The Brain as Game

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This paper takes Wellcome Collection's casual Flash game *Axon* as the starting point for an investigation of the representation of the human brain in scientific and popular visual culture. It looks at the re-emergence of the neuron as a dominant image of the brain, against a historical background of brain-mapping technologies, from phrenology to fMRI. It then considers the representation of the brain in videogames in particular, in both entertainment and educational contexts. The role of rules in both games and brain development is explored, as is the idea that videogame interaction may be related to humans' unique spatial understanding of the world. The paper concludes that while *Axon* suggests some of the possibilities of videogames in communicating neuroscience, games offer a larger potential for helping us to understand the brain than has currently been exploited.

Human body. Brain. Video games. Visual culture.

1. INTRODUCTION

In March 2012 at Wellcome Collection we published the latest in a series of casual online games designed to engage audiences with the subject matter of our exhibitions. In this case, the accompanying exhibition was 'Brains: The Mind as Matter', an exhibition dealing with the material culture of the human brain, examining the ways in which it has been treated, preserved, studied and manipulated.

The game, *Axon*, is based on observations of foetal neural growth. The concept emerged from a collaborative brainstorming session convened by the authors at Wellcome Collection that included the exhibition's curator Marius Kwint, neuroscientist Richard Wingate and games agency Preloaded. This kind of collaboration is at the heart of our approach to making games: we understand that the kind of learning that games make possible only works when the content is embedded in the gameplay (Birchall and Henson 2012).

Through rapid and skilful clicking, *Axon*'s player selects protein targets to stimulate the growth of a neuron's axon (the central fibre of the cell along which electrical pulses will travel once connections are made with other neurons via synapses) (Fig. 1). The longer they play, and the more protein targets they hit, the longer their axon (measured onscreen in μm) grows. The player loses once they run out of

protein targets within their shrinking 'circle of influence' (Fig. 2).

The science of neuron growth is explained within the game (Fig. 3), and when the player is given their score it is accompanied by a link to a Wikipedia page describing a neuron of roughly similar size to the one they have just 'grown' (Fig. 4). In this paper, however, we seek to go beyond 'learning outcomes' and ask what the implications of a game about neuroanatomy where the player 'plays' the brain might be.

Through looking at the representation of the brain in both scientific and popular visual culture, we then look at its representation in video games in particular, before returning to *Axon* to suggest that its focus on the individual neuron offers an extension of a new visual understanding of the brain, and consider how an interactive video game might activate a different understanding of the brain as a dynamic, multiplicitous and fluid entity.

2. IMAGES OF THE BRAIN

Compare a late nineteenth century phrenological map of the head (Fig. 5) and a contemporary fMRI scan of the brain (Fig. 6). Phrenology is a now-discredited pseudoscience and functional magnetic resonance imaging not only uses sophisticated contemporary technology but is also subject to rigorous scientific method and peer review. Both

Figure 1: A screen from Axon showing growing axons and protein targets.

Figure 3: The science pages from Axon.

Figure 2: A screen from Axon showing the shrinking circle of influence.

Figure 4: The results screen from Axon showing neuron type linking to Wikipedia.

systems, however, share an interest in both localising certain cognitive functions (whether 'hope' and 'veneration' in the phrenological diagram or the more mundane 'recognising familiar faces' in the fMRI) and in mapping the whole of the brain. While debates about the scientific merit of mapping cognitive function to blood flow in the brain animate the scientific community (Diener 2010), the image of the 'brain scan' as a map of both the personal and general brain has long dominated the popular visual imagination of the brain.

One alternative to the mapped brain is the image of the neuron. In their paper 'Imagining the brain cell: the neuron in visual culture', Marius Kwint and Richard Wingate (2006) trace the history of imaging the neuron from Golgi's staining technique (Fig. 7) and Ramon y Cajal's structural sketches of individual neurons (Fig. 8) to contemporary representations of its complex dendritic form. These are both simulated, like Michael Hausser's images of pyramidal neurons made using the TREES toolbox (Fig. 9) and 'real', like Jeff Lichtman and Joshua Sanes' 'brainbow' images of mouse brains in which neurons have been genetically modified to randomly fluoresce in different colours; a confocal microscopic photograph then allows the eye to see them as separate entities occupying a three-dimensional space (Fig.10). Kwint and Wingate suggest that it is time for 'the neuron to step up and take its place in twenty-first century visual culture'

In the popular visual culture of the brain, the image of the neuron lags behind the image of the brain as either substance or environment: the food of zombies, or the territory the intrepid scientists of *Fantastic Voyage* have to navigate. Manipulation of the brain is often a source of fear: in James Whale's 1931 film of *Frankenstein* the evil of Boris Karloff's stumbling monster spring from his illicitly transplanted criminal brain (Kwint 2012). The brain without a body is often a symbol of the dangerous and perverse power of the intellect isolated, as in the *Dr Who* serial *The Brain of Morbius*; or its parodic reflection: *Futurama*'s giant brains, or the brain-headed Martian's of *Mars Attacks*. Neurons themselves are harder to find: the five animated 'neurons' in the BBC children's programme *Nina and the Neurons* bear little resemblance to actual neurons, but instead represent the five senses.

3. THE BRAIN IN VIDEO GAMES

Games, like films, have featured various representations of the brain in some form. The gothic appeal of the naked brain is perhaps responsible for its appearance as a player's opponent, one of the 'baddies', in a number of games. In *Metroid*, Mother Brain is a huge and

monstrous brain in a jar to which she is connected with cables, one eye leering out from her centre and metal spikes protruding from the top (Fig.11). The imagery and character clearly made an impact, and she was named number nine in IGN's top 100 video games of all time (IGN).

Similarly disembodied brains appear as baddies in *Duke Nukem 3D* and *Duke Nukem Forever*, where you might find yourself facing swarms of apparently very angry eight-legged flying Octabrain (Fig. 12). These could perhaps have been inspired by the more grounded spider brains from the earlier first person shooter, *Doom*. The *Gradius* series, scrolling shooters from Konami that were first published in the 1980s, features a boss called Brain Golem, a brain floating in space with arms and, like Mother Brain, just one eye. The first game also has a brain as its final boss, another bodyless brain which in this case is controlling the mothership of your evil adversaries.

Brains have also been food in various zombie games, and the subject of a quest, in Monty Python's predictably silly game from 1990. But very few games have used the brain as territory as *Axon* does. One example is *Brainpipe*, which represents the brain as bright neon tunnels of light and shapes which the player must move through, dodging obstacles and collecting "illuminated glyphs" (Fig. 13). There is only the slightest nod to real brain structure in the names of the areas you pass through: "You are now entering the hyperthalamus" states the game as the player begins.

A fleshier, though still fairly unrealistic, vision of the interior of the brain appears in an educational game called *Neuromatrix*, part of a suite of games about brain science from Morphonix. Here the brain is a landscape the player must travel through in search of evil nanobots, intent on destroying the brain (Fig. 14). Another educational game released in 2011, *Wondermind* (also from Preloaded for Tate, and part-funded by the Wellcome Trust), uses metaphor to describe the functions of the brain, and in one mini game represents brain pathways as garden paths that must be kept in use to remain open (Fig. 15). The evil, disembodied brain may have been the more dominant representation in the video game in the past but that perhaps is changing, and there would seem to be much untapped potential in using the brain as either the subject of a game or its stage.

4. AXONS AND NEURONS

When developing our own game about the brain, we started from the idea that if we could find some key rules about brain behaviour, especially at the cell level, then we could turn those rules into the

Figure 5: A late-nineteenth-century phrenological map of the head

Figure 6: A contemporary fMRI scan of the brain

Figure 7: A human neocortical pyramidal neuron stained via Golgi technique

Figure 8: Ramon y Cajal's sketches of individual neurons

Figure 9: Michael Hausser's computer-generated images of pyramidal neurons

Figure 10: Jeff Lichtman and Joshua Sanes' 'rainbow' images of a mouse's brain

rules for a game. These rules would need to be simple and game-like and translatable into something playable, coherent and fun. If we could do this, it would have the effect that learning the rules of the game was the very same thing as learning something about the brain, a particularly interesting idea to us.

During a day of collaboration with Preloaded, Richard Wingate and Marius Kwint, we began to come to the conclusion that these rules could be found in the way that neurons use protein targets to grow within the developing embryo. At this point, they must also 'out-compete' other neurons or risk dying away. These features already sounded somewhat game-like. They became the basic principles of *Axon*, with a few other gameplay mechanics (such as power-ups) to add to the entertainment value: of course the game had to be fun to play as well.

In their 2006 paper, Wingate and Kwint suggest that 'the neuron seems poised for rebirth as a source of artistic inspiration' (Kwint and Wingate 2006). In developing *Axon* it was our intent to use the neuron as the starting point not only for gameplay, but also aesthetically. There were two key points of reference for *Axon's* design. The first was the film of neurons developing in a chicken embryo which features on the 'science pages' of the game (Fig. 16). The second was the 'rainbow' imagery mentioned above; fluorescent neurons, usually on a black background, associated with the work of researchers into connectomics.

These were the starting points, but over the development of the game the design pushed these concepts into new territory. Preloaded exploited some of the sophisticated capacities of the Flash medium: not only is each neuron created by a player during a game unique, the game's opening animation is subtly different each time the game is loaded, making use of generative computational techniques that mimic the growth and branching in biological behaviour. It was this image of the branching reaching axon that we hoped would be the defining and lasting image from the game (Fig. 17).

We were interested, however, to see whether what this fairly unusual use of neuronal imagery in *Axon* would concur or conflict with players' existing mental images of the human brain. In an evaluation survey attached to the game, we asked players 'Did playing *Axon* change your mental image of a human brain?' Perhaps surprisingly, 46% of those surveyed replied that '*Axon* was similar to my existing mental image of the brain' (Fig. 18). This suggests that we may be close to the ascent of the neuron as a prevailing image of the brain in visual culture. When asked for more detail, players said

that it had made them see the brain as being more connected, dynamic and "more alive, less mechanical" as well as more "complicated and beautiful".

5. PLAYING THE BODY

As well as seeing biological structures in new ways, interactive digital media also offer the opportunity to understand them anew. Natasha Myers' (2008) ethnographic study of protein crystallographers explored the extraordinary extent to which their understanding of the complex structure of proteins is based on embodied and gestural communication. This held true even when protein models were manipulated through computer-based modelling and representation programmes. The body-work of understanding the protein structure is done through the computer interface, as 'digital models acquire a materiality and tangibility through their manipulation onscreen'.

Though Myers' study was of scientific professionals, there is evidence that some of the same principles of spatial reasoning and embodied thought apply to non-expert game players. The crowdsourced protein structure solving game Foldit hit the headlines last year when players solved the structure of a protein belonging to a close relative of the HIV virus found in monkeys (Khatib *et al.* 2011). The distributed work of protein solving had previously been done by the purely computational distributed software Rosetta@home, but Foldit's success suggests that some molecular problems are more amenable to solution by non-expert human beings than computers. Foldit's designers Cooper *et al.* (2010) suggest that 'humans' innate spatial reasoning ability makes it possible for non-experts to make useful contributions to this problem'.

Axon is neither an expert tool nor crowdsourced science. But the same relationships between spatial reasoning and digital interaction may be at work, albeit reversed. Rather than using the spatial reasoning of humans to produce answers, *Axon* intimates that brain development is a fluid, dynamic process by asking the player to physically and spatially guide that process. The experience of directing and activating a simulated neuron through developing brain tissue offers an alternative to typically 'interactive' models of the brain (BBC Science & Nature) which offer only a chance to examine the brain's 'map' in the manner of phrenology or fMRI. *Axon* may have more in common as a game with the scientifically dubious *Brainpipe* than drier educational models.

Figure 11: Mother Brain, as depicted in *Metroid* and *Metroid: Zero Mission*

Figure 12: An Octabrain in *Duke Nukem Forever*

Figure 13: A screen from *Brainpipe*

Figure 14: Inside the cerebellum in *Neuromatrix*

Figure 15: Pathways game in *Wondermind*

Figure 16: Still from Richard Wingate's film of neurons inside a developing chicken embryo

Figure 17: Branching neurons in *Axon*

Did playing Axon change your mental image of a human brain?

Figure 18: Survey answers to date on whether Axon changed players' mental image of the brain.

How did you find out more about neurons and the brain?
(please choose as many as apply)

Figure 19: Survey answers to date on the ways in which players found out more about the brain after playing Axon.

6. CONCLUSIONS

As we write, *Axon* has been played around the world, on our website and through dedicated casual gaming portals, nearly two million times. Provisional results from our survey of over 4,500 players suggest that the majority (75%) felt they learned something from the game, and that of those, 80% felt that they learned something about 'how neurons grow and connect in the brain'. Over 70% of respondents were also prompted to find out more under their own direction (Fig. 19). We feel that it has been a success in educating people about and engaging them with contemporary neuroscience.

If *Axon* is also part of the ongoing resurgence and rebirth of the neuron as part of the visual culture of the brain, it adds two new dimensions to that visual culture through virtue of being an interactive, playable game. The first dimension is that of rules. Good rules make a good game: the balance between the elements of goal, jeopardy and score is essential to satisfying gameplay. Our experience of making *Axon*, taking as one of its starting points the rules of brain development, suggests the potential for mapping the rules of biology onto the rules of games; or at the very least conveying the idea of those rules.

The second dimension is that of physical interactivity and the relationship between the player and the things they are manipulating. Active participation rather than passive engagement engenders a different view or 'feel' of the brain, not only at the level of the neuron rather than the whole brain, but also in the understanding of the brain as a place of circuits and connections.

Axon is scratching the surface of what it may be possible to communicate or learn about the brain through the medium of games. Its global reach, and our ongoing research, however, suggest that games, not least through being fun, challenging and exciting to play, have a power far exceeding that of static representations to communicate some of the intriguing realities of our most complex organ.

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