The phenomenology of *Angry Birds*: Virtual gravity and distributed proprioception in videogame worlds [draft version]

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Seth Giddings, Winchester School of Art, University of Southampton
s.giddings@soton.ac.uk

Abstract

This article explores the nature of sensation, perception and proprioception in contemporary digital and mobile culture, as exemplified in digital games. It argues that the application of theories of the phenomenology of perception to digital media and games needs to be extended and adapted to acknowledge and describe the sensing and proprioceptive abilities of technological bodies (both hardware and software) as well as human bodies. The article explores the idea that the embodied 'feeling' (proprioception) of virtual physics, particularly gravity, in gameplay experience must be understood as distributed across and through human and non-human sensing bodies. It will take the popular mobile game *Angry Birds* as a starting point, but will then explore the achievement of distributed proprioception in other games and games hardware more broadly.

Keywords

Videogames, virtual physics, virtual gravity, phenomenology of perception, postphenomenology, machine sensing

Introduction

The virtual worlds of videogames are formed as much from simulations of physical forces as from simulated space. Virtual physics such as friction, collision, gravity and acceleration are experienced by players not only visually, as would the movement and action viewed on a cinema or TV screen, but are also *felt*. Somewhere between the on-screen action, the algorithmic and interactive operations of the game software, and the visual and tactile feedback between the game hardware and software and players, virtual forces have actual effects. This article explores the nature of sensation and proprioception in digital gameworlds. It argues that the application of theories of the phenomenology of perception to digital media and games needs to be extended and adapted to acknowledge and describe the sensing abilities of technological bodies (both hardware and software) as well as human bodies. Proprioception is a key concept here. Broadly speaking proprioception is the sense that a body (human or otherwise) has of its own position and movement in space, for instance how a blindfolded person knows whether their arms are by their sides or held up in the air. I will argue that the proprioception of virtual physics (particularly gravity) and their effects in gameplay experience, must be understood not as simply the human player's internal sensing of position and movement, but as *distributed* across and through human and non-human sensoria. I will take the generation of virtual gravity by the popular mobile game *Angry Birds* (Rovio 2009), among others, to open up an enquiry into the achievement of distributed proprioception across the diverse bodies in digital gameplay.

A glance over the shoulder of someone playing *Angry Birds* would tell us little about how it feels to the game. The birds' hardwired irascibility, their epic and eternal conflict with the smugly grunting porcine foes, and the rickety, puzzle-like architecture are reminiscent of Loony Tunes, particularly *Road Runner*. Their world also echoes the dyadic simplicity of earlier computer simulated ecosystems with predators and prey, such as *Foxes and Rabbits*. This world too is a simple, eternal, war between two species: virtual nature, red in tooth and beak. Its microtemporality is repetitive and minute, its landscape and structures nothing but architectonic puzzles.

However, this article is less concerned with the game's visual genealogy in popular animation, nor its simulated zoology than with what its *physical laws* might tell us about virtual gameworlds – and hence videogames as a medium – more generally. Or – to be more precise – it will explore what the game *feels* like – and how it achieves this feeling in its players. The effects of virtual gravity are central to *Angry Birds'* game mechanic and gameplay, and to many other popular videogames throughout the medium's 40-odd year history. There are few popular games for smartphones and videogame consoles that are not built around a model of virtual physics in which simulated gravity, collision, friction, or acceleration is key to the gameplay. Taking the nature and operations of virtual *gravity* in particular, I am concerned here with the relationship between – or co-constitution of – virtual and actual worlds. Not in terms of space, but rather in terms of forces, affects, sensation and bodies – material and virtual, human and non-human.

As mobile phone hardware and software draw on the development of kinaesthetic and sensing technologies in games culture more generally (notably the Nintendo Wii and Microsoft Kinect systems), this game, or more precisely the playing of this game – is indicative of significant yet under-acknowledged developments in everyday digital technoculture. It does not just model a world of virtual physical forces – acceleration, gravity, momentum, collision, etc. – it brings into being new relationships, new circuits, between the human sensorimotor system and computer simulation.

Recent theoretical and empirical work in game studies on gesture, technology and play (e.g. Ash 2010; Crogan 2010; Giddings and Kennedy 2010; Giddings 2014; Simon 2009), and on videogame play as 'assemblages' of human and non-human actors (Taylor 2009; Banks 2014), demands that we do not limit our understanding of sensing, and kinaesthesia to the human players. Building on, but critiquing, the influence of the phenomenology of perception on-screen studies and game studies, I will explore the nature of human and non-human proprioception in everyday gameplay and ask how the sensing of gravity is distributed and achieved across the virtual and actual, software, hardware, nerves and perception, across human and non-human players. I would suggest that we think seriously about digital media technologies not only as *extensions* of the human body, but as sensing bodies themselves, alongside – in collusion with – human bodies, a collusion that we might think of as *distributed proprioception*.[1]

Virtual gravity in *Angry Birds*

The game mechanic of *Angry Birds* is simple and accessible. The player's only significant input, in the early levels at least, is the triggering of the catapult by placing a fingertip on the waiting bird (on the phone's touchscreen), drawing the catapult elastic taut through a single slide of the finger, and releasing by removing the fingertip from the screen. The momentum of the bird on release, and its initial trajectory, are determined by the length of the stretched elastic and its angle, all established by the same single finger-swipe. Angle and tension are the only variables accessible to the player and the relationship between the two must be carefully judged for maximum or strategic effect.

However, the simplicity of this tactile and gestural interface belies the complexity of the communicational and perceptual circuits between the game's virtual world and its player's actual, embodied world as they come together and constitute the gameplay event. The simple physics is made experientially vivid through a combination of audio-visual feedback and the game software's processing of the player's gestural input, as Brendan Keogh explains:

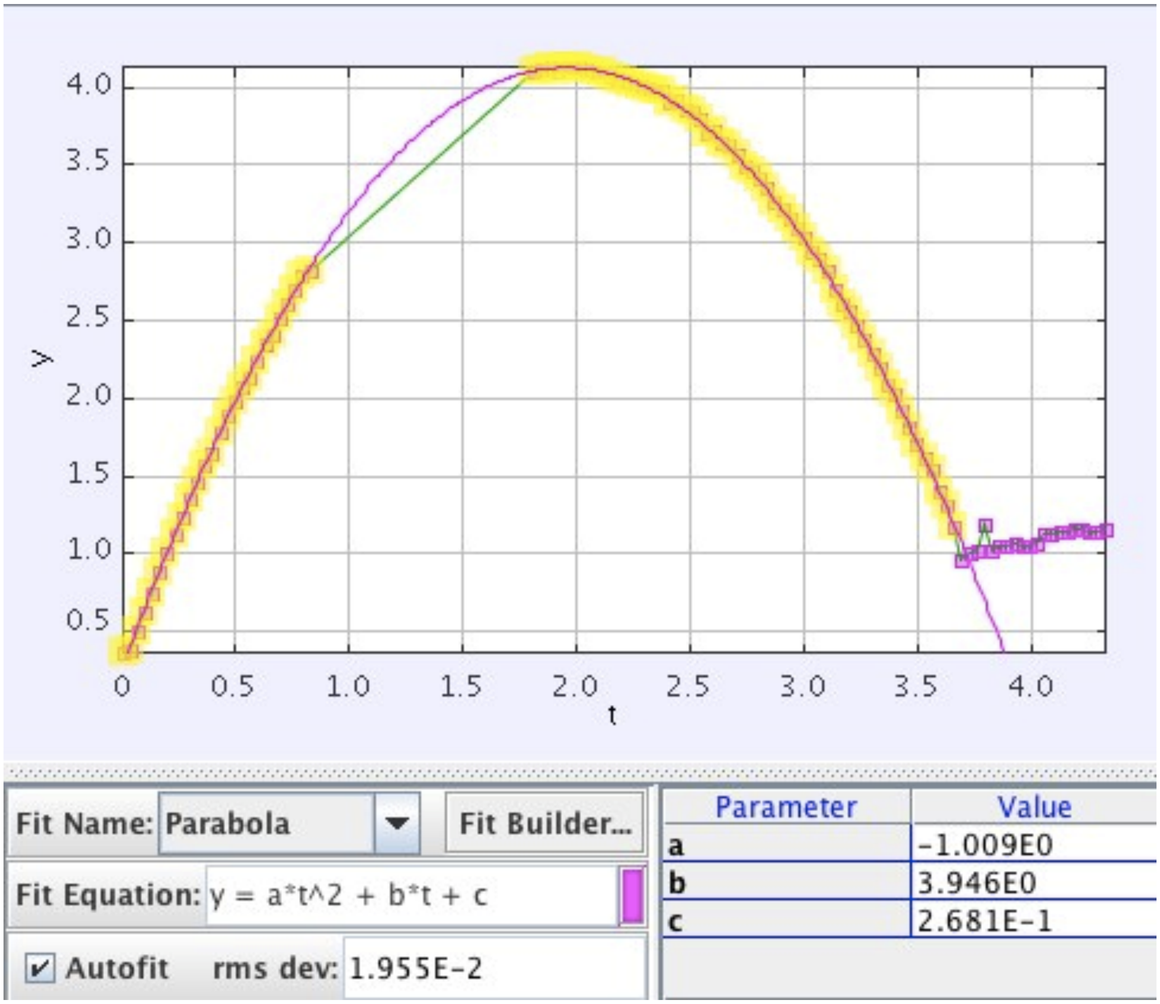
> Angry Birds's audiovisual design gives the game a sense of physicality. When the slingshot is drawn back, it makes a rubbery, stretchy noise, giving a sensation of tautness under the player's finger. Birds feel weighty as they fly through the air on a slow parabola and hit the structures with a satisfying 'thud.' The player makes the smallest input (dragging a finger) and the game offers the satisfaction of watching entire towers fall down via simulated physics, amplifying the player's input with excessive feedback. (2014: 272)

This model of gameplay – corporeal and cybernetic, mediated and kinaesthetic – underpins this article's approach. I am particularly interested in how virtual movement and action is 'felt', how an angry bird might 'feel weighty' when the game circuit seems to allow for no direct physical or proprioceptive feedback between virtual and actual bodies. How the 'weight' of simulated objects in movement is felt, and hence the nature of virtual gravity, will be the focus.

What is virtual gravity?

The interplay between elastic tension and angle of launch is only part of the game's virtual physics. Propelled high into the air, the bird traces a graceful arc as its momentum is countered by the pull of a simulated gravity. Most videogame worlds are consolidated with a simulation of gravity, sometime its workings are as simple as keeping their characters on the ground, rendering predictable movement when they jump, or plunging them plausibly to their death when they stray from the edge of a cliff or platform. In many games, such as *Angry Birds*, virtual gravity is fundamental to the play mechanic and appeal, and its pull has been felt throughout the history of computer games. The development of one very early game, *SpaceWar!* (1962), was transformed by the introduction of virtual gravity. This two-player game featured battling spaceships, animated on the oscilloscope display of a PDP-1 mainframe computer was changed from a eye-catching example of real-time interaction into a compelling game by the addition a 'sun' with a simulated gravitational pull to the centre of the game screen. With this a key strategic element was introduced. Rather than a simple shoot 'em up relying on motor skills, now players had to work with the sun's gravitational pull. This would 'give you speed as you circled it, but if you weren't careful and got too close, you'd be drawn into the sun' (Levy 1984: 63). This virtual gravity opened up new possibilities for players to develop their own strategies and play styles. These included 'the 'lie in wait' strategy, in which the player 'stayed silent while the gravity whipped you around the sun, then straightened out and began blasting torps at your opponent' (Levy 1984: 64).

So, what is virtual gravity? How does its simulated pull act on actual bodies? On one level, virtual gravity is nothing but the operation of computer code on objects within the game as a program. In a playful but incisive article in *Wired*, Rhett Allain (2010) has decoded the simulated physics of *Angry Birds*, reverse-engineering and analysing the game's relationships of scale and force. Allain's analysis highlights the relatively simple mathematics that generate virtual gravity, and, by extension, the fact that virtual gravity has no direct physical relationship with actual gravity. The interaction of mathematical variables in the algorithms of a dynamic software simulation, the 'gravity' here is merely graphical output (see Figures 1 and 2). There are no bodies with mass, and hence actual gravitational attraction, in this gameworld. The simulation of gravity is effected by the plotting of a bird's movement through the relationship between the x and y axes, not by the action or pull of the ground. However the graceful parabolic trajectory produced by this interplay, despite its algorithmic generation and the stylized and abstracted cartoon world that it crosses, 'feels' convincing and somehow familiar from our actual experience of, say, firing a catapult or throwing a ball.



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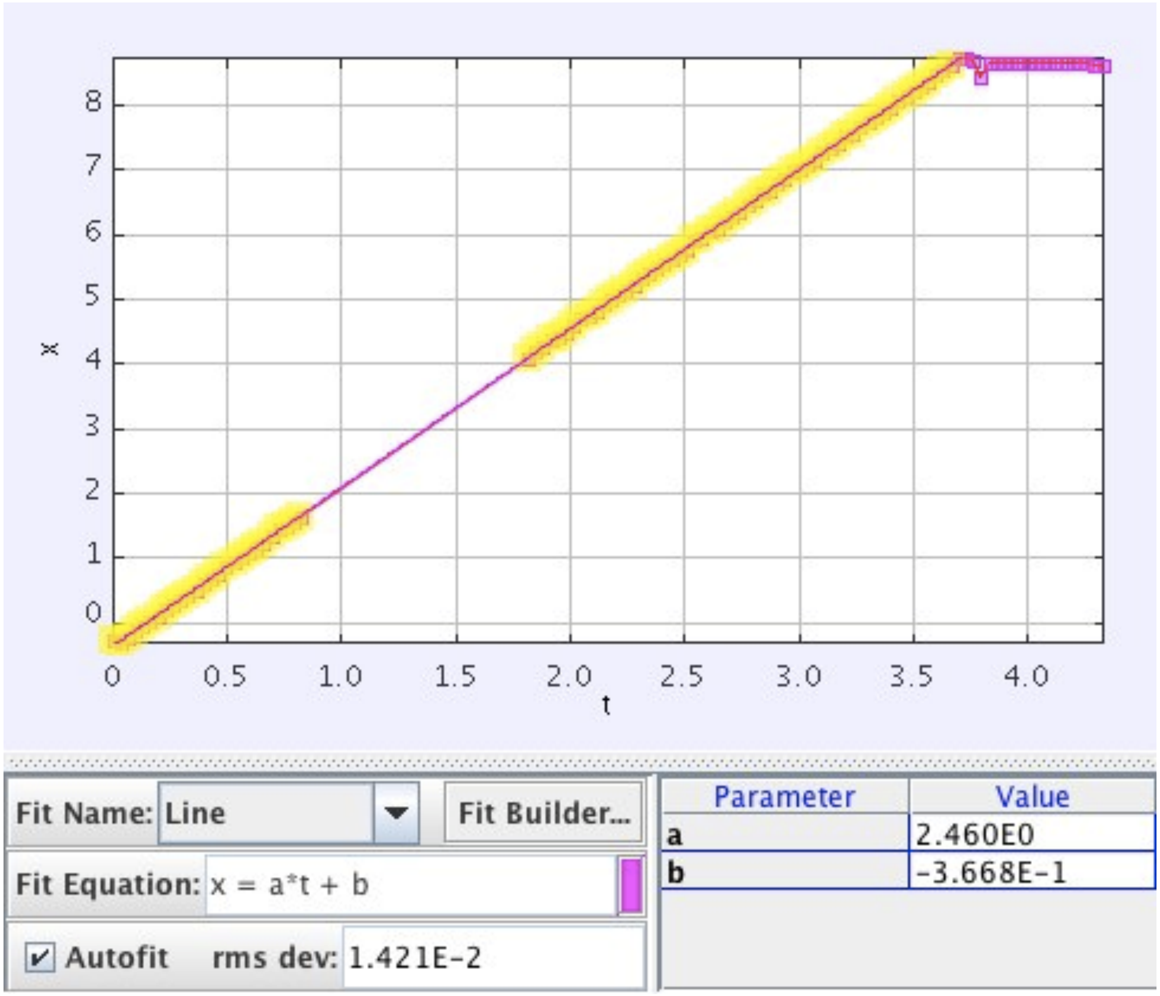

Figure 1: Top: Horizontal motion of an Angry Bird in flight (Allain 2010). Courtesy of Rhett Allain. Bottom: Vertical motion of the Angry Bird in flight (Allain 2010). Courtesy of Rhett Allain.

The player then is not shooting the bird-projectile in a straight line, as the first-person shooter player might with his or her more familiar armoury and linear ballistics.[2] Rather, like aficionados of tank-warfare simulation games, the player must predict the possible curved lines of flight of missiles up and over the landscape, and hence range as well as direction of aim. Whilst he or she does not sense the drag of virtual gravity in their own viscera, they must think it, *anticipate* it as possibility. Similar code could generate on-screen movement that simulated quite different physical forces, for instance the forward motion of a boat or swimmer crossing a river as they interact with a strong current. They would be pushed sideways rather than pulled downwards, but the arc of movement could be broadly the same. Importantly though, the player's sensori-motor investment in the bird's trajectory, his or her visual tracking of its flight, and his or her embodied memories of other missile-based games, together form an experience that cannot be separated into its constituent stimuli, nor straightforwardly translated into other simulated movement. So when we play *Angry Birds* the pull of virtual gravity is a synaesthetic assemblage of screen imagery and movement, player investment through interactive agency (and moments of loss of control), and memories of other, actual, interactions of play and gravity such as ball games or swings. This feeling takes the form of either intense satisfaction and kinaesthetic pleasure – as the bird hurtles towards precisely the spot that will collapse the tottering pieces of scaffolding that will dispatch the level's last pig, or – as the player realizes that the bird will overshoot and bounce harmlessly beyond the smugly grunting green snout of this same last pig – in a palpable yet impotent willing of the arc to tighten itself, for gravity to exert an extra pull, for the bird to plummet faster.

The phenomenology of perception and digital culture

Game studies offers a wide range of theoretical and empirical approaches to studying players' embodied relationships with videogame images and action. For the purposes of this article, I will initially focus on work that addresses Vivian Sobchack's writing on the perceptual phenomenology of contemporary screen media (1994, 2004; see also Marks 2002). Sobchack has adapted and applied Maurice Merleau-Ponty's work on the phenomenology of perception (Merleau-Ponty [1945] 2002) for cinema spectatorship, and her work has proved particularly influential on game studies.[3] Put very simply, Sobchack takes Merleau-Ponty's insistence on the lived body's integral role in sense-making, 'sense' in terms of both knowledge or meaning and bodily sensation or feeling, that the 'processes and logics of sense-making […] owe as much to our carnal existence as they do to our conscious thought' (Sobchack 2004: 4). At the cinema then, our experience is more than audio-visual and cognitive, our ears, eyes and minds are inseparable from the rest of our body and senses, lived experience and memory. These 'complete' the experience, our sensual engagement with the technologically mediated world projected before us:

> Even at the movies our vision and hearing are informed and given meaning by our other modes of sensory access to the world: our capacity to proprioceptively feel our weight, dimension, gravity, and movement in the world […] the movies provoke in us the 'carnal thoughts' that ground and inform more conscious analysis (Sobchack 2004: 60).

Bryan G. Behrenshausen (2007), Tim Crick (2011), and Melanie Swalwell (2008) all draw on Sobchack's theorization of the embodied nature of cinema spectatorship to explore embodiment in digital game play. On one level then, videogames are screen media and operate a similar play of animated imagery on the vision of their players. On this sensual level, the videogame player's physical experience shares some of its aspects with intense engagements with other screen representations in which the forces of gravity play an integral role, particularly in action cinema and television where the audience is gripped, willing the protagonist to make the near-impossible leap over a ravine, or to recover his or her balance as they teeter on the edge of a tall building, grappling the enemy. As Tim Crick puts it,

> Similar to filmgoing, videogaming is a holistic experience and it is precisely our capacity as sensual embodied beings in the world that allows us to engage with a game's artificial world in a way that would engage those senses in real life. Our imagined perceptions are, as Merleau-Ponty claims, just as much a part of experience as nonimagined ones: 'My field of perception is constantly filled with a play of colors, noises, and fleeting tactile sensations, which I cannot relate precisely to the context of my clearly perceived world, yet which I nevertheless immediately 'place' in the world'. (2011: 266)

These writers however are careful to acknowledge and address the key differences between cinema and videogames in their embodied and sensual pull on their viewers and players. Swalwell for instance, explains how the interactive and performative demands made of the player by a videogame necessitate not only embodied experience and memory of sensations (as does cinema) but also a training and habituation of bodily movement and performance, 'kinaesthetic knowledge' (2008: 78).

Virtual gravity is just one of a range of videogame features that address the player as an embodied and sensual being, however it is generally overlooked yet integral to many games' appeal, and, as will be explained below, offers a critical insight into embodiment and sensing bodies in postdigital everyday life. The phenomenological concepts set out above will help to explain its workings, however in their tendency to centre the human body as the site of sensing and sensation they do not fully account for proprioception in digital game play. I will return to this point, but first will briefly explore why gravity itself is worthy of critical attention: from the nature and significance of *actual* gravity for biological embodiment and proprioception, to some of the anxieties that the ostensibly gravity-free *virtual* realities of digital media have generated.

Gravity, ecology, virtuality

In a book on the ecology of children's imaginative play Edith Cobb (1977) offers some rich ways of thinking about the body, mind, play and proprioception in a holistic, ecological framework. Cobb was a contemporary and friend of Margaret Mead and Gregory Bateson and as such was part of an intellectual milieu that synthesized anthropology and cybernetics up to half a century before the cybercultural studies of the 1990s. Cobb posits perception as a 'first order drive' shared across the animal kingdom and by even quite simple organisms. Even the most primitive animal, Cobb argues, may be defined as 'something that perceives' (Cobb 1977: 40). The first evidence of mammalian proprioception is the ability of the developing foetus to adjust its orientation within the womb in relation to gravity. Citing Gesell, she asserts that the foetus is a 'growing action system '[…] Its first and foremost function is to adjust to the ceaseless pull of gravity' (in Cobb 1977: 41). Through this function this animal system fundamentally organizes itself in relation to the earth, to up and down. Moreover, this orientation provides a foundation for all experience and behaviour:

> This experience permeates all later behaviour and is the primary adaptation to the logic of nature's aesthetic […]. Eventually 'postural attitude issues into postural action' as these early layers of information extend into behavioural forms and patterns. (Cobb 1977: 41)

Or, more succinctly, '[…] the counterpoint with gravity is fundamental to the effort to know and to be' (Cobb 1977: 43). This antenatal sensing is the first engagement with and reaction to the world, and, Cobb asserts, is developed and explored as the child grows, primarily through physical play and its kinaesthetic joy in body and environment.

Cobb began her research in the 1940s and her account of childhood is of a natural realm largely separate from the adult world and without reference to entertainment media. The general transformations of childhood and children's culture in the developed world wrought by media culture from comics and television to videogames are not of immediate concern to this article, but it might be useful to consider the terms and assumptions bound up in anxieties that directly touch on this essay's interest in embodiment, ecology and gravity in digital media culture. In the early to mid-1990s tremendous excitement and anxiety was generated across popular fiction, journalism and the academy about the apparent, imminent dissolution of a fixed boundary between the physical and biological world and the virtual worlds of computer graphics, simulations and networks. The human mind, as at once informational and intangible (and newly understood as informational and intangible in the light of new computer technologies), was seen as particularly susceptible to transit from the biological to the digital (Featherstone and Burrows 1995). Whilst the wildest claims for the imminent absolute separation of mind and body (with the possible 'uploading' of consciousness out of the body and into virtual networks) were questioned within critical work on emergent electronic/digital media technoculture, a sense of threat to the body and its sense of location and physical presence was evident in much of this serious work. Vivian Sobchack, in an influential and much-anthologized essay, addressed the fate of the body in new electronic screen media and spaces in specifically gravitational terms:

> […] at this historical moment in our particular society and culture*, the lived-body is in crisis. Its struggle to assert its gravity*, its differential existence and situation, its vulnerability and mortality, its vital and social investment in a concrete life-world inhabited by others is now marked in hysterical and hyperbolic responses to the disembodying effects of electronic representation […] […] *constant action and 'busyness' replace the gravity that grounds and*

> *orients the movement of the lived-body* with a purely spectacular, kinetically exciting, often dizzying sense of bodily freedom (and freedom from the body). In an important sense, *electronic space dis-embodies*. (Sobchack 1994: 103, emphasis added)

Given the primacy of gravity to embodied orientation and agency in the world, any such loss of proprioception in the emergent digital media environment would clearly have significant if not catastrophic consequences. Thus whilst – as will be explained (and with the benefit of over twenty years of digital-cultural hindsight) – I do not share Sobchack's diagnosis of the proprioceptive gulf between electronic worlds and human corporeality, the issues she raised – and the theoretical tools she deployed – are of direct relevance to this discussion. I will argue that the virtual worlds of videogames *do* affect a gravitational pull on the body, but that this pull is of a different order to actual gravity alone. To explain this, I will add to the phenomenology of perception and media technology (outlined above) some key concerns and concepts from cybernetics, with the aim of opening out the relationships between human and non-human embodiment and perception, and their interrelationships.

Beyond the phenomenology of perception

To begin to grasp the fundamental differences between videogame play and the viewing of other, non-interactive, popular screen media in their generation of sensory experience, it is useful to note that the physics of, and movement within, the virtual world are not given – as are those in live action film and television – but *designed*.[4] Friction, gravity, collisions, etc. are decided upon, coded, tested and tweaked. Moreover, these variables are not engineered primarily for their visual aesthetic appeal (as are the manipulations of gravity in cartoon and experimental animation for example), but precisely for their *kinaesthetic* effects on the player. The game designer Steve Swink calls this ‘game feel’, a ‘powerful, gripping, tactile sensation’, ‘a blending of the visual, aural and tactile’ (2009: xiii). His advice to students on this key aspect of game design is in effect an applied, practical phenomenology of perception, and his questions resonate with those asked in this article:

> It seems like proprioception is an important clue, because the feeling of controlling a game is clearly something more than visuals and sound alone would indicate. If we can’t actually experience the G-force of a hairpin turn when playing a game, how can we explain why it feels so similar? (Swink 2009: 27)

What then are the implications of this generation of virtual gravity across computational and biological domains for the phenemonology of perception as applied to the study of digital media technology? In addition to the work in film and game studies mentioned above, much of the most interesting recent thinking on technoculture and everyday lived realities has closely engaged with phenomenological and post-phenomenological thought, for instance Paul Dourish and Lucy Suchman’s technomethodological studies of interactive systems (Dourish 2004; Suchman 2006). All are centrally concerned with the inseparable relationships between mind, body, senses and technologies. This attention to embodiment and perception in human-machine systems, when applied to game studies in particular, is a welcome correction to formalist, semiotic and cognitivist approaches to media experience in which the materiality of bodies and technologies is downplayed or elided. It opens up the study of gameplay and culture to the physical, social and technical environment that encompasses the player’s embodied and cognitive experiences.

Merleau-Ponty's famous example of the embodied perception of an everyday technologically augmented human is illustrative:

> The blind man's stick has ceased to be an object for him, and is no longer perceived for itself; its point has become an area of sensitivity, extending the scope and active radius of touch, and providing a parallel to sight. In the exploration of things, the length of a stick does not enter expressly as a middle term. (Merleau-Ponty 1962: 165–66)

Here, in the act of walking, the blind man and his white cane are one, the simple technology of the latter an extension of the former. Crick applies this insight to digital game play:

> the experience of one's body is not fixed or rigid but adaptable to the numerous tools or technologies that may be embodied. This furthers our understanding of how players form an embodied relationship with the avatar in the game world through their habitual mastery of the control device in the actual world. (Crick 2011: 266)

Thus the phenomenology of perception opens up cultural and media research to the integral place of technologies in everyday life, embodied experience, action and cognition. A game controller then 'acts an extension of the player's body', that, once mastered, 'rarely requires any conscious thought to navigate the avatar's body' (Crick 2011: 266).

Yet the usual start and end point for work in this tradition is the human body and human experience. In the spirit of Marshall McLuhan's dictum, media are 'extensions of man', of the human motor capabilities and sensory apparatus (1964). Here, then, media augment the human senses, their agency as sensing bodies in themselves is ambiguous, and certainly not autonomous in their sensate behaviour. Thus, though the phenomenology of perception understands the human body as extended out to its environment through prostheses, media and other technologies, this body remains central, the agential, cognitive and sensorial core from which its augmentations take their direction, meaning and purpose. The phenomenology of perception then persists as primarily a philosophy of the *human* body and sensorium. Following Jaime Banks' suggestion of a postphenomenology of perception – an empirical as well as theoretical refusal to 'impose a priori boundaries or criteria for what constitutes a 'proper' assemblage of play' (2014: 240) – I will argue through the rest of this article that sensory interaction in the digital era is not adequately accounted for in such an anthropocentric world-view. There are heterogeneous bodies in play in media culture in general, and in videogame play in particular. These bodies are non-human and human, synthetic and biological, software and hardware, virtual and actual.

Sensing and cybernetics

Computer science, by practical necessity, has entertained no such qualms about the reality and agency of non-human sensing. Cybernetics and robotics in particular are predicated on it. Norbert Wiener described 'instruments which act as sense organs' ([1950] 1988: 157), and a fundamental characteristic of robots is their ability to sense and respond to their environment (Winfield 2012). In their influential book on digital game design, Katie Salen and Eric Zimmerman identify sensing as one of the three fundamental actions of a cybernetic system. In such a system, the *sensor* 'senses something about the environment or internal state of the system', the *comparator* determines if a change to the system is needed in the light of the sensor's reading, then the *activator* puts that change into operation (2003: 214). Salen and Zimmerman are here explaining the workings of videogame software, but it is crucial to note that cybernetics in general makes no assumptions about, nor establishes any hierarchy between, the elements of a system, be they animal, human or artificial. It follows that there is no necessary a priori division of sensory labour in a cybernetic system. The governor on a steam engine or thermostat in a heating system sense physical pressure and temperature respectively and respond to change the state of the system. For Wiener, the cybernetic system 'corresponds' to the animal as an organism in terms precisely of the sensate:

> the all-over system will correspond to the complete animal with sense organs, effectors, and proprioceptors, and not, as in the ultra-rapid computing machine, to an isolated brain, dependent for its experiences and for its effectiveness on our intervention. ([1950] 1988: 157)

It is important to establish here that Wiener is not using terms such as 'sense organs', proprioception and 'experience' metaphorically or anthropomorphically. They are analogous, they 'correspond' to animal perception. These machines and devices are not biological but like animals they sense and act in response to certain aspects of their environment. Ian Bogost has applied recent philosophical critiques of the anthropocentrism of phenomenology to the technology of videogames, questioning why human experience and perception should be at the centre of the world. The videogame phenomenologist should not 'seek to understand how a human player perceives the sounds and images and tactile sensations that comprise the videogame playing experience' but rather should attend to 'the way the machine perceives its own internal and external states independently of whether and how the human player views or manipulates the artefact' (Bogost 2008: 36). Here then is his description of a videogame platform in which only machinic perception and action is in operation:

> Atari VCS players see the same sorts of images that they would have come to expect from television broadcasts – the sense of a moving image like film. But the Atari VCS *itself* does not ever perceive an entire screen's work of graphical data in one fell swoop. It only apprehends the syncopations of changes in registers. Its components see things still differently: The 6502 processor encounters an instruction read sequentially from program flow, performing a lookup to execute a mathematical operation. The TIA graphics chip modulates sends [*sic*] electrical signal when it witnesses a change on one of its input registers. The RF conversion box coupled to console and television transmutes an endless stream of data into radio frequency. Time moves forward in syncopated bursts of inbound bits and bursts of signal, then of color from joystick to motherboard to television. Despite the fact that the machine must manually synchronize itself to the television display at 60Hz, it has no concept of a screen's worth of image or a note's worth of sound. (Bogost 2008: 36, original emphasis)

This vivid ethology of the autonomous life of an artificial system is a compelling challenge to anthropocentric thinking. However it runs the risk of reinscribing an unhelpful division between the human and the non-human. Technical systems, and entertainment systems such as videogames, are complex and animate objects in their own right, but they are not 'independent' from the human systems – corporeal, cultural, sensate – that they connect with in their everyday operation. In play, we are reminded that the game is designed to initiate, sustain and be constituted by aesthetic, kinaesthetic, social and proprioceptive behaviour with and through human minds and bodies, with and through the game system's own bodies and sensing operations. Virtual gravity as I discuss it here cannot exist solely in either the hardware/software of the videogame system or the body and mind of the human player, it is inseparable from either its biological or technical substrates. The move I want to make then, is to retain attention to human embodiment and perception but to resist re-centring them, to resist seeing technologies (hardware, software, techniques) as peripheral *extensions* of a central human body and sensorium.

Accelerometers and non-human proprioception

Technological systems that sense their own environments or internal states can be dated back to at least the beginnings of the steam age, everyday digital entertainment and communication applications are increasingly predicated on non-human sensing in new ways and in actual space (satellite positioning that facilitates satnav in cars, GPS mobile phone maps, and innovations in location-aware apps and games), and military/corporate research is casting a net of sensing systems over the globe (Bishop 2015). To understand the specific proprioceptive operations of recent videogames however, I will to focus on a key technical component in mobile and gestural games: the accelerometer.

Accelerometers in smart phones and the Nintendo Wii controller (wiimote), allow these devices to recognize their own acceleration and orientation, and respond both physically to the player's movement, and virtually to positioning and action within the devices' software. Linking solid state circuits and simple mechanics, accelerometers measure movement in three axes, and one of their simplest functions is to trigger the rotation of a smartphone display as the device itself is rotated, keeping the screen image oriented to the earth's gravitational pull. Another is the detection of and compensation for 'shake', small movements of a digital camera user's hand that might result in a blurred image. Numerous smartphone games use this proprioceptive sensing as a core gameplay mechanic (though not incidentally *Angry Birds*). In one of the earliest, *Crayon Physics* for the iPhone (Petri Purho 2008), the player drew simple geometric shapes to help navigate a ball through each puzzle level. The shapes took on simulated mass and kinetic energy and thus the gameplay was generated through the interaction between accelerometer, player, physics simulation, and screen display.

The movement-detection of the Nintendo Wii console is affected in part by accelerometers in wiimotes. However, as Bart Simon explains, the Wii system relies on a multisensory apparatus (proprioception and vision):

> The Wiimote has an internal accelerometer (an ADXL 330) that allows for the measurement of motion in a three dimensional space and this information is communicated to the console wirelessly via a Bluetooth radio chip. This alone would be enough to measure horizontal, vertical and forward motion, as well as rotation, but the measurements produced by the accelerometer alone are not accurate enough to correctly correlate the motion with what is happening on the screen. For this, Nintendo developed the infrared LED ‘sensor bar’ which is actually not a sensor at all. The bar contains infrared LEDs at either end that emit light which is detected by a simple IR camera in the tip of the Wiimote. Position calibration is made possible then by triangulating the position of the controller relative to the light emitting diodes. (2009: 10–11)

Thus we are presented with domestic entertainment and communication technologies that, whilst not biological, must be understood as proprioceptive, as self-sensing bodies. Whilst on the other hand these bodies must in turn be understood not simply as two discrete interacting entities, but as constituting and constituted by an assemblage of technical and biological subsystems.

In arguing for a correspondence or collusion between human and non-human sensing bodies we should not assume identity between these bodies and their sensoria. The bodies in these playful assemblages sense the world and their movement through it in very different ways. An accelerometer perceives its motion in space and in relation to other bodies, including the Earth, very differently from mammals. In the Wii system, this difference is evident in two key ways: first, as every Wii player's body quickly learns, the wiimote does not fully capture the body's movements and gestures and nor then does it faithfully transcribe these movements and gestures into those of the on-screen characters. Learning the game includes figuring out which gestures will have an instrumental effect in the game, and which are redundant. Indeed this difference can provide the very basis for gameplay practices and pleasures. Simon has noted how Nintendo's marketing reorients players to the screen and shifts the perceptual relationship from one dominated by vision to one of kinaesthesia. He argues that the Wii apparatus, its 'gestural interface system' is concretely implicated in a significant phenomenological shift, and demands of its players new bodily techniques and experimentation. Nintendo's marketing of the Wii insisted that the system breaks down the virtual/actual boundary as the player's existing bodily expertise is directly registered and replicated in the gameworld. However effective play necessitated an embodied understanding of the clear disjuncture between the movement or gesture required of the player by the system to swing a tennis racquet for example, and the movement or gesture of the tennis swing enacted by the screen avatar.

In Wii Sports for instance, regular players discover quickly that not only is there a very weak correspondence between their arm motion and the screen effect but also that, understandably, the many nuances of bodily motion that go into performing better or worse swings cannot be captured by the Wiimote. The implication then is that the Wiimote captures some of the player's bodily motion and not all. At the other end of the spectrum it also becomes clear as one plays that the Wii console and the game software does not use all the positional information it captures. The game software only used just what it needs, as it were, to produce a correlative screen effect' (Simon 2009: 18–19).

One does not have to play a Wii game for long to establish something of the bandwidth of this gestural transduction. Through play, the player builds up 'the minimal gestural map to facilitate the most efficient gameplay' (Simon 2009: 21). This may be achieved through instrumental trial and error, or incrementally – and more or less subconsciously – as the player is taught by the system over hours of play. The swiping of a sword in *The Legend of Zelda: Twilight Princess* (Nintendo 2006) can be just as effective through a flick of the wrist as by a swing of the whole arm, as satisfying as the latter may be: Simon points out that 'gestural excess' of the sword swipe may be sustained for kinaesthetic pleasure even once its redundancy for instrumental effect in the gameworld is recognized (see also Giddings and Kennedy 2010).

Secondly, whilst we can understand the wiimote as a body that registers and responds to its own position and movement through space, it becomes clear that this space has a peculiar topology. The device registers movement in a space of *gesture*, not the position of the player's body in some notional Euclidean grid nor in relation to the domestic environment of furniture and walls. Whilst arm movements of the Wii Tennis player are registered and responded to in some detail, the player can wander around the room freely without affecting the position of the tennis-playing Mii within the space of the virtual court. To give another example, Wii Bowling ignores any attempt to perform most of the necessary movements in actual bowling, notably the player's approach to the lane, ball in hand, building momentum for its release. It does not register the whole body's movement through space. The movement of the player's arm *is* registered, and so the walk is economically condensed into, and affected by, the swing of the arm. Thus the arm swing to release the ball also moves the on-screen avatar through virtual space. Interestingly, whilst the virtual gameworld simulates gravity (the bowling ball falls to the floor when released), the wiimote is less concerned with obeying natural laws. It is possible to play Wii Bowling by standing with one's back to the screen and bowling with an overhead (in gestural terms 'upside down') motion. The system registers this as a normal, if generally not very effective, movement. The movement-sensing process takes no account of the player's or wiimote's bodies' orientation to the Earth. The system keeps a crude check on the player's position in space as it notes, with an on-screen message, if the player moves out of the zone within which the wiimote's infrared sensor can see the 'sensor' bar, but this is registered by a loss of signal – by 'vision', not a proprioceptive sense of place or position. YouTube now hosts numerous videos of domestic accidents as new Wii players collide with furniture: evidence of the disjunction between biological and machinic sensory regimes. The system issues its screen-based warnings as the console is switched on, but it pays no attention thereafter as it takes hold of the player's attention and demands it responds only to its own non-Euclidean world.

The point I am making here is not to account for performative gestures, as important as these may be to the kinaesthetic pleasures of Wii play. Rather it is to draw attention to the fact that the gesture's excess or precision is always in relation not merely to an input signal to the game, but also in relation to the Wiimote system's own non-human proprioception in any particular gameworld. Successful play demands the implicit, embodied negotiation of the human body in space and motion with the inhuman sensing technics and regimes of the Wii hardware and software.

Games and gravity

The discussion above opens up ways of thinking about the more or less interwoven workings of human and non-human sensing in technological systems, providing a broader context for the consideration of natural and artificial proprioception in general and virtual gravity in videogame play in particular. I will now return to the primary assertion made in this essay: that virtual gravity cannot be fully understood as located within either the code of the gameworld software or the player's body and sensorimotor system. It is a function or product of their collusion. As Swink notes, whilst there is no 'real' proprioceptive sense in the controlling of an object in a videogame, there is – through technological amplification and cybernetic design – a virtual proprioception *felt* by the player:

> When you move a mouse, thumbstick or Wiimote, your proprioceptive sense is still active. Your thumbs, though their movements are small, are still giving you feedback about their position in space and about how the buttons or thumbstick on the controller is pushing back on them. You have a sense of where your body is in space, even if your primary feedback is coming from virtual objects in virtual space. In this way, controlling something in a game is a kind of amplification of your sense of space because you get a huge amount of reactive mileage out of very little real-world motion […] When we're controlling something in a game we're not using a debilitated proprioceptive sense, but an amplified one. (Swink 2009: 28)

So, simulated gravity *has* actual world effects, it acts – through graphic display, interaction, and feedback – on the player's sensorium and proprioception. It fuses with the current and remembered gravitational pull of the actual world on the player's body. Rather than dis-embodying it *re-embodies*.

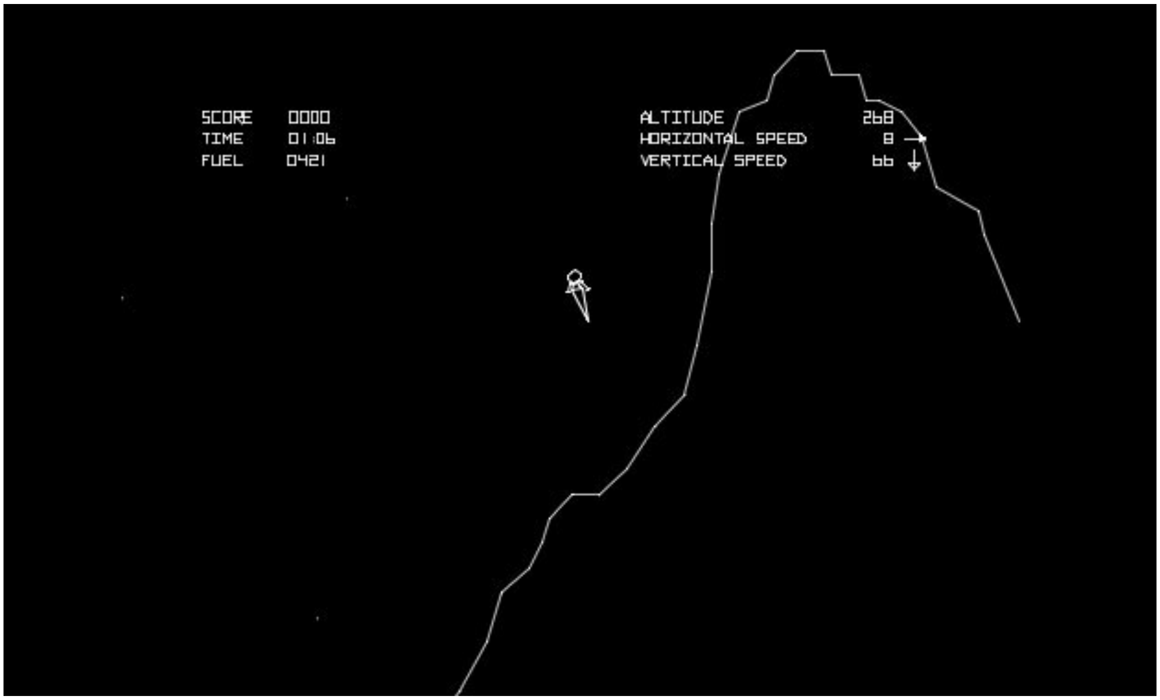

Figure 3: *Lunar Lander* (*c*. 1980).

With its white wireframe graphics on a vacuum black background, the early home computer game *Lunar Lander* looked something like *Spacewar!*, its mainframe ancestor (Figure 3). And, like *Spacewar!*, virtual gravity was fundamental to its gameplay. Atari released an arcade version in 1979, and versions were written and rewritten for home microcomputers in the early 1980s. The game is simple: the lander – something like the Eagle landing module from the Apollo space missions – descends towards a treacherous moonscape, its speed increasing exponentially as though accelerating under the influence of a gravitational pull. The player must press a key to fire retrorockets to slow the lander's descent. Press too long and the lander will begin to ascend again, with the risk of running out of time or fuel. Not enough retrothrust and the craft will land too heavily and be destroyed.

> Ace space pilot, Captain Flash, is sitting next to you as you take the final part of your Advanced Spacecraft Handling Test (Part III). Your lightweight, two-man landing craft is rapidly approaching the Moon's surface. Your velocity must be almost zero as you touch down. Deftly you control the thrust, pressing A to increase it and D to decrease it, watching your progress on the screen all the time. If you use too much thrust you will begin to go back up again. Too little and you will make a new crater on the Moon. Can you impress Captain Flash with your skill? (Isaaman and Tyler 1982: 30).

Captain Flash's approval notwithstanding, this proved a compelling game, the responsiveness of the virtual physics belied by the simplicity of the graphical display of environment and vehicle. Isaaman and Tyler's book listed versions of the game's BASIC code for players to type into their microcomputer:

```
(For TRS-80 and VIC 20).
power = 0.3;
yspeed = 0;
gravity = 0.1;
thrust = 0.75;
if (Key.isDown(Key.UP))
yspeed -= power*thrust;
if (Key.isDown(Key.DOWN))
yspeed += power*thrust;
yspeed += gravity;
_y += yspeed;
```

The gameplay and controls of the game are very simple, as are its algorithms. The code above sets up only four key factors – including one controlled directly by the player (thrust), a value for gravity (against which the player exercises thrust through a key press), and the resulting (one-dimensional) movement of the lander – yspeed. Yet to play the game is to *feel* the interplay between these simulated forces. Pressing the key to fire the retrorockets does not immediately propel the lander upwards. Rather it slows its descent. Similarly, releasing the key does not immediately halt this counter-force: if the lander has slowed almost to a hovering halt, the upward thrust initiated by the player may be enough to send it back upwards again. The resistance built into the algorithmic interplay between gravity and thrust is experienced in the player's body as the key press either pulls against gravity. The sense of willing the lander to slow as it heads towards the ground too quickly, or the agonising realization that one has overcooked the retrorockets and over-run the time limit is palpable. Moreover, the thematic, temporal and ludic milieu of the gameworld itself intensifies this feeling. As the lander sails back up away from a near fatal impact and the clock ticks towards its deadline, the virtual physics set a spatio-temporal boundary to the possibility of success. The artificial gravity drags more powerfully on the player's body as we will it to relax or ease just a little. Thus virtual gravity cannot be separated from either the human body's proprioceptive experience or the simulated physics. In fact 'inseparable' is not the right term: this sense is generated by and across all these bodies – human, software and hardware – and through both embodied memory and immediate cybernetic feedback. It is distributed, and an artefact.

Conclusion

The *Angry Birds* are just one popular exemplification of new sensual and kinaesthetic relationships with media technology that have emerged with videogame virtual worlds and physics. These relationships are reducible to neither the human body and senses nor digital hardware and software. Rather they emerge through their distribution across these platforms: artefacts of code and physical input, haptics and proprioception, both human and non-human.

I have argued that in the study of contemporary digital technoculture, following the insights of phenomenological media studies, questions of embodiment and perception are key. But that we should not limit our understanding of sensing, kinaesthesia, proprioception and embodiment to the human players alone. The software of *Angry Birds* and *Lunar Lander* might be considered virtually proprioceptive – i.e. they operate through the tracking of their various bodies or components in virtual space, and the various simulated forces acting upon them. With current haptic, gestural, sensing and location aware media in games (Wii, Kinect, mobile device screens and accelerometers) and beyond (satnav, infra-red motion detection, automatic CCTV cameras, military sensing systems), media technologies should not be thought of merely as extensions of the human sensorium, but on the one hand fully environmental – both virtual and actual, surrounding the human, enfolding and co-opting it, and on the other they are sensing bodies themselves. This collusion between human and non-human bodies, between actual and virtual environments offers a way into addressing contemporary digital technoculture in all its sensate and experiential dimensions.

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Notes

[1] The notion of 'distribution' of human and non-human behaviour and agency in technosocial systems is in part inspired by Edwin Hutchins' 'distributed cognition' (1996).

[2] Thus games in which the physical realism of weaponry is a key factor *will* simulate the effects of gravity on ballistics – as well as simulations of tank warfare see for example, http://www.rockpapershotgun.com/2013/10/28/going-ballistic-arma-3s-bullet-physics-detailed-in-video/.

[3] See Gregersen and Grodal (2008), Toft Nørgård (2011) for work in game studies that engages with Merleau-Ponty directly.

[4] Though this point ignores the deliberate kinaesthetic design of action sequences and special effects in popular cinema which, though not interactive as such, share with videogames techniques of image and motion designed for visceral effects in the player's body.