about the process as about the product of drawing. This approach can be successful, if the drawing techniques adopted impact positively on the accuracy of the drawings produced using them.

Openness to experience appears to exert the most influence on other elements of the model, compared with the other four personality factors of the Big Five Personality Inventory. It impacts upon time, technique and academic attainment, as well as predicting deep approaches to learning. Open individuals seem to be motivated to try different modes of working in drawing, to practice more, and to strive for a deeper understanding of the drawing process. However, they do not follow the more direct and forceful route through achieving approaches to studying to drawing ability, but are still likely to succeed in producing more convincing drawings. It is possible that students receive much praise for

drawings that look like the target object at school, and therefore achieving students strive hard to develop this faculty, rather than exploring the artistic medium.

I argue here that academic attainment (represented by GCSE results) is another independent predictor of drawing ability. This conjecture is supported by the finding in section 6.3 (results of the local-global processing chapter) that NVIQ does not predict drawing ability. This suggests that general intellectual ability is not necessary for the development of drawing and does not supersede relation between drawing ability and academic attainment. However, an achieving approach to learning predicted success at GCSE and therefore this strategy for learning appears to be most conducive to success in the academic medium, and subsequently to drawing ability. It can be concluded that intellectual ability is neither necessary nor sufficient for expertise in representational drawing, but academic attainment in isolation from IQ does have a role to play in drawing expertise attainment. The educational model suggests that there is little that is associated with drawing that cannot be learnt and developed, and that drawing training should focus on the way in which individuals engage in learning and practice. I will now turn from cognitive aspects of drawing expertise acquisition, to the most fundamental theme to be drawn from this thesis as whole; the role of visual perceptual processing in the drawing system.

9.2.2   The Perceptual Core

To a large extent the behavioural investigations in this thesis aim to provide evidence for the central role of visual perception in drawing. Within the interview study, it became clear that artists placed perceptual enhancement at the core of successful drawing. They reported selectively restricting visual input, in order to simplify the whole or parts of the stimulus image for rendering. This finding corroborates earlier work by Cohen and Bennett (1997) and Kozbelt (2001) who concluded that a large amount of the variance in drawing scores could be accounted for by individual differences in visual perception. However, these authors did not explicitly state which kind of perceptual errors or enhancements are associated with representational drawing. This thesis has elaborated substantially on these claims by revealing elements of visual perception that contribute to drawing accuracy; in particular the role of local visual processing and of perception of angles and proportions, which have been prevailing themes of previous research in drawing (Cain, 1943; Drake et al., 2010; Drake & Winner, 2011).

Both angular and proportional perception in rendering and non-rendering tasks were found to relate to drawing ability in the study presented in Chapter 5. The study of local processing and drawing accuracy in Chapter 6 revealed that enhanced local processing was related to drawing ability but not artistic ability more generally, and that this association

was more likely to be a result of enhanced perceptual functioning than weak central coherence. Furthermore, a link between local processing and angular/proportional perception was found, suggesting that local processing facilitates perception in a rendering situation by aiding the deconstruction of both complex and simple spatial relationships in the visual scene.

I will now discuss these findings in relation to two prominent explanations of visual perceptual enhancement in drawing: top-down and bottom-up accounts. Aspects of these accounts are supported by evidence throughout the thesis, and point toward an integrated bottom-up and top-down approach to the drawing process, with perceptual findings supporting bottom-up processing, and the role of VLTM supporting the influence of top-down processing on drawing.

9.2.2.1 Bottom-up Accounts of Perceptual Contributions to Representational Drawing

The emphasis on a detail-focused approach to drawing from the interview study (Chapter 2), alongside existing experimental evidence indicating that enhanced local processing is associated with drawing ability (Drake & Winner, 2011; Drake & Winner, 2012), drove the hypothesis in the present thesis that individuals who show superior local processing might possess superior representational drawing skills. The following quotation from the interview study makes clear the role of local processing in successful representation:

> I can look at the world and break it into forms. That's what I do when I need to convey something from reality to drawing.

> [Male, 30, Painter]

What is striking from this quote is that the block design and embedded figures tasks used to measure local processing performance in the experimental study of local processing requires the participant to perform exactly the kind of task that this painter is describing. This quote provides support for the ecological validity of these paradigms, as they appear to mimic the kind of visual manipulations that artists are applying to the visual world when they perceive it during drawing, although undoubtedly the visual scene to be drawn is far more complex than the patterns presented in the two local processing tasks. Artists report that they are not able to perceive in this manner for much of the time; instead they use techniques and devices to stimulate focus on local processing while drawing. The following quote describes one example of the way in which artists use ways of restricting their perception of the to-be-

drawn stimulus, in order to enhance their local processing and ignore irrelevant holistic cues and semantic properties of objects and scenes.

> I look at patterns a lot, so rather than drawing things just picking out.

[Female, 35, Painter]

The role of local processing in representational drawing and the perception of simple angles and proportions seems to argue against a strongly 'top-down' account of drawing. Local processing tends to lead the artist away from holistic, abstract, semantic conceptions of visual stimuli, and indeed may actually be employed to avoid top-down processes that may lead to inaccuracy. As argued in the introduction (1.4.2. The Innocent Eye) top-down influence of stereotypes and over-generalised schemata may override accurate perception of a particular instance of an object or scene (Mitchell et al., 2005; Reith & Liu, 1995; Sheppard et al., 2008). Therefore, it can be argued on the basis of the data presented in this thesis that, for at least a proportion of the time when drawing, artists actively avoid holistic, top-down processing in favour of a detail-focused, concrete and non-semantic visual representation. As one student in the interview study appropriately stated:

> I mean one thing about observational drawing is that there's no hierarchy it's sort
> of about giving attention to the whole of the surface; so it might be that you begin
> with a negative space or something else.

[Female, 27, Sculptor]

It can be contended that a local processing strategy helps artists to 'give attention to the whole surface' and which prevents the artist from being biased by semantic connections with the stimulus. This contention is supported by research conducted by Glazek (2012), which showed that artists were not affected in their copying ability by familiar shapes, whereas novice artists showed superior copying for novel over familiar stimuli. Whilst the connection between local processing and averting semantic connotations of visual stimuli has not been proven in the context of the current thesis, this relationship is a rich avenue of investigation for future research. Data from the Navon task in Chapter 6 suggest that local processing enhancements manifest themselves, not necessarily in the ability to perceive the local elements of a hierarchical stimulus faster or more efficiently in isolation, but in the ability to ignore irrelevant global properties of the same stimulus when the task is not to focus upon the local level. This suggests that enhancement of local processing accounts for

only part of the explanation. It is the interaction between local and global elements and the ability to view one or another independently that drives successful drawing.

The role of simple angle and proportional perception also supports a bottom-up approach to drawing. In Chapter 5, it was shown that the ability to match angles and proportions online in a non-rendering context predicted drawing accuracy, suggesting that the foundation of drawing ability is a non-domain-specific enhancement of the perception of orientation and magnitude features in the visual environment. This association was greatly ameliorated when individuals had to commit the angles and proportions to short-term visual memory, suggesting that stored representations are weakly linked to enhanced drawing ability in this instance. Ability to reproduce these simple geometric properties also correlated with local processing ability, further corroborating the view that these abilities are evidence of a bottom-up approach to drawing; successful perception of angles and proportions to some extent relies upon breaking down global properties into local elements, even in very simple tasks. Furthermore, there is tentative evidence to support Cain's (1943) contention that this ability may to some extent be innate, as this ability was not found to be related to recent drawing experience. The aforementioned evidence establishes some evidence for bottom-up processing in drawing that is independent of practice and global schematic perception. I will now go on to summarise the evidence produced for the influence of higher level representations on the drawing process.

9.2.2.2 Top-down Perceptual Contributions to Representational Drawing

Despite the main line of research supporting the importance of local processing in drawing, it appears to be the case that global processing is also important. Global processing is more likely to represent 'top-down' approach to drawing as it requires the processing of stimuli as wholes rather than abstract parts. The contention that global processing is also an important component of proficient drawing is supported by data from the survey study, which show that the most commonly used drawing devices are those that promote the translation of global structure of an object or scene onto paper. In a contrary manner to the techniques used to enhance local features and patterns, using techniques like squinting to blur the field of vision appear to be enhancing global aspects of an image and actively disregarding detail.

> The job is to try to draw the light and not the details of the face, and it's the "come on everybody squint"
>
> [Female, 27, Sculptor]

These kinds of techniques appear to be the most popular techniques on assessment of the results of the survey data (Chapter 3.4.2: Observational Drawing Ability and Devices); including producing quick drawings without detail, plotting the pivotal geometrical framework of a drawing first and squinting to extract global tonal information were used most frequently by the students surveyed. Meanwhile approaches to negative space may emphasise either local or global strategies for perception, but seem to emphasise the importance of abstracting away from the meaning of objects, which is a quality that may be in play when trying to reduce perceptual constancies (Ostrofsky et al., 2012). Both the interview and survey study data do not seem to place enhanced importance on global or local processing, in that responses to the attention to detail subscale of AQ were not predictive of drawing ability in the local processing study. These findings suggest that expert draughtsmen possess enhanced perception of both global and local attributes. Therefore, this trio of evidence leads to the conclusion that both local and global processing help to enhance drawing, and that expert draughtsmen need to employ both approaches to production.

More research, particularly focusing upon global processing, needs to be conducted in order to assess the relative roles of global and local processing, and how switching between local and global levels is controlled during the drawing process. Table 9.1 demonstrates how various visual tasks, many of which have been employed in the experimental work in this thesis, can be used to assess the various components of local and global processing including testing functioning on certain aspects of the block design, embedded figures and the Navon hierarchical shape tasks, and testing susceptibility to visual illusions and impossible figures (for methodological explanations of the local processing tasks used in this thesis refer to 6.2.2).

Table 9.1. Tasks used to assess local/global processing

Global-Local Processing Ability	Tasks Employed
Global Advantage	Navon shape task, Impossible Figures, Block Design Task
Global Interference	Navon shape task, Visual Illusions
Local Advantage	Navon shape task, Embedded figures task, block design task
Local Interference	Navon shape task
Global-Local Switching	Navon shape task

The Navon task is the most flexible task of local and global processing as it incorporates divided and selective attention conditions as well as the opportunity to observe

how individuals deal with the demand of switching their attention from one level to the next. Impossible figures and visual illusions can also be used to assess global advantage and interference; the success of many visual illusions is dependent upon the ability to perceive an image holistically whilst ignoring conflicting local information from its component parts as in the case of the impossible triangle. Illusions like the Ebinghaus rely on the interplay between the central circle and its surrounding elements to induce the sensation that the left circle is smaller than the right (see Figure 9.2).
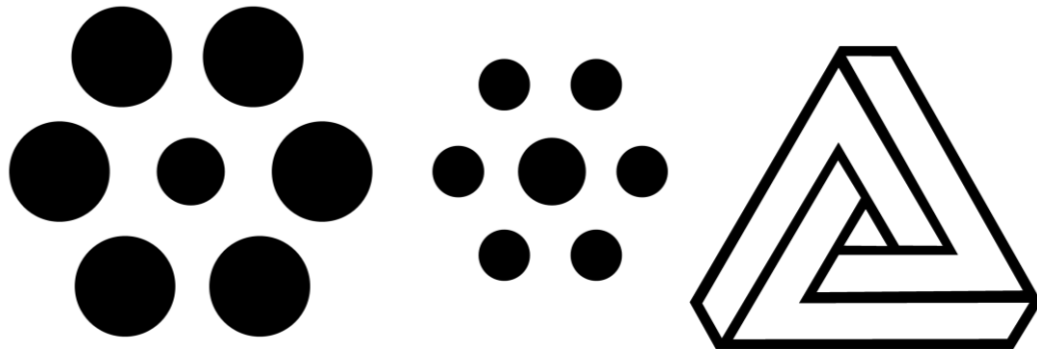
Figure 9.2. The Ebinghaus Illusion and the Penrose Triangle

It is critical to explore ways of characterising the switching between local and global processing modes and when and where this is most useful during the drawing process. The role of local-global switching may only be tractable by monitoring the drawing process online, through hand and eye movement tracking during the drawing process, and assessing the extent to which expert draughtsmen switch between local and global modes of perceiving. Artists appear to enable local and global processing strategies intuitively, by reporting that they use various techniques for these two modes of perception. A structured approach to perception for drawing that is informed by the conclusions presented in the experimental components of this thesis would help artists to use local-global processing more efficiently. The impact of such strategies for pedagogy is discussed in section 9.4 of this chapter.

Evidence from the visual memory research presented in this thesis suggests that top-down influences through cognitive penetration and top-down visual processing do play a role in the drawing process, as VLTM was found to be consistently associated with drawing accuracy (7.3.1 Rey Osterrieth Complex Figure). It can be argued that the role of VLTM is domain-specific; as it was found that VLTM in a rendering but not in a non-rendering task was found to predict drawing ability. As the effect of VLTM is domain-specific, this is suggestive of a top-down contribution that is 'switched on' when the artist perceives a stimulus with the intention of drawing it. This finding contrasts with local processing and angular/proportional perceptual contributions to drawing which represent bottom-up

processing and which are not specific to the rendering scenario, but appear to be reflective of a visual processing style that is not dependent on whether the artist is drawing or not. That is to say, enhanced local processing and angular/proportional perception is seen in cases in which the participant is perceiving both within *and* outside the drawing process, whilst enhancements of VLTM are only present when the participant is engaged in the drawing process. It is argued that VLTM guides visual attention and motor planning in relation to the drawing process, and this is the focus of discussion in the following section.

It can be concluded that drawing is facilitated by both top-down and bottom-up perceptual processing, the former by VLTM and cognitive strategies, the latter by influences on lower level perception including local processing. Table 9.2 demonstrates the differing characteristics of bottom-up and top-down processing in relation to drawing. Domain-general attention to local elements that abstract away from semantic relations and enable faithful perception of low-level geometric properties represent bottom-up processing, whereas the use of domain-specific schemata in VLTM represents top-down processing. Furthermore, it is argued that whilst top-down processing is experience-dependent as it relies upon existing stored representations built up from prior drawing episodes, bottom-up perceptual processing can result from innate disposition as well as enhancement over time as a result of practice and restrictive visual exercises when drawing.

Table 9.2. Summary of attributes pertaining to top-down and bottom-up perceptual processing in drawing

Bottom-Up	*Top-Down*
Domain-General	Domain-Specific
Visual Perception (Draws on local visual processing, perception of simple geometric attributes)	VLTM Schemata (Draws on stored visual representations)
Innate and experience dependent	Experience dependent
Perceptual	Semantic

9.2.3 Visual Memory and Motor Processing

> No matter how slight the interval is from the time you look at the model until you
> look at your drawing or painting, you are memorizing what you have just seen.
> (Nicolaides, 1941, p.40)

This quote from an instructional book on drawing represents a commonsense conception of the relationship between visual memory and drawing process. However, what is striking from previous literature as well as from the interview, survey and experimental data in this thesis, is the lack of evidence that differences in VSTM performance and visual imagery underpin differences in drawing ability. If visual memory is in fact integral to the drawing process, it is not the case that individual differences in this ability have an impact on productive output. Therefore, from an impact point of view, it would seem that there is no benefit in targeting VSTM training in order to see an improvement in drawing. More practical benefit may be seen from targeting long-term memory structures to enhance drawing ability. This conclusion follows on from the theoretical positions of Tchalenko and Kozbelt, in placing emphasis on relationships between long-term memory stores and perception, and perception and action as the foundation for the drawing process (Seeley & Kozbelt, 2008; Tchalenko, 2009). Interestingly, in the present thesis the role of memory seems to be dependent on whether an individual is engaged in drawing or not, suggesting that stored representations function in a top-down, domain-specific manner. This result contrasts with the findings in visual perception in relation to drawing, in which performance in rendering and non-rendering conditions was related to drawing ability, suggesting a more domain-general enhancement.

The richness of long-term rendering-specific representations can be argued to impact upon the way in which novel visual stimuli are interpreted and attended to during drawing. This contention is supported by expertise findings in chess in which chess masters have better LTM for functionally relevant board configurations (Charness et al., 2001; Chase & Simon, 1973; Ericsson & Charness, 1994; Ericsson, Charness, Feltovich, & Hoffman, 2006; Reingold et al., 2001). The underlying argument to explain these results is that rapid and efficient encoding of meaningful board configurations aids performance. In a similar way rapid and efficient encoding of domain-relevant stimuli in drawing could be facilitated by more sophisticated representations in LTM. However, whilst in the instance of chess it easy to identify board configurations that are relevant to a real game of chess and those that are not, in the context of drawing it is more difficult to identify domain-relevant versus domain-irrelevant stimuli. As a result it is worth modifying the expertise account in this context; for the draughtsmen the domain-relevance applies to the activity they are

undertaking rather than stimuli they are attending to. In this instance the act of drawing makes all stimuli domain-relevant. Therefore rendering for encoding in the case of the Rey Osterrieth Complex Figure Test has a positive bearing on future instances of drawing by enabling effective encoding and visuomotor processing of new stimuli no matter their visual content. That being said, for artists who do have a particular specialism, for instance a portrait artist, more specialised LTM function may be seen in relation to the stimulus in question. The relationship between stimulus specialism and perceptual expertise is reflected in a study in which portrait artists show increased local processing of faces (Zhou et al., 2012). This paradigm could be adapted to test portrait artists' memory for faces versus their memory for non-human objects.

Whilst the focus of memory research in this thesis has been on *visual* memory, given the role of motor control and execution in drawing, as evidenced by the neuroimaging findings in Chapter 8, it can be argued that procedural memory is also pivotal to the drawing system. This ability has thus far been overlooked and warrants attention in future research, through the more detailed study of motor behaviour during drawing. It appears that the role of long-term memory is to some extent trimodal, consisting of: categorical verbal representations and associations that add richness to semantic content of the incoming visual input, visual templates that determine the way in which new visual information is encoded on the basis of previous rendering experiences, and motor procedures that make the execution of complex hand and arm movements more efficient and effortless. The role of visual memory is reflected in the toolbox for drawing ability in 9.3 in which stored representations come into play for attentional guidance.

9.2.4   The Neural Basis of Drawing

This thesis presented the first structural imaging study of differences between artists and no-artists and neural correlates of long-term drawing experience (Chapter 8). The results corroborated previous functional studies, in localising the drawing process to the cerebellum and the medial frontal gyri, but contrasted with expectations in revealing no structural changes to parietal or occipital regions in relation to drawing ability. These findings suggests that long-term structural differences due to drawing expertise function for hand-eye coordination, fine motor control and procedural memory but not for perception. This dissociates the neuroimaging from the behavioural findings, in placing the perceptual firmly in the motor. In previous functional studies (Makuuchi et al., 2003; Miall et al., 2009; Solso, 2000), no purely perceptual regions were associated with the drawing process, suggesting that it is impractical to talk about perception in drawing in relation to the brain without relating perception to the enactment of motor plans in response. This finding also serves to

explain the commonplace argument of novice draughtsmen; that they can see what they are supposed to be drawing but still fail to translate the visual stimulus onto the paper before them. However, it is interesting to consider whether this strong perceptuomotor relationship is present in all instances of expert drawing. In the instance of savantism in which the difference between individuals with ASD and those without is assumed to be perceptual, it would be interesting to assess structural brain differences in relation to savant drawing ability to see whether different brain regions are implicated in such cases of atypical acquisition of expertise.

Local processing ability overlaps with some areas responsible for drawing, again in regions associated with motor processing rather than those responsible for perceptual processing. At this stage it remains unclear why this association is manifested at the visuo-motor level and further research is necessary in order to explain the apparent overlap between these two abilities. Again, in this instance there could be a dichotomy between typical and atypical functioning in response to drawing. Evidence from an fMRI study of performance on a local processing task suggests more prefrontal involvement by controls, with more occipito-temporal activation in ASD (Ring et al, 1999). It could be possible that individuals have different cognitive strategies for this task resulting in the activation and development of different regions. However, it is clear from the neuroimaging findings that both drawing and local processing confer the development of motor rather than perceptual structures, providing evidence for the role of visuo-motor transformation in drawing.

9.2.5   Summary

Qualitative and quantitative lines of enquiry in the present thesis have provided evidence for the importance of accurate perception in representational drawing, and the relative downplaying of short-term memory stores in place of a more direct connection between perception and action. The neuroimaging evidence has weighed on the side of fine motor control and procedural memory functions in drawing, that have not been previously attended to in the behavioural literature and should be of primary concern in future research. Furthermore, and of importance for art and design practitioners and teachers, the data in this thesis have provided evidence for when practice and skill development can be of most benefit for the student of drawing. Having summarised the key findings and themes of the research I will now present a toolbox for drawing ability that draws on the evidence presented in the thesis, and the theoretical and evidence from existing research, to bring together semantic, visual and motor aspects of the drawing process in one single framework.

9.3   A Toolbox for Drawing Ability

The toolbox for drawing presented in Figure 9.3 takes its influence from previous models of drawing and artists' perceptual advantages (van Sommers, 1989; Guerin et al, 1999; Kozbelt & Seeley, 2007), previous behavioural research into drawing accuracy (Cohen & Bennett, 1997; Ostrofsky et al, 2012; Drake et al, 2011) and experimental evidence from studies in the current thesis. However, it differs from previous models of the drawing process as it focuses specifically on features of the drawing process that may give rise to an enhancement in drawing ability. It does not provide a working description of the process of drawing itself, but highlights the key elements necessary for the development of refined drawing ability. The toolbox brings together the role of perception, action and memory in drawing, placing visual perception at the heart of development of drawing ability, as well as personality factors that underpin drawing skill acquisition. As the toolbox focuses upon defining the features that account for individual differences in drawing ability, there is little emphasis placed on working memory stores or visual imagery processes. The lack of focus on VSTM and imagery in the toolbox results from null or inconclusive evidence on imagery and VSTM presented in this thesis. The role of working memory in the toolbox becomes one of LT-WM (Glazek, 2012); as an intermediary between long-term representations, perceptual processing and fine tuned motor plans.

I will now outline the three 'compartments' that constitute the contents of the toolbox (Figure 9.3). These are the educational mechanism, the visual hierarchy and the visuo-motor module. As a triad they represent an expert system oriented towards perception for drawing that is constantly interacting with stored, semantic representations and with procedural and novel motor processing throughout the drawing process.

DRAWING ABILITY

Practice and Use of Drawing Techniques

Approaches to studying and Educational Attainment

Personality Factors

THE EDUCATIONAL MECHANISM

Long-Term Working Memory (encoding and attentional guidance of perception)

Integration of global proportional attributes and local angular relations

Local angular and proportional relations

Fine-tuned motor processing and Procedural Memory (including eye-hand interaction)

THE VISUO-MOTOR MODULE

Independent angular and proportional relations

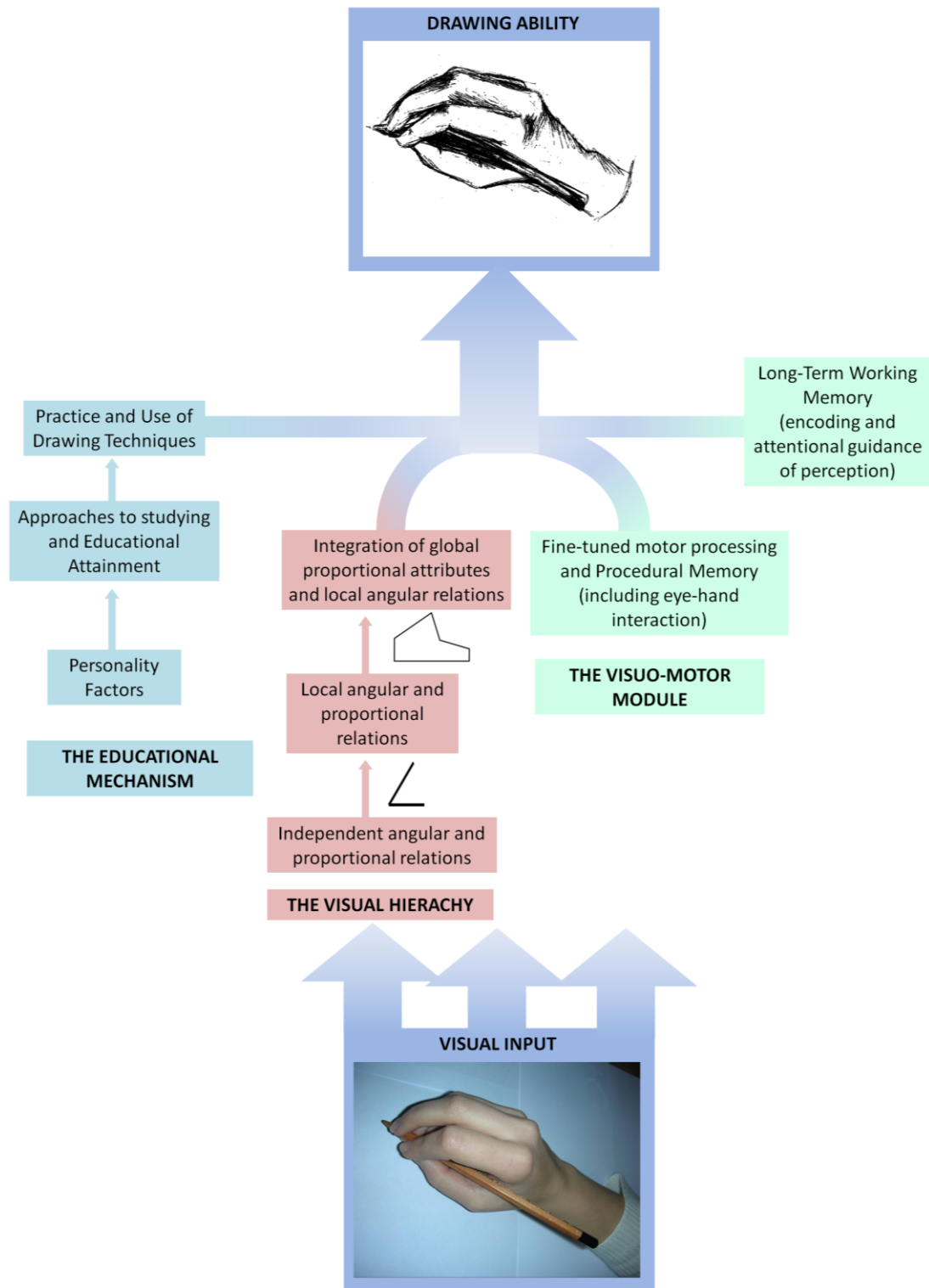**THE VISUAL HIERACHY**

VISUAL INPUT

Figure 9.3. A Toolbox for Drawing

9.3.1   The Drawing Toolbox: The Educational Mechanism

As stated previously, the survey study in Chapter 3 highlighted a complex network of background variables which serve to influence the development of drawing ability. This network was developed and simplified by conducting a path analysis, which gave rise to the educational model of drawing learning presented earlier in this discussion chapter (Figure 9.1). A simplified version of this model has been incorporated into the drawing toolbox. The educational mechanism is the process by which individuals come to develop drawing expertise by engaging in purposeful, productive and exploratory practice. Educational attainment refers to the relationship between GCSE grades and drawing ability which was found to be independent of the other pathways in the educational model, but is included with approaches to studying as it falls into the theme of 'education' in the educational model of drawing ability displayed earlier. The use of drawing techniques may lead to changes in perception, and therefore there is probably some crosstalk between the educational mechanism and the perceptual hierarchy. The relationship between specific drawing techniques or processes and the kinds of perceptual advantages seen in relation to drawing is a potential area of future study.

9.3.2   The Drawing Toolbox: The Visual Hierarchy

The visual hierarchy was initially presented in Chapter 5, on the basis of findings from the perception of angles and proportions in the Cain House drawing and line matching tasks. It now forms the central element of the drawing toolbox, reflecting the empirical focus on perception in the current thesis and the strong connection between drawing and perception that has arisen from the data herein. The foundation of the visual hierarchy consists of accurate perception of angles and proportions. This ability is arguably innate (Cain, 1943) and is to some extent dependent upon local processing ability, as angular and proportional perception for pairs of lines was found to be related to local processing performance (6.4.7. Local Processing and Perception of Angles and Proportions). This lower-level ability feeds into more complex representations, in which local focus is arguably of even greater importance in order to avoid semantic and visual illusory biases. Finally within the top level of the hierarchy local percepts are integrated with more accurate perception of more global proportional relationships resulting in enhanced drawing ability for more complex stimuli.

The perceptual hierarchy likely interacts with both educational mechanism and with the visuomotor module. The long-term memory element of the visuo-motor module may control for global/local focus by influencing visual attention for rendering, as spatial schemata do in Seeley and Kozbelt's (2008) model for perceptual enhancements in artists. If

the visual input was not received with active intention to render, the particular connections with drawing procedures in VLTM and procedural memory would not be activated. The visual hierarchy accounts for the reception, interpretation and deconstruction of visual input for drawing while visual attention is mediated by long-term visual memory within the visuo-motor module for focus upon global or local features.

9.3.3 The Drawing Toolbox: The Visuo-Motor Module

The visuo-motor module encompasses both motor processes and the impact of semantic structures on drawing ability. The long-term working memory component explains the findings from the series of visual memory studies in Chapter 7, by placing it in the context of expertise model of visual chunking. The motor processing component takes in findings from the neuroimaging study, as well as previous studies on hand-eye interaction during the drawing process. It is evident that both of these components may have some interaction with the visual hierarchy, however currently it is not possible to explicate these interactions, although this is a fruitful avenue for further study and may be aided by novel technologies for studying the drawing process presented in the next section of this discussion (9.4.2. Methodology: Technology).

9.3.3.1 Long-Term Working Memory

The long-term visual memory component of the drawing toolbox represents the role of long-term representations and approaches to perception and production in proficient drawing that are informed by top-down processes. As previously outlined in the discussion of the visual memory findings, VLTM is likely to interact with the drawing process by facilitating efficient visual analysis and encoding via spatial schemata (Glazek, 2012; Kozbelt, 2001; Kozbelt et al., 2010; Seeley & Kozbelt, 2008). It helps to 'chunk' visual input in much the way that chess players chunk parts of a chessboard for more efficient recognition, which in turn helps the artist to capture more information per gaze fixation (Glazek, 2012). It also shapes the way incoming visual information is interpreted by activating procedural motor plans for both efficient visual and motor functioning during the drawing process. In this way the long-term working memory component interacts with both the perceptual hierarchy and the fine-tuned motor component.

9.3.3.2 Fine-tuned Motor Processing

Fine-tuned motor processing is a feature of the drawing toolbox as a result of the neuroimaging findings in Chapter 8, which also point toward the role of procedural memory, providing support for Seeley and Kozbelt's (2008) visuomotor model of artists' perceptual

enhancements (Figure 8.6). There is further emphasis within this element of the role of the hand in guiding the eye. From the point at which visual attention is engaged with the purpose of rendering the intimate connection between the hand and the eye ensues. The pivotal role of motor monitoring is supported by previous research into hand-eye interaction in drawing, most notably from Coen-Cagli's (2008) research on computer models of hand-eye coordination. Glazek's (2012) evidence for increased hand-eye interactivity and increased motor output in skilled artists also emphasises the importance on the motor processing steam in a model of drawing. Furthermore, lack of evidence for a role for VSTM representations in the toolbox for drawing places more importance on immediate links between perceptual representations and motor planning and execution, such that 'the shape of the line to be drawn is acquired by the hand during the time that the subject is looking at the original' (Tchalenko & Miall, 2009, p. 370).

Having elaborated on the toolbox for drawing ability I will now go on to discuss how the toolbox and other findings in the field can inform future directions of the research and how they can be applied to art education through strategies for teaching, drawing on two teaching strategies used currently by colleagues in the field.

9.4   Future Directions for Drawing Research

Due to youth of the field and the exploratory nature of this thesis, the research described and discussed within it inevitably poses far more questions than it answers and a great deal of further research is needed in order to flesh out components of the drawing process that were not explored in the context of the current investigations. I will now briefly outline the main avenues of future research, with some suggestions of methodology and directional hypotheses where possible, followed by the possible application of the present research to existing drawing teaching and practice.

9.4.1   Methodology: Longitudinal and Training Studies

The most promising avenue of research in the current thesis concerns the study of the relationship between perceptual processing and drawing ability, as individual differences in perceptual processing have been shown to demonstrate reliable associations with individual differences in observational drawing ability. This avenue of research will also serve to elaborate upon the processes underlying the visual hierarchy in the toolbox of drawing ability, more specifically in the interaction between local and global processing strategies. The present thesis has found evidence to suggest that enhanced local visual processing is associated with drawing ability, and that this association is most likely to be accompanied by enhancement in global processing or in local-global switching. Paradigms that would

allow for assessment of these local/global/local-global switching abilities are discussed in section 9.2.2 (The Perceptual Core). A key question in this field is whether individuals development local processing with drawing practice, or whether this ability is innate and therefore predisposes individuals to perceive in a way that is conducive to good representational art.

Very little research has been conducted to look at the causal links between perceptual enhancement and drawing ability. Schlegel et al's (2012) study assessed the impact of a brief period of training on the perception of visual illusions but did not find any reduction in perception of illusions by the drawing and painting trained participants. Furthermore, in the studies of the present these there is little evidence of a relationship between the amount of time spent practicing drawing in the last two years and local processing performance. However, it could be case that these faculties develop over years, if not decades, and therefore that reports of time spent drawing in the last two year and the training period of Schlegel et al (2012) were not long enough time periods to isolate training effects. Also Schlegel et al's (2012) study only looked at one aspect of perceptual processing, susceptibility to visual illusions. It is now understood that drawing is associated with a wide range of enhanced perceptual functioning that could develop at different trajectories and to variable extents in relation to training. In this vein, it would highly advantageous to conduct a longer training study, with more explicit instruction such as the protocol that was recently piloted in a workshop at the RCA, with assessment of a wider range of perceptual factors thought to be associated with drawing expertise (section 9.4.3. The Impact of Drawing Research on Educational Strategies). Longer-term structural MRI studies could be conducted to observe the way in which neural structures change over time in individuals engaged in sustained drawing training, in a similar manner to the taxi driver training studies conducted by Ellen Maguire's spatial cognition group (Maguire et al., 2000; Woollett & Maguire, 2011).

The training paradigm could be an effective paradigm for identifying talent in children. If the perceptual faculties of individuals can be tested before they undergo extensive training and practice in drawing, it will be possible to ascertain whether perceptual abilities predetermine ability at drawing, or whether they develop as a function of engagement with representational media. As has been reiterated many times during the course of the present thesis, it can be predicted that there is an interactive and supplementary relationship between talent and training. That is, there may be some degree of innately disposed perceptual functioning that predisposes particular individuals to excel at artistic representation from a young age. In turn these individuals will be motivated to practice and engage in training. In addition, training which focuses upon particular modes of perceiving

may actively change and enhance perception so that perceiving for drawing becomes less effortful and results in more convincing representations. It will be challenging for research to extract these two foundations for superior functioning in the arts, but through longitudinal and interventional studies it will be possible to define at which point and to what extent innate qualities and training and practice play a role in expertise development in artistic representation.

Another avenue for investigation which has been alluded to in 6.4.1 (Differences in Local Processing Ability between Art Students and Controls) assesses drawing accuracy in contrast to faculties associated with artistic functioning. The data from the local-global processing study implied that only drawing conferred enhancement in perceptual functioning, as there were no significant differences in performance between artists and non-artists in this study. This raises questions concerning the nature of perceptual processing in other artistic domains. Does painting elicit the same perceptual changes as drawing? It could be the case that in this context there is less emphasis on local processing and a greater sensitivity to tonal and colour contrast. Painters may be less susceptible than other kinds of artists to tonal illusions like the checkerboard illusion (Figure 9.4), which has been investigated in a previous study of artists' susceptibility to context effects (Pedreau & Cavanagh, 2011). In this way it may be possible to characterise psychological processing across different visual art forms.
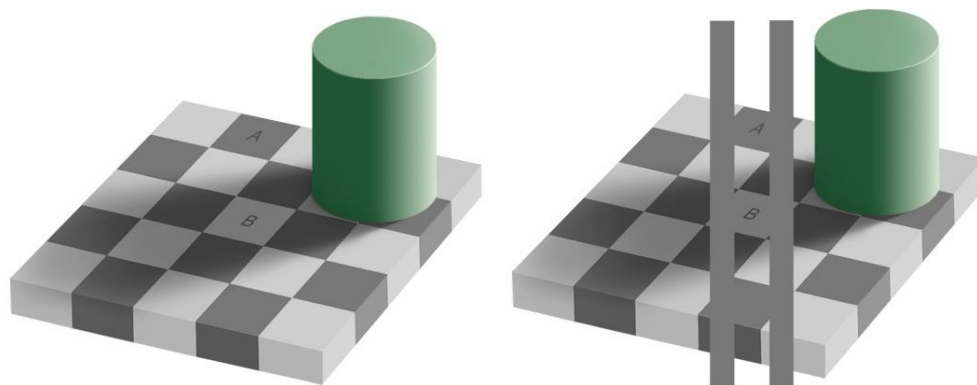
Figure 9.4. The Checkerboard Illusion: Square A appears darker than square B due to semantic knowledge about the effect of shadows on tone

9.4.2 Methodology: Technology

The following section assesses how we can harness new technology in order to further the study of drawing ability. Firstly, I will give an overview of the studies into drawing accuracy reported in Chapter 4, which demonstrate the utility of image analysis and manipulation for drawing accuracy investigation, and then move onto the potential of methods for recording hand and eye movements in future research.

9.4.2.1 Judging the Accuracy of Drawings

A key aim for the present thesis was to produce a reliable and valid measure for assessing accuracy of drawings and to provide a critical analysis of currently used subjective rating methods. In relation to this aim, shape analysis approaches to assessing drawing accuracy were adopted in response to previous research into the accuracy of portraiture (Costa & Corazza, 2006; Hayes & Milne, 2011). It has become clear that the subjective rating method of drawing accuracy assessment is strongly correlated with shape analysis measures of accuracy, validating the current methodology which is used in the behavioural and neuroimaging studies in this thesis. Indeed, the conclusion that was drawn from this study was that the subjective rating method is appropriate for the demands of the current research. However, some interesting nuances in the data in the drawing accuracy study require further comment and may stimulate an independent line of enquiry in their own right. Data from this study suggest that perception of accuracy differs according to the type of stimulus that is being assessed. More organic or 'life-like' stimuli are judged for accuracy on a holistic basis, whereas more geometric objects are judged on a more local basis. The positive role of local distortions in organic stimuli like the hand supports the contentions of Ernst Gombrich (1960); that artists emphasise features unique to an individual viewpoint whilst omitting certain visual details, encouraging the viewer to 'fill-in' the gaps. The ability to leave out detail however does not appear to be the case for more geometric stimuli like the block and Malevich task. This finding provides tentative evidence for deliberate emphasis or manipulation of key local elements of the image, whilst preserving global shape features of a subject in the representation of organic stimuli. This will be the focus of future research, in which the aim will be to identify particular features of an image and assess the direction and type of distortions that correspond to judgements of increased subjective accuracy.

From the analysis of drawing accuracy, an intriguing novel methodology was developed for assessing the role of shape vs. non-shape attributes (quality of line, conveyance of depth through tone etc.) of drawing for accuracy judgement. It is now possible to warp inaccurate drawings onto a set of coordinate points on a baseline image. This technique can be used in a rating study, much like those employed for the behavioural experiments presented in this thesis in order to assess the role of extra-shape attributes on accuracy perception. Participants could be given a series of warped images that all have approximately the same landmark structure that must be rated for accuracy. A qualitative analysis of the underlying structure of the ratings will give an impression of what kind of drawings give a feel of accuracy once shape differences have been eliminated. Undoubtedly this is a highly fruitful avenue for investigation; however a large methodological problem exists in the fact that the selection of coordinate points is still a relatively subjective matter.

Image analysis techniques could also be used to overcome this potential criticism, and this is currently being investigated in the context of analysing curves. The use of drawing applications on tablet devices such as the iPad may also help to make this process more efficient and reliable as drawing is recorded in real time and automatically digitised. Indeed iPad art has been embraced by the artist David Hockney who displayed some of this iPad paintings as part of a retrospective exhibition at the Royal Academy in London (David Hockney, A Bigger Picture, 2012), lending credence to the notion that tablets would be an acceptable medium by which to study drawing in practicing artists.

9.4.2.2 Hand and Eye Movements

The order of construction of drawings has been used to assess drawing ability in individuals in ASD but not in typical or artistically gifted adults. A global approach (i.e. by drawing the outline of a figure first to get the major axes and proportions correct before progressing on to more local details) could be conducive to enhanced performance, thus negating the need for enhanced local behaviour in this context, and therefore the study of construction hierarchy and serial order in drawing movements, will provide more insight into the relationship between planning and perception during the drawing process. Drawing construction relates to the role of the global and local processing modes in the visual hierarchy with the toolbox for drawing ability presented earlier, in refining their deployment and potential interaction with the supplementary semantic and motor processing streams. For instance, it could be the case that with greater coupling of hand and eye movements comes with movement toward a particular strategy of local-global switching.

In the future it will be possible to use computer tablet technology like the iPad to record the progress of a drawing and then to assess the extent to which global or local strategies are in use at different time points of the drawing. It may be also be possible to develop the use of camera pens to record drawing movements and for digitization of drawings. In much the same way as eye movement analysis can group eye movements as long-range or short-range, drawing movements could be categorised as such, with longer range movements characterising global elements of the images. This approach has been used in research in visual aesthetics in which scan paths have been assessed to draw conclusions about the role of complexity and beauty in perception of artworks (Nadal, Forster, Paul, & Leder, 2013). By calculating the proportion of time spent making large vs. small drawing movements in a series of predefined epochs in the drawing timeline, it will be possible to analyse the timing of local and global drawing behaviours for good and poor drawers. Interactions between the timing of hand and eye movements is pertinent to the question of hand-eye coordination for drawing and would further characterise the interaction between

visual and motor processing during drawing. Eye movement could also be used to restrict visual input. It is possible to use gaze-contingent paradigms to restrict the viewer's input to a small aperture, or to blur the part of the image attended to while still providing clarity to the peripheral vision. Restricting visual input in these kinds of ways in an interventional study could help to improve individuals' drawing, or to assess whether artists are less disadvantaged by an enforced local approach to the drawing process.

9.4.3   The Impact of Drawing Research on Educational Strategies

One of the aims of the current thesis was to provide a psychological exploration of drawing that would have the potential for application in the field of art and design pedagogy. In response to this aim, the following section provides some suggestions and evidence of a small-scale teaching programme that focuses on particular aspects of the experimental body of work. These recommendations could be tested in light of training studies outlined in the previous section (9.4.1. Methodology: Longitudinal and Training Studies). Some of the techniques used are already in practice in artists' work, so in this way the training scheme does not offer any completely novel strategies for rendering. Rather, the tutors focused on those techniques in drawing tuition that relate most strongly to the findings of this thesis.

9.4.3.1 Drawing Training in Art and Design

In order to elucidate the causal relationship between perceptual abilities and drawing ability in art students, it was necessary to explore whether the implementation of a structured teaching programme focused upon these faculties would improve drawing ability. This approach to drawing has already been adopted by our research group in a small qualitative pilot training programme at the RCA in the summer of 2012, in which the results are more anecdotal than concrete but raise the possibility of similar kinds of schemes in the future. A group of dyslexic students recruited by Qona Rankin the dyslexia coordinator, who reported having drawing problems ,attended a two-day drawing workshop convened and taught by Howard Riley, professor of visual arts at SMU.

It was thought that greater figure-ground independency supported by global and local strategies for perceiving, could be established by teaching techniques that encourage the awareness of concepts such as negative spaces and contrast boundaries. The judgement of simple angular and proportional relations could also be improved by relating salient points of the primary geometry (the relationships between edges, corners and surfaces in the perceived world) of the subject-matter to the secondary geometry (the relationships between points, lines and tones on a drawing's surface) of the drawing itself. In this way the course intended to strengthen both the visual hierarchy and visual LTM in the drawing toolbox. By

providing strategies for perception, attention for rendering will be directed toward the most important visual features, and procedural knowledge can be developed for rendering these particular features. The students will have more control over the deployment of local and global modes for processing and better control over motor prodecures. Furthermore, by providing an awareness of underlying geometry, the programme provides a means for developing angular and proportional perception in the local processing mode within the visual processing stream.

The teaching programme integrated these perceptually-driven concepts with more general concepts for improved pedagogical practice. An Eight-step Strategy for Teaching Drawing, based upon research by Nist and Mealey (1991) into strategies for teaching dyslexic students, was used that aimed to first focus on a series of strategies for enhancing global/local and angular and proportional perception, followed by four steps that offer recommendations as to how this might be applied in a pedagogical context:

1. To focus attention upon the subject matter and the relationship with the surroundings (figure/field relations).

2. To construct a general or global structure for the drawing students are encouraged to create a network of scaffolding by relating the main axes of the drawing paper to the main axes of the subject-matter. In the case of life drawing this involves constructing the 'N-grid' of lines running across the figure that connect salient points such as Nose, Nipples, Navel, kNees, and kNuckles.

3. To introduce visual concepts such as 'contrast boundary' in place of the common term 'outline'. This immediately engages the student with the variety of tonal values across the whole subject matter and, in particular, allows the student to notice how the contrast boundary fluctuates at the edges between figure and field. The concept of 'negative space' (spaces between those items in the visual field normally labelled with language), can also aid students to look without language, to apply specifically non-verbal methods in the process of drawing.

4. To repeat these first three steps at the beginning of every new drawing.

Step one focuses on developing the ability to switch between local and global processing modes. Step two encourages both global appreciation of proportions and the perception of abstract angles and proportions that are not incorporated into the visual environment. By reducing the scene to a finite number of simple global angles and proportions the student can also hone their angular and proportional judgement. Finally, step three helps to enhance local processing by reducing the impact of semantic processing of the scene.

The following four steps are related more to the application of the process by the drawing tutor, having less concern with the application of perceptual strategies to drawing. However, by including both elements of the training programme it can be seen how theoretical constructs can be developed into an active training programme in schools and colleges:

5. To discuss with the tutor the process under way on the drawing board.

6. To repeat the instructor's strategy with support from the tutor.

7. To draw independently at unsupervised open-access sessions.

8. To re-demonstrate the practices and strategies offered by the tutor in order to reinforce them.

Figure 9.5 shows a student's progression through one day of the workshop and highlights some of the different exercises used to shift perceptual focus. The first drawing made looks disconnected and flat. Exercise in identifying regions of negative space and contrast boundaries result in a more integrated and 3D output by the end of the day. Interviews taken with the students over the course of the workshop are telling of the typical problems faced by novice draughtsmen:

> My drawing is a bit insecure it's not as beautiful as it is in my head I struggle
> with knowing how to get the proportions right on the sheet of paper.

> [fashion student, day one]

The same student was interviewed after the workshop and demonstrated the benefit of focusing away from the semantic content of the to-be-drawn stimulus and perceiving things in a different way in order to translate more directly from image to paper:

> I think what we have been talking about contrasts and spaces and just paying
> attention to other things rather than stressing about how to get the object on the
> paper has really helped. So you start approaching it from a different position you
> start approaching it from behind in a way. You focus on different things and by
> focusing on different things the object appears more effortlessly on the paper and
> if you just follow the guidelines then it appears to look right.

> [fashion student, day two]

Figure 9.5. Progression through a Drawing Workshop. a) first attempt b) negative space c) contrast boundaries d) final attempt

This method of drawing training is very pragmatic and removed from the experimental means of testing perceptual abilities like local processing in the laboratory. However, it can be seen that by applying psychological reasoning to the steps outlined previously, that development of drawing makes sense in terms of the drawing toolbox. Semantic structures are built up which have an impact on the way in which visual input is interpreted within the visual hierarchy There are also influences within the educational mechanism that may have a role to play in this method of drawing training. Increasing the students' confidence in their ability and providing a framework for them to follow is likely to have an impact on their approach during the drawing process that may facilitate them,

encouraging them to adopt deep and achieving approaches to learning that will be more conducive to success.

It can be argued that it is just as likely that strategies in the development of perceptual faculties may prove useful to art students' training without using drawing as a starting point. It may be possible in the future to develop perceptual training programmes that are taught independently of explicit drawing instruction. Practice in mental rotation exercises, hierarchical perceptual tasks like the Navon task, and the perception of orientation and proportion in paradigms like the line matching task may help students to develop fundamental skills before applying them to drawing in which visuomotor transformation, planning and colour and tonal associations complicate the task at hand.

Previous research has emphasised the importance of the connection between the eye and the hand during drawing (Glazek, 2012). Alongside the apparent importance of action planning, monitoring and procedural memory as revealed by the VBM study in Chapter 8, these findings suggest that techniques that emphasise the coordination of eye and hand movements may also be of use. This could be measured using novel technologies that are being brought into the psychological study of drawing. Angela Brew at University of the Arts London (UAL) has pursued drawing instruction that focuses on a more intimate connection between the eye and the hand (Brew, 2012). Brew's three step drawing instruction asks the drawing student to a) look at the original (stimulus) image, b) execute the drawing 'blind' (without looking at the line being made on the paper) and c) continue to draw while looking at the paper to control the spatial position of the line. Students must practice gaining synchronicity between the eye and the hand during the second stage. This strategy no doubt encourages the student to draw shorter line segments, which is arguably a feature of more expert drawing (Tchalenko, 2009; Tchalenko & Miall, 2009). The notion here is that transformation of perception occurs not in a vacuum, but through physical engagement with the environment, and that the eye becomes almost another physical motor organ and relies on proprioceptive awareness of the line of gaze of the eye in space. A quote by the artist August Rodin expresses this notion beautifully:

> What is drawing? Not once in describing the shape of the mass did I shift my eyes from the model. Why? Because I wanted to be sure that nothing evaded my grasp of it… My objective is to test to what extent my hands already feel what my eyes see. (Ludovici, 1926)

The techniques presented here are just two ways of utilising theoretical advances in the field to inform teaching practices. In the future it will be of interest and worth to develop training

strategies that focus on particular elements of the drawing toolbox, perhaps with more laboratory based approaches that can be more targeted to particular processes, alongside more general strategies for drawing improvement, as well as with an appreciation of the cognitive factors that may interact with drawing practice and engagement that have been previously summarised (9.2.1. Cognitive factors in drawing ability: Practice makes perfect). The approaches cited here have taken the first step toward this goal.

9.4.3.2 Identifying Talent in the Arts

The research presented in the present thesis has the potential to highlight key attributes that may predict an individual's future disposition to excel in the visual arts. In particular, those abilities that are not seen to change significantly in response to practice may be indicators of latent talent, such as low-level perceptual abilities. As Cain (1943) suggested in his study of art students' ability to draw irregular six-sided shapes,

> a test of the sort employed in this experiment, since it involves no foreshortening or complex interrelationships of details (which, according to the writer's teaching experience, call for aspects of drawing ability especially subject to influence of training) but requires accurate perception of fundamental proportions and character of shape (which probably is much less influenced by training), and since it approaches to within about 95 percent of perfect objectivity in its manner of scoring, is probably a much more effective means of selecting art students of inherent ability in drawing.

> (Cain, 1943, p. 51)

This quote suggests that low-level perceptual talents are most likely to result from innate abilities, whereas more complex aspects of drawing such as representing the interplay of parts into a whole. This is supported by the fact that neither the ability to draw the Cain houses, nor the ability to replicate angles and proportions in the line task related to the ability to draw in the experimental studies. A diagnostic marker of talent for drawing then may be the ability to perceive angles and proportions accurately from a young age. Further investigations of precocious child drawers in which they are tested for low-level perceptual faculties as well as their higher-level representational ability may help to tease out those measures which are most predictive of talent development. There is also no doubt that talent and training are interactive, and therefore those individuals who possess the qualities outlined in the results of the survey data may show the best progression through training structures on the basis of latent talent. Genetic studies that assess the concordance rates of

monozygotic and dizygotic twins may also help to reveal those talents that transcend generations of individuals. They will also help to illuminate the interplay between innate ability and development of expertise through the familial and educational environment. The overwhelming message here should be that anyone can learn to draw by employing the right perceptual, motor and memorial strategies in conjunction with the right approaches to learning.

9.5   Conclusion

This thesis contributes a wealth of new data and speculation to the field of psychological research into the visual arts and sheds light on intuitive strategies for drawing that have been used throughout centuries of artistic expression. One of the fundamental questions posed at the beginning of this thesis was whether it is by innocence of the eye or by culturally determined schemata that artists harness the power of representation. Indeed this has been a fervent debate in the literature for quite some time. In response to this question it has been shown that different psychological elements that constitute the drawing process represent the contribution of both bottom-up and top-down influences on memory, vision and motor control. This thesis has reaffirmed the centrality of perception in an account of drawing as well as emphasising the role of fine motor processing, and illustrating where and when stored representations are valuable to the drawing process. It has also contributed methodologically to the field by proposing new and innovative ways for measuring and analysing the drawing process, which will provide more reliable and valid means for exploring ongoing questions in this domain in the future. The toolbox presented in 9.3 conceptualises the contributions of cognitive, visual and motor processing in relation to drawing. This will help to frame the future research programme, by emphasising the need for research concerning the role of hand-eye coordination and global and local perceptual switching during the drawing process.

It is hoped that with a comprehensive account of the technical skills underpinning talent in the visual arts that we can start to unpack the more elusive elements of visual arts practice such as creation and aestheticism. It must be emphasised that by aiming to do this scientific research is not aiming to reduce or explain away these seemingly intangible and mysterious abilities, but instead it is aiming to expose and emphasise the sophistication and complexity of the artistic mind.

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The role of drawing within artistic practice

Drawing to enhance perception

> **Interview 3 Line 178**. I think it's a basis for seeing, you see more of the world if you draw.

> **Interview 3 Lines 3-5**. Incredibly practical, incredibly important, I think it's about seeing, I think even if you end up being completely abstract, looking really hard is the absolute basis, whether you're creating a painting or a sculpture it's really about looking.

> **Interview 5 Lines 229-234**. That sort of touches on why it's important to teach drawing from observation from an early age because it does give you an appreciation of reality, otherwise you know today, we, it's kind of difficult to appreciate when you're kind of bombarded with images, which is again a very cliché thing to say but, um, it's true I find myself quite bored from a lot of things, I see them over and over again.

> **Interview 5 Lines 157-158**. I definitely think drawing from observation is important again as a practice, just as a basic appreciation of reality.

> **Interview 6 Lines 330-333**. But after a while your eyes click, this is the experience I have anyway, my eyes click into something and it's like dropping some acid or something because suddenly you start to, I don't know how to explain it, yeah, you start to kind of have a hyper awareness.

Drawing to enhance communication

Internal communication

> **Interview 1 Lines 23-25**. Obviously as an observational, representational painter it's completely essential to what I do. I think that drawing can help, uh, people who are learning to make new connections, because it is like learning a language.

Interview 4 Line 16. It's a form of thinking for me.

Interview 5 Lines 30-32. It's important as a practice as an everyday thing, just reading and writing if that's what you do. Um, so yeah drawing is, I think it's an integral part of your practice as an artist, whether you're a painter or a conceptual artist, I mean as a painter you could be a conceptual artist, but it's yeah, I find it very important.

Interview 6 Lines 8-11. Generally but there's something about drawing that can be the first response, and because it's quite a simple thing to do, you don't need to deal with trying to make a product out of it you can have it as note taking in non-language form you know?

External communication

Interview 7, Lines 32-35. It makes me feel kind of connected with the world, that's a very basic kind of thing and if I draw something, sort of you kind of engage with it in a way that you don't any other way, and I can feel like I can communicate something through a drawing of something.

Interview 2 Lines 2-5. I think it's [drawing] rather essential to any creative process. You have to, you're trying to create a process of communication and if you can't translate it onto paper yourself, how are you going to translate it to anybody else. You have to be able to get your ideas down before you get them out there.

The drawing Agenda in Education

Desire for more drawing in art education

Interview 4 Lines 66-67. Don't underestimate how good observational drawing can be for your work.

Interview 2 Lines 99-100. You'd have to find lots of people to teach it, um, so you know that's a problem because like you said a lot of people can't. Um, and that's I suppose why the drawing school exists.

Interview 3 Lines 178-180. All children draw instinctively, but at some point they stop and it's a real shame because part of their perception generally gets eradicated because they themselves aren't practising it.

Interview 4 Lines 95-96. Aberystwyth University they actually have a compulsory life drawing course in the first year, I think it's a really good idea.

Interview 5 Lines 158-161. And some people are more inclined to it than others, I'm not talking about the drawing I'm just talking about perceiving, looking at reality, um, and some are less inclined, so I think that has to be pronounced more in art education.

Interview 5 Lines 172-173. I definitely think whether it is more traditional drawing or not it's important to learn to draw from observation.

Interview 6 Lines 135-140. The drawing education that they need I think is a basis of learning how to wake up their eyes, um, and then knowing like knowing all of those components that make up visual language, you have to, knowing that it's a language to begin with, and knowing what components build up that language and know what that language is for you and how you understand it.

Lack of drawing training at school or art college

Interview 1 Line 41. We did the occasional bit of life drawing for GCSE, probably was quite lucky to get that.'

Interview 2 Lines 77-78. I learnt a lot of drawing techniques at school, I had fantastic art teachers, um, but that's unusual.

Interview 3 Lines 80-82. Certainly not at primary school, we moved to france from the age of 11-12 to 16, and half a day a week I went and just painted and did

a bit of drawing, and I loved that. Um, but apart from that, I did art A-Level, um, but this drawing course [at the Princes Drawing School] has been the most sort of intellectually challenging in a way.

Interview 4 Lines 29-30. I remember being taught or told to draw these really dry still lifes, everyone hated to do, and, um, finding them very sort of dull and quite frustrating.

Interview 6 Lines 151-154. And I just don't think people are given that grounding I don't think they are in school and then in university the, from what I can see the trend of universities now are even more against a taught solid ground, so it felt like jumping off a cliff into nothing.

Approaches to Drawing

Approaches to Perception

Interview 1 Lines 105-108. A tonal drawing is a more in a literal sense is a more accurate representation of what you see. So I suppose the device I use for that, is to pretty much blur my eyes, and half close them, because that helps you work out what the brightest thing is that you're seeing and what the darkest thing is, and that's how I always start, with the darkest area.

Interview 3 Lines 110-114. I suppose another useful thing is to half close your eyes and you look for the lightest and the darkest area, you use it to capture things that we know exist and giving a hierarchy, so if you're looking at a woman on a park bench we think oh woman on a park bench the woman is the most distinct thing, but then when you close your eyes the tone of her, the bench and grass is the same and it's just volume, and that's all the world is, just volume.

Interview 4 Lines 136-138. So the high contrast ones where you've got the figure standing in front of the window and so the job is to try to draw the light and not

the details of the face, and it's the come on everybody squint and um that seems to work really well.

Interview 3 Lines 39-41. One of the tutors goes on about not drawing the thing that you're drawing but drawing everything else, or a sort of more crass version of that is draw negative space, but it's sort of more subtle.

Interview 3 Lines 115-116. Another one is just I look at patterns alot, so rather than drawing things just picking out.

Interview 4 Lines 210-212. I mean one thing about observational drawing is that there's no hierarchy it's sort of about giving attention to the whole of the surface, so it might be that you begin with a negative space or something else.

Interview 5 Lines 117-118. I can look at the world and break it into forms, that's what I do when I need to convey something from reality to drawing.

Interview 6 Lines 31-35. I mean the examples of breaking things down are you know, textures, tone, you know effects of lights, lines, shapes all of those things working in composition, um, so you know those things that you could break down and you could just work on textures for a year or you could just look at tone for a year.

Interview 3 Lines 39-43. One of the tutors goes on about not drawing the thing that you're drawing but drawing everything else, or a sort of more crass version of that is draw negative space, but it's sort of more subtle, for example, if you're drawing a human figure the classic thing is to draw the outline of the leg, whereas if you draw the shadow of that is cast from the side you're sort of drawing the inside of a figure, you're forgetting that it has an outline.

Interview 4 Lines 210-212. I mean one thing about observational drawing is that there's no hierarchy it's sort of about giving attention to the whole of the surface, so it might be that you begin with a negative space or something else.

Interview 5 Lines 107-109. I think it mainly is breaking reality into form, and negative spaces, whether they're negative spaces or not, um, and that is when I really kind of that really harnessed my natural ability to draw.

Approaches to Production

Interview 1 Lines 172-174. By limiting the kind of mark I can make, it means I give the same focus to everything, because I can't change my language to take in things that, wouldn't appear within that way of looking.

Interview 1 Lines 196-198. The best work I've put out I've done is, out of the children, is when I've set them quite a clear task. Quite clear tonal tasks. Divide everything up into just black and white, they really struggle with it and once they get it, it really frees up how they look at things.

Interview 4 Lines 41-44. On that page we want 20 drawings by the end of it and we've only got 20 minutes to do it so with one drawing a minute that's, and you'll find that their drawings are beautiful but that's because they're not kind of they're not being allowed to think, and thinking is generally the enemy of drawing.

Interview 4 Lines 145-147. That's why I like the more we're only painting with this stick in a pot of ink that you have to do quickly, yeah, I like the sort of giving one rule and everything else is out of bounds.

Interview 6 Lines 231-237. I've tried to create a device for myself at the moment, to narrow down the world in you know some way, um, and err, one thing I like is things that go through things. So I've started to draw scenes that are framed naturally by the world, by something, and by a bridge, or two trees, something that's already framed and taking the frame and breaking down all the shapes that are in it. And that I like because it gives me, it closes something off for me, and then I can think about the interaction of shapes within the enclosed space.

Interview 6 Lines 259-262. I am out of everything I'm looking at extracting the same thing at the end of the day, and my notes become completely repetitive, and then you go actually even though I thought I was looking at everything, my subconscious is requiring something specific.

Interview 3 Lines 56-58. Fast drawings are always really helpful, because your brain just works at a different speed so you just stop thinking, if you have a long pose you tend to get bogged down and you start to overthink.

Appendix B. Questionnaire

1. Artistic Ability and Interests

1.1. Self-perceived artistic and design ability

	Much below average	Below average	About average	Above average	Much above average	
Drawing from observation (e.g. life drawing)						
Drawing from imagination						
Use of perspective, shadow and shading						
Confidence in mark making when drawing						
Use of contrast and tone in drawing						
Technical drawing (geometric and engineering drawing)						
Mixing, copying and using colour						
Using colour for aesthetic effect						
Visual composition in two dimensions						
Interpreting technical drawings of 3D objects						
Modelling in 3D (e.g. making sculpture)						
Sensitivity to texture, feel and touch of materials						
Visual composition in three dimensions						
Mentally rotating objects to see them from other positions						
Product design (making objects to solve verbal problems)						
Using hand tools such as chisels, to craft objects						
Using mechanical tools and machines						
Verbal creativity (using words in novel and unusual ways)						
Visual creativity (seeing objects in novel and unusual ways)						
Mechanical creativity (using materials and objects in novel ways)						
Public speaking and communication						
Spelling						
Using word-processors						
Numerical skills (e.g. mental arithmetic)						
Using calculators						

1.2. Interest in areas of art and design

How interested are you *in general* in the following areas of art or design?

	Very	Fairly	Not really			Very	Fairly	Not really	
Painting					Ceramics and glass				
Sculpture					Product/furniture design				
Print-making					Film and animation				
Photography					Graphic design				
Fashion and textiles					Illustration				
Theatre design					Multimedia design (websites etc)				
Architecture					History and theory of art				
Jewellery					Other _____				

1.3. Artistic Pursuits

How often do you?	Every day	A few times a week	Once a week	A few times a month	Once a month or less	A few times a year	Never
Listen to popular music							
Listen to classical music							
Go to pop concerts / discos							
Go to classical music concerts / opera							
Play a musical instrument							
Go to museums or art galleries							
Read about art in newspapers, magazines or books							
Draw or paint							
Read a novel							
Read non-fiction books (not for work or study)							
Read poetry							
Go to the cinema							
Go to the theatre (plays/musicals, etc)							
Act or otherwise take part in theatre							
Watching classical or modern ballet/dance							
Going dancing (any form)							

	------------ Most days for -------------				2-3 times a week	Once a week	Less often
	4+ hours	2-4 hours	1-2 hours	1 hour or less			
Watch television							
Listen to radio							
Listen to podcasts							
Browse the internet							

1.4. Drawing and painting experience

How much time in the past couple of years have you *typically* spent painting or drawing?

Think back **over the past year** (Oct 2009 to Sept 2010) and estimate how often you drew or painted, *either* in a class *or* in your leisure time, and indicate how much it would have averaged out at.

		- - - - - Most days for - - - -				- - Most weeks for - - - -		- - Most months for - -		- Over the year -		
		4+ hours	2-4 hours	1-2 hours	1 hr or less	2-3 hours	1 hour	2-3 hours	1 hour	3 to 6 hours	1 to 2 hours	Never
	Draw											
	Paint											
Now do the same for the year before (Oct 2008 to Sept 2009)	Draw											
	Paint											
And finally, for the year before that (Oct 2007 to Sept 2008)	Draw											
	Paint											

1.5. Observational drawing methods

Which of the following methods have you come across when learning observational drawing?

	Never heard of it	Been taught or shown it	Use it occasionally	Use it frequently
Use of a plumbline to assess vertical aspects of the image				
Use of outstretched finger/pencil to assess proportional relationships				
Focussing on negative space				
Squinting/blurring the eyes to enhance tonal contrast				
Framing a view with the hand/cardboard frame				
Triangulating (referring to two points to locate a third point)				
Focussing on pattern/texture over objects				
Quick drawing to limit detail				
Knowledge of the mechanics/anatomy of objects				
Closing one eye to eliminate 3D depth cues				
Sketching out pivotal points first (plotting eyes, nose, navel, etc)				

And how important to you is improving your observational drawing skills while you are at art school?
Not at all important / Somewhat Unimportant / Slightly Important / Very Important

1.6. Perceptions of observational drawing

A few questions on your perception of drawing...

	Strongly Disagree	Disagree	Agree	Strongly Agree
Understanding how we see is important				
My language affects the way I see the world				
My drawing ability could do with improvement				
Seeing 'negative space' is easy for me				
I have difficulty seeing 'contrast boundaries'				
Controlling proportion in my drawings is easy for me				
I have difficulty judging lengths and angles in my drawings				
Fitting my drawings in the sheet of paper is easy for me				
Getting the outline right is the first ask when drawing objects				
I am aware of the main axes within the sheet of paper before I begin drawing				
I understand how to create a 'scaffolding' of lines in my drawing which connect salient points on the objects I draw				
I understand the difference between 'primary geometry' and 'secondary geometry'				

2. Visual Imagery

2.1. Object and spatial imagery questionnaire (OSIQ, Blajenkova et al., 2006)

A few questions on your ability to form and manipulate mental images

	Strongly Disagree	Disagree	Agree	Strongly Agree
I was good at geometry as a student				
Visual images are always in my mind and sometimes I find it difficult to ignore them				
I find it easy to recreate a scene in my head that I have recently encountered				
My graphic abilities would make it easy for me to enter a profession like architecture				
I find it easy to imagine and manipulate 3D figures in my head				
My mental images are quite vivid, like a photograph				
I find architectural art forms more interesting than paintings				
My mental images of objects are a lot like objects I have actually seen before				

2.2. Vividness of visual imagery (VVIQ, Marks, 1973)

The following exercise involves *imagining a visual scene*. Please do it <u>with your eyes open</u>.

Think of a country scene which involves trees, mountains and a lake, and think carefully about the image that comes into your mind. Please indicate the vividness of the image that comes to mind

	No image at all, I'm just thinking about the object	Vague and Dim	Moderately clear and vivid	Clear and reasonably vivid	Perfectly clear and vivid as normal vision
The contours of the landscape					
The colour and shape of the trees					
The colour and shape of the lake					
A strong wind blows over the trees and the lake causing waves					

3. Lateralization and Learning Difficulties

3.1. Handedness

Which hand would you use?

	Always use left	Usually use left	Slightly prefer left	Slightly prefer right	Usually use right	Always use right
To hold a pen to write a letter?						
To throw a ball at a target?						
To hold a pencil while drawing a picture?						
To hold the *thread* while threading a needle?						

And also:

	Always use left	Usually use left	Slightly prefer left	Slightly prefer right	Usually use right	Always use right
With which *foot* would you kick a ball at a goal?						
With which *eye* would you look through a keyhole?						

Are your parents left-handed? *Neither / Mother only / Father only / Both / Don't know*

3.2. Left-right confusion

	Never	Rarely	Occasionally	Frequently	All the time
Do you have difficulty in distinguishing right and left?					
As a child did you have difficulty distinguishing right and left?					
If someone tells you to turn left or right when driving, do you have difficulty quickly deciding which way to turn?					
Do you have difficulty when giving directions?					
When reversing a car, do you have difficulty deciding which way to turn the steering wheel to go in the direction you wish to go?					

3.3. Communication and numerical difficulties

A few questions about conditions which might give you problems

Have you ever been told that you have developmental dyslexia?

Never / No, but I've wondered if I might be dyslexic / Yes, I have been diagnosed as dyslexic (if so, at what age_____)

Have you ever been told that you have dyspraxia or other motor problems?

Never / No, but I've wondered if I might be dyspraxic / Yes, I have been diagnosed as dyspraxic (at what age?_____)

Have you ever stuttered or stammered?   *Never / Yes, in the past but not any more / Yes, at present*

Is there anyone in your close family (parents, brothers, sisters, grandparents, aunts or uncles) with dyslexia, dyspraxia, stuttering or stammering?   *No / Yes: If Yes, who and what?*

3.4. Spelling test

Almost everybody has problems with spelling certain words. This can be a particular problem for people on college or university courses. It would help us if you could look at the following sets of words, and ring the one word of each group of four which you think is correctly spelled. Please answer <u>on your own</u>, and <u>without looking up any of the words</u>.

accademic	acaddemic	acedemic	academic
acomodation	accomodation	acommodation	accommodation
choclate	chocolete	chocolate	choclete
contempory	contemporey	contemprary	contemporary
corespondance	corespondence	correspondence	correspondance
cristal	crystal	crystle	cristle
emphasis	emphesis	emphisis	empheses
February	Febrary	Febuary	Febary
heigt	hieght	heigth	height
immediately	imediately	immedietely	immediatly

labratory	laborotory	labrotory	laboratory
medisine	medecine	medicine	medicen
necessary	necesary	neccessary	neccesary
parliment	parlimant	parliamant	parliament
sentance	sentence	sentince	sentense
sinserely	sincerly	sincerely	sinserely
techniques	technics	technicues	teckniques
temprament	temperament	temprement	temperamant
truley	truly	truely	trueley
writeing	writing	writting	wraiting

3.5. Mathematical attitudes and ability

We're interested in how art and design students felt about studying maths at school.

How much do you agree with these statements?

	Strongly disagree	Disagree	Agree	Strongly agree
Maths seemed a waste of time				
Learning maths was enjoyable				
I felt confident when doing maths				
Maths is important in everyday life				
I am good at using computers to do maths				
I cannot understand how anyone could enjoy maths				
I have a mathematical mind				
Maths does not scare me at all				
I concentrated hard when studying maths				
I get a sense of satisfaction from solving maths problems				
Maths seemed a useful, worthwhile subject				
I always feel nervous when I look at a maths problem				
The challenge of maths appealed to me				
I could not see the point of most maths				
I could never understand all the symbols in algebra				
Geometry always seemed much easier than other aspects of maths				
Arithmetic was something I always had problems with				
I usually enjoyed studying maths at school				

4. Personality and Demographics

4.1. Big five personality measures (John et al, 1991; 2008; Furnham et al, 2003)

Do you agree with the way these statements describe you as a person?

I see myself as someone who...

	Strongly Disagree	Disagree	Neutral	Agree	Strongly agree
... does a thorough job					
...is talkative					
...is sometimes rude to others					
...worries a lot					
...is original, comes up with new ideas					
...has a forgiving nature					
...tends to be lazy					
...is outgoing, sociable					
...gets nervous easily					
...values aesthetic, artistic experiences					
...is considerate and kind to almost everyone					
...does things efficiently					
...is reserved					
...is relaxed, handles stress well					
...has an active imagination					

4.2. The shortened study process questionnaire (Fox et al, 2001)

Do you agree with the way these statements describe the way you study?

	Strongly Disagree	Disagree	Agree	Strongly Agree
While I'm studying, I often think of real life situations to which the material that I'm learning would be useful.				
I chose my present course largely with a view to the job situation when I graduate rather than their intrinsic interest to me.				
I find that at times studying gives me a feeling of deep personal satisfaction.				
I want to do well in most or all of my courses so that I will be able to select from among the best positions available when I graduate.				
I think browsing around is a waste of time, so I only study seriously what's given out in class or in course outlines.				
I try to work consistently throughout the term and review regularly when exams or assessments are close.				
I would see myself as an ambitious person and want to get to the top, whatever I do.				
I have to do enough work on a topic to form my own point of view before I am satisfied				
I try to do all of my assignments as soon as possible after they have been set.				
I find that studying academic topics can at times be as exciting as a good novel or film.				
I usually become increasingly absorbed in my work the more I do.				
I restrict my study to what is specifically set as I think it is unnecessary to do anything extra.				
I almost resent having to do further years studying after leaving school, but feel that the end results make it all worthwhile.				
I see getting high marks as a kind of competitive game, and I play it to win.				
I find it best to accept the statements and ideas of teachers and question them only under special circumstances.				
Whether I like it or not, I can see that further education is a good way to get a well-paid or secure job.				
I try to relate new material, as I am taking it in, to what I already know on the topic.				
I keep neat, well-organised records of my thoughts for most subjects				

4.3. Masculinity/femininity scale (Spence & Helmreich, 1978)

Each pair of phrases below describes two behaviours. Each of us is somewhere between the two extremes. Put a mark between the two to best describe yourself.

	+++	++	+	-	+	++	+++	
Not at all independent								Very independent
Not at all emotional								Very emotional
Very rough								Very gentle
Not at all competitive								Very competitive
Not at all kind								Very kind
Not at all aware of feelings of others								Very aware of feelings of others
Gives up very easily								Never gives up easily
Not at all self confident								Very self confident

4.4. Schizotypal personality questionnaire (SPQ-B, Raine & Benishay, 1995)

Do you agree with the way these statements describe you as a person?

	Strongly Disagree	Disagree	Agree	Strongly Agree
I sometimes strike people as aloof and distant				
I sometimes sense that some person or force is around me even though I can't see anyone				
People sometimes comment on my unusual mannerisms and habits				
I am sometime sure that other people can tell what I'm thinking				
I have noticed that a common event or object seems to be a special sign for me				
Some people think I am a very bizarre person				
I feel I have to be on my guard even with my friends				
some people find me a bit vague and elusive during a conversation				
I often pick up on hidden threats or put-downs from what people say or do				
When shopping, I get the feeling that other people are taking notice of me				
I feel very uncomfortable in social situations involving unfamiliar people				
I have had experiences with astrology, seeing the future, UFOs, ESP or a sixth sense				
I sometimes use words in unusual ways				
I have found it is best not to let other people know too much about me				
I tend to keep in the background on social occasions				
Sometimes, I suddenly feel distracted by distant sounds that I am not normally aware of				
I often have to keep an eye out to stop people taking advantage of me				
I often feel I unable to get "close" to people				
I am odd, unusual person				
I find it hard to communicate clearly what I want to say to people				
I feel very uneasy talking to people I do not know well				
I tend to keep my feelings to myself				

4.5. Educational background

Finally, some questions about your educational background.

What GCSEs, AS- and A-levels (or Highers) have you gained? Please give the grade for each subject.

Subject	GCSE	AS level	A level
Art			
Biology			
Business studies			
Chemistry			
Dance			
Design & Technology			
Double Science			
Drama			
Economics			
English Language			
English Literature			
French			
Geography			
German			
History			
ICT (Inf'n & Comm'n Tech.)			

Subject	GCSE	AS level	A level
Latin			
Law			
Mathematics			
Music			
Physical Education			
Physics			
Politics			
Psychology			
Religious Studies			
Sociology			
Spanish			
Welsh			
Other: _____			
Other: _____			
Other: _____			
Other: _____			

What other formal qualifications do you have (e.g. degrees, etc.)? _____

4.6. Demographics

Are you male or female? *Male / Female*   What is your date of birth? ___ *(day)* / _____ *(month)* / 19____

What is your nationality? _____   What is your first language? *English / Welsh / Other_____*

If *English* is not your first language, how old were you when you learned English? _____

Are your parents *practising artists* or in related professions? *Neither / Mother only / Father only / Both*

Would you describe your parents as *sympathetic to the arts*? *Neither / Mother only / Father only / Both*

Appendix C. Shortened Form of Raven's Advanced Progressive Matrices Stimuli

Examples of test trials for Shortened Form of Raven's Advanced Progressive Matrices.
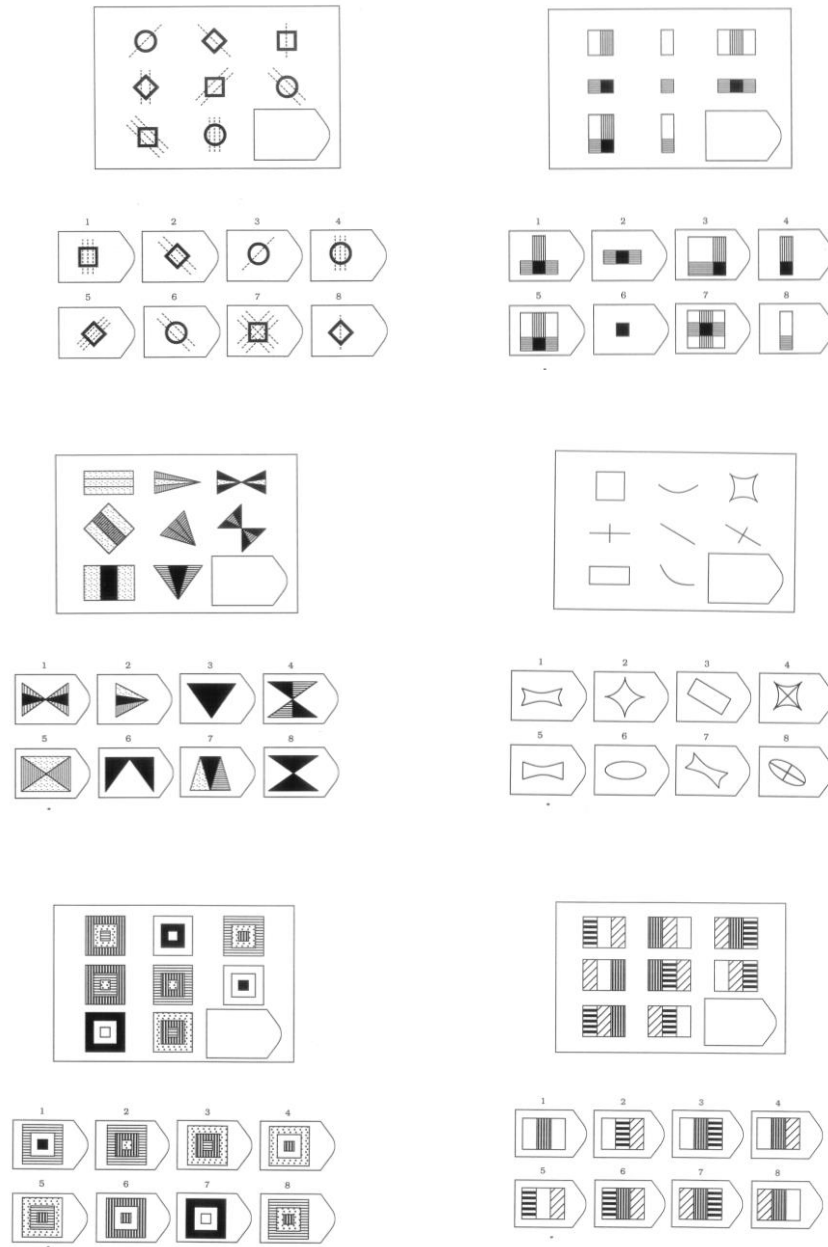
Appendix D. Group Embedded Figures Task Stimuli

Stimuli used in Embedded Figures Task (practice and test trials)

Simple Figures
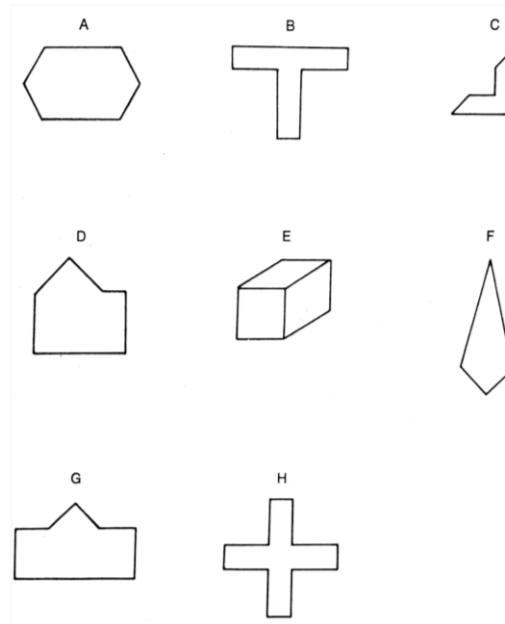
Examples Trials
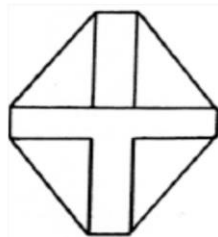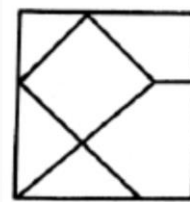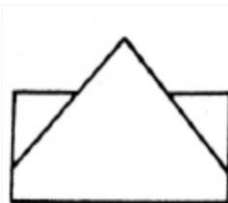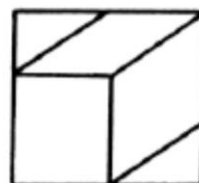
Practice Stimuli (9 and 4 Blocks)
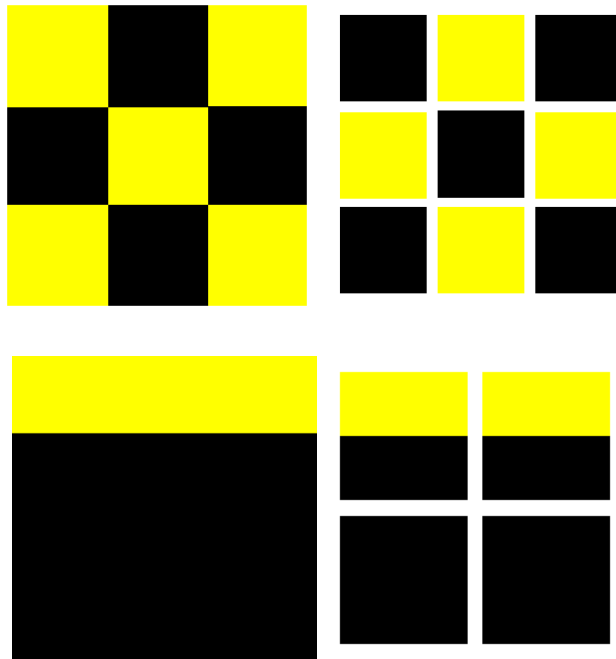
4 Block test stimuli (segmented and unsegmented)
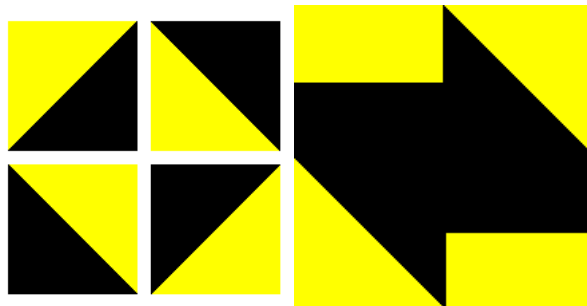
9 Block test stimuli (segmented and unsegmented)
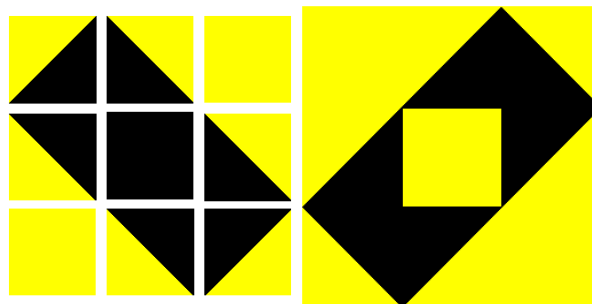
Appendix F. Rey-Osterrieth Recognition Test Stimuli

Components of the Rey-Osterrieth Complex Figure and the Taylor Complex Figure used in

the Rey-Osterrieth Recognition Memory Test
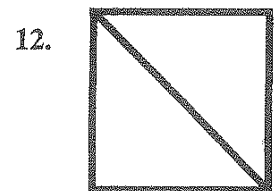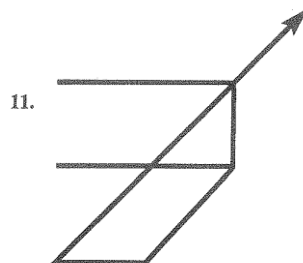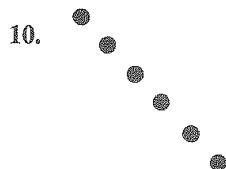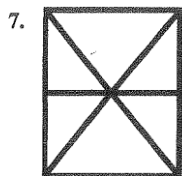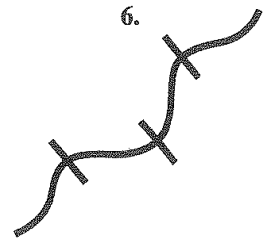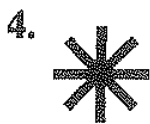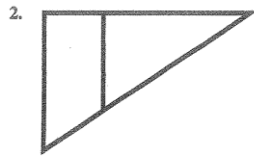
13.
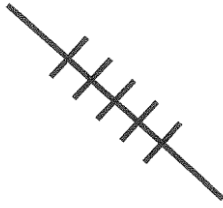
14.
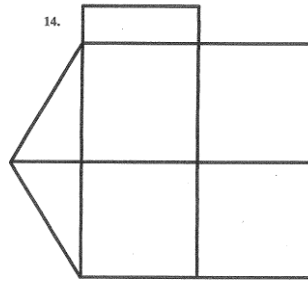
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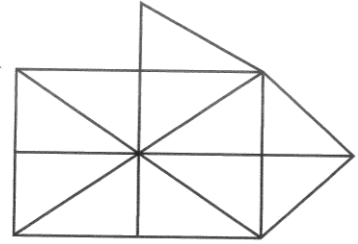
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17.
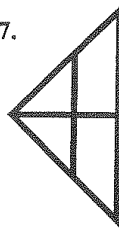
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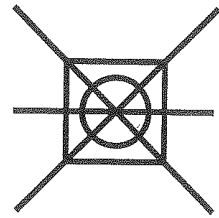
19.
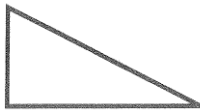
20.
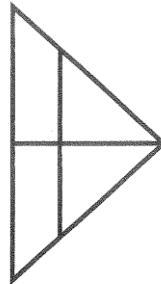
21.

22.

23.
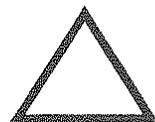
24.

Appendix G. Rey-Osterrieth Scoring Scheme
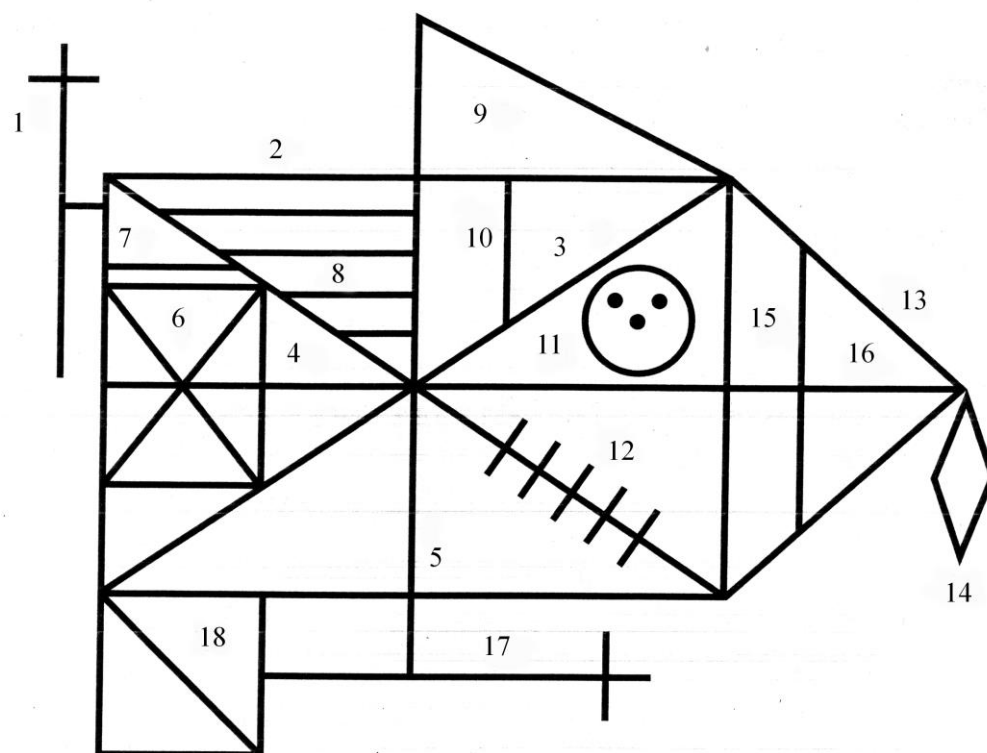
Scoring Criteria for ROCFT Drawings

Scoring Criteria

Score	Accuracy	Placement
2	Accurately drawn	Correctly placed
1	Accurately drawn	Incorrectly placed
1	Inaccurately drawn	Correctly placed
0.5	Inaccurately drawn, but recognisable	Incorrectly placed
0	Inaccurately drawn and unrecognizable, or omitted	Incorrectly placed

Description of each numbered component of the Rey-Osterrieth Figure

       1. Vertical Cross

       2. Large Rectangle

       3. Diagonal Cross of the Large Rectangle

       4. Horizontal Midline of the Large Rectangle

       5. Vertical Midline of the Large Rectangle

       6. Small Rectangle within the Large Rectangle

       7. Small Horizontal Line above the Small Rectangle

       8. Four Parallel Lines within the Large Rectangle

       9. Small Triangle above the Large Rectangle

       10. Small Vertical Line within the Large Rectangle

       11. Circle with Three Dots

       12. Five Parallel Lines intersecting the Diagonal Cross

       13. Sides of the Large Triangle attached to the Large Rectangle

       14. Diamond attached to the Large Triangle

       15. Vertical Line within the sides of the Large Triangle

       16. Horizontal Line within the sides of the Large Triangle

       17. Horizontal Cross

       18. Square attached to the Large Rectangle

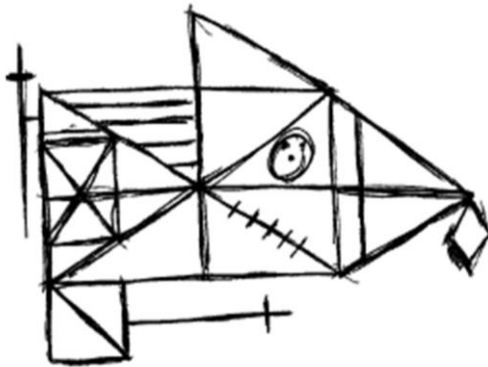Examples of Rey-Osterrieth Scored Drawings

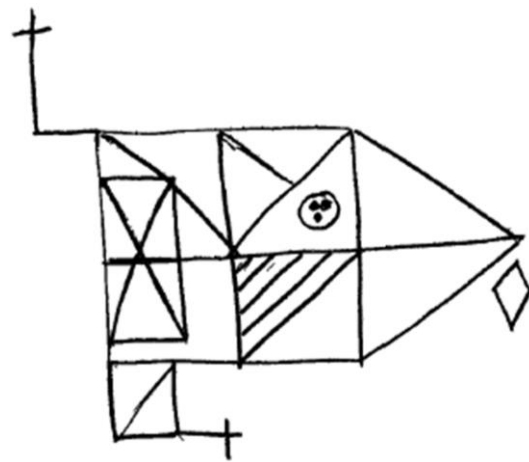Good copy of Rey-Osterrieth (Score=35)   Poor copy of Rey-Osterrieth (Score=16.5)
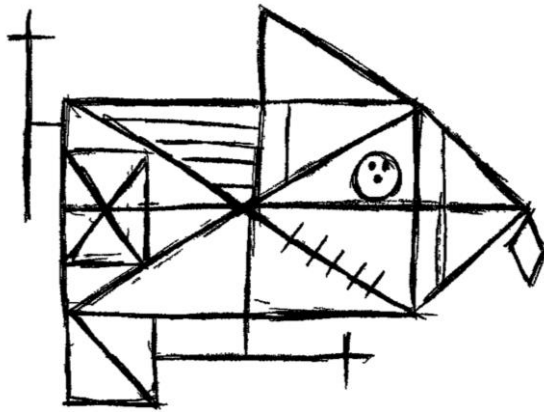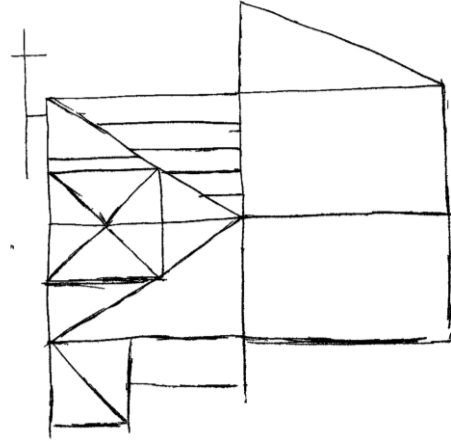
Good recall of Rey-Osterrieth (Score=33)   Poor recall of Rey-Osterrieth (Score=15.5)

Appendix H. VSTM Icon Task Stimuli