ABC: Abstraction – Brain – Cognition

1. Who are you? The names and affiliations of all applicants.
Dr. Richard Shillcock, Informatics (IANC); Dr. Rob McIntosh, PPLS (Psychology)
Dr. Matthew Roberts, PPLS (Psychology). Mentor: Professor Andy Clark (Philosophy).
Mentor: Terry Sloan (EPCC).

2. What will you do? A brief outline of the project and its background, including the objectives and methods to be employed.
We will pilot a means of “doing science” in cognitive neuropsychology, in which the researcher utilises physical affordances to navigate within a specific literature by moving within the 3D brain, taking advantage of a philosophy-driven, comprehensive framework of abstractions. This approach enables the individual researcher to curate voluminous cognitive neuropsychological literatures in a manner that facilitates insightful research, and it provides students and researchers new to a literature with an intuitive access to that subfield.

Background to the problem:
♠ The brain is the most extensively and intensively interconnected entity that we know. The fundamental problem of cognitive neuropsychology is how we can understand any one part of this totality.

♠ This is a philosophical question. Behavioural, neuroanatomical and neurophysiological data of ever-increasing sophistication all contribute, but the central problem is still the philosophical one of understanding things that are essentially conditioned by their relations with the rest of the totality. Taking something out of its essential relations with other things violates its integrity and defeats attempts to understand it. The richer the data become, the more acute the problem of interpretation becomes.

♠ Most brain researchers cannot articulate their philosophical assumptions. Laboratory-based research is “spontaneously materialist”, but our facility for linguistic abstraction instantly tends to lead us astray in theorizing, implicitly operating with versions of positivist and empiricist assumptions in which the individual is seen as passively building their cognition from incoming information, and in which cognition is understood by analysing it into simple components, each interacting externally with the rest, each understood in static, abstract, ideal terms. Ignoring philosophical questions leaves researchers open to indefensible philosophical assumptions.

♠ The literature is growing at an accelerating rate. The search term “hypothalamus” produces “about 556,000” hits on Google Scholar. We cannot avoid the necessity of individual researchers reading individual papers. Typically, individual researchers produce necessarily dense, linear textual reviews of research on particular, limited aspects of some part of the brain, which are necessarily written and read without immediate detailed recourse to the whole of the rest of the literature on that part of the brain. Such reviews are hard to assimilate and to retain.

Background to the solution:
❉ There are two{1} complementary, philosophy-driven solutions to the fundamental problem described above. The solution explored here is based on a comprehensive framework for

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{1} We have successfully pioneered the second solution in a philosophy-based program of computational cognitive modelling of eye-movements in reading; see, Shillcock, Roberts, Kreiner, Obregón, & Monaghan (submitted).
abstraction, in which the entity under investigation is explored in a structured way based on Extent, Level of Generality, and Vantage Point (Ollman, 2003; see also Levins, 2006, for an application of this approach within biology), with maximally flexible abstractions providing the theorist with the fullest all-round consideration of the entity in all its changing contexts.

This concentration on abstractions is not a substitute for facts and theories; rather, it is a discipline that helps the researcher to uncover every aspect of a particular fact or theory by comprehensively reordering and reshaping the facts and the contents of the theory. RS is currently developing this theoretical approach in the specific case of the analysis of the dorso-ventral debate in vision (cf. Clark, 2009; Schenk & McIntosh, in press), and this work is the basis for the current application.

The individual researcher stays at the centre of the work. The intellectual procedure and tools we propose will facilitate an individual researcher in coming up to speed with a literature, investing it with that researcher’s own interpretations and exporting that expertise to the rest of the field. Equally it will be an effective teaching and learning procedure.

The tool eventually developed will be maximally accessible and fun to use. The proposed pilot study will first provide the scientific content for a graphical user interface in which physical affordances accessed by tapping, moving and pinching with the fingers will be used to navigate the philosophical abstractions in the literature by moving around and within a 3D representation of the brain. Signage within the representation will indicate the nature of the abstraction, with increasingly detailed trails leading to individual notes, abstracts, research reports, and papers. The proposed pilot study will also provide a mock-up of the graphical navigation of the content developed.

Figure 1 (from BrainVoyager Brain Tutor) gives a feel for the way that brain entities can be appreciated visually, and rotated for inspection. A visual metaphor for the different abstractions works well, helping us to understand particular research on particular entities in the brain from the full range of different abstractions.

As an example, Figures 2a and 2b show how Extent (i.e. how much of the brain is considered) can be increased from just the dorsal stream, in this case, so that the researcher encounters work involving the dorsal and ventral streams. Increasing Extent provides the scope for more extensive interactions to be considered. Signage indicates the domain being considered: first “whole ventral
stream” and then “whole ventral and dorsal streams”. Conversely, decreasing Extent would allow concentration on particular parts of the system, such as the shared early stages of the two processing streams. Temporal extent may also be specified, corresponding to a developmental profile of the domain.

Once Extent has been used to select the particular subdomain, manipulating Level of Generality and Vantage Point makes further information available.

Figure 2c shows how Level of Generality (i.e. how much detail is “in focus”) can be increased to move from dorso-ventral differences in vision research to dorso-ventral differences in language research (involving the auditory cortex, speech recognition and auditory-motor integration), or in inter-species research (dorso-ventral differences in frog and hamster vision). The first signage encountered includes “language”, as shown in 2c; successive finger taps (3a) then produce the researcher’s notes on the language-related difference, followed by access to the abstracts and finally the full .pdfs of the relevant papers (Hickok & Poeppel, 2004; Wise et al., 2001). Level of Generality also takes in high-level theoretical models such as Milner and Goodale’s (2008) perception-action model of the dorso-ventral system.

Figure 3b shows how a decrease in Level of Generality might take the researcher towards information about specific cell-types and specific microstructure in the selected domain of the human brain, or towards that least general data – the details of single-case studies of impairment.

Figure 4a shows how Vantage Point (i.e. the particular perspective adopted) can be manipulated to see research that monitors effects “within” the lower dorsal stream looking “upwards” into the higher dorsal stream and beyond. It is with Vantage Point that the abstractions made can become really elastic, in contrast to the reductionism too often seen in cognitive neuropsychological theorising. Thus, situating Vantage Point inside the dorsal route, and looking “upwards” to the higher reaches of the dorsal stream and beyond temporarily expands the upper dorsal route to encompass all of its dealings with the rest of the brain. In 4a, “orienting” has been clicked to reveal notes on how executive behaviour by the viewer can reorient the viewer to control the visual input to the dorsal and ventral streams. Further access to relevant papers (on differences between processing in the upper and lower halves of the visual field) is also included on the screen.

Figure 4b shows how looking “down” from the dorsal route to the ventral route temporarily expands the ventral route to encompass all its interactions with the rest of the brain. Thus, for instance, Obhi and Goodale’s (2005) study of landmarks on pointing movements places the researcher in the dorsal stream taking account of input coming from the ventral stream.

Critically, all these judgements about the abstractions employed in different studies are made by the individual researcher and eventually laid down in an intuitive way using the graphical tool. It is as if we swam around and through the brain, squinting and peering at a particular structure from every angle, trying to imagine where its processing came from and where it is going. In contrast, the conventional approach to cognitive neuropsychological theorising too often considers just one view – a sharper or blurrier snapshot from just one birds-eye angle.

The pilot research will address research on the dorso-ventral visual streams – “one of the most exciting, important, and productive debates in recent decades” (Clark, 2009). Edinburgh is an international focus for research on this issue. Concern for specifics is a principle of the explicit
philosophical approach taken in this proposal; there is no question of trying to “prove” any of the philosophical principles involved. Publishable papers on the dorso-ventral debate are the most important immediate goal. Developing the intellectual procedures required by the approach is a richer, overarching goal. Developing the software eventually required by the approach is a later goal.

Our 3-months pilot study will do following:
(a) Carry out the scientific groundwork that validates the approach. The researcher will analyse the large dorso-ventral literature, recording the specific abstractions made in each piece of research, producing the scientific content for the graphical tool, and making the intellectual procedure more rigourous.
(b) Generate the specification for the graphical tool through interaction with potential users (i.e. researchers in cognitive neuropsychology) and produce a mock-up of that tool.
(c) Research sources of longer-term funding, with particular reference to European funding possibilities on reading from novel interfaces.

References
Schenk, T. & McIntosh, R.D. (2009). Do we have independent visual streams for perception and action?, *Cognitive Neuroscience. DOI: 10.1080/17588920903388950*

3. How is it novel? What is exciting about it?
This proposal is novel and exciting because:
(a) it involves a philosophically nuanced approach to theorising in cognitive neuropsychology;
(b) it concerns a hot psychological topic;
(c) it will eventually be realised in a sophisticated graphical interface;
(d) it will develop the best current research practice into a new, comprehensive scientific paradigm for cognitive neuropsychological theorising.

Mind-maps and similar graphical ways of connecting information are not new. What is new in the current proposal is (a) the explicit philosophical grounding for the work, (b) the tight, principled, interdisciplinary application to cognitive neuropsychology (c) the rich multidimensionality of the resulting representation of the theorising, situated in a very intuitive interface. We have an exciting, interdisciplinary team involving different expertises from across and outside the College of Science and Engineering.
4. **What will you do next? What opportunities will it open up?**

After the pilot study we will:
(a) apply for longer-term funding to create the GUI, and to develop the approach in teaching;
(b) develop the approach in ongoing research into the dorso-ventral system;
(c) develop the theoretical approach for publication in *Biology and Philosophy*;
(d) apply the approach locally in teaching and research.

5. **What constitutes success? How risky is it?**

Success is measured by:
(a) approval by potential users, *i.e.* academics whose teaching and research involves the dorsal-ventral system;
(b) generation of insightful, testable hypotheses;
(c) generation of publishable outcomes;
(d) physical pleasure experienced by novices using any system eventually produced.
(e) indications of the intellectual usefulness of the approach, apprised from the detailed debriefing of the researcher carrying out the project (who does not have specific expertise in the dorso-ventral debate).

The certainty is that conventional research in cognitive neuropsychology will continue along its current path, encountering more critical versions of the problems discussed above, as the literature becomes larger.

6. **What resources do you bring to the project?**

(a) Knowledge of a number of cognitive neuropsychological literatures, specifically the dorso-ventral system.
(b) Current research on abstraction in cognitive computational modelling.
(c) Expertise in graphical interfaces.

7. **What resources and expertise do you need? Have you already identified sources for these, *e.g.* suitable staff available for short-term employment?**

A postdoctoral researcher experienced in assimilating cognitive literature will be required for three months fulltime. Dr. Matthew Roberts has been identified.

8. **What shared resources, if any, will the project create?**

The scientific results of the research will be open-source. The GUI will be something we wish to develop more carefully; the proposed pilot project will only produce a proof-of-concept mock-up of the GUI.

9. **What is the timescale?**

Three months, starting immediately.

10. **Projected costings**

Three months’ salary (from March 1st): £10,861. No other costs.
Figure 2. 2a and 2b: Changing the **Extent** of the brain under consideration, from just the dorsal system to the dorsal *and* the ventral system. Increasing **Extent** increases the scope for interesting interactions and contradictions to be expressed and understood. 2c: Increasing **Level of Generality**, bringing up **Signage** denoting further information and theory on dorso-ventral implications for language, and for its role in different species (in the frog and the hamster, in this case).
Figure 3. Increasing **Level of Generality** brings up information on more general levels of structure and function related to the dorso-ventral system. Previously clicking on “language” in 2c has brought up the researcher’s notes on a similar dorso-ventral distinction in language processing, and makes the relevant abstracts and full papers also clickable. “High-level” theoretical glosses on the whole dorso-ventral system (e.g. Milner and Goodale’s, 2008, *perception-action* model) are also reachable via this type of abstraction. Decreasing **Level of Generality** (as in 3b) has brought up links to information about specific cell-types in the human brain. It might also bring up idiosyncratic data from single-case studies.
Figure 4. Changing Vantage Point: the location of the viewpoint defines the behavioural and neurophysiological effects being considered, so that, for instance, a very elastic temporary abstraction makes the “upper ventral stream” encompass all the input and interactions of the brain viewed from the lower ventral stream, looking upstream. 4a shows a case in which signage listing “orienting” was clicked to reveal notes about how executive control can cause the viewer to change visual fixation so as (potentially) to change the respective inputs to the dorsal and ventral streams. The relevant abstracts and full .pdfs are flagged in the lower part of the screen.

4b shows the Vantage Point located in the upper dorsal stream looking “down” at the ventral stream. It expands the latter to encompass all the input and interactions of the ventral stream with the rest of the brain. Previous finger-tapping on “visual context” has led to the clickable information shown in 4b on Obhi and Goodale’s (2005) study of landmark information.