Cultural Cognitive Differences in the Spatial Design of Three-Dimensional Game Environments

Alan, Summers
University of Chester
a.summers@chester.ac.uk

Abstract

Research into cognition has indicated cultural differences between Western and East Asian subjects in the perception of two-dimensional screen based images. East Asian subjects are able to process complex changes in visual information across a screen space better than Western subjects, who deal best with centralised changes. This paper discusses how these cultural cognitive differences transfer to the design and interpretation of three-dimensional virtual space, as represented on a two-dimensional screen.

Space syntax measures where used to analyse East Asian and Western game environments. Initial results indicate that there are statistically significant differences between the spatial parameters of the two cultural groups of chosen game environments.

The analysis of three-dimensional game space also indicates spatial design differences between original Western game environments and their adapted form for the East Asian games market. These adapted game environments are spatially comparable to game environments from other East Asian games, indicating a considered design approach to the design of three-dimensional environments for a different cultural market.

The question of whether cultural influence on the design of each game space is tacit or explicit is also considered. Local spatial characteristics that a designer may visually manipulate, where correlated with global spatial characteristics a designer cannot visually determine.

The findings indicate cognitive differences in the design of three-dimensional space are present between the groups of Western and East Asian game environments. Results also indicate that these can be discussed in terms of known cultural cognitive differences in the interpretation of two-dimensional imagery.

Keywords: Culture, cognition, design, games

Introduction

Research has determined that when interpreting two-dimensional images, subjects from East Asian backgrounds demonstrate discernible cognitive differences to subjects from Western backgrounds (Nisbett, . Masuda and Nisbett demonstrated that Japanese participants where more attentive of the field or environment within an image, while Americans where more focussed upon the objects within an image. Further studies using photographs of city environments, animations and web sites also evidence these cultural cognitive differences . In a study by Faiola & Matei users performed better when using a website developed by a designer from their own cultural background, rather than a comparable website by a designer with differing cultural knowledge. It can be hypothesised that the tacit cultural influences evidenced in the interpretation of two-dimensional imagery will be evident within the images a designer produces. This in turn enhances the perception and usage for users with the corresponding tacit cultural knowledge.

Questioning how these cultural cognitive differences affect the design and interpretation of three-dimensional materials is the aim of this study. Three-dimensional space that is designed and viewed on a two-dimensional screen is the starting point for this study. This enables the correlation of the previous research using two-dimensional imagery. Thus if a designer creates two-dimensional images containing implicit cultural differences, then how might this affect the design of a three-dimensional space, built and displayed on a two-dimensional display?

In the form of digital games analysed in this study, the two-dimensional image on the player's screen is the visual field from the player's location in the three-dimensional game environment. The player's screen frames the geometry dependent on the way finding decisions the player makes. Player way finding is orchestrated by the designer's decisions on the structure of the three-dimensional environment.

Boduroglu et al offer a practical consideration for questioning the two-dimensional screen images formed from three-dimensional space. They demonstrated East Asians were better than Americans at detecting colour changes when a set of coloured blocks is expanded to cover a wide screen region and worse when it is shrunk. East Asians were slower than Americans at detecting changes in the centre of the screen. This indicates that East Asians allocate their attention more broadly across the screen dealing with changes in complex images better than Americans. Therefore this study explored the possibility of a comparative methodology that can analyse a three-dimensional environment, correlating this with the complexity of the resulting two-dimensional screen image. This could then indicate an understanding of cultural influence upon the design decisions made when constructing the space. Space syntax metrics for three-dimensional space offered a way forward in developing this methodology.

Designing Game Spaces on a 2D screen

Design theories for three-dimensional digital game space converge with architectural theory, because the users of both spaces experience a designed narrative. This is informed through the exploration of the form and the function of the space. Each space is conceived through a design process that is intended to fine tune the user experience, enhance the usability, and the intended function of the space. The anticipation of the user led inquiry of space, and their way finding through it, means that architecture and game design have common ground in the design skills required to shape three-dimensional spaces.

Design theory relevant to both game design and architecture has been recognised by many game scholars. Licht worked as a level designer at Lucas Arts and discusses design methodologies learnt while studying architecture in *An Architect's Perspective on Level Design Pre-Production* . Explaining how useful architectural principles are in the game design process, he maps primary architectural functions to the design process for game levels. Götz discusses this convergence of architecture and game space practices in his paper *Load and Support: Architectural Realism in Video Games* . Further design discussions concern what both disciplines can learn from each other, and the new typologies of space where the physical and the virtual are overlaid .

This research focused on game spaces that represent fictional real world spaces. These facilitate the transfer of the player’s experiential knowledge into the game world, informing gameplay decisions. Game designers rely on a player using their experiential knowledge of the functions of real spaces and applying it to interpret the virtual space. The transfer of basic spatial experiential knowledge, as recognised by game designers, indicates cognitive maps used for way finding in the real world may be assumed to be used in a game world that mimics it. In research not directly connected to game design Conroy concluded a strong statistical correlation exists between movements in virtual environments and movements in real environments. This led to the investigation of spatial parameters and space syntax measures for use in this study’s methodology.

Interestingly game design theorists have discussed the work of Lynch and the theory of imageability, that helps to understand these cognitive maps. Earlier research into the use of architectural forms in virtual environments correlated with Lynch’s interpretations of how to read the image of a city . Game environments contain the same elements; paths, edges, districts, nodes and landmarks as do real environments. This correlation of criteria for reading a real environment, with those in game environments, makes sense when considering a designer must identify the most important elements a person uses while navigating an environment.

A player views a game space on a two-dimensional visual display and the designer also builds the game space using a two-dimensional visual display. The display frames the composition of the three-dimensional space and a game designer will create specific locations framing fixed viewpoints within the gameplay. Nisbett’s cultural model indicates differences in the cultural interpretation of two-dimensional visual fields, including those seen on a computer monitor . Therefore the framing of the three-dimensional game space as a two-dimensional image will be subject to the cultural interpretation of the designer and the player. Space syntax measures offer a starting point to consider specific locations within the game environment and the complexity of the resulting screen image.

The designer of the game space also has a comprehensive understanding of the global structure of the space when considering individual locations within the larger space. Game designers will map out game spaces considering the player movement and actions within the space. They may consider when they wish to reveal environmental or narrative information to the player, or aim to control how the player uses the space within gameplay. The player will also build their own cognitive map of the relationship of spaces within the game environment. Space syntax measures also enable the interpretation of the global configuration of a game space as well as specific local configurations.

Space Syntax Measures in Game Design

Isovists

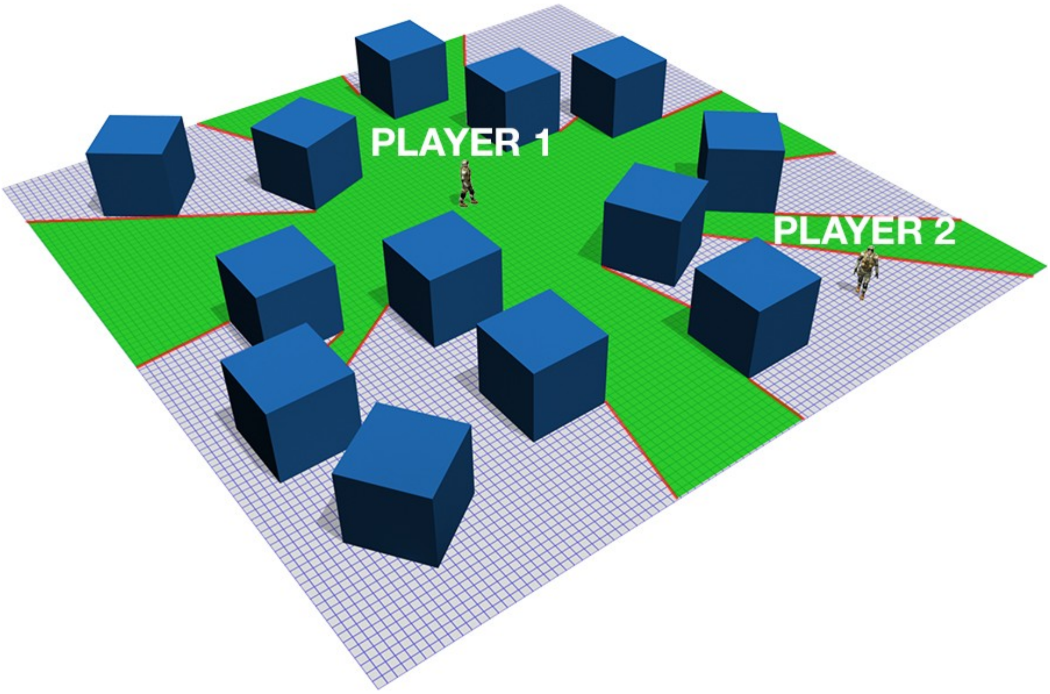

Figure 1: A player isovist.

The space syntax measure that offers the most direct potential to deconstruct the design of a game environment is the isovist. The isovist is drawn as a polygon, mapping the complete view field that a player can see from a single location.

In figure 1 the position of player 1 demonstrates a complicated isovist view field, marked in green, with occluded edges in red. Player 1 is unaware of player 2 within the arena, as player 2 is not within the isovist. The occluded edge of the isovist means player 2 can step out into the view field, therefore posing a threat to player 1. Player 1 will recognise that there are occluded edges to their field of view and, depending on the form of gameplay, anticipate that this may mean danger or a possible direction for investigation.

The game designer will naturally consider isovist properties due to their influence on player behaviour. The length of the isovist perimeter a player has to watch is determined by how much of the perimeter is occluded. Occlusion makes the player position harder to control as the perimeter becomes more complicated to observe as occlusion increases. Maximum distances for isovists across the environment offer an understanding of the largest and smallest view distances within the environment. Gameplay decisions can often be made based on a position that offers long lines of sight. Landmarks for navigation need to ensure there are positions with long lines of sight in order to see them. In studies using virtual environments Wiener states that, “With respect to movement decisions, participants reliably chose the option that featured the longest line of sight.” .

The compactness of an isovist is a measurement of how convex or concave, or alternatively how detailed or jagged, the isovist perimeter shape is. Isovist compactness, maximum distance and occlusion offer measures to indicate how complex a view field on screen might be for the player to watch. A view field that has a complex, jagged, perimeter, with a lot of occlusion, is difficult for the player to observe and to make way-finding decisions. The resulting two-dimensional screen image will also involve a higher level of complexity for the player as a result of compactness and occlusion.

Miyamoto et al examined the holistic and analytic perceptual affordances of real world environments. They concluded that Japanese scenes contained more elements than American scenes and that “culturally characteristic environments may afford distinctive patterns of perception”. In game environments representative of real world environments the isovist in a Japanese scene may be expected to be more compact than that in an American scene, due to the increased number of elements.

Compactness has been correlated with navigational performance and Wiener states:

> The basic initial hypothesis that isovists capture behaviourally relevant environmental properties was supported by the result that the isovist measure jaggedness was strongly negatively correlated with navigation performance…

This implies that if a specific cultural group of players were less able to deal with screen based complexity then they could be disadvantaged in navigational tasks. This is too simplistic a correlation with cultural differences and the cognitive interpretation of the two-dimensional image of a game environment, but it does offer a starting point. Compactness, occlusion and maximum distance give a measure of the complexity of an environment and for cultures that interpret complexity differently this could indicate areas of cultural design differences within the design and interpretation of game environments.

Visibility Graph Analysis

A space syntax methodology useful to consider the global characteristics of a game environment is Visibility Graph Analysis (VGA). This is where the whole environment is filled with a grid of vertices and the relationship of each vertex to other vertices within the space can be discussed. The metrics are either *global* considering all the vertices in the grid, or *local* considering the surrounding vertices, or neighbourhood, within the grid. The term *visual* is applied to the resulting metrics as they are derived through the use of visibility graph analysis.

The global property of visual integration is calculated on the shortest number of visual steps to any other vertex in the environment. It is a reciprocal of the mean depth within the grid compared to all other vertices in the environment.

This indicates that areas of high visual integration are more easily seen from other parts of the environment.

In certain forms of game design a player is often moving around the environment at speed. Areas of high visual integration will be areas that a player will move through more frequently until they become more familiar with the environment.

The local property of the visual clustering coefficient is how convex or jagged a neighbourhood is for a vertex. It measures how many vertices within the neighbourhood can see each other, against how many are in the neighbourhood. It has been discussed as locations where subjects stopped to make decisions (Conroy 2001), so can indicate levels of the complexity of environments.

Relativised visual entropy analyses the change in depth moving from one area to another. It indicates how ordered an environment is as moving rapidly from a small area to a large area indicates an unordered environment with sharp changes between areas. This is indicative of balance of space within a game environment.

Visual control and controllability are local measurements indicating areas that are visually dominant within the overall grid by comparing the size of the current neighbourhood with the size of the adjoining neighbourhoods. A location in a game environment that can be both controlling and have high controllability has gameplay implications.

These VGA metrics enable the deconstruction of a whole game environment. A designer changing one area will have an impact on the global or local measurements across the environment. These metrics will not be visible to a game designer considering the design of a single location in a game environment on screen, or the whole environment on a design drawing. This means VGA measures may indicate implicit design thinking, as opposed to the explicit design thinking involved in isovist measurements.

Selecting the Game Spaces

The game environments analysed where from the First Person Shooter (FPS) genre that used environments representative of real world space. In these environments players are able to move, jump or crouch in a direct representation of experiential knowledge from real world space. The games chosen for this study used no narrative factor affecting a player's movement, such as abnormal gravity or game objects that enhance movement.

Initially the FPS game *Counter-Strike* (Valve, 1999) was chosen as it is one of the earliest games to appear in world championship gaming tournaments and is played globally. The Nexon Corporation based in South Korea has developed a version of *Counter-Strike* called *Counter-Strike Online* (2008) specifically for the East Asian market. In order to choose environments from other East Asian games it was ensured they corresponded with the modes of gameplay in *Counter-Strike*. The games *Sudden Attack* (GameHi, 2005), *Special Force* (Dragonfly, 2004) and *Combat Arms* (Doobic Studios, 2008) had a range of gameplay modes comparable to *Counter-Strike*.

Initial analysis was of five game environments, known as maps, from *Special Force,* five from *Combat Arms* and two from *Sudden Attack.* At present it is not known if these maps have been adapted over the life of the game. They have been chosen because of early development dates, or their specificity to the South Korean version of the game.

In analysing different game environments it was possible with some games to process game models, reducing them down to component floor plans. The East Asian FPS games did not facilitate the extraction of models meaning the construction of plans for their environments where built up from available imagery in game guides from developers. This was cross-referenced with video and screens shots from within the games. To ensure comparable scale for spatial measurements the standard object in all environments, used across most FPS games, the crate, gave a comparable measure.

Spatial Analysis

The game maps where spatially analysed using the software *Depthmap* (Turner, 2009) resulting in a large body of data covering a range of spatial analysis parameters for each map. The data was then statistically analysed using *SPSS* software.

The first test was to see whether the individual game environments from the different South Korean FPS games offered statistically different environments, or were comparable as a single group of environments. A Kruskal-Wallis test was run to determine if there were differences between space syntax measures between game environments grouped by game. The isovist parameters of area, compactness, maximum radial, occlusivity and perimeter where tested along with the VGA parameters of visual integration and relativised visual entropy. Results are shown in Table 1.

Parameter	*Sudden Force Mdn*	*Sudden Attack Mdn*	*Combat Arms Mdn*	$\chi^2(2)$	*p*
Area	1123	512	984	5.915	0.052
Compactness	0.197	0.270	0.206	1.646	0.439
Max Radial	63	43	57	6.346	0.042
Occlusivity	133	67	123	4.231	0.121
Perimeter	275	169	260	4.846	0.089
Visual Integration [P-value]	0.415	0.367	0.448	0.746	0.689
Relativised Visual Entropy	2.33	2.48	2.35	0.254	0.881

Table 1 : Results for the Kruskal-Wallis comparison of South Korean Games

There was no statistically significant difference between the three game groups except for the parameter maximum isovist radial, where pairwise comparisons were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. The maximum radial parameter was not statistically significantly different when corrected for multiple comparisons between the games of *Sudden Attack* and *Combat*

Arms (*p* = 1), *Sudden Attack* and *Sudden Force* (*p* = 0.067) or *Combat Arms* and *Sudden Force* (*p* = 0.197),

This established an initial position that these environments are comparable as a group of environments from South Korean games in terms of these spatial measures.The twelve maps where then considered to be consistent as a group of South Korean maps. This meant the five maps from *Counter-Strike Online* designed for the East Asian market could be compared to the new group of South Korean maps.

A Mann-Whitney U test was run to determine if there were differences in spatial parameters between *Counter-Strike Online* maps and the group of South Korean maps. Distributions of all the spatial parameters were not similar, as assessed by visual inspection. There was no statistically significant difference in spatial parameters between *Counter-Strike Online* maps and the group of South Korean maps as shown in Table 2.

The maps for *Counter-Strike Online*, either chosen or developed specifically for the East Asian market by the South Korean developer, match the characteristics of other game maps for this market.

Parameter	***U***	***z***	***p***
Area	14.00	-1.687	0.092
Compactness	17.00	-1.370	0.171
Max Radial	17.00	-1.370	0.171
Occlusivity	27.00	-0.316	0.752
Perimeter	20.00	-1.054	0.292
Visual Integration [P-value]	39.00	0.949	0.343
Relativised Visual Entropy	6.00	-0.422	0.673

Table 2 : Mann-Whitney comparison of *CS Online* and South Korean Games

The next test was to compare these environments against a group of original Western *Counter-Strike* environments. A Mann-Whitney U test was run to determine if there were differences in spatial parameters between *Counter-Strike* maps and the group of South Korean maps, including the maps from *Counter-Strike Online*.

Spatial parameters were not statistically significantly different between *Counter-Strike* maps and the group of South Korean maps for isovist area and isovist compactness, as reported in Table 3. Spatial parameters were statistically significantly different for isovist maximum radial, isovist occlusivity, isovist perimeter, visual integration and relativised visual entropy, as reported in Table 4.

Parameter	***U***	***z***	***p***	***Counter-Strike Mean Rank***	***South Korean Mean Rank***
Area	169.00	1.567	0.117	13.73	18.94
Compactness	90.00	-1.416	0.157	19.00	14.29

Table 3 : Non significant results comparing *Counter-Strike* and South Korean maps

Parameter	***U***	***z***	***p***	***Counter-Strike Median***	***South Korean Median***
Max Radial	195.00	2.549	0.011	41.58	56.79
Occlusivity	182.00	2.058	0.040	92.86	123.63
Perimeter	182.00	2.058	0.040	191.39	247.42
Visual Integration	182.00	2.058	0.040	0.34	0.45
Relativised Visual Entropy	63.00	-2.436	0.015	2.50	2.35

Table 4 : Significant results comparing *Counter-Strike* and South Korean maps

This indicates there are a range of spatial parameters that are significantly statistically different between the group of maps designed for *Counter-Strike* and the group of maps designed for South Korean games including *Counter-Strike Online*.

The significant differences in occlusivity, perimeter and maximum radial values, but not compactness, are interesting from an analysis of cultural design influences. It was to be expected that the view field for the player in a game developed by an East Asian developer, for East Asian markets, would indicate significant differences in compactness; as research into cultural cognitive differences had demonstrated East Asian subjects have an ability to read more complex images than Westerners. This was not the case.

These results indicate the East Asian designed maps have a longer maximum radial, higher occlusivity and longer perimeters than the group of Western designed maps. The higher occlusion parameter is indicative of a more complex isovist boundary. The parameters of a larger maximum radial and larger perimeter can be argued either way; these may mean longer more focussed fields of view suiting the Western model, or wider fields of view suiting the East Asian model.

Visual integration is higher for the East Asian maps, indicating more considered environments and lower entropy indicating less rapid changes in the nature of the environment as a player moves through it. This would indicate the East Asian maps are more controlled environments for the player to move through as they are more integrated without rapid changes in depth.

These initial results indicate there are differences between the two cultural groups of game environments but the expected areas for visual design differences have not been significant. Compactness of the view field has not been significant in comparisons between Western and East Asian maps.

Deeper Visibility Graph Analysis

The next aim was to determine where any complexity in East Asian environments might be indicated, as it is not in the expected isovist metric of compactness.

The isovist metrics of occlusivity, perimeter size, maximum radial and compactness are measures that can be ascertained from a single viewpoint in the game space by a designer. These are under the direct control of designers who may position themselves in an appropriate place to adjust these through the manipulation of elements within the environment. The designer can move a wall, place an object in a line of sight or block an occluded element of the perimeter to alter these metrics. Moving away from isovist measurements of locations to VGA metrics that consider the whole environment was the next step.

A Mann-Whitney U test was run to determine if there were differences in visual clustering coefficient, visual control and visual controllability between the group of Western *Counter-Strike* maps and the group of South Korean maps. Distributions of the spatial parameters were similar, as assessed by visual inspection.

The median visual clustering coefficient was statistically significantly higher in Western maps (0.756) than in South Korean (0.715), $U = 55$, $z = -2.738$, $p = .006$. The median visual controllability was statistically significantly higher in Western maps (0.379) than in South Korean (0.308), $U = 64$, $z = -2.398$, $p = .016$. The median visual control was not statistically significantly different in Western maps to the South Korean, $U = 135$, $z = 0.238$, $p = .777$.

The VGA measures of visual integration, visual clustering coefficient, visual controllability and relativised visual entropy can be said to be significantly statistically different in the comparison of game environments from the Western version of *Counter-Strike* to those from the South Korean games.

The evidence that visual integration, visual clustering coefficient, visual controllability and relativised visual entropy are significantly different means that there is a set of spatial metrics that are not immediately obvious in terms of visual design decisions. Any design change affecting these metrics is altering the characteristics of the environment and not just a single location. These metrics can be considered as indicative of the implicit knowledge of the designer, intuitively designing the game environment.

In order to examine what was important in terms of creating the levels of visual integration a comparison of the isovist metrics influencing visual integration for each environment was implemented. The R^2 value was used for the isovist metrics of perimeter, occlusion, compactness and maximum radial. A Mann-Whitney U test was run for measurement of correlation to visual integration for the isovist parameters between the groups of maps. This indicated statistically significant differences between the category of East Asian and Western environments only in the area of compactness.

The distributions for Western and East Asian environments were similar, as assessed by visual inspection. Median R^2 compactness was statistically significantly higher in East Asian environments (0.374) than in Western environments (0.302), $U = 51$, $z = -2.551$, $p = .011$. This result indicates that in the design of the East Asian environments, which demonstrate higher levels of visual integration than Western environments, the consideration of compactness is stronger.

Results

The initial results indicated that there are design differences between the original Western designed *Counter-Strike* maps and similar maps from East Asian designed FPS games. The *Counter-Strike* environments adapted for the East Asian market and distributed with *Counter-Strike Online* are comparable to the maps from the other East Asian FPS games. This indicates a considered design approach, either implicitly or explicitly, for the different cultural market.

The results listed in table 5 give indicative spatial design differences between the two groups of Western and East Asian game environments. The isovist metrics describe more explicit design thinking considering individual locations. East Asian maps indicated higher perimeter, occlusion and maximum radial measurements, but with no difference in area. Compactness may not indicate a significant difference, but the perimeter length being higher and occlusion being higher, indicates more complex isovist shapes. This is as suspected from the cultural hypothesis that East Asian subjects cope better than Western subjects when viewing complex images; so may explicitly design more complex locations, resulting in more complex two-dimensional screen images.

Spatial Parameter	Western	East Asian
Isovist Area	No Difference	No Difference
Isovist Perimeter	Lower	Higher
Isovist Occlusion	Lower	Higher
Isovist Maximum Radial	Lower	Higher
Isovist Compactness	Weaker influence on visual integration	Stronger influence on visual integration
Visual Integration	Lower	Higher
Relativised Visual Entropy	Higher	Lower
Visual Clustering Coefficient	Higher	Lower
Visual Control	No Difference	No Difference
Visual Controllability	Higher	Lower

Table 5 : Comparison of significant spatial differences

The VGA metrics describe more implicit design thinking across the whole environment and therefore may be indicative of more implicit cultural differences in the design process.

The design of the East Asian environments involves higher levels of visual integration strongly influenced by the compactness of individual locations. These environments are more complex in terms of the neighbourhoods of vertices in the VGA. The lower visual controllability in the East Asian maps indicates fewer locations where a space can be dominated by the spaces around it. The lower relativised visual entropy indicates less rapid changes in distribution when moving through the environment. These indicate environments with smaller more evenly distributed spaces.

The East Asian environments can therefore be considered to contain more complex view fields and be better ordered and integrated across the environment. The stronger influence of compactness on the visual integration of East Asian maps implies implicit knowledge more than an explicit design strategy on the part of the designer. It can be considered that the designer of these environments is able to deal with the complex imagery of the designed space, whether as a two-dimensional plan, or a three-dimensional model. This can also be considered important in the context of the user of these game environments and the cognitive spatial map they need to create in order to navigate the space.

In Conclusion

The results begin to indicate interesting cognitive cultural differences in three-dimensional design that correlate with known cognitive differences in the interpretation of two-dimensional design. The results have to be carefully considered as there is a need for a greater diversity of game environments to establish more definitive answers. The analysis of other three-dimensional design artefacts would also be a consideration in advancing this early research. What can be taken from these results is that space syntax measures offer a promising direction for any methodology to discuss these cultural differences further.

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