

Comparative Content Analysis of Virtual Environments Using Perceptual Opportunities

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Our understanding of Virtual Reality (VR) as a communications medium is not as well developed as the technologies of VR themselves. This paper presents the practical application of a content model of VR, which aims to alleviate this problem. First of all a characterisation of the aesthetics of VR is put forward against which the practicalities of the content model can be judged. Then, the content model, based around Perceptual Opportunities (POs), is briefly outlined before it is illustrated in greater detail through its application to the analysis of five Virtual Environments (VEs), two drawn from traditional VR and three from computer games. From the separate analyses a comparative content analysis is presented which makes surprising links between apparently diverse VEs and allows some insights into VR itself to be drawn. The conclusions document current and future research into POs in particular and VR theory and its practical applications in general.

1. Introduction

If we take an inclusive definition of VR to variously refer to desktop and high end VR, 3D computer games, Hybrid TV, and so on, it seems that VR will constitute one of the principal communications media of the new century. We could predict with some confidence that such interactive 3D virtual systems will be to the 21st century what the moving image was to the 20th and will significantly change the way we view ourselves and the world around us.

However, for a variety of reasons, our understanding of VR as a communications medium is not as well developed as the technologies of VR themselves. Thus our ability to construct effective, user centred virtual environments (VEs) is still very much reliant on individual knowledge and experience. The problem with such knowledge is that it is not generic and does not easily allow us to apply it to other applications areas particularly within the inclusive scope of VR we are taking. In the field of computer games Church recognises just this problem when he calls for a set of “formal, abstract design tools” (FADTs) for the analysis and comparison of games as well as their design (Church,1999). Church’s FADTs are perhaps best viewed as a characterisation of the aesthetics of VEs. In other words as an attempt to, first of all, characterise and then design for the particular pleasures that interactive media offer. His characterisation consists of intention, perceivable consequence and story. Murray characterises the aesthetics of interactive media as agency, immersion and transformation where agency can be seen as consisting of both intention and perceivable consequence (Murray,1997). Immersion is understood as the *willing suspension of disbelief* in the fact that the environment is mediated. In the VR world immersion is used to refer to the embodying interface, the technology, while the term presence is used to refer to the mental state of accepting a virtual environment as real and we will use this terminology. From both aesthetics we can derive a useful working characterisation of the particular pleasures of VEs:

- Agency – on being able to set goals, plan their attainment and be rewarded by sensing the VE change appropriately as a result of the actions taken.
- Narrative potential – the sense that the VE is rich enough and consistent enough to facilitate purposive experience that will allow the user to construct her own narrative accounts of it.
- Presence – the perceptual illusion of non-mediation (Lombard and Ditton,1997).
- Transformation – temporarily becoming someone or something else as a result of interacting with the VE.

Of course there are other possible characterisations of the aesthetics of VR but these will suit our purposes for the present. One question we would like to ask ourselves is how do we go about designing VEs so as to generate and exploit such pleasures?

POs are a generic model of the content of VEs which perform the kind of practical, generic role that Church calls but in the wider context of VR in general (Fencott,1999a). The content model for VEs functions something like the syntax and grammar of a natural language. It is based on the aesthetics of VR and focus on the fundamental communicative properties of VE content. POs also provide a generic structuring mechanism that is used to relate communicative components into a coherent whole. In Fencott (1999a) the content model is illustrated with references to a virtual model of the historic, water balanced cliff lift at Saltburn by the Sea in the North East of England. The model is a virtual tourist site developed for the Saltburn Improvement Company (Fencott,1999b).

In this paper the content model is applied to the evaluation of a range of VEs from both the VR and the computer games worlds so as to demonstrate that apparently unrelated VEs do indeed have commonalities of structure and content. These analyses in terms of POs can then be used to relate particular VEs to the general aesthetics of the medium as given above. This process is then continued when the analyses of individual VEs are compared and contrasted to see what further we can learn about them collectively and about VR in general.

Section 2 of this paper introduces POs as a content model for VEs. In section 3 Perceptual Maps are introduced as a structuring mechanism for POs. In section 4 a number of VEs from both traditional VR and the games industry are evaluated in terms of POs. In section 5 a comparative content analysis of these VEs is given. Finally, in section 6 other current work utilising and building on POs is referred to.

2. Perceptual Opportunities

POs are a content model for interactive media and VEs in particular and were initially developed to assist in the teaching of VE design (Fencott,1999a). The model addresses the psychological and communicative qualities of a VE that seek to gain and hold the visitors' attention through the human senses and perceptual system. The perceptual is about details that arise naturally from the spatial world and involve the visitor both consciously and unconsciously. The latter is very desirable because there is something very fundamental about unconscious involvement - accepting a place or activity without thought.

The content model we will introduce in this section can be used as both a design tool and a model with which we can construct experiments into the nature of users interactions with VE of all genres. It is very often the case that the overall goal of a VE will not be a particular place or object. Nor will the means of achieving that goal be explicit and concrete but will require the user to explore, formulate and solve problems, and generally progress through such activities towards completion of the VE - in the various forms that completion might take in this context. The keyword here is opportunity. The art of VE design is surely to provide users with carefully structured *opportunities* to allow them to explore, strategize, and generally feel some sense of control over what they are doing.

Content for VEs is thus the appropriate configuration of a set of POs allowing the visitor to accumulate over time a set of experiences, which maintain a sense of purposive presence. We will call such a configuration a perceptual map and discuss its structuring mechanisms after a detailed discussion of POs themselves. Creative design in VEs is thus concerned with attracting visitors' attention through patterns of mediated stimuli, which will achieve purpose if the visitor perceives and responds to them as the designer intended. A discussion of a wide range of material which has been influential in developing the theory can be found in (Fencott,1999a).

Figure 1. Characterising Perceptual Opportunities

The PO theory consists of a set of syntactic categories (figure 1) which can be seen as attributes of any object that might conceivably be placed in a VE. These attributes specify the way in which the object is intended to function as part of the overall communications package of the VE. The syntactic categories into which perceptual opportunities can be characterised identify their role in achieving purpose and it is their planned interaction that gives us the overall structure we are looking for. A perceptual map is thus a loosely grammatical structuring of POs which seeks to ensure that users construct an appropriate temporal ordering over their attentions and activities within the VE. Together POs and associated perceptual maps are a means of specifically designing agency and narrative potential into VEs.

The figure above shows how the range of perceptual opportunities may be broken down into three

principal forms, each of which will be defined and investigated in the sections that follow.

2.1. SURETIES

Sureties are mundane details that are somehow highly predictable - their attraction is their predictability. They arise directly from the architecture of the space and are concerned with the logic of the environment unconsciously accepted (Spinney,1999).

The following quote gives an insight from photography into the nature of sureties in VEs:

Hence the detail that interests me is not, or at least is not strictly, intentional, and probably must not be so, it occurs in the field of the photographed thing like a supplement that is at once inevitable and delightful. (Barthes,1984)

Sureties are thus concerned with vection, ego scale, perceptual noise, distance, limit, self image, past, physics, and so on. They are often given by unremarkable objects such as lamp posts and street furniture which never the less support the above. This is important because, for instance, sureties for distance, as people would normally recognise them, are largely absent in VEs. Distance or depth sureties are very difficult and encompass loss of colour with distance, depth of focus, loss of fidelity, small objects disappear faster with distance than large ones, and all this decreases with decreases in display resolution. This is also true for the scale of objects and one's own avatar. Space should not be static and sterile but dynamic and messy. We are used to the *real* world being like this so it helps if virtual ones are as well. VEs and mess/clutter don't however go naturally together. A useful aphorism is that in interacting with the real world we are trying to make sense of too much information but that in interacting with VEs we are trying to make sense of too little. Perceptual noise refers to this apparently redundant clutter. Simple objects such as street furniture can often variously support vection, ego scale, distance cues, perceptual noise and so on.

Sound is an important spatial surety in reality and greatly supports presence. It gives important information about the nature and scale of the space that we are currently experiencing, i.e. small, large, inside, outside, etc. (Anderson,1999). We are very susceptible to reflected sound as sureties in this sort of way. We are not very good at locating objects accurately in 3D space based on the sounds emanating from them. The nature of sound in VEs means that sound can be used for atmosphere etc. but not as well for spatial and directional cues. This depends on the nature of the sound system itself being used, i.e. stereo, surround sound, and so on.

Sureties are closely allied to the fidelity and immersiveness of the embodying interface in that both seek to convince the visitor that the mediated environment is real.

2.2 SURPRISES

The idea for surprises as perceptual opportunities came from the "appropriately designed infidelities" of Whitlock et al (1996) who used them for emphasis in virtual worlds and thus to precipitate conscious learning. In other words, non-mundane details that are not predictable but they do arise however surprisingly from the logic of the space consciously accepted. Surprises therefore are designed to deliver the purpose of the VE by allowing visitors to accumulate conscious experience from which narratives can be constructed after the visit.

Surprises can be: implausible but beneficial or totally plausible but unexpected, and there are three basic types:

- attractors
- connectors
- retainers

POs can be both sureties and surprises depending on the context in which they are offered - there is no mutual exclusivity between them. Some things will be more or less surprising than others, eg. limit sureties may sometimes be perceived as choice points, the animated vehicles are attractors at a distance but retainers when the visitor gets close enough to take a ride.

2.2.1. ATTRACTORS

Attractors are POs which seek to draw the attention of a visitor to areas of interest, retainers, that will deliver interaction sequences whose collective aim it to satisfy the high level objectives of the VE.

Attractors are the means by which users are tempted into setting goals for themselves. It is thus important that major attractors are associated with perceptual opportunities, retainers, which reward users/visitors with things to do, remember, excite, puzzle, etc. and which will allow them to feel they have attained the goal they set themselves as a result of the attractor. To aid in these further perceptual opportunities, connectors, should be carefully designed to allow visitors to formulate plans to achieve the goals they have given themselves using available connectors, such as axes and choice points. All attractors rely on peoples' natural curiosity and their prime purpose is to draw people into areas of conscious activity, called retainers, which are designed to deliver the main purpose of the VE. See the section on perceptual maps for more details on this.

Attractors will often be seen or heard from afar. Animation is a particularly successful form of attractor in that it makes things stand out because of our deep-rooted perceptual affinity for movement. However, attractors may be static and quite local. Doorways as both entrances and exits are examples of static attractors as are partially obscured objects and spatialised sound.

Attractors may be characterised according to the reasons they draw attention to themselves:

- Mystery objects - partially obscured/revealed objects, strange or unknown objects, both closed and open doors and doorways.
- Active objects - movement, flashing lights, sounds changing pitch or volume
- Objects of desire - objects that have some benign significance to the visitor and more particularly to the task at hand
- Objects of fear - objects that have some malign significance to the visitor and to the task at hand
- Alien objects - objects that belong to another world, VE, or context altogether, 2D maps, strange symbols to indicate the end of levels
- Sensational objects - objects which attract attention through non-visual senses, spatialised sounds, vibrations, smells etc.
- Awesome objects - large, famous, expansive, etc.
- Dynamically configured objects - objects that are relocated in space/time

In addition an attractor may exhibit a combination of characteristics. For instance a flashing light may be partially or wholly obscured behind an archway or other object and yet its effects may still be perceived. A sensational object such as a localised sound or a seabird above a beach may be also dynamically configured in that it 'reappears' in different places to indicate an affordance, help or information, for example.

2.2.2. CONNECTORS

Connectors are configurations of POs that help visitors achieve goals by supporting strategic thinking, making plans, semantic matching, and exploration (Smith et al,1999). Connectors are thus the means by which visitors make connections, both mental and 'physical', between attractors which stimulate goal formation and retainers which allow visitors to achieve their goals and deliver objectives specific to the purpose of the VE. The actual objective of a retainer might well be hidden or not clear from the point of view of its attractor(s) but lower level goal formation should lead visitors into situations where objectives can be realised. Connectors are the means by which visitors are coaxed into following a particular course, choosing between possible courses, or changing course perhaps because they are approaching the limits of the VE. There are three types of connectors:

- Axes
- Choice Points
- Deflectors

There are various techniques that can be used including direction signs; new routes appearing, degraded reality and so on. They can be closely allied to guide and limit sureties that seek to achieve similar objectives through unconscious perception. Thus an axis might lead a visitor into a position where an attractor becomes perceivable and follow this to a previously undiscovered retainer. Choice points are noted by Murray to be of great dramatic potential in interactive media (Murray,1997). However, Bleszinski cautions that the consequences of making choices should be at least hinted at so that a perceptive visitor will be able deduce the consequences of their choices or at least understand them after the fact

(Bleszinski,1999). Deflectors are unconscious counterpoints of choice points which offer a choice between high levels and low levels of detail to lead the visitor into a loaded choice. As the culture and cultural acceptance of VEs grows it may well be the case that all deflectors will be perceived as unconscious guide and limit sureties.

2.2.3. RETAINERS

Retainers are major patterns of interaction that seek to deliver specific objectives of the VE and collectively therefore its purpose. Retainers should be designed to deliver the memorable experiences of the VE as well as ensuring that visitors linger appropriately from time to time as they move around the world. In virtual tourism for instance the longer visitors linger overall the more likely they are to find the virtual experience memorable and perhaps retain the desire to actually visit the place the VE is modelling. Retainers come in two forms, local and peripatetic. They seek to keep visitors in a particular place in the VE, in the case of the local form, or provide visitors with interactions that they can access from wherever they are in the VE, as is the case with the peripatetic form. The local form may be dynamically configurable as in such games as *Driver*, a game by Reflections, where retainers in the form of getting out of collisions can occur anywhere in the game space.

2.3. SHOCKS

Shocks are not perceptual opportunities normally built into VEs but arise as by-products of the design and construction process. They give rise to perceptions that jar, that aren't received as expected in the established context of the VE. They draw attention to the mediated nature of the environment and thus undermine presence. Shocks are thus perceptual bugs that need to be actively sought out and eliminated.

- end of the world shock - in earlier versions of the cliff lift there were a variety of shocks such as the sea not being big enough so that visitors could see where it ended
- film set shock - buildings etc. only complete from certain angles, called *Breaking the Metaphor* in *Snow Crash* (Stephenson,1993).
- polygon leaks - seeing through cracks between solid objects to something/nothing beyond.
- latency and motion sickness
- and so on

3. PERCEPTUAL MAPS

Surprises should work together in patterns to form possible temporal orders on retainers and thus the coherent set of purposive experiences that are intended to deliver the purpose of the world. Perceptual maps, as these patterns are called, are thus an abstract characterisation of the comprehensible labyrinth (Murray,1997;Arseth,1997). Attractors should draw attention to sites of retainers and, if properly designed, lead visitors around the world in a meaningful way using connectors. Attractors may also themselves be retainers. Seen from a distance an animated object may act as an attractor but when experienced close up the object may be some sort of vehicle to ride in and control thus becoming a retainer. Patterns of attractors, connectors and retainers may be quite localised and in effect work as games. The oystercatcher avoiding visitors in the cliff lift works in this fashion (Fencott,1999b).

A perceptual map consists of the specification of the set of intended perceptual opportunities and their intended configurations. This will mean that when implemented in a VE they will allow a visitor to accumulate, over time, a set of experiences that maintain a sense of purposive presence. A perceptual map should therefore contain specifications of the range of sureties and surprises together with the perceptual interrelationships. We have already stated that sureties are the mundane details that seek to establish the believability of the world.

Since surprises are of three forms namely attractors, retainers and deflectors they will require different kinds of information to specify them. However, some general rules apply:

- visitors should be rewarded if they follow attractors
- retainers don't have to have attractors
- retainers can be their own attractors
- retainers can have multiple attractors

- connectors should lead to an attractor or directly to a surprise
- thus connectors, like attractors, should be rewarded if followed
- limit sureties can back up limit deflectors as the last line of defence to prevent *end of the world* shocks.
- And so on

3.1. PERCEPTUAL MAPS AS A TABLE OF SURPRISES

The simplest way of documenting an intended perceptual map is by way of a table with three columns which relate attractor/connector/retainer triples. Rows indicated the suggested relationships left to right and cells give brief descriptions. Their generic form is thus:

Attractor	Connector	Retainer
Details of attractor, the goal it should generate is the retainer	Resources available to affect planning the achievement of the goal identified as a result of the attractor left	Activity or other reward identifiable as a major part of achieving purpose

Perceptual maps have much in common with the way painters arrange the composition of a work so as to catch the viewers attention and lead it around the canvas in a particular way. Although it is not possible to tell a story in a VE as in a film or TV program, there is never the less an important narrative potential in VEs which needs to be designed for. This refers to the purposive accumulation of experience. This is more obvious in 3D games or Virtual Training Environments (VTEs) such as the classic Hubble Space Telescope VTE used for training the flight team (Loftin et al,1994). Because of resource limitations, objects should only be placed in a VE if they provide a clearly identified perceptual opportunity integrated into the VE's perceptual map. They will then support the purpose of the world if they are conducive of the aesthetic pleasures of agency, narrative potential, presence and transformation.

3.2. SURETIES AND SURPRISES WORKING TOGETHER

Sureties and surprises in VEs work together much in the way jokes do:

- My dog has no nose!
- How does he smell?
- Terrible!

The first two lines are unremarkable and mundane, sureties. The third line comes as a surprise but is plausible from the logic of the first two statements. Jokes seem to be all much like this - you set up an imagined and consistent, however fantastical, world and then give it a bizarre, implausible twist, which must somehow be derivable from the former. Sureties and surprises in VEs work together, supporting each other and thus the virtuality they inhabit by seeking to catch and retain the attention of the visitor and thus maintain presence and belief. If a perceptual map constitutes the labyrinth then sureties are the means by which it is grounded, virtually, in a believable world.

4. CONTENT ANALYSIS USING POs

In this section of the paper we will apply POs to the analysis of a range of VEs from both the traditional VR community and the games industry. The documentation of these analyses can be quite lengthy and for this reason only summaries are presented.

4.1. HUBBLE SPACE TELESCOPE VTE

The Hubble Space Telescope VTE is a classic high-end VE that was used to train the ground based flight team for NASA's Extra Vehicular Activities (EVAs) to repair the Hubble space telescope (Loftin et al,1994). The system utilised a Head Mounted Display (HMD), data glove to point and select objects, joystick controls for movement, sophisticated sound to deliver intelligent help system. It was thus highly immersive in the technological sense of the embodying interface as all movement is also mediated.

Evaluative questionnaires and qualitative feedback to evaluate its effectiveness accompanied the VTE. Experimental results showed the VTE to have been highly effective in familiarising the ground-based staff with the intended activities of the astronauts. The latter incidentally did not experience the VTE but made use of a water based simulation system instead.

4.1.1 SURETIES FOR PRESENCE

- Vection - space shuttle cargo bay interior and telescope itself,
- Depth Sureties - no long range depth sureties, the known dimensions of the cargo bay and telescope itself,
- Perceptual Noise – the basic details of the Hubble including that not used on the particular EVA,
- Degraded Reality – space itself is its own degraded reality,
- Limit Sureties – see above
- Self Image - space suit glove that responds to user hand movement in the data glove
- Past - stages in the repair mission already accomplished.
- Physics - weightless in space, etc.

4.1.2. SURETIES FOR CO-PRESENCE

There is no co-presence as such except the on-line intelligent help system, which uses audio as if from the mission control team.

4.1.3. SURPRISES

Attractors

- Objects of desire - known components for next task of repair mission, Hubble itself is an object of desire when world first entered
- Alien attractors - green dot over next component of mission if unsure what to do next, red pointer on finger of glove for accurate interaction, opening mechanisms for compartments etc.

Connectors

- **Axes** - no *physical* axes such as corridors, and so on, but cargo bay provides sight lines, and hubble, virtual axis formed by sight line to next part of Hubble to interact with. Being weightless in space means the axis of sight can be the axis of movement.
- **Choice Points** - components to choose, open, select, insert, remove etc.
- **Deflectors** – interesting components not part of the EVA, the abyss of space itself.

NB. Additional external resources are provided in the form of on-line audio help, and green dots to indicate the location of the next part of the mission.

Retainers

- Undertaking the specific details of the pre-planned stages of the EVA

4.1.4. A PERCEPTUAL MAP FOR THE HUBBLE VTE

The Hubble VTE consists of a set of separate repair missions which correspond very closely to the separate levels of single player games such as shoot-em-ups, 3rd person stealth games and so on. Each level is tightly constrained in that the repair is broken down into an ordered set of tasks and each task is itself broken into a sequence of specific interactions which includes precise navigation instructions as well as repair activities. Thus we have a highly specified set of attractor, connector, retainer groupings supported by real-time help where necessary. The perceptual map can thus be seen as a recipe rather than an offering of a table of surprises.

4.1.5. OBSERVATIONS

Hubble is a VR classic partly because its rigorous evaluation demonstrated the appropriateness of VR in stimulating the required learning experiences. But also because of its pragmatic use of the aesthetics of the medium through alien attractors: the red pointer, green dots, etc. which if used subtly to help the user are not seen as shocks detracting from presence. In Hubble retainers take precedence. Successfully undertaking predetermined tasks, perceivable consequence is one of its primary pleasures because all the high level goals and objectives are set for the user. Transformation is also a major pleasure of Hubble because the ground based flight team could temporarily become astronauts.

4.2. OSMOSE

Osmose is a highly sensual as well as highly abstract VE which uses a HMD with full 3D sound and was designed by the artist Char Davies (2000). It investigates the notion of both bodily presence in a VE as well as mental presence. The former is accomplished through the innovative navigational interface, which allows users to rise or fall as they breathe in or out and to move in the direction they lean towards. The sensuality comes both from the bodily involvement and the translucent organic imagery of the central areas as well as from Davis' *aesthetics of ambiguity*. There are a number of concurrent worlds within Osmose which blend into each other as the user navigates around. Unlike Hubble there are not further interactions, in the traditional sense, of buttons to press or doors to open etc.

4.2.1. SURETIES

- Vection - lots of things passing by, leaves, branches, text, code, etc.
- Perceptual Noise - there is a lot of potential information and great depth of focus
- Scale - scale is ambiguous and this probably adds to the sense of belief in this fantastic world
- Distance - a great sense of depth induced by many small objects overlapping in the visual field in all directions, also a judicious use of transparency
- Limits – changing nature of information indicates moving from one world to the next, lack of information, degraded reality, indicates leaving Osmose altogether

4.2.2. SURPRISES

Attractors

- Objects of desire – nothing is quite as known as in Hubble but translucent trees and ponds connected by flows of point lights etc. are highly desirable as well as being mystery objects perhaps.
- Alien attractors – despite the abstract, other worldly nature of Osmose there are no alien attractors within its worlds/levels as such because of their strong sense of internal consistency, perceptual realism, but see partially obscured objects next
- Partially obscured objects – the borders between worlds present contrasting objects partially obscured and act as strong attractors which could also be seen as alien attractors

Connectors

- Axes – these vary with the different worlds, or areas, of Osmose. Some are dense and organic with flows of coloured lights leading the user gently from retainer to retainer, some are geometrically structured, as in the text and code worlds and lead the user through layers of information.
- Choice Points – the range of attractors to choose from, central retainers, the tree, roots, light flows etc. or partially obscured objects in the middle distance.
- Deflectors – no obvious.

Retainers

In a sense the whole VE is a retainer due to the peripatetic navigation controls which focus the mind/body on floating and exploration. There are specific retainers in the sense of the tree with the firefly sap flowing through it. Retainers may be beautiful rewards as well as doors to open ...

4.2.3. A PARTIAL PERCEPTUAL MAP FOR OSMOSE:

Attractors	Connectors	Retainers
moving lights	flow of lights leading to the tree, pond etc. luminous streams,	following light flows to concentrations of lights in the tree and pond etc. localised
partially revealed objects through transparency	gradual unfolding of images in next world, moving towards and into	another world (level)
spatialised sound	increasing detail	something visual (static)
	delicate transparency, ambiguity of images	peripatetic controls, breathing, leaning

4.2.4. OBSERVATIONS

As with Hubble, there are no action analogues, you do not click and drag a mouse instead of walk, and because it is a fantastic world you do not expect to navigate in the same way as in reality. Osmose is highly immersive, you are enveloped by the technology visually, HMD, aurally, spatial sound, and bodily, breath and posture. The world is also highly inductive of presence partly because of the sensual and illusory nature of the stimuli but also, and very importantly, because of the direct connection between body and navigation in a very fundamental way. The very act of breathing and body posture facilitates movement and must contribute immensely to high levels of presence. This is not *the bodiless exploration of Cyberspace* (Gibson, 1995) because here the body is made concrete in the VE even though it cannot be seen by the user. Once again, the importance of purpose and genre in determining the nature of the perceptual content is clear. Much of the successful content here would be quite inappropriate in other VE genres. The transparent tree with firefly sap and ambiguous scale would effectively be a PO shock in most other VEs of whatever genre. Research shows that enveloping technology heightens the intensity of the experience (Slater, 1999).

From the PO point of view we can observe that the subtle nature of retainers means that attractor/connector relationships are very important in Osmose. This means that setting goals, and planning and undertaking their attainment are of primary importance. The high level goals are realised by each user in their own way. Osmose employs attractor/connector relationships rather than specific retainers and thus emphasises intention over perceivable consequence. We will see this later in some of the games analysed.

4.3 SINCITY: A DEATHMATCH LEVEL FROM RITUAL ENTERTAINMENT'S SIN

Sin is a 3D shoot-em-up in the classic style. There are endless labyrinthine corridors meeting in strange open areas patrolled by all manner of enemies that have to be annihilated. Guns and other weapons, boxes of health, and power ups float just above floor level for the user to collect. You have indicators of your current health, weapons and ammo etc. Sin can be played as a single player (SP) game or as a multi-user game. Sincity is a Death Match (DM) level within Sin where multiple users are present, via avatars over a network, in real time. Like most games it is moody and atmospheric and does not *look like VR* as many of the high-end VEs do.

4.3.1. SURTIES

- Vection - Street furniture, ladder rungs, chain fence, doors, walls, etc.
- Depth Sureties - Buildings at a distance good, people at a distance not so good
- Perceptual Noise - lots of textures, architectural complexity, background textures simulate views outside the playable level

- Degraded Reality - some doors don't open etc., you see your health status rather than feel it (thankfully)
- Limit Sureties – on the far sides of the unfinished building there are views not accessible space, can see the rest of the city but cannot move through it, navigation is degraded.
- Bodily Representation - guns and hands etc. can be seen to enhance the sense of presence.

Sureties for Co-presence

Other players realistically represented with fairly realistic looking movements etc. With clothing and faces appropriately menacing.

4.3.2. SURPRISES

Attractors

- objects of fear - gun fire ricochets (peripatetic?), movement of opponents (peripatetic)
- alien attractors and objects of desire – guns, ammo and health boxes, etc. floating just above the ground are alien (static) because they are not natural in the context of the level, do not obey the laws of physics etc. (however they are intrinsic to the genre)
- other objects of desire – ladders etc. which offer access to vantage points (static), vantage points (Again specific to this type of genre but would not be shocks in others, just not so noticeable) (static)
- animated and awesome objects - the revolving crane (localised)

Connectors

- **Axes** - ladders, pathways etc. all leading to vantage points, weapons, ammunition, health etc. create sub-goals to facilitate the main goal. (NB. these components are not the axes but configuring them creates an axis to satisfy the sub-goal *get some more health*).
- **Choice Points** - choosing between axis components, selecting a vantage point to climb to, etc.
- **Deflectors** - door ways with doors that don't open, you can hide, collect health maybe but you have to retrace your steps eventually

Retainers

- climb ladders, open doors, pick up ammo, (local)
- fire guns, change weapons, etc. (peripatetic)
- also hiding, setting up an ambush, etc. (localised?)

4.3.3. A PARTIAL PERCEPTUAL MAP FOR SINCITY

Attractors	Connectors	Retainers
Guns, ammo, health	Mental map of level, alleyways, ladders, etc.	Collect useful items
Ricochets	Large objects	Get out of line of fire
Moving pixels, enemy at a distance	Various	Take pot shot at enemy or navigate to gain better position relative to him/her
Vantage points	Ladders, walkways, parapets, etc.	Establish position for ambush

4.3.4. OBSERVATIONS

We are not dealing with objects but the role objects play in the communication process. There is a cross hair sight for the guns which is a surprise because it does not work the same way as it would in

reality. It is a necessary component of the affordance *shooting a gun*. The primary goal might not be an object or place in the VE but an abstract property of it. For instance score a lot of points, visit all the tourist attractions, remember a virtual place, learn how to operate a piece of equipment, etc. The distinction between object, in other words scene graph node, and perceptual opportunity is made clear here in that very often in Sincity your view of your opponent consists of only 1 or 2 pixels moving against a static background (opponent moving at a distance). It is only in the context of the game that the player clearly perceives such a pattern to be another opponent's avatar. This is clearly a perceptual opportunity and not the object as defined in the scene graph. In another genre of VR such tiny object movements might go completely unnoticed. However, in a DM level such POs are vital to the success of the level. As observed, attractors can be static, localised or peripatetic much in the same way that retainers can be. Consideration of genre in VE design is vital. Such game worlds are also active VTEs in the sense that they attempt to train you to navigate, collect resources, become skilled with the interface and its complexities, and all this before you can explore the level, learn where resources are, build a mental map of the level, learn about vantage points and hideaways or other good places to be. Later on you have to score points, pursue main goal, formulate mini-missions, connector-retainer configurations, to move you to the goal. Good games actively design for the learning process.

Players need to establish retainers, mini-missions, for themselves and put these together appropriately, configure them, so as to find ways of achieving the overall goal of the world. Mini-missions arise through identifying an obstacle or problem or simply noticing an attractor and then using connector components to establish a retainer situation, which will help their goal if successfully achieved. This DM level is a balance between goal setting and planning, attractor/retainer groupings, and actual fighting – preferably on your own terms. Notice that retainers are dynamic in that they occur where players choose to establish them and not where the game designer mandates them. This is about a sense of control, opportunity for strategy, and the opportunity for discovery. All very much concerned with our aesthetics of VR.

4.4. DRIVER

A third person driving game by Reflections. You play the getaway driver for a criminal gang and have to negotiate streets, junctions, bridges, traffic etc. and all in the presence of psychotic police cars whose only pleasure in life is ramming criminals into oblivion. Like Sin, Driver is desktop VR in that it uses a standard PC interface. Like Sincity it also relies heavily on co-presence – the sense of being with others – but does so in a in the context of the way people interact whilst driving in their cars.

Such games would really seem to be second person because they refer to a specific you and not an abstract or distant he or she.

4.4.1. SURETIES

- Vection - Street furniture, building fronts, all give realistic sensation of appropriate speed.
- Depth Sureties - Buildings at a distance good, people and vehicles at various relative distances give very good distance sureties.
- Perceptual Noise - a lot of detail in the city, buildings, moving cars and people, petrol stations, underground car parks etc.
- Degraded Reality – sometimes you reach walls of trees, many roads outside town enclosed by small walls so you can't always drive where you want.
- Limit Sureties - shorefront and other areas just bitmaps, can see the rest of the city etc. but cannot move through it, navigation is degraded.
- Self Image - you can only see the car you are driving but that behaves very realistically, wheels turn to steer, suspension, collision damage etc.
- Past - crashed vehicles, skid marks in grass verges etc. the remaining damage to your car and the police car.
- Physics - you can crash through tables, chairs, parking meters etc. but not street light poles and trees etc.

Sureties for Co-presence.

- Appearance - pedestrians realistically represented with fairly realistic looking movements.
- Behaviour -
 - pedestrians walk quite well and jump out of the way of speeding cars etc.
 - cars horns being sounded to indicate danger and annoyance etc.
 - There is also the very real behavioural co-presence of the extremely aggressive police cars constantly trying to ram you.
- Communication - could also categorise car horns being sounded to indicate danger and annoyance etc. as an appropriate communication surety.

4.4.2. SURPRISES

Attractors

- Objects of desire –
 - stationary traffic, traffic crossing at right angles, gaps in buildings on either or both sides of the road ahead etc. indicates junctions and turnings
 - junctions etc. can also function as attractors by analogy in the sense that they might first become apparent on the 2D map which is so important to the gameplay of Driver.
 - gaps between traffic both oncoming, in the same direction, and both
- Objects of fear - police cars approaching from in front or in the rear view mirror
- Alien attractors - large red arrows, dots and explanation marks indicating main objectives of each level/mission (see perceptual map below).

NB. The latter are not at all perceptually realistic but because they appear on the map in a similar way and are such important points in the game they do not function as shocks as might be expected. The large red dot acts like a giant red traffic signal telling to you where to stop to complete the section.

Connectors

- **Axes** -
 - threading your way through the dynamic configuration of traffic
 - streets define natural axes to draw you towards junctions which are potential focuses of activity and retainers
 - crashing into breakable street furniture and scaring people etc. maintain activity levels rather than just driving to the next junction etc.
- **Choice Points** –
 - junctions make natural choice points as do side turns, alleyways, entrances to underground car parks etc. The choices at junctions are particularly dramatic, as you don't know where the traffic will be in front of you.
 - Other choice points are which side to overtake traffic, dodge on-coming traffic and traffic crossing in front of you at junctions etc.
- **Deflectors** - none identified so far.

NB. The map and arrows (bottom right of screen) provides the necessary additional external resources to navigate to banks and lockups etc. You can plan ahead to a certain extent for choice points and axes on the way to your objective.

Retainers

- driving the car (peripatetic) basic retainer of the game
- staying on the road,
- trying to loose the police car,
- avoiding other traffic, buildings and street furniture, including trees that could impede your escape
- changing direction, particularly negotiating junctions etc.
- trying to get out of collision situations with police car ramming you (dynamic localised)
- avoiding being seen breaking the law by police cars which essentially means trying to drive slowly and object traffic laws (very difficult in driver)

4.4.3. A GENERIC, PARTIAL PERCEPTUAL MAP FOR DRIVER

Attractors	Connectors	Retainers
traffic moving at right angles gaps in buildings to left/right	threading a route through traffic and street furniture, use 2D map to plan ahead	change direction at junction, alleyway, or open space etc.
Police car in rear view mirror	Other cars and buildings	Swerve to get police car to crash
none you don't try to reach this retainer	none as for the attractor on this row	attempting to get away from a collision situation
Alien attractor, question mark	Local streets	You're too early, drive round the block
Alien attractor, exclamation mark	Check view mirror, user local streets	You're got a police tail, lose it and come back
Alien attractor, red dot	None. You're close to the end of the level	OK, stop under red dot.

4.4.4. OBSERVATIONS

There is a strong narrative component both in the game itself and in each level. For example, in the bank job you have to get to the bank and then get the gang to their lockup. Being able to revisit the effects of previous actions, eg. crashed vehicles, tyre marks in grass verges, broken street furniture etc. reinforces your sense of presence through past sureties and also heightens the narrative creation possibilities.

Co-presence would seem to be quite strong in Driver. There is the obvious *behavioural co-presence* of pedestrians who usually have co-presence sureties in that they jump out of the way of speeding cars. There are also other *people* sounding horns in *anger* and sounds of police radio messages about you.

The localised retainers in Driver are dynamically reconfiguring in the sense that it all depends on whether or not you manage to avoid collisions caused by your own driving or as a result of being rammed by a police car. Collision situations are very exciting because you tend to be trapped to some extent and rammed and hemmed in by the police car. In such a situation you are very close to failing the level so you get very involved with and aroused at such points. It is hypothesised that such dynamically configured local retainers are more presence inducing than retainers localised to a particular place. Such retainers are also not tied just to the state of the controls but to the general state of the system much of which is not in the control of the player which can only add to the excitement. Because of all this Driver is very definitely a form of labyrinth which is no doubt why it is often more fun to prolong the car chase around crowded streets than to race off down the highway and achieve the purpose of the mission.

The 2D map in Driver is a connector and attractor. At the beginning of the level, on the first run through, it is an attractor and helps formulate the principal goal for the level. Having formulated an objective, the map then functions as a connector by offering suggestions as to how to achieve that goal. Essentially the map provides resources to allow you to identify possible connectors, choice points and axes, that you can configure in order to plan your way to the goal. Connectors can be figuratively represented as avenues and junctions, in this case, or they can be analogously represented as in the 2D map which here provides future planing or the configuration of choice points and axes. Notice the role of repeated level play here. In a first run of the level the player uses goal matching [Smith et al,1999] to try to find their way to the geographical location which is the objective of the level. In successive runs of the level the user formulates an internal plan of the way to attain the objective, plan formation [Smith et al,1999]. Eventually,

the user will use plan following to finally achieve the level's objective. Of course it is possible to achieve the objective the first time and thus only use goal matching. Again Driver would seem to be making extensive use of attractor/connector relationships as well as retainers.

4.5. THIEF

A third person sneak-em-up game by Eidos. You play a member of a criminal/dissident gang in a steam punk VE. The whole game is very atmospheric and moody in a film noir sense. The locations are modelled in a great deal of detail and there are many things, boxes, incidental objects, scrolls, doors, etc, to interact with. As this is a sneak-em-up you will loose if you thrash around in a mindlessly violent fashion. For this reason planning, taking your time and problem solving become important.

4.5.1. SURETIES

- Vection - Street furniture, building fronts, furniture, carpets, textures for walls etc. all give realistic sensation of appropriate speed.
- Depth Sureties - mainly interiors of houses, palaces, dungeons etc. so no real depth is often present but in the abandoned mine in level 2 the long narrow galleries with intersections, rail tracks and rising and falling ground give good depth sureties. Noise of people singing and whistling, machines humming etc. also give good depth sureties ...
- Perceptual Notice - a lot of detail in the buildings, people, furniture, ornaments, people moving, shadows, sign posts etc.
- Degraded Reality - very little, some doors don't open etc.
- Limit Sureties - confined interior spaces so no need for limit sureties.
- Self Image - you can only see the weapon you are currently using etc.
- Past - if you take things they will not be there again, people stay where they fall, doors stay open or shut as you last left them.
- Physics - you can't move furniture - its fixed in position, the flight of arrows from the longbow is quite convincing, when you throw things away they fall quite convincingly if they are small, throwing people away is less convincing.

Sureties for Co-presence

- **Appearance** - people appear quite convincing, this is helped because the guards wear helmets and visors etc. so the modelling can be quite simple and yet effective. The prisoners released towards the end of level 2 are quite convincing - again hoods and cowls help as the faces are largely obscured. Ghouls etc. are quite convincing
- **Behaviour** - guards and other people react with surprise fear, aggression in your presence, voice reactions are good
- Ghouls are menacing but slow to move etc. which seems about right
- prisoners panic and react with fear to your presence
- **Communication** - not much in the way of real communication but the guards react verbally as well as physically quite well. Sometimes the people say hello as you pass if you are not where you shouldn't be.

4.5.2. SURPRISES

Attractors

- **General** - people moving, doors to open, in level 1 the coat of arms hanging on walls signifies proximity to the owners living quarters where the object you are to steal is located, also in this context the floor and sumptuous decorations, books, ornate furniture all tell you that you are in the right part of the building and must be getting close (these might well thus be a subtle form of connectors, see below)
- **Objects of Desire** - gold and other valuables, holy water, keys, books and manuscripts to read, in this game shadows are desirable attractors because they offer places to hid and be relatively safe,

- **Objects of Fear** - the hammerers, ghouls, exploding skeletons etc.
- No obvious **alien** attractors to date.

Connectors

- **Axes**
 - corridors, underground passageways etc.
- **Choice Points** -
 - doors to enter, rooms with multiple exits/entrances, branching corridors,
 - choosing paths through shadows to avoid enemies
 - choosing where and how to confront enemies
 - choosing to stop and collect valuables
- **Deflectors** - the change of decoration and floor coverings etc. indicates you are getting to the owners apartments, going back less well decorated rooms and corridors is a choice but a loaded one, the sumptuous apartments are the ones to choose on level 1.

NB. Additional external resources are provided in the form of signposts etc. and the 2D analogues of the things you have collected and the weapons you have at your disposal. Simple map is provided at the beginning to give you some very general clues but you can't plan a complete strategy for the level from it.

Retainers

These are mainly, though not always, interactions with other people:

- fighting with hammers and ghouls etc., dynamic as the same combat and combatant could occur in quite a wide range, although perhaps less so than Driver, for instance.
- clever use of shadows to avoid combat in intense situations such as the control room of the jail in level2, localised/static
- getting the key to open the guards room in the 4 cellblocks where 'Cutty', a colleague, is being held, there are various ways to do this, eg. shooting the spy camera at the entrance to the prison, or trying to get the guard out of his room and then shooting him before he gets to you, dynamic/multiple
- puzzle sequences, eg. trying to open Cutty's cell on level two.

4.5.3. A PARTIAL, GENERIC PERCEPTUAL MAP FOR THIEF

Attractors	Connectors	Retainers
sound of guards and other baddies movement at middle or far distance	basic navigation, perhaps using shadows and other things to hide behind	use of shadows and objects to hide behind in order to outwit baddie without drawing attention to yourself
sound of guards and other baddies movement at middle or far distance	basic navigation, perhaps using shadows and other things to hide behind	use of weapons and other possessions to defeat baddies in combat
see key on guards belt in control room	none	shoot spy camera, steal key from guard when he leaves the control room to investigate

4.5.4. OBSERVATIONS

There is no need of the 2D map that is indispensable in Driver, for instance. In fact, the suspense in Thief comes from not quite knowing where you are supposed to be going unlike Driver where the overall

goal is pointed at from the beginning of the level and you can start putting together a configuration of lower level goals with which to attain your main objective. In Thief, mystery, or the mysterious is the key to the drama and you have to apply stealth and strategy in order to succeed. Knowing in advance where you have to get to would spoil the fun.

There is a lot of connecting play (use of connectors) in this game, probably because it is largely a stealth game. Is this a characterisation of a stealth game - that there is a lot of preparation and manoeuvring and less major interaction sequences, retainers/ mini-missions, etc. In this respect it helps if you are very observant and remember such things as the sign to the barracks in prison block 1 of level 2 as this will be useful to you when you realise that freeing your accomplice is not all you have to do. Being part of game culture is important here. Seeing the prison control room and its occupant and sensing that it is worth finding out if there is anything to be gained here comes with understanding the culture of such games. You can just creep past but this will mean a more difficult task ahead of you later - without the key you will have to fight one of the guards to free Cutty.

5. COMPARTIVE CONTENT ANALYSIS

Interestingly, the three games studied are desktop, PC based and non-immersive, while the other two VEs are highly immersive HMD based. We are analysing the content and not technology of VEs. Using POs as the basis to undertake comparative content analysis is a fairly recent enterprise but we are in a position to start to make the kinds of constructive comparisons between diverse VEs that Doug Church calls for (Church, 1999).

For instance, we can see that all the VEs studied with the exception perhaps of Hubble VTE make extensive use of peripatetic retainers, ie. additional controls that *follow* the user around. Interaction is not just about specific affordances such as opening doors or pulling levers. Peripatetic retainers are directly related to a users ability to feel part of the world, they are the users specific interaction in the VE and are thus conducive to agency and presence in particular.

Perceptual realism, the internal consistency of worlds, appears more important than adherence to the real world. We see this particularly in Osmose, which does not model aspects of everyday life, social realism (Lombart and Ditton, 1997), in any real sense. However, all the VEs studied have a range of sureties that seek to convince the user of the internal consistency of that particular VE. Yet their approaches in this respect differ markedly even though three of them Hubble, Sincity and Driver all purport to model aspects at least of the real world. There is no co-presence in the high-end VEs whereas co-presence is important to all the game VEs. Being present with others is a major presence factor and particularly useful in desktop VEs where the immersive capacity of the technology is low. In the three games sureties for presence have been carefully thought through yet again they differ markedly from appropriate car horns to highly alert prison guards.

Hubble, Sincity, Driver and Osmose all make use of alien attractors without apparently detracting from presence. In Hubble there is the red pointer on the space suit glove which can be used for accurate selection of components as well as objects which can be indicated with green dots by the help system. In Driver we have the red dots, arrows and exclamation marks all indicating variations on the end of a level. In Sincity we have floating guns and boxes of health. In Osmose we have partially obscured objects from adjacent worlds which can seem incongruous as well as mysterious. Alien attractors in Hubble and Driver are used as help in an informative way. Whereas those in Sincity are direct help in the sense that they represent resource users need to complete levels. In Osmose the appearance of partially obscured text, for instance, at the edge of an organic world could be construed as an alien attractor very similar to the punctuation marks in Driver and acts similarly as a way finder.

All the VEs provide strongly identified attractors which offer users plenty of opportunity for goal setting and planning. In Osmose the flows of lights act as attractors in the first instance then act as connectors to guide visitors along to major areas of spectacle and finally as retainers to bathe in. In Sincity the principal attractors are ricocheting bullets and minute patterns of a few pixels moving, usually at a distance, to indicate the location of your opponent(s). In Hubble there is a predetermined pattern of activity to follow in order to complete each maintenance task. In Thief exploration and short term planning are mandated and there are attractors usual to the genre such as doors, branching corridors, valuable objects. There are also things such as keys, which would be collected by someone who knew the genre but would not be quite to collectable to someone new to it.

Driver and Thief are very similar games despite the fact that their genres are different - one is a

driving game while the other is a *sneak-em-up*. Both use fake endings to prolong levels. Both use analogues as connectors - health indicators, shadow, possession and shadow indicators, etc. are all 2D - as the damage indicator, time indicator, and local map in Driver. There is not a great deal of skill involved in fighting or shooting arrows unlike Driver where you have to have reasonable *driving skills* in order to complete levels and avoid manic police cars. Both rely on attractor/connector patterns to build suspense and, like Osmose, do not have clearly identified retainers.

Sincity and Hubble both use clearly identified retainers with associated attractors as a means of delivering the purpose of the world. In terms of Sincity, *shoot-em-ups* rely completely on the intense bouts of fighting to deliver purpose. The patterns of connectors can be used for planning and preparation but drama come from shootouts. In games such as these, unless you get to the retainers on a regular basis the game soon becomes pointless. All the connectors you plan with don't deliver purpose but simply allow you to accumulate weapons and ammo, and set yourself up in a good ambush point. The same is probably true, though in a different way, of VTEs where the objective is conscious learning through executing relevant tasks. One could argue that there are retainers in both Osmose and Driver but they are far more integrated with the patterns of attractors and retainers in the VE and can very often be ignored or missed altogether and yet the user can still achieve purpose

Osmose and Sincity have the most open perceptual maps in the sense that there is no right or wrong, complete or incomplete pre-ordering of user activity. In the former case this is because all levels are equally open to visitors and the purpose is for the user to find and/or construct their own interpretation of the meaning of the VE. In the latter case the open structure of the perceptual map is due to the nature of DM levels that require flow concentrated in a relatively limited area to enhance the drama and sense of action. One of the attractions of DM levels is that the patterns of activity are based almost entirely on the behaviour of other humans. In Hubble there is a single route through the perceptual map in order to effect the repairs appropriately. Hubble is also structured in distinct levels much in the way Driver and most other computer games are.

As Driver and Thief are *single player* games we find that their perceptual maps are more structured than Osmose and Sincity but less structured than Hubble. There are often a variety of routes to follow and tasks can often be undertaken in a variety of ways and in various orders. This is due to the nature of SP levels where agency constrained and enhanced by challenges ahead replaces the excitement of the human interaction, albeit at a distance, of Sincity.

In terms of narrative potential we can make some interesting observations:

- patterns of obvious retainers, as in Hubble and Sincity, can create narrative potential, with attractors and connectors creating suspense and meaningful orderings
- patterns of attractors and connectors, with very subtle retainers, can also create intense narrative potential where suspense is the name of the game.

The outcome of the analyses allows us to suggest that POs are indeed a practical content model for VEs and allow us to compare and contrast VEs from a diverse range of application areas. Comparative content analysis allows us to:

- see how similar instances of POs are used in different VEs,
- compare the relationship between agency and narrative potential, on the one hand, and their construction through POs on the other,
- get behind the apparent genre to what a VE is actually about
- further investigate the relationship between POs and presence and transformation

5. CONCLUSIONS

As a practically oriented model POs are being validated and put to use in a number of ways. From the outset POs were intended as a practical model of VR content to support VE development. One of the roles of a model is to test it against data generated in appropriate manners in order to see how the model correlates with actual experience. The work presented in this paper is part of that process.

Perceptual opportunities arose first out of the direct practise of VE creation and later from VEs viewed as the object of investigation. In a very real sense the mode of investigation was the series of trials and errors the author encountered in learning to build VEs and trying to make sense of why some apparently obvious content inclusions appeared to go largely unnoticed while others perhaps less obvious caught visitors attentions readily. The process of trial and error was made positive through a series of

observations of and discussions with some 200 users of the VRML model of the cliff lift discussed in some detail above (Fencott,1999b). POs arose out of a desire to generalise the mistakes and successes of the cliff lifts development process. For several years now the model has been used to teach students, undergraduates and graduates, the principles of VE design. In discussion with students it has become clear that the perceptual map of the cliff lift does indeed achieve its purpose but also that the goals and plans users construct are not as straightforward as the map would like to suggest. For instance, many students do indeed say that they established goals as predicted by the perceptual map but that they put off achieving those goals until they had explored more and found out if there was anything else to do. Through such exploration they would establish a number of goals, prioritise them and then set about planning and achieving them. The results are the desired ones but the process is more complex than simple perceptual maps would suggest.

A different but complementary form of validation is to conduct experiments to ascertain whether the general and particular predictions of a perceptual map for a given VE induce the expected behaviours from users. For each of the various forms of PO there are measures which can be experimentally investigated. This work is at an early stage but pilot experiments have been run. One early finding is that the power of attractors is easily offset by the effort required to realise goals associated with them. This work is currently proceeding and an experimental investigation to correlate actual user data from interacting with the cliff lift VE, making use of eye tracking technology, with the predictions of the perceptual map for the cliff lift is about to be run.

POs are not a universal panacea for the problems of VE design but focus particularly on designing VEs to communicate effectively. POs along with a variety of other techniques can be correlated to form a design methodology for VEs (Fencott,1999c).

If VR is ever to be more than motor skills training or a generator of visceral thrills we will need to master the more subtle communicative qualities it surely possesses. How can we, for instance: create atmosphere, suspense and drama, trigger appropriate emotional responses, convey concepts and abstract ideas, and facilitate the experiential creation of narrative. It is the purpose of this paper to demonstrate that POs are a basis from which we can go on to achieve such mastery. Work is now afoot to use Pos to undertake a more detailed analysis of the tropes of VR so that we may come to understand more rigorously the communicative potential of the medium.

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