A Case of Horizontally Inverted Visuospatial Cognition

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Abstract

Some individuals have difficulty in distinguishing mirror-images from one another. This is found in healthy controls, in mild forms. However rare cases exist in which patients appear to literally see objects in mirror-reversed form, or to represent them as such in their drawings from memory. Very few cases of this type have been reported in the literature, the exemplary case here being the patient AH (McCloskey, 2009). We have identified another case, BS, who, on the face of things, has a disorder identical to that of the case described by McCloskey. The mere description of another case with such an extremely rare disorder is a contribution in its own right. The study aims mainly to verify the nature of the participant's disorder, and to compare and contrast her presentation with that of AH, by administering the same tests of visual-spatial cognition as McCloskey did. In beginning to theorise what horizontally inverted visuospatial cognition might mean for our understanding of normal cognition, this case provides useful new information regarding the notion of 'frames of reference', and specifically regarding the 'coordinate-systems' hypothesis of spatial reference. Furthermore, the case has implications for the 'two-streams' conception of visuospatial cognition.

Key Words: Visuospatial cognition, mirror vision, visual reflections, frames of reference, coordinate-systems hypothesis, dorsal and ventral visual streams.

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Introduction

For us to see, our brains must hold some representation of the details of which our visual field is constituted; therefore, investigation into the nature of vision must entail some study of these mental activities at work (Marr, 1982). A large proportion of the information that we have gathered thus far, and a critical source of evidence in new understandings, comes from lesion studies and the systematic conclusions about normal processes that can be derived from deficits in function (McCloskey, 2009). Of particular interest in relation to visuospatial cognition here is the notion of visual reflections or mirrored vision. As seen in the case studies of AH by McCloskey (2009), TM by McCloskey, Valtonen and Sherman (2006), and PR by Pflugshaupt et al. (2007); whereby visual stimuli become reflected on a vertical or horizontal axis. Subsequently what such phenomena might suggest in terms of theory and broader understanding of spatial cognition, and vision as a whole is of particular interest here. Complex cognitive processes underlie vision, and the bizarre artifact of mirrored vision may provide an interesting piece of information regarding such processes due the very specific nature of the impairment. The research presented here in the form of a case study of patient BS, builds upon the previous cases mentioned above, and hopes to begin to provide further evidence in terms of this theory.

There is a concise but significant body of literature regarding specific instances of problems involving stimulus reflection. A case by Holmes (1918), whose patient showed errors in reaching, constitutes one of the earliest instances of deficits in visual location and orientation. The chief area of investigation here, however, is exemplified by McCloskey's (2009, p. 59) case of AH who, "suffered from a selective developmental deficit in visual location and orientation perception". Most of the errors made by AH involve left-right and, occasionally, up-down reflections; this deficit not only involved recognition and direct copying and matching, but extends to a wide range of tasks including reaching and interacting spatially. TM (McCloskey, Valtonen, & Sherman, 2006) a right-handed female who showed signs of visual reflections following presentation with developmental reading and visuospatial deficits, is also similar to AH. A similar case exists in that of patient PR, reported by Pflugshaupt et al. (2007), whose deficit is acquired but shows similar left-right reflection errors and problems with reaching and direct copying and matching. Important to note is that in AH and PR a number of visual variables impact positively on performance; these are described by McCloskey as, "exposure duration", "motion", "flicker", "contrast"

and “eccentricity” (2009, p. 60). All of these variables pertain to the stimulus presented during testing, as in the viewed object ‘flickered’ or was in ‘motion’ and so on. This effect is used as evidence that the nature of the deficit is one of a higher (non-basic) level of processing, in that these visual variables improve performance in both AH and PR, which suggest that a separate process which is influenced by these factors of ‘motion’ (and ‘exposure duration’, ‘flicker’ and ‘contrast’) is relatively intact. This is also used in support of the distinction between the two, ventral and dorsal, pathways or systems of visuospatial cognition, which is dealt with in more detail below.

Further cases involving mirror vision have been reported: Turnbull and McCarthy (1996) describe patient RJ who also has trouble distinguishing left-right reflection stimuli, but who differs from AH in terms of the localization of objects in space, and in that he shows no improvement based on the visual variables mentioned above. Record also exists of a patient GR who has particular difficulty in discriminating mirror stimuli following a right temporoparietal cerebrovascular accident (Prifitis, Rusconi, Umilta & Zorzi, 2003). Solms, Kaplan-Solms, Saling and Miller (1988), report a related sort of deficit whereby the visual field is inverted in an up-down manner. This deficit results from frontal lobe damage and also is not affected by the visual variables (‘motion’, ‘flicker’ and so on) indicated earlier. The research presented here from literature indicates that the phenomenon of visual reflections is an intricate one, but a specific focus will be made here, in this research, by paying close attention to the case exemplified by McCloskey (2009)’s AH.

These phenomena of inverted visuospatial cognition can add to our theories on vision and they might impact on our understanding of visual cognition in general. The growing body of evidence within the field of spatial cognition points towards subsystems of specialised processing within the brain, and that what is required is further investigation into how these systems might interact (Landau, 2002). Landau (2002) goes on to describe spatial cognition as “the capacity to discover, mentally transform and use spatial information about the world to achieve a variety of goals” (p. 395). The very foundation of spatial cognition is dealt with in this case study by means of a focus on three areas: firstly, the notion of reference frames in relation to representations of object location and orientation, secondly a coordinate-system hypothesis in understanding reference frames, and finally the broader concept of visual subsystems themselves.

Frames of Reference

The term ‘frame of reference’ is well established within the spatial cognition literature as a key tool for the understanding of visual processing (Committeri et al., 2004; Gallistel, 1990; Gregory & McCloskey, 2010; Klatzky, 1998; Marr, 1982; Soechting & Flanders, 1992). The concept itself applies in that “spatial locations and orientations can be specified only in relation to a reference system of some sort – that is, within a frame of reference” (McCloskey, 2009, p. 137), thus reference frames are a fundamental concept to consider when working within visuospatial cognition. A primary distinction is made between allocentric reference frames – that is, in terms of exterior constraints, for example seeing an image in relation to the page it is printed on; and egocentric reference frames – which are related to object or bodily position, for example seeing that same image in terms of its being positioned in front of you (Committeri et al., 2004; Klatzky, 1998). This dichotomy provides coherence, and looks to answer the first of two key questions raised in the literature, namely, “in relation to what are locations defined?”; for the second question, “In what form are locations represented?” (McCloskey, 2009, p. 138), the conceptualization of object location and orientation in terms of a ‘coordinate’ based system of representation emerges as a sophisticated and comprehensive hypothesis.

A Coordinate-systems hypothesis. Importantly, a Coordinate-system Orientation Representation hypothesis (COR) can be useful in understanding this problem of visual reflections; a phenomenon which is found not only in cases such as AH or PR, but in milder forms in healthy controls too (Davidoff & Warrington, 2001; Gregory & McCloskey, 2010). Briefly, COR involves the encoding of object information in terms of elaborate coordinates in order to form the representations necessary for spatial cognition. An object is viewed in terms of its position in terms of various axes, possibly those specified as ‘frames of reference’. Important is that this can also accommodate for tilt and rotation. The coordinates and degrees away from said axes are encoded and processed in visual cognition (McCloskey, Valtonen, & Sherman, 2006). It suffices to say that many of the authors of these central cases of mirror image difficulties, as well as the relevant theorists involved in the investigation, propose a COR point of view as paramount in understanding and interpreting the deficits surrounding reflections of objects in space (Lambon-Ralph, Jarvis, & Ellis, 1997; McCloskey, 2009; Priftis, Rusconi, Umilta & Zorzi, 2003; Valtonen, Dilks, & McCloskey, 2008); hence its use in understandings regarding the case at hand here.

Visual Systems

Moving away from the foundational concepts of reference frames and the positioning of coordinate systems in understanding the notions surrounding mirror images, a step can be made towards the impact of the mirror image problem on broader theories of vision. Earlier, the mention of the influence of visual variables on the functioning of AH and PR was mentioned as evidence of a high-level of processing being implicated in the visual deficits of these individuals. Drawing from the anatomically established distinction between magnocellular (M) and parvocellular (P) pathways in the ganglion cells of the visual brain (Livingstone & Hubel, 1988), McCloskey (2009, p. 228) posits "transient" and "sustained" subsystems of higher order visual processing, respectively. He argues, based on the effects of visual variables on AH, that her deficit can be explained as an instance of impaired sustained, and intact transient, systems.

The phenomenon of mirror images has further implications for another important dichotomy in vision, that of the ventral, 'what' versus the dorsal 'where', pathways (Mishkin, Ungerleider, & Macko, 1983; Rizzolatti & Matelli, 2003); this is also conceived of as dorsal vision for 'action' versus ventral vision for 'perception' (Goodale & Haffenden, 1998; Goodale & Milner, 1992; Milner & Goodale, 2008). The general conclusion here being that in AH and PR, and with the problem of visual reflections in general, the 'where' system is vulnerable whilst the 'what' system is unaffected, as object recognition is not impaired. McCloskey (2009) would position his distinction between 'sustained' and 'transient' systems under the dorsal pathway thus aligning his understanding with this ventral-dorsal distinction, and adding ramification and depth to this concept.

Rationale for Research

On initial presentation BS gave a strong impression that her deficits corresponded with McCloskey's (2009) AH. This was some two years ago and currently the first step is being made in taking record of the comparison of these two cases. We know that the deficits (rotations and reflections on horizontal and vertical axis) as seen acquired both developmentally and following brain injury can be accommodated by a coordinate system hypothesis of object representation. Furthermore, the cases of AH and PR illustrate dissociation in terms of intact ventral and impaired dorsal visual streams. With the impact of visual variables further distinction can be made within the dorsal stream in terms of impaired sustained (M) and intact transient (P) pathways (McCloskey, 2009; Pflugshaupt et al., 2007). What remains to be established is further empirical evidence in relation to the suggestions already made. In particular cases such as McCloskey (2009)'s AH, and our own BS need to be synthesized and explored in terms of their implications on frames of reference, coordinate systems, visual systems of visual cognition. Expansion in regard to empirical evidence, and theoretical implication and interaction is necessary.

Aims and Hypotheses

The aim of the present research is to provide a detailed case study of an individual with perceptual deficits that seem to suggest mirrored vision. An attempt will be made to compare the current case, BS, with predominantly that of McCloskey (2009)'s AH; and to assess if similarity exists, what might differ, and in turn to relate this back to theory. It is hypothesized that the case will bear similarities to that of AH; and furthermore that a coordinate-systems hypothesis and a two-stream (dorsal and ventral) theory of vision may be useful in understanding her deficits.

The nature of the research at hand here is significant if only because of the rarity of the sort of deficit found in the case being studied here. The phenomenon of mirrored vision has some precedent, and in the form of visual reflections is even known to be present in normally functioning individuals (Gregory & McCloskey 2010; McCloskey 2009). A case such as the one here, in which mirrored vision occurs developmentally, is really only seen in the case of McCloskey (2009)'s AH. A need, therefore, emerges to extend this author's findings with what may be a similar case; and that may, or may not, lend itself to being interpreted in terms of a similar theoretical framework, namely, a coordinate systems hypothesis and a two-stream theory of vision. Whatever may emerge from this case study can be construed as important simply due to the fascinating and unique nature of the deficit and BS's subsequent compensation. What the results of the investigation might mean for relevant theory, then, adds to the extent to which the work here may be considered significant.

Methods

Participant

BS approached a lecturer at the University of Cape Town (UCT), Jill Mosdell, who then with the Head of Department, Prof. Mark Solms, conducted a few basic tests to assess what she claimed to be a problem with vision and remembering faces. Her performance on the Rey-Osterrieth Complex figure (Rey, 1941) showing signs of reflection on a vertical axis was the main reason for thinking that her problem resembled that of AH.

The case study presented here is that of a 20 year old, right-handed, female student from UCT, who approached one of the faculty members in the Department of Psychology in regard to perception and vision. She subsequently presented as being uniquely impaired and hence forms the basis of the current enquiry and research. She is referred to here by her initials, BS, so as to retain anonymity. As per ethical compliancy, informed consent was obtained from BS, after having made clear her rights in voluntarily participating (see Appendix A). There was virtually no potential for harm towards her by participating, in fact she seeks to gain in that we look to shed light on something that she struggles with on a daily basis**.** A purposive sampling technique has been employed.

Measures & Procedure

The research procedure is strictly a case study, and consists of the administering of a number of tasks which all pertain to vision, perception, object recognition and the orientation of objects in space. In particular the tasks revolve around direct copying of stimuli, in accordance with McCloskey (2009)'s initial procedure. I then recorded the participant's responses to these tasks for analysis and comparison. Furthermore I took record of a full medical and educational history of the case. This all took place in a quiet, private, room in the Library of UCT upper campus. The entire procedure consisted of four sessions of testing, lasting just over an hour each; and the history taking which was another hour and a half. The Magnetic Resonance Imaging (MRI) took place at Tygerberg Medical Campus and lasted roughly half an hour, bringing the total time spent observing the case to roughly six hours, spread over the six meetings.

Medical and Educational History. A session of roughly an hour and a half was devoted to the conducting of a full medical and educational history with BS, in accordance with McCloskey (2009)'s initial procedure. Responses to extensive questions on medical history, family background and a full developmental and educational history were recorded. As well as specific questions asked to; "describe the problem she has, when did she first notice this, did others (parents, teachers or friends) notice, and when did she start to and can she give an account of the strategies she uses to overcome her difficulties?".

Task 1. The first measure of investigation and assessment is the Rey-Osterrieth Complex figure (Rey, 1941), as seen in Figure 1. I gave the image, first, as a direct copy and match task to illustrate gross visual states, and second with a delayed recall of half a minute so as to incorporate a working memory component (Turnbull & McCarthy, 1996). This was done, on two separate occasions, one for performance 'normally, trying her best' this is also referred to as performance 'with coping strategies'. The second, performance 'as she sees it in her head, also referred to as performance 'without strategies', which means without using her hands or body to compensate. The Rey task is well-known within the clinical neuropsychological field and is often a first step in regards to cases of visual impairment (McCloskey, 2009; Turnbull, Laws, & McCarthy, 1995).

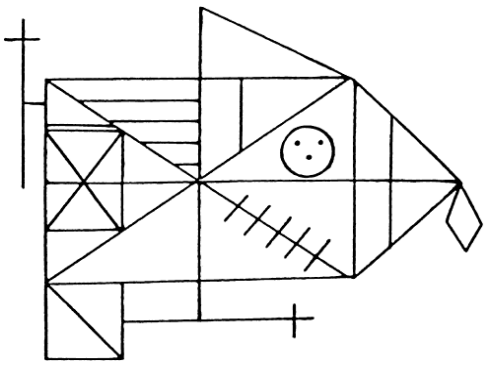

Figure 1. The Rey-Osterrieth Complex Figure (Rey, 1941)

Task 2. The second task administered is the Benton Visual Retention Test (BVRT) (Sivan, 1992). This test is a common measure of perception and object recognition in terms of assessing an individual's performance, and has proven to be widely regarded as reliable and valid in such instances. Its construct validity is particularly well-established (Larrabee, Kane, Schuck, and Francis, 1985; Spreen, 1995). The measure also provides normative data

for comparison. As a measure this is a useful component to a flexible battery approach for assessing perception (Bauer, 1994; McKenna and Warrington, 2009). Each stimulus consists of one to three shapes, mostly simple geometric figures, in a series of ten which constitutes one form.

We did a few variations of this test, as per McCloskey (2009)'s procedure; one, a direct copying task done with Form C of the test. Two, a direct copying task with the instruction to go carefully and to then mark as to whether the copy was correct or not, done using form E. Three and four are trials of recall from memory (the stimulus did not remain in view). Three being a ten second exposure to the stimuli with immediate recall, four being a ten second exposure with a 15 second delayed recall; both using Form D of the BVRT. All of these variants on the test were done for performance 'with' and 'without strategies', as per the instructions outlined above.

Task 3. I presented a series of 26 'Simple Nonsense Shapes' one at a time, as a direct copying task (see Figure 2). Trials were done on separate occasions for performance 'with' and 'without strategies'. These shapes where sketched and designed using Adobe Illustrator, and where then vectored and made print-ready using Adobe Photoshop. The presentation of these is crucial in that it forms a core component of McCloskey (2009)'s initial case study procedure. The shapes are designed so as to clearly indicate any reflections occurring as a result of the BS's direct copying of the images, three of which are directly from McCloskey (2009), and the rest I designed for this study as was necessary due to no exact specification of these images in McCloskey's initial procedure. In addition to the direct copying task, BS was asked to score her responses as being either correct or incorrect copies, so as to assess detection of any reflection errors.

Figure 2: Two of the 26 Simple Nonsense Shapes to be presented (McCloskey, 2009).

Task 4. The fourth task in the research procedure is a copying of the nine Bender-Gestalt Figures (Bender, 1938). Jensen (1959) testifies as to the figures' reliability and validity in terms of object recognition and perception. In their very nature the figures, as with the 'simple nonsense shapes', indicate any gross visual reflections occurring when presented as a direct copying task; as is the case here. The figures are all copied onto one A4 sheet, at the discretion of the participant, thus indicating some element of planning in visuospatial cognition. This task also is part of McCloskey (2009)'s procedure. Again, instruction for one trial is to copy normally 'with strategies', and another separate trial for 'without strategies', or not using her hands or body to compensate.

Task 5. The copying tasks extend to the copying of three simple line drawings of scenes and objects, as per McCloskey (2009)'s initial procedure, (see Figure 3). These too are designed to indicate gross visual reflections in the perception of visual stimuli, and thus will certainly shed some light on the BS's ability in terms of visuospatial cognition, and the forming of mental imagery. The use of these images, as they are well-known objects – something unique to this task as the others, barring words and numbers, involve mostly geometric and abstract shapes – is important to see whether any reflections or copying errors apply not only to abstract stimuli, but to everyday scenes and objects too. Performance was assessed for 'with strategies' and 'without, as she sees it in hear head'.

Figure 3: One of the three Line Drawings to be directly copied (McCloskey, 2009).

Tasks 6 and 7. I gave direct copying tasks for numeral and word stimuli. These comprised of firstly, a list of the ninety two-digit Arabic numerals (i.e. 10-99) presented individually, in a random order, copied into a space to the right of the number; whilst the stimuli remain in view. Secondly, 144 concrete nouns (e.g. flower) ranging in length from

three to twelve letters, were presented in the same way (one by one and at random, to be directly copied in a space to the right of the word). These are all printed in lowercase MS sans serif font. Subsequently these same word and number lists were dictated and copied down by BS, so as to have evidence as to multi-modal perception of words and numerals.

Other Words. It was brought to our attention, by BS herself, that there is a difference between how words are pictured 'in her head' and how she knows they are spelt and therefore how she can recall and copy them. Accordingly we did an impromptu request of a written expression of how she pictures a few random words 'in her head'. We dictated the words; 'good, peacock, ball, fantastic, yacht, and working' and the instruction was for her to write down how these words are pictured 'in her head'. On a separate occasion we repeated this same process. Furthermore, we recorded an account of her performance writing these words from dictation trying to spell correctly. The same words were also given to be directly copied, that is direct copy spelling, as in Task 7 above.

Clock Drawing. Whilst giving an account of ways in which her problem manifests in everyday life, BS, gave the example of how she pictures a clock face. I then asked her to draw a depiction of how a clock is pictured in hear head, and she explained her thinking alongside the completing of this drawing.

Imaging. A functional MRI scan (T1WI 3DMPRAGE; T2WI axial and sagittal acquisition; FLAIR axial acquisition; 3D TOF; DWI at b=1000, 3000; ADC Map; GRE; fcMRI) was conducted to assess the anatomical integrity of BS. See Figure 4., for an example of a healthy control's MRI. The scan session was conducted on the 13th of October 2014 by Dr. Coenie Hattingh and lasted roughly half an hour.

Figure 4: Control example MRI sagittal section.

Results

Medical and Educational History

In the history taking, all corresponds to the medical history of AH, i.e. no evidence of prior illness or any factors that may have had a neuropsychological impact. “She had never been diagnosed with a neurological disorder; she had never suffered blackouts, seizures… and she had no history of diseases or illness that might have caused brain damage, such as complications during birth, blows to the head, or very high fevers. No other significant medical conditions, no history of psychiatric disorders, and no problems with drugs or alcohol” (McCloskey, 2009, p. 8). BS went to a very rural primary school, but states that she had no difficulties with academics throughout schooling. She reported that no one really seemed to notice that she had any deficits. The first time that she started to become aware of them was in first year (2 years ago). Interesting to note is that when asked about how she sees her problem, she regards her inability to remember faces as her chief problem. The example that she provided was that of, if someone had to ask her what her own mother looked like, she would not be able to tell you. She cannot mentally picture her face in a meaningful way; she said she only knows facts about her appearance, that people have told her (like her mother has lighter skin). She said she tries to associate people’s faces with features, (she said she would remember me by my glasses, but would probably not recongise me if I wasn’t wearing them). I asked whether hearing someone’s voice would make her recognize the person – she said not always. She gave the example that there is a student at residence with her that she is friendly with and often chats to (they have been in the same residence for this year), and that on one occasion the student was talking to her and BS had no idea who she was. She only recognized who it was when the girl mentioned something BS knew only that girl could know. In terms of the ‘strategies’ that she seems to use, using her hands, body and logic to compensate; BS can give little account of how they developed or her experience thereof.

The Rey-Osterrieth Complex Figure

On the first testing session BS’s direct copy of the figure revealed no errors and was practically a perfect copy, see Figure 5.1. However, she seemed anxious about having to draw it, and wanted to rotate the page to look at it from another angle; she also tilted her head at

times when copying. She started drawing the diamond above, then paused for a few seconds, erased it and drew it below the top of the triangle on the right, that is, in its correct position.

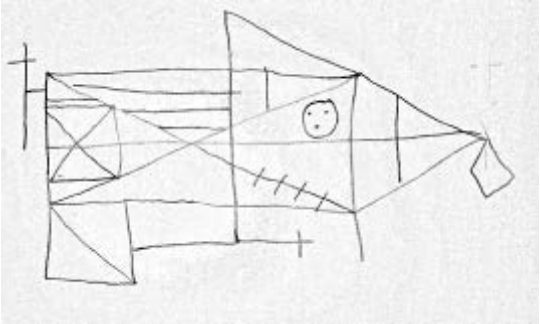

Figure 5.1: BS's first direct copy of the Rey figure. Almost no errors are present.

Following the direct copy, a trial of immediately recalling the figure from memory showed a different picture (see Figure 5.2). The depiction has inversions of some parts, with some elements retained and others omitted. The drawing contains parts that can be described as 180° clockwise rotations or as being mirrored on a vertical axis, but this is only for some aspects and not the whole figure.

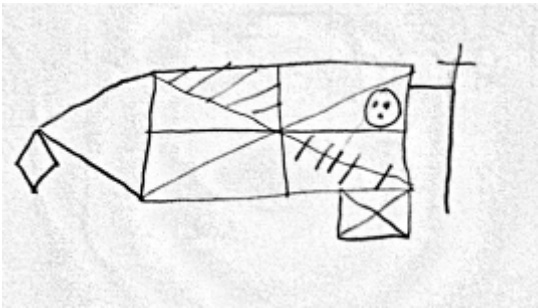

Figure 5.2: Immediate recall of the Rey figure. Mirroring errors are present.

After completing these and some of the other tests during our first session, it became apparent to us, due to BS's comments, that there is a difference, for her, between how she can produce responses in trying to 'get them right', and how things are actually perceived in her mental imagery. This also manifests as a difference in performance 'with' and 'without strategies'. With the above two depictions representing how BS performs 'with strategies'; I, thus, repeated the presentation of the Rey figure on a separate occasion with instructions aimed at trying to see 'how she sees it in her head'.

For the direct copy, ‘without strategies’ the drawing is heavily distorted; the figure is mirrored, but the whole drawing is not maintained as a whole. The left half of the figure is maintained but the right half is mirrored and depicted as a separate shape (see Figure 5.3). For the immediate recall, ‘without strategies’ this same splitting of the figure into two is present, with mirroring; but less of the detail is present (see Figure 5.4).

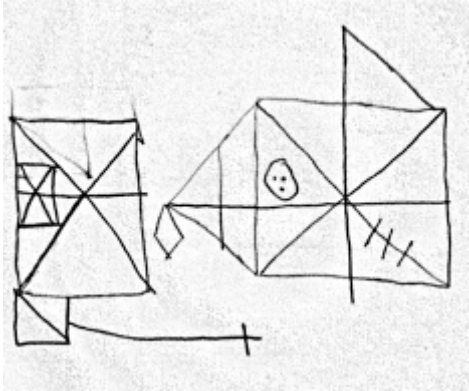

Figure 5.3: Direct copy of the Rey figure ‘as BS sees it in her head’.

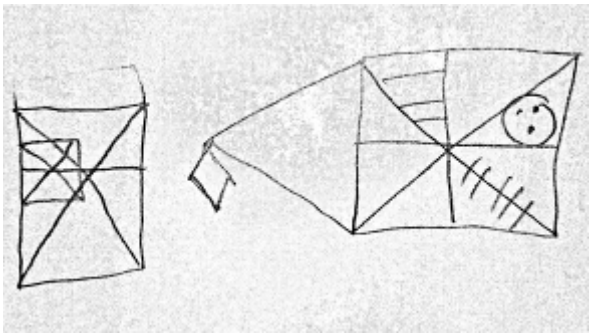

Figure 5.4: Immediate recall of the Rey figure ‘as BS sees it in her head’.

This performance in the copying of the Rey figure differs from that of AH, as AH copy shows a somewhat pure vertical reflection, with most elements retained but simply reflected (see Figure 5.5). Furthermore AH’s direct copy and immediate recall do not differ very much.

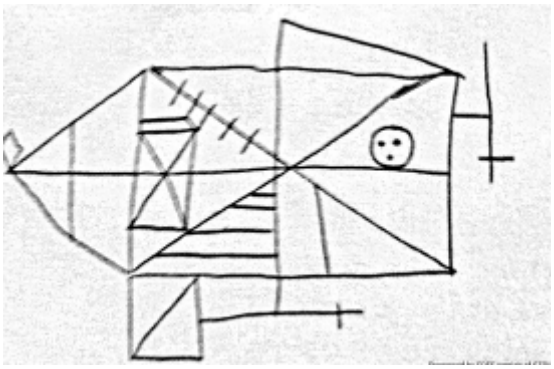

Figure 5.5: AH's direct copy of the Rey Figure (McCloskey, 2009).

Benton Visual Retention Test (BVRT)

The BVRT gives two scores; one, a simple score out of ten referring to each stimulus in the form holding a value of one or zero depending on whether the figure was copied correctly (and there are guideline for what qualifies as correct). The second is a total error score, where on each stimulus more than one error can be made and each of these errors (of which the types of errors are extensively described and categorised) are tallied up, each with a value of one.

The first trial of the BVRT was a direct copy, using form C. when using 'strategies' BS scored 8/10 correct with a total error score of 2, when assessing 'without strategies performance she received the same two scores. However her errors are not the same, 'with strategies' the errors are displacements (i.e. shifting of a figure up or down), whereas 'without strategies' a mirror error (or 180° rotation) occurs. In terms of norms, these scores are still in the 'average' range, the best performing of four categories differentiated by the BVRT's norms (Benton, 1974). In terms of a comparison with AH, her scores for the same trial was a 4/10 correct with a total error score of 9.

The second version is a direct copy with instruction to take care and to score responses as being a correct or incorrect copy (after completing all ten figures), conducted using form E of the BVRT. When using 'strategies' BS scored 7/10 correct with a total error score of 3. She did not detect these errors. When trying to assess 'without strategies' performance she scored 9/10 with a total error score of one, and she did not detect this error.

AH's scores, in comparison are 3/10 correct with a tot err score of 8. She detected 3 of these 7 errors. Norm scores are not available for this, or the final two variations of the test.

On the 10 second exposure with a 15 second delayed recall task conducted using form D; BS scored 8/ 10 correct with a total error score of 2 for 'with strategies' performance, and for 'without' her scores were 0/10 correct with a total error score of 21. It seems this is the trial of interest here as not a single item was correct and more than one error is made on each stimulus. These errors vary but are predominantly rotations and reflections. AH scored 2/10 with 12 errors, on this variation.

The final version; 10 second exposure and immediate recall, without the stimulus in view, administered with form D: BS scored 7/10 with a total error score of 3, 'without strategies'. When assessed for performance 'with strategies' she scored 6/10 with a total error score of 4. AH's performance was the same as for her delayed recall trial, 2/10 and 12 total errors (McCloskey, 2009). These score comparisons are summated in Table 1.

Table 1

Comparison of BS and AH's BVRT Scores

	BVRT Trial			
Performed by	Direct Copy	Direct with care and self-scoring	10 second exposure immediate recall	10 second exposure 15 second delayed recall
AH	4/10 (9)	3/10 (8)	2/10 (12)	2/10 (12)
BS (with strategies	8/10 (2)	7/10 (3)	6/10 (4)	8/10 (2)
BS (without strategies)	8/10(2)	9/10(1)	7/10 (3)	0/10 (21)

Note. Values in brackets show total error score.

While copying many of the drawings, BS looked intently at the drawing and moved her hands – it almost looked like she was counting on her fingers, she moved her hands/fingers in the shape of the angles. She also did this during the delay recall of the figures. During the admin of this task she stopped and said "are you sure you want me to draw it how I see it in my head?", she is therefore aware of her compensation.

Simple Nonsense Shapes

On presenting the 26 simple nonsense shapes there was little difference between performance 'with' and 'without strategies'. BS only made one incorrect copy in each of these testing procedures. These errors are, in the trial 'with strategies', a rotation (90° Counter-clockwise) of stimulus 12 (marked correct, but diff. in mental image); and, 'without strategies', a complete mis-reproduction of stimulus 24 (marked incorrect, but correct in mental image). As for the marking of her own responses, we asked BS to give one mark of whether her copy looked correct or incorrect 'with strategies' and another mark for 'how she sees it in her head' (alluded to as 'in mental image' in the errors stated above). These seem to vary widely and seemingly at random. Across all responses to the stimuli her judging of correct or incorrect in these two categories varies, with all combinations of possible responses found (see Appendix B for a full record). AH on the other hand, erred on 8/26 in comparison, her errors were mostly left-right or up-down reflections and she only detected half of these errors (McCloskey, 2009).

BS, again, uses her hands to work out angles and direction. When asked more about the strategy she used with her hands, she said "her hands tell her brain what to do", for example, keeping her hand on the left side means that the element must be on the left side. On the last item she initially mirrored left and right, and then looked like she was using her right hand to help her. She then rubbed out the inverted triangle at the top of the drawing, as well as the small lines and corrected her initial copy.

Bender-Gestalt Figures

The full set of figures contains 9 stimuli, however we chose to omit item 1(b) as it comprises a row of dots in a line, which was deemed inappropriate for its inability to indicate reflections on either a vertical or horizontal axis. BS's performance on the Bender-Gestalt figures totals to 5/8 for 'without strategies' and 7/8 for 'with'. Errors include a reflection of Figure 1(a) on a vertical axis (i.e. 180° rotation clockwise), see Figure 6.1., note here that she marked her copy as being incorrect. This same kind of reflection/rotation error is made for Figure 3 in 'without strategies' performance. AH also made three errors (5/8) on these figures, one of which is the same errors in Figure 6.1. (McCloskey, 2009).

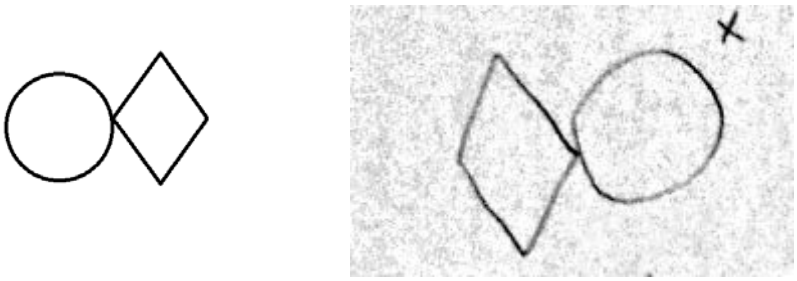

Figure 6.1: Bender-Gestalt stimulus 1(a) depicted (left) with BS's copy 'without strategies' (right).

Line Drawings

On directly copying the three simple line drawings, 'with strategies', BS's performance is not out of the ordinary, in fact her drawings are perfect, with some leeway given for artistic capability. However, with performance for 'as she pictures things in her head' ('without strategies') this is not the case. Her depictions become heavily distorted and contain elements of reflections on a vertical axis (See Figures 7.1-7.3).

She said, during testing that while she is *not* using her hands to help her draw, she *was* still using her body. She said it is difficult for her not to use these strategies. She said "she doesn't trust her brain". For the giraffe, she told us that what was in her head was *not even complete*. She said that in her mind, the *left is empty* but there is the picture on the right (see Figure 7.2). She says she knows what it is (she could recognize and name all three stimuli) and she knows what it's supposed looks like, she nonetheless drew it how the drawing looked in her head.

Her performance does differ compared to AH, whose errors involve somewhat perfect copies simply reflected on a vertical axis (see Figure 7.4), rather than the more distorted and incomplete copies of BS (McCloskey, 2009).

Figure 7.1: Copy of simple house scene by BS, ‘without strategies’.

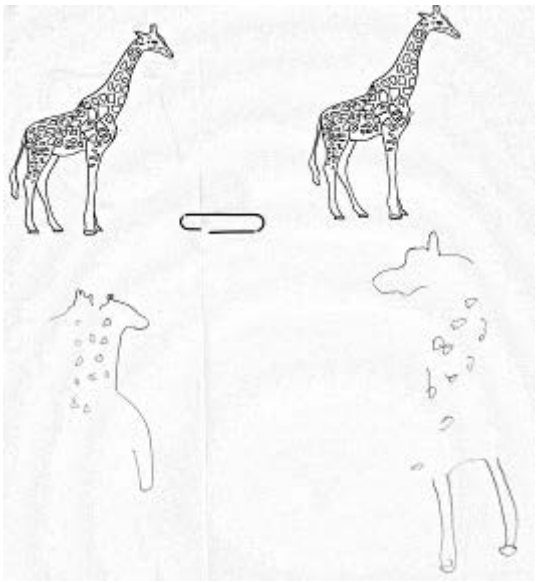

Figure 7.2: Copy of giraffe line drawing by BS, ‘without strategies’, on occasion one (left) and on a second occasion (right).

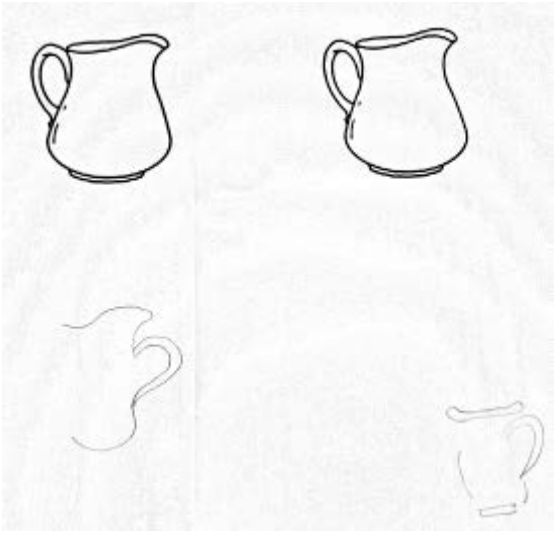

Figure 7.3: Copy of jug line drawing by BS, 'without strategies', on occasion one (left) and on a second occasion (right).

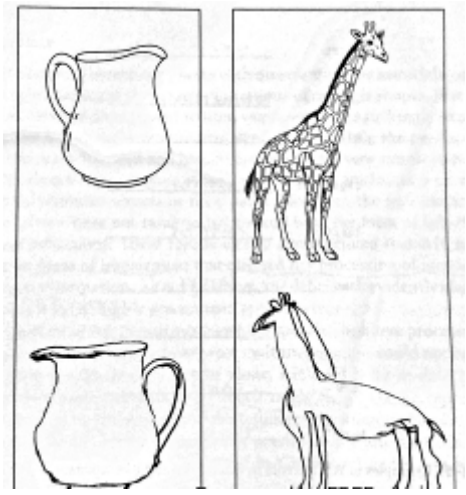

Figure 7.4: AH's direct copy performance on the simple line drawings (McCloskey, 2009).

Words and Numbers

BS's performance for direct copying of the words and number lists is without error, and stands at 100% for both. AH's performance is much worse; she erred on 12 of the 90 numerals, and on 47 of the 144 words (McCloskey, 2009). When these words and numbers are dictated, again, numbers are 100%; however for the words, two out of 144 are mis-reproduced. These are, cello becomes *chelloo*, and hedge to *hatch* (possibly misheard). Of

more interest is the anecdote provided to us by BS, during the testing of these words, that she 'knows how' to spell words (and thus read and write) but when picturing words in her head something other than the correct spelling is seen.

Other Words. Six words were dictated and a response of how they are mentally perceived by BS was recorded. This was done on two separate occasions. The responses are best studied in their original form, see Figures 8.1 and 8.2 for the responses on the first and second occasions, respectively. The two performances are not entirely the same but do share some similarities. When asked to spell these words 'as she knows them' via dictation and a direct copy task (similar to that of the direct copy spelling of task 7 above) BS makes no errors on these words. Thus, again there is a clear distinction between mental imagery or percept and 'with strategy' ability.

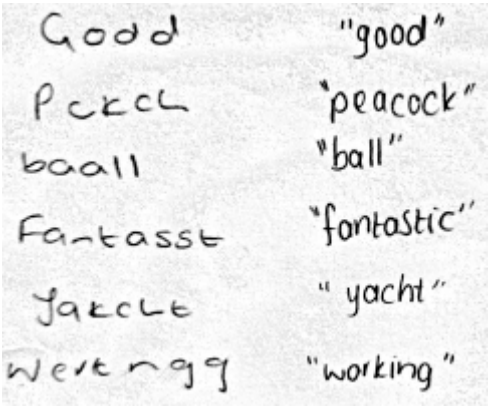

Figure 8.1: How BS pictures random dictated words, 'in her head' (First account).

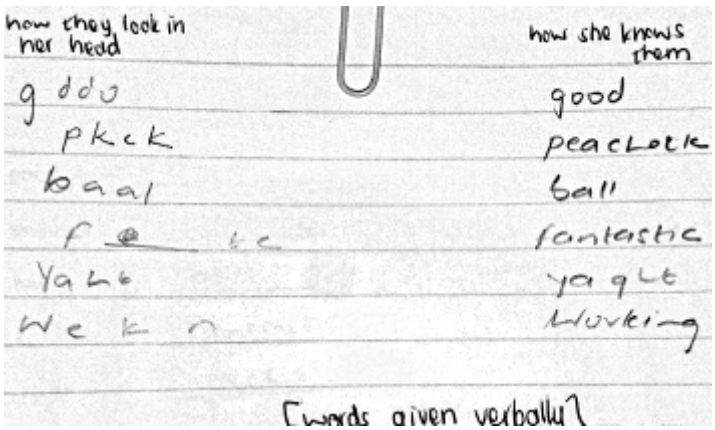

Figure 8.2: How BS pictures random dictated words, 'in her head' (Second account).

Clock Drawing

During the history taking BS gave the example of a clock face as an everyday item that is depicted differently in her mental imagery. She gave a drawn account, to the best of her ability, of what this entails (see Figure 9). Her drawing was accompanied by a verbal description which explained the positioning of the numbers visible in the drawing, she admitted to knowledge of the reflected position of the number three; and furthermore, that the dashes at the bottom of her drawing represent all the other numbers clustered together and barely recognisable.

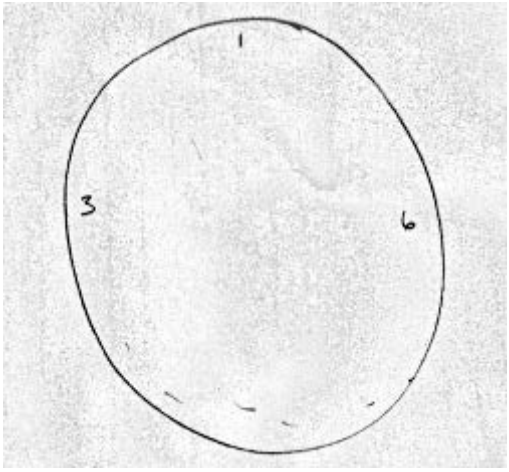

Figure 9: Graphical representation of a clock-face, as pictured mentally by BS.

Imaging

MRI results – the details of which only became available to us after completing all other testing and inquiry – certainly shed new light on BS's deficit somewhat. Her imaging scan showed no intracranial masses or extra-axial collections, no evidence of haemosiderin, and no evidence of aplasia, dysplasia or hypoplasia of any structures. The sagittal midline is preserved with a normal convex superior border of the midbrain. Her ventricles are normal as well as their communications with the subarachnoid space. The vasculature in the patient is intact with no evidence of ectasia, stenosis or aneurysm. There is no evidence of arteriovenous malformations.

However, most pertinent to our case, there is an occipital architectural distortion. This is most pronounced on the left hemisphere. The parieto-occipital sulcus appears normal, leading into the calcarine sulcus anteriorly, however the lingual gyrus comprising the inferior bank of the calcarine sulcus and area 17 of Brodmann, is not seen as a separate entity as it should be. The calcarine sulcus (of occipital lobe) is discontinuous posteriorly, interrupted by what looks like a bridging gyrus leading from the superior aspect of the inferior bank into the inferior aspect of the superior bank (See Figure 10). In the right hemisphere, the lingual gyrus is more regular; however the inferior bank of the calcarine sulcus appears underdeveloped and small when compared to the superior bank. This kind of abnormal gyral architecture is constant with a cortical dysplasia. Cortical dysplasia is associated with epilepsy and seizures, which BS shows no signs of.

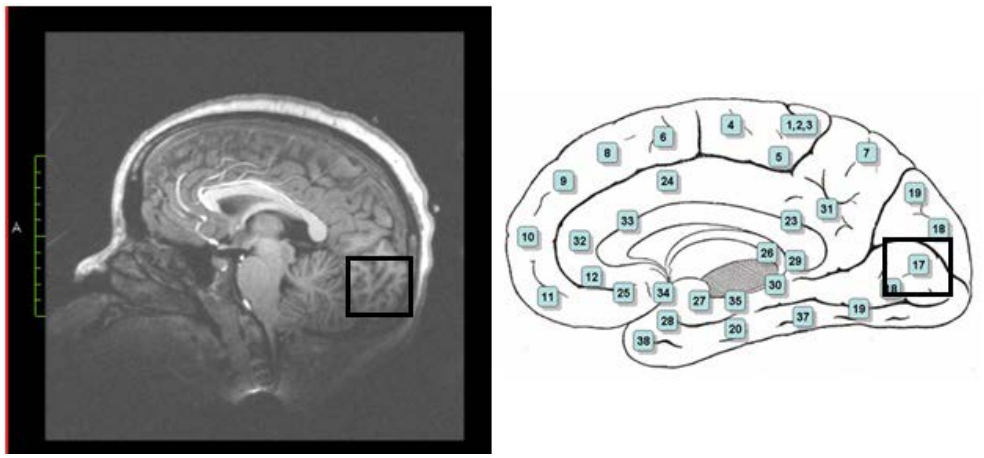

Figure 10: MRI sagittal section of BS's left hemisphere, her structural abnormality of the calcarine sulcus, roughly corresponding to Brodmann's Area 17.

Discussion

The case of BS case, as presented here, is certainly one that captivates the interest of the investigator. The nature of her developmental deficits are such that she functions relatively normally, at first glance; but when enquiring further and when taking into account her self-reports, it becomes clear that she certainly has an extensive, and apparently unique impairment. This a particular point of interest. There is a difference between the representations of her mental imagery ('how she sees things in her head'), and how she actually uses this information to function and adequately perform in daily life. Therefore some strategies or coping mechanisms must have been developed along the course of her developmental trajectory.

All that was set out to do here is lay some initial ground work, and at least make a first step into the recording and assessing of this case, which may very well prove to be a vast body of information when investigated further; and to then compare and contrast this evidence with what seemed like a similar case. Due to the fact that this has been a project with such exploratory research archetypes in mind, the process has been, and results are, fraught with surprises. Both similarities and differences do exist between BS and AH, and the exact nature of these does lie somewhat contrary to expectations. But, certainly, this disjuncture between expectation and reality is the very basis of good scientific research. There are some pieces of evidence about BS – that have been recorded as a result of the spontaneity inherent to this research – about which we cannot, currently, speculate on how they compare to AH. But nonetheless, these facts give weight to the case, and certainly help us to better understand the specificity of BS's situation.

On the Rey complex figure, there is a clear difference between BS and AH. For both direct copy and immediate recall; AH shows a pure and blatant mirroring of the image on both a vertical and horizontal axis (McCloskey, 2009). The entire image's individual elements are retained and reflected, and for the recall the result is not very different. For BS, with strategies, the direct copy she can reproduce perfectly, but her immediate recall contains elements reflected on both a vertical and horizontal axis. In contrast, 'without strategies' performance is much worse. Both direct copy and immediate recall show the figure as reflected on a vertical axis; however there is also the matter that the figure is not retained as a whole but rather split into two halves both of which are reflected. Immediate recall shows this same pattern but simply with less elements of the drawing included due to working memory

constraints. The evidence regarding performance of recall ('with strategies'), mentioned above, finds a complement in the fact that the only other recall task throughout the procedure, one of the BVRT trials, also indicates worse performance when including this working memory component. This effect of working memory was not present in AH, and concludes that it is not a part of her deficit. The delayed recall BVRT trial is the one in which BS performs the worst, by far; it is the only one in which she does worse than AH, and her score is worse than in the other three forms where she consistently does better than AH. On this trial BS gets 0/10 with 21 errors compared to AH's 2/10 with 12 errors (McCloskey, 2009). This evidence from the Rey and BVRT point towards a conclusion that recall, delayed and immediate, results in more errors; and thus possibly that working memory decreases the effectiveness of her 'strategies' for coping.

The simple non-sense shapes do not really provide much comment when focusing on the errors, and again BS does much better than AH with these; but they do allude to an issue that is also apparent in some of the BVRT performance. The scores for 'with' versus 'without strategies' do not differ to a great extent; in fact they are the same with the nonsense shapes and sometimes even better in the BVRT. This suggests that perhaps our current understanding of the dichotomy of 'with' and 'without' strategies, or 'as she sees thing in her head' is not as simple and clear cut as that. Although it does point towards a clear difference that shows up in much of the testing; and the very reason for incorporating this distinction came from the comments of BS herself regarding the tests we gave. More work certainly is required in properly operationally defining exactly what these differences are and how they manifest.

The evidence from the Bender-Gestalt does paint a somewhat clear picture, one that is most akin to our initial hypothesis. BS's performance, that is 'without strategies', is almost exactly the same as that of AH here, at 5/8. The errors are reflections on a vertical axis and the two have an exact error in common. BS's performance is better when using 'strategies', as we would expect.

However, when moving on to the Line Drawings, the unusual surprises – similar to those seen in the Rey copies – return. Here we see that 'with strategy' performance is perfect, but when asked to draw 'as pictured in her head' the result is problematic. The depictions echo the reflections combined with breaking down of the image as a whole of the Rey performance. And interesting to note is the absence of content on the left as a reoccurring

factor throughout the drawings. BS claims that “the left is empty” in her mental percept, however she does not appear to have either neglect or a hemianopia. BS’s performance here compares to AH in the same way performance for the Rey did. AH retains the entire image but just mirrors it on a vertical axis, whereas BS has a more pervasive deficit where the figure is also reflected in a similar way but is not entirely retained or complete.

When it comes to the performance on word and number lists, the difference between BS and AH is great. BS’s performance is perfect, providing evidence of the strength of her ‘strategies’ in bringing her to fully functional ability here. AH however, makes a substantial amount of errors, common across numbers and letters, and most of these are a clear result of reflections, that is, issues confusing letters *p, b, d,* and numbers *6, and 9*. More interesting, but indeed perplexing is BS’s account of ‘how she pictures words in her head’ and not ‘how she knows they are spelt’. Her errors here are a surprise; they differ slightly across two occasions, but retain some similarity in characteristic. A doubling of letters; ‘good’ becomes *gddo,* and *godd,* and ‘ball’ becomes *baal,* and *baall*. Omission and grater retention of consonants is also present. Further investigation into this artefact of BS’s experience is certainly warranted.

The depiction of the clock face is also a baffling component to the case’s deficit. To note here is that BS’s errors of representing the clock face ‘in her head’ are also found in some other tests, such as the unequal weighting of elements in space, and rotating and reflecting stimuli. A question to address is whether this jumbled representation of a clock face is akin to the misrepresentations of people’s faces that BS claims to have trouble with too.

The MRI results this certainly do complicate the matter further. We do not know whether the anomaly in the architecture of BS’s calcarine sulcus in the occipital lobe has been with her since birth or whether it is something that has occurred recently. Subsequently BS has been debriefed on the matter and has been assured that she is in no immediate physical danger as a result. Furthermore that focus must be placed on the fact that she is so high functioning as is; and that this does give some insight into her condition and provides new evidence in moving forward with the work of understand her problem. For our purposes though it does certainly give a new take on the deficits observed here. But hopefully the way that this information is used can translate into further defining structure to function relationships, due to the errors made by BS, and perhaps further work can look into BS and

AH's brain activation in the same area (Brodmann's area 17) during performance on similar tasks. To summate, BS is both similar and different to AH. Firstly, MRI suggests a congenital physical difference. This may be used to argue as to this structure's role in producing the error results seen here. None the less, the errors themselves must be synthesised. AH presents with a pure case of mirror agnosia, that is visuospatial cognition reflected, predominantly on a vertical axis. Entire visual stimuli are retained as a gestalt but consistently reflected, this shows in all direct copying and in written words and numbers. BS, on the other hand, shows a less clear picture. She has intensive coping strategies, that manifest as her hand hovering over and in the periphery of the stimulus she focuses on; as well as a logical approach of orienting using the one side of her body, and telling herself facts to remember about the problem at hand. She is so accustomed to this that she functions very well and is a good student. She has no manifest difficulties with words or numbers. However a different situation results when considering her internal representations of visual stimuli. She claims to be unable to picture faces, and has a skewed perception of clocks, words, pictures and shapes when considering 'how she sees them in her head'. Delayed recall drastically impacts her performance negatively, and working memory thus is an issue. Her errors can be briefly stated as being; a lack of retention of the gestalt of stimuli, with reflections on both vertical and horizontal axis, as well as rotations and mis-locations of figures present. Thus BS presents with a much better situation that AH on the surface, but at the same time has a deficit that is far more pervasive that that of AH.

In terms of how the results of this study relate back to theory, there are important tentative conclusions that can be drawn. Although BS differs from AH in some ways she does still make some similar errors, and the theory that was used to explain AH's deficit can also explain BS's unique array of deficits too.

Firstly a 'frames or reference' understanding is evident in the way BS uses, and explains the use of, her coping 'strategies'. She often is seen to be relating the visual stimuli she was tested on in reference to her hands and body, and she acknowledges this when asked about it. This is a classic example of an egocentric frame of reference (Committeri et al., 2004; Klatzky, 1998). BS recalls how she uses her hands and body as a reference as to where figures are on a page as well as for the facts relating to the left and right aspects of her visual field; in that she uses what she knows to be her left hand as in indication of what else should be on the left. She relies heavily of these frames of reference to compensate for her visuospatial perception deficit. The coordinate-systems hypothesis which is so adept at

accounting for AH's problem of reflections, because of its reference to (and being conceptually founded in) the axis of reflection, can also accommodate BS's deficit. The COR explains visuospatial cognition in terms of coordinates, which reference to an axis. Thus the reflection of a visual stimulus on either a vertical or horizontal axis becomes easily quantified in these terms (McCloskey, 2009). COR is easily used to understand rotations, one of the other kinds of error BS makes too. The case of TM (McCloskey, Valtonen, & Sherman, 2006), who makes the exact same reflection error as made by BS and AH seen in Figure 6.1, has this and other errors interpreted in terms of external frames of reference and incorrect mapping in terms of COR.

The 'visual variables' mentioned earlier, particularly, 'motion', 'flicker' and 'duration', which improve both the performance of AH and PR (McCloskey, 2009; Pflugshaupt et al., 2007); bear an uncanny resemblance to BS's 'strategies'. She uses a moving hand to orient ('motion'), and her fingers waver over the image ('flicker'), interesting is that the variables originally pertained to the stimulus itself, but here BS almost imposes the effect with her hands. Finally this same evidence of the correspondence of BS's strategies to the 'visual variables' of McCloskey (2009) also supports the distinguishing between a dorsal and ventral visual system. McCloskey himself concludes that the thinking behind the 'variables' comes from his distinction between transient and sustained pathways which in turn fall within a ventral and dorsal system distinction. But furthermore, as expected, there is a distinction between ability in terms of 'what/ventral' and 'where/dorsal' for BS. She has no trouble at all with the 'what' (ventral), but does struggles with the specifics of 'where' (dorsal). This is the domain of her errors. We can add to this the fact that her brain malformation is in a region exactly within this dorsal stream. Thus, it seems that 'frames of reference' and COR are useful in understanding the errors of BS. Furthermore, this deficit and BS's 'coping strategies' for it, also seem to stand as a piece of evidence in favor of a distinction between 'ventral' and 'dorsal' visual systems.

In looking to further research, a few immediate points need following up on. Further research should; inquire more thoroughly into possible other neuropsychological deficits or disorders that BS might have. Also it would be ideal to follow up with AH in light of the findings on BS, and to extend the comparison and contrast; not to mention the sheer interest into perhaps getting the two to discuss their deficits. Furthermore, work certainly needs to be done, in this light of extending of the comparison, in continuing to move ahead from these initial steps of McCloskey (2009)'s procedure and replicate his other testing.

Conclusion

In closing, we believed to have found a case of inverted visuospatial cognition; instead BS shows a much more complex picture. She functions and performs very well when trying to, and using ‘strategies’, however the way she sees things ‘in her head’ shows signs of vertical and horizontal inversions, as well as rotations, and even the lack of a retaining of a figure’s gestalt. This shares some characteristics with AH, whom we set out to compare BS to all along, but it is more pervasive than the pure inversion shown by AH. And furthermore the factor of working memory playing a part in BS’s errors; and the notion of the ‘strategies’ are two big differences between BS and AH. Still it seems that the theory used to explain the deficits of AH (McCloskey, 2009) and TM (McCloskey, Valtonen, & Sherman, 2006), namely, ‘frames of reference’, a coordinate-systems hypothesis, and the distinguishing between ‘ventral’ and ‘dorsal’ visual systems, are all applicable in understanding BS’s deficits. Furthermore it seems that the nature of BS’s ‘strategies’, and taking into account the location of her anomaly in brain architecture, do seem to stand as evidence for making this ‘visual/dorsal’ distinction. This briefly is the extent of what this study has found, and as outlined above further inquiry is indeed warranted.

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Appendices

Appendix A: Informed Consent

University of Cape Town
Faculty of Humanities

Informed Consent Form

A Case of Mirrored Vision: Implications for Visuospatial Cognition

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Nature of the research: This study is being undertaken as part of the training involved in Honours in Psychology. The research aims to look into the nature of the processes surrounding vision and the localisation of objects in space.

Participant's involvement: *What's involved:* As the focus of this study, you will be asked to complete a number of relatively straight forward tasks, which the researchers will take you through step by step. These tasks will vary but will predominantly pertain to object recognition and spatial awareness.
Risks: there are no risks to you as the participant.
Benefits: some benefit to you may be found in the fact that the work done here may provide insight into your condition and cognition in general. SRPP points will also be awarded
Costs: the only cost to you will be in terms of the time that we ask you to take in completing the research tasks.

I agree to participate in this research project.

- I have read this consent form and the information it contains and had the opportunity to ask questions about them.

- I agree to my responses being used for education and research on condition my privacy is respected, subject to the following: - that my details will be kept anonymous and I will not be personally identifiable

- I understand that I am under no obligation to take part in this project.

- I understand I have the right to withdraw from this project at any stage.

- I understand that this research might be published in a research journal or book. In the case of dissertation research, the document will be available to readers in a university library in printed form, and possibly in electronic form as well.

Signature of Participant / Guardian (if under 18): _____

Name of Participant / Guardian: B[redacted] S[redacted]

Signature of person who sought consent: _____

Name of person who sought consent: S.T. Grobler.

Signatures of principal researchers: a) Mark Solms **(name)**

b) Aimee Dollman **(name)**

Date: 4/9/2014.

Appendix B: Simple Nonsense Shapes Scores

‘With Strategies’.

Stimulus number 1 - 7 correct (marked correct)

* 8 – change instruct to mark according to ‘in her head too’ –
copy is: correct (marked correct, but diff. in mental image)

9- correct (marked correct, in mental image too)

10 – correct (marked correct, but diff. in mental image)

11 - correct (marked correct, in mental image too)

**12 – incorrect (rotated 90deg. Counter-clock) - (marked correct, but diff. in mental image)

13 - correct (marked correct, in mental image too)

14 - correct (marked correct, but diff. in mental image)

15 - correct (marked correct, but diff. in mental image)

16 – correct (marked incorrect for both)

17 - correct (marked correct, in mental image too)

18 – correct (marked incorrect for both)

19 - correct (marked correct, in mental image too)

20 - correct (marked correct, in mental image too)

21 - correct (marked correct, in mental image too)

22 - correct (marked correct, in mental image too)

23 - correct (marked correct, but diff. in mental image)

24 – correct (marked correct, in mental image too)

25 - correct (marked correct, in mental image too)

26 – correct (marked correct, in mental image too)

‘Without Strategies’.

1 - correct (marked correct, in mental image too)

2 – correct (market correct, but diff. in mental image)

3 - correct (market correct, but diff. in mental image)

4 - correct (market correct, but diff. in mental image)

5 - correct (market correct, but diff. in mental image) *how seen in head indicated in drawing too.

6 - correct (market correct, but diff. in mental image)

7 – correct (marked correct, in mental image too)

8 - correct (marked correct, in mental image too)

9- correct (marked correct, in mental image too)

10 – correct (marked correct, but diff. in mental image)

11 - correct (marked correct, in mental image too)

12 – correct (marked correct, in mental image too)

13 - correct (marked correct, but diff. in mental image)

14 - correct (marked correct, in mental image too)

15 - correct (marked correct, but diff. in mental image)

16 – correct (marked correct, but diff. in mental image)

17 - correct (marked correct, in mental image too) * some issue with lines here.

18 – correct (marked incorrect for both)

19 - correct (marked incorrect for both)

20 - correct (marked correct, but diff. mental image)

21 - correct (marked correct, but diff. mental image)

22 - correct (marked correct, but diff. mental image) * started by drawing triangle mirrored.

23 - correct (marked correct, but diff. in mental image)

**24 – incorrect (marked incorrect, but correct in mental image)

25 - correct (marked correct, in mental image too)

26 – correct (marked correct, but diff. in mental image)