Spatial Play Effects in a Tangible Game with an F-Formation of Multiple Players

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Abstract

Drawing on Kendon's F-formation framework of social interaction, we analysed the game-space activity of collocated players engaged in a tangible multiplayer game. Game input from groups of 3 players interacting competitively in a natural spatial arrangement via balance-boards requiring whole-body movements was logged and analysed quantitatively. The spatial analysis of a range of players' activities in game-space revealed synergistic effects combining perceptual-motor factors with game-strategy behaviour which were reflected in preferred game-board playing regions. The findings illustrate the importance for HCI designers of considering interactions between human spatial behaviour, physical space and virtual game-space as games become increasingly embodied and social.

Keywords: Game analytics, tangible, embodied, multiplayer, digital game, collocation, F-formation, spatial analysis.

1 Introduction

Tangible multiplayer games are well-established and popular. Successful commercial interfaces of the genre are the Nintendo Wii gaming console played with the Wiimote and Nunchuck, and Microsoft's ReacTable played with tokens. Games played with these interfaces are embodied through the use of physical objects to interact with digital content. The games are physically engaging because the players' movements determine the game-play, and they make for rich social interaction because the players are collocated and the tangible interaction design includes both perceptual and motor elements (Djajadiningrat, Overbeeke & Wensveen, 2004). An important feature of tangible interaction is the direct engagement with tangible, non-digital artefacts through object-specific manipulations, which may involve the entire body (Hornecker, 2005). While the degrees of embodiment and social interaction vary depending on the design of the interaction and the nature of the game, players share themselves through physical expression, context and space (Buur, Jensen & Djajadiningrat, 2004).

Typically, designers of games with these interfaces focus the design on the virtual space while the structure of the physical environment is less-considered from the point of view of creating a game experience that seamlessly connects physical with virtual space to form a true hybrid (combined virtual and physical) space. In our research, we are interested in better understanding spatial aspects of play-areas and how they can be configured so that physical and virtual spaces come together in a tangible interaction experience for players. Based on this research interest, we designed a multiplayer game that exploits spatial relationships through players' position and orientation in the interface and the physical dimensionality of board games in the gameplay. In the design of the game, we utilised a principled approach by incorporating natural spatial patterns formed in social encounters, which we shall describe further in section 1.2. We also drew on culturally familiar gaming contexts, to maximise a player's presence and physical engagement.

We opted to design our own game for the purpose of creating a research platform rather than modifying an existing game because our approach is equally inclusive of digital technologies and social elements that are spatially-determined (as in traditional, non-digital play and games, e.g. street or board games). While current game consoles such as the Wii still closely adhere to the spatial layout of conventional computer setups where the user faces the screen during the interaction, future collocated gaming will continue to develop towards spatial arrangements in which players are oriented towards each other during gameplay (e.g. Microsoft's holodeck gaming experience). Our research anticipates these future developments.

The focus of this paper is on the study of the players' interaction and spatial relations.

1.1 Related Literature

Not only games benefit from collocated tangible interfaces with embodied interaction, they are also found across many applications in HCI (Hornecker, 2005), particularly for tasks that encompass collaborative learning and designing. Spatial relationships, though, have mostly been considered in context-aware computing where space factors into the design of applications for devices reacting to a situational change (e.g. Schnädelbach, 2012). Even proxemic interaction mostly concerns itself with sensing proximity and the triggering of connectivity switches (e.g. Ballendat et al., 2010). To-date, the challenge with these applications for researchers has been the hardware design - the social dynamics of contexts in which spatial relationships are expanded into hybrid space is typically not explored.

On the other hand, researchers who have empirically studied tangible interaction spaces and games have mostly focussed on teasing out the performance benefits of tangible interfaces and applications by comparing them to more conventional GUIs. These investigations have demonstrated that spatial cognition is enhanced, specifically in collaborative tasks where tangible interfaces promote the discovery of spatial relations between virtual 3D objects (Maher & Kim, 2006), and that physical gestures are signals that improve communication among players (Speelpenning et al., 2011). A study of Wii players showed that players actively construct spatial awareness of each other by announcing their position in game-space (Voida et al., 2010). Yet, these studies do not reveal much about the relationships between physical movement, collocation, and the spatiality of hybrid spaces. Our study aims to address those issues. Sim-Suite, the game we designed, combines movement-based collocated gameplay with the natural spatial arrangement of social encounters (Kendon, 1990) - one in which players are aware of their co-players' presence and actions (i.e. co-players are within a player's arc of peripheral visual attention).

1.2 Natural Arrangement of Player Positions

Kendon (1990) studied how two or more people arrange themselves casually, when meeting in public spaces - "focussed encounters" in his terms. His investigations showed that people cooperate with each other to physically maintain a space between them to which all participants have direct and exclusive access, a space he describes as a "joint transactional space". Kendon noticed that there are two basic configurations of two-person interaction, and that these configurations repeat themselves when more than two people meet up in a focussed encounter. One configuration positions two people face-to-face and frontally across from each other, the other is when two people are arranged in a right angle to each other, in an L-shaped configuration. Both configurations come together in a three-person focussed encounter that Kendon called the F-formation system. In the structure of the F-formation system, Kendon identified three kinds of functional spaces (Fig 1): the o-space, or joint transactional space, is the central space between individuals where they establish systematic relations in those aspects of their behaviour that maintains the o-space. Surrounding the o-space is a narrower, intimate space called p-space where individual bodies and personal belongings are located. Newcomers must receive permission to enter the p-space because it requires all other participants to adjust their spacing. Beyond the p-space is the r-space, a kind of buffer space, which is actively monitored by the participants and non-participants (passers-by, for example). It is also where others may wait to gain entry into the p-space.

F-formations have been used to analyse, inter alia, spatial patterns of interaction in real-world physical environments (Marshall et al., 2011), virtual environments (Nguyen & Wachsmuth, 2011) and blended reality contexts (Dim & Kuflik, 2013). F-space conceptualisations have been applied to non-competitive tasks and social interactions. In our research, we focus on the F-formation system's physical component - the natural positioning and orientation of persons - to support the conceptualisation of the game design. We then study the gameplay in relation to the players' natural positioning in the game and Kendon's associated psychological meaning of cooperative and competitive engagement.

In our game design, we therefore emphasise the concept of embodied facilitation from the perspective of real-world physical structure (the player arrangement) and full-body movement to engage with the digital content (Hornecker, 2005). Kendon (1990), drawing on Cook (1970), describes how, in two-person interactions, face-to-face configurations are preferred for competitive interactions whereas L-shaped configurations are associated with cooperative interactions. In the game we designed, player positions and their orientation to each other reflect the F-formation (Fig. 1). Game outcome predictions are made on the basis of this arrangement (Aim, section 3.1.2).

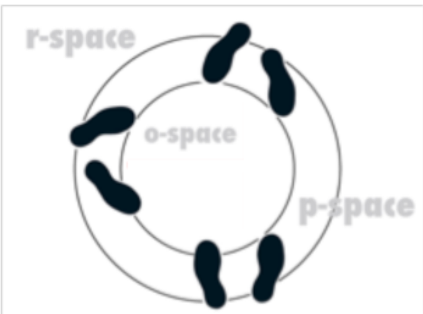

Figure 1: Kendon's F-formation system

2 The Tangible Game - Sim-Suite

Sim-Suite is a tangible game, designed as an installation with traditional and digital materials. It was conceived as cooperative group interaction that draws for its movement elements on street games and full-body play, and is for that reason more closely related to those games than to video games. It has three playing stations. Each station is associated with a unique token and is fitted with a balance-board on which the players move to play the game. Players move their tokens across fields on the virtual board via postural movements forward, backward, left and right on their balance-board. Balance-board movement is captured via infra-red sensors and transmitted to a Phidget interface and forms the input to a game created in Java. The playing stations are embedded in a platform that also houses a large LCD screen panel. The screen is centrally placed between the players, in a horizontal position, just below foot level. Players observe the screen via a window into the platform (Fig. 2). Each player has an equivalent view of the game graphics irrespective of which playing station she is using. A more detailed description of the game and its construction can be found in Jungmann & Fitzpatrick (2009).

Figure 2: Participants playing Sim-Suite

2.1 Game-play in Brief

The game is played with three types of virtual token (Fig. 3) that are placed onto a game-board consisting of a 10 X 10 array of fields. The game is played over a series of timed rounds. New rounds continue until one player wins the game by building a 5-token cruciform pattern using her tokens. At the start of each round a player's token is placed on a field at a quasi-random starting position on the board. The term 'quasi-random' is used because the game software employs an algorithm that maximises the distance of the start position from tokens of the same kind placed by the player in preceding rounds.

The tokens differentiated by shape and colour. Each playing station is associated with a token shape and colour (Fig. 3). A green circle is used by the centre player, a blue square for the player to the left of the centre, and a red triangle for the player to right of the centre position. The gameplay requires coordinating physical movement with strategic decisions of where to place the token on the game-board. A player wins a game when she is the first person to score two points and achieve the game objective. The objective is to create cruciform pattern by placing 5 tokens next to each other. Players navigate by 'teetering' on the balance-board leaning forward, backward, left and right. Over the course of the timed, consecutive rounds a player builds up her cruciform unless she chooses to use her token to block an opponent player; or because her token 'flies off' (i.e. she loses the token by failing to continuously move on the balance-board), or because she does not settle her token on an unoccupied field. To 'settle' her token on a field (i.e. occupy it) she must be in place on the field when the countdown timer ends the round. Note that players must devise an idiocratic manner of moving or teetering on the balance-board to 'claim' a field with their token. Static standing causes a time-out after two seconds and the virtual token flies off the game-board.

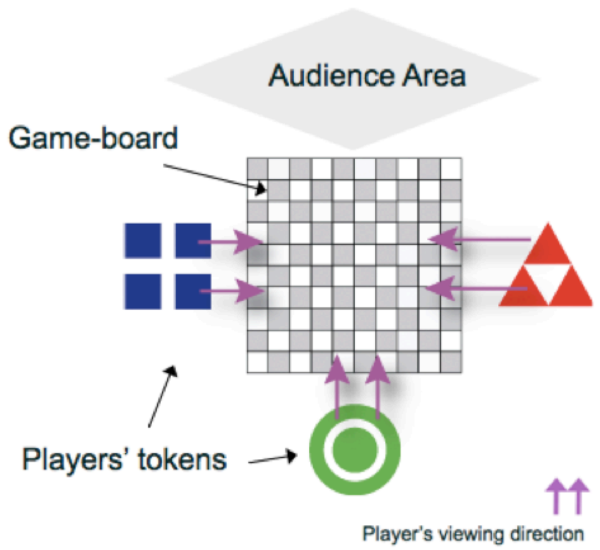

Figure 3: Spatial game-layout with tokens

Three players play simultaneously and must coordinate their actions with each other as well as with the virtual artefacts of the game. The players must also track the game-play of two opponents. The game's complexity emerges from the combination of physical movements and visually tracking multiple perceptual targets.

2.1.1 The role of Kendon's transactional space

The space between the players which is occupied by the virtual game-board represents Kendon's o-space, or joint transactional space. It is utilised for token movements and game-events, which are designed to create feedback loops to the p-space (the zone which is adjacent to the o-space) where players articulate expressive movements on the balance-board to animate tokens and navigate the events in the o-space. The r-space is where the audience assembles, to watch and cheer, and from which they can step up onto one of the balance-boards to play the game.

3 Method

3.1 System Instrumentation, Data Logging and Derivation of Measures

Gameplay metrics and user-metrics (Drachen & Schubert, 2013) in the form of balance-board movements, token placements, token movement paths across fields, and fields occupied by players were derived from raw data logs. The raw data was captured at millisecond resolution from both the game software and balance-board sensors. We also derived metrics of players' interactions with each other. These consisted of players' reciprocal interactions of offensive and defensive play, in which players respond to other players' actions on the game-board by using their tokens and the available interaction mechanisms. By offensive play we mean that players are placing their tokens in strategic positions for the construction of the cruciform token pattern that fulfils the game objective. Defensive play entails blocking each other and finding techniques to prevent other players from completing the winning token pattern.

Instrumenting the game has a key advantage compared to audio-visual recordings that would have been intrusive to players, and which are difficult to transcribe accurately. Our data logging and game analytics approach did not intrude upon participants' engagement in the busy, authentic and ambient festival settings in which data were collected. In our approach to the study of physical player interaction, we draw on a methodology that was applied in obtaining player social interaction data in a massively multiplayer online game (MMORPG). Ducheneaut & More (2004) studied anonymous online players in two locations in the game 'Star War Galaxies'. The researchers logged the real-time content that players posted in public chat boxes at specific locations in the game. Once the data was obtained, they devised a custom-made parser and proceeded in several detailed steps to extract patterns of information via quantitative analysis. We utilised a similar approach to the study of social interaction in our purpose-designed game, yet we focus on physical player behaviour by logging the sensor values that are coupled to the game-mechanics and generated through the movements of the balance-boards.

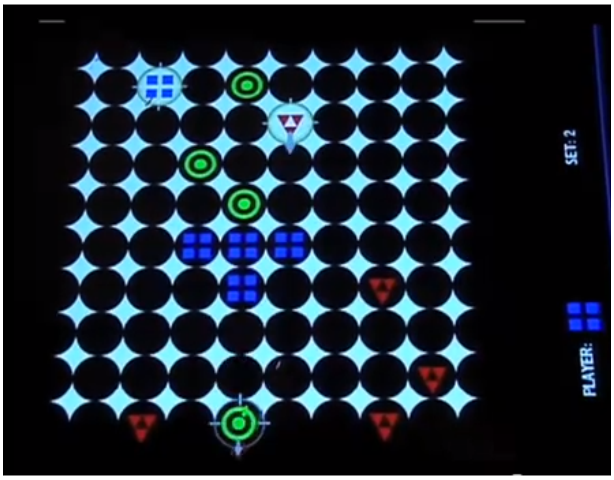

Figure 3: Sim-Suite's virtual game-board with the dashboard partially visible. The square (blue) player's almost completed cruciform has been blocked by (green) circle player. Tokens are highlighted white when placed by the system at round beginning.

3.1.1 Data Sample

Data were collected 'in the wild' from nearly 400 players at a number of digital media, music and science festivals in the UK. Participants played anonymously and they experienced the installation as part of the festivals' activities. The players' ages ranged from 10 to 60 years. Player triads were formed on an ad hoc basis and were comprised of all gender-mix permutations (i.e. all female players, all male players and mixed groups). At all times during each exhibition of Sim-Suite one of the authors (MJ) was present to administer the installation. This was required for setting-up the installation and for ensuring that it ran smoothly. Informal observations suggested that very few participants played repeat games. Player turnover was high in the busy and crowded festival settings.

Seventy-eight games were analysed. The criteria for selecting games for analysis were, 1. completed games with a definite winner; and, 2. games with at least seven rounds. The number of rounds in a game ranged from 7 to 24 (mean = 10.1 rpg). Average round duration was approximately 20 to 24 seconds. Short games (i.e. fewer than 7 rpg) were excluded from analysis because when viewed using a game replayer program, they seemed to be associated with players' casual experimentation and did not contain significant sequences of engaged 3-player interaction.

3.1.2 Aim

The aim was to investigate how players interacted in terms of joint spatial play actions and patterns in the shared game-space. Adopting a spatial game analytics approach (Drachen & Schubert, 2013), we aimed to examine the effects of player positions (F-formations) upon spatial patterns of play, considering players' relative positions with respect to each other and the game-board. On the basis of Kendon's F-formation framework, we wished to investigate whether circle player, the player at the central position of the triad, would be disadvantaged in form of game outcomes. Circle player is orthogonally aligned to the other two players forming two L-shaped configurations with them. We hypothesised from the F-formation framework that circle player's cooperative positioning in Sim-Suite's competitive game would disadvantage circle in relation to the other two players, whose face-to-face positioning supports competitive contexts (Fig.1).

3.2 Analyses

Win rates were unequal across players: Circle = 28 games won, Triangle = 32, Square=18. This was unexpected since our prediction was that circle player would be the outlier in terms of game win or loss rate. To follow-up, we looked at the relationship between a player's F-formation position and game strategies. A potential artefactual explanation was the possibility that square player's balance-board was less responsive than those of the other players. However the average movement rates over fields per round were comparable (respectively 9.8; 9.3 and 8.9 for circle, triangle and square), there was no evidence of defective operation.

Next, players' spatial play patterns on the game-board were characterised in terms of game 'state' sequences. For parsimony, the game-board size was reduced from a 10 x 10 grid of fields to quadrants (quads) each consisting of 25 fields (numbered 1-4, Fig. 2a). The quads' area was not arbitrarily chosen it was selected because it corresponds (approximately) to the 'useful field of view' of 15-20 degrees of subtended visual arc from the balance-board playing position. This is approximately the maximum area that a person can visually attend to in detail at any single point in time (Yokoi et al, 2006; Green & Bavelier, 2003).

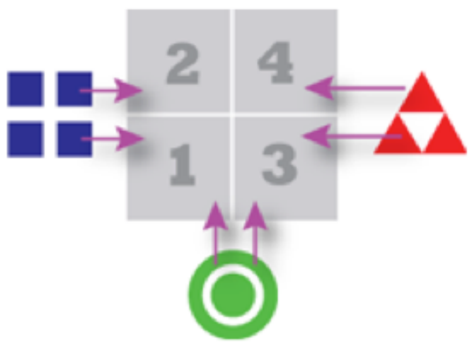

Figure 4: Game-board indicating the four quads used in the analysis.

Players' moves on the game-board occurred at different rates e.g. one player might be stationary and attempting to occupy a field whereas her co-players are moving (usually at different rates) in other parts of the game-board. Quad states are 'snapshots' of tokens placed within the quad division over the course of a round. Quad states were searched for using a computer program that identified states in which all 3 players occupied fields within a constrained time-band (<1 sec.). Approximately 3 quad states across all rounds of 78 games were sampled (2235 quad states in total).

4 Results

A 3 row by 4 column table was computed with the cells containing the frequency of field moves by each of the 3 tokens (players) in each of the 4 game-board quadrants. Field move activity differed across the 4 quads as a function of player's position (X^2=56.2, df=6, p<.0001). The stacked column graph in Fig. 5 shows the trends. Player position (token) is associated with different quad field move and occupancy frequencies. Triangle player is more active in quad 2 than in the other quads, circle in quads 3 and 4, and square in quads 1 and 3.

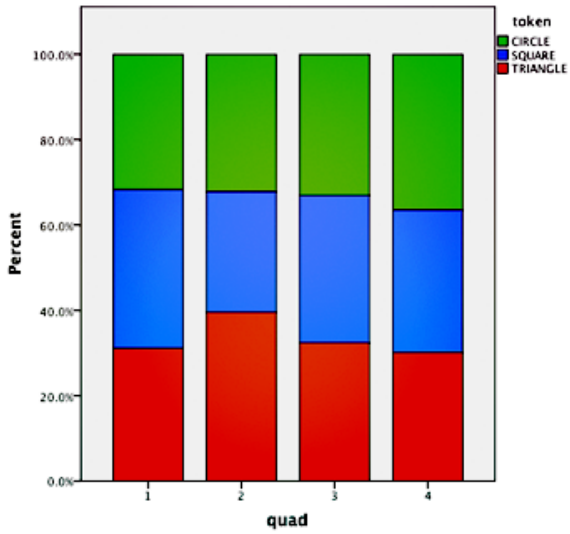

Figure 5: Proportion of game-board field activity in each quad for each player (token).

Further analyses identified three basic patterns of quad activity (Fig. 6). State 1 (S1) occurred when all 3 players were collocated in the same quad (which could be quad one, two, three or four, see Fig. 4). In State 2 (S2), two players were collocated in one quad with the third in a different quad. In State 3 (S3) each of the 3 players was active in a different quad. Players rarely all play in the same quadrant and tend to avoid such crowding. Of the various possible S2 sub-configurations, each token was equally likely to be the player in the different quad (circle 18.6%; triangle 18.7% and square 17.6%).

A closer look at S2 sub-patterns revealed that circle showed a marked tendency to play in either quad 3 or 4 when the other players were in quad 1, compared to the other permutations of S2 quad arrangement. In S2, triangle markedly favoured quad 2 when the other tokens are in quads 3 or 4. There was also a marked tendency for square to be active in quad 1 when the other two tokens are in quad 3.

Hence each player seemed to seek out different 'sociofugal' spaces (Sommer, 1967) in which they could evade the other players.

In S3 states, each token is active in a different quad. The most frequently occurring configuration for this play state was for circle in quad 4, square in quad 3, and triangle in quad 2 (6.5% of S3 states). Twenty-four different S3 configurations were observed. The 10 most frequent configurations accounted for 51% of S3 states. Within these, circle was most frequently active in quads 3 or 4, (70%), square in quads 1 or 3 (70%) and triangle in quad 2 (50% cf quad 1, 20%; quad 3, 20%; quad 4, 10%).

When considered from each player's egocentric play perspective the S2 and S3 patterns show consistent trends (described below).

We also examined the quads in which winning cruciform patterns were built. On games won by triangle, 66% were won with a cruciform built in quad 2 (25%) or quad 3 (41%). For square, 72% of games were won in either quad 1 (33%) or quad 4 (39%). Circle token won most often in quad 4 (36%). For circle, quad 3 or quad 4 located winning patterns accounting for 57% of games won.

Considered from each player's play perspective, the two facing players tend to win along quad diagonals. The diagonals are mirrored - nearest right (quad 1), furthest left (quad 4) for square and nearest left (quad 3) and furthest right (quad 2) for triangle. Circle, on the other hand, wins most frequently in quads 3 and 4 which are horizontally arrayed and distal to that player.

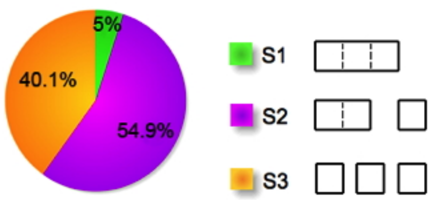

Figure 6: Distribution of gamestates.

5 Discussion

The results strongly suggest that a player's position in physical space - i.e. her play situation relative to those of her opponents and to the game-board - systematically influences her spatial behaviour in the virtual game-space. Systematic effects were observed across a range of different game behaviours. These included 1. the frequency of overall activity across quadrants, 2. quadrant preferences within two of the 'uncrowded' play state configurations (S2, S3) and 3. game-board areas associated with winning token placements. Considered from their egocentric play-position perspectives the two facing players show consistent preferences for playing on the right-hand side of the game-board (triangle in quad 2, square in quads 1 and 3). The player 'to the side' (circle) showed the same tendency to play on the right-hand side, which involved the quads that were on the perpendicular axis (quad 3 & 4) to those of triangle and square. Taken together, these results indicate a relatively strong tendency for players to prefer to play more in their distal and/or right-hand perceptual-motor fields than in their left-hand and nearer game-board areas. In addition, players appear to seek 'safer' game-board regions that are as far away from their opponents' scrutiny as possible. They also seek quads on the 'open' side when to do so is consistent with the 'distal-right' perceptual-motor bias. These spatial gameplay effects are summarised in Figure 7.

Asymmetrical spatial behavioural effects akin to the 'distal right' tendency we observe have also been demonstrated in virtual environments by Gerin-Lajoie et al. (2008). Their study of obstacle-passing by pedestrians walking in virtual and real environments revealed that when participants passed obstacles they tended to require significantly more personal space when the obstacle was on their non-dominant (usually left) side. This bias is consistent with the tendency we observe in our results.

In the study reported here, the handedness of the (self-selected) player sample could reasonably be assumed to reflect that of the general population (i.e. approximately 90% right-handed, 10% left-handed). However, controlling the balance-board required postural adjustments mediated via the legs and feet and therefore leg preference and 'footedness' of participants would be expected to exert a greater influence on balance-board performance than handedness per se.

Research findings on the relationship between handedness and footedness suggest that for responses such as tapping speed, right foot responses are faster in right-handed people but also in 62.5% of left- handed respondents (Peters & Durding, 1979; Peters, 1988). It is reported that, in general “humans are typically right-footed for actions of mobilization and left-sided for postural stabilization” (Sadeghi et al, 2000, p.37). Peters (1988) states that “the specialization for the right foot can simply be seen within the larger context of a preference for focusing on the limbs of the right body half in the realization of a movement goal” (p.190).

Such preferences have real-world implications. For example, a study of shoppers’ in-store supermarket travel paths showed that 11 out 14 “canonical paths” identified via RFID tagging were ones in which people walked a right-hand path upon entering the store (Larson et al., 2005).

In the context of playing Sim-Suite the movement goal consists of balance-board ‘teetering’ and players may have tended to use their left legs for postural stabilization and their right legs for producing ‘teetering’ responses. It seems likely that lateral asymmetries in movement control accounted at least in part for the spatial play patterns that we observed.

Further research on the implications of lateral asymmetry in perceptual-motor responses seems warranted as an important topic of further research for HCI particularly in embodied controller contexts where the influence of such effects might be underestimated.

In the case of circle and triangle players, the ‘distal right’ perceptual-motor factor interacts with the strategic need to seek the less scrutinised, player-free side of the game-board in order to minimize blocking by other players. This seems to their advantage as reflected in their higher game win rates compared to square. Square players also manifest a rightmost quad bias but tend to opt for the nearer quad rather than (from their perspective) the more distal quad 3. This is probably because quad 3 is very much right ‘under the nose’ of both of square’s opponents.

5.1 Kendons L-shaped configuration: right versus left-side

The right-hand side play preference and right-side physical positioning between circle and triangle players naturally supported the forming of an L-shaped formation which, in the spatial context of the players positioning around the game-board, provided both players with an “outlet” towards the game-board’s player-free side to focus on (Fig.7), and potentially diverted the focus from playing defensively against the partner in the L-shaped formation.

From the circle player’s perspective, this would explain why the square player was adversely affected in terms of wins compared to the triangle player. The circle-triangle L-shaped relation regulates the spatial relationship between square and triangle players, because circle player’s right-side play preference and right-side physical alignment with triangle player creates a natural rightward alignment between the circle and triangle players. In the circle-square L-shaped relation there is no physical right-side alignment for circle, and square does not access the right-side ‘outlet’, the player-free side, because that side is on square player’s far left-side. Circle’s right-side alignment with triangle player and triangle’s right-side access to the player-free side seem to exert a strong influence on the overall play-dynamics of the players’ interaction.

According to Kendon’s circular F-formation system Sim-Suite’s player-free, open side connects people in the ‘focussed encounter’ with the surrounding ‘world’. In Sim-Suite we see a conceptual and physical interplay between o- and r-space. Players’ seek out advantageous play-spaces on the game-board based on strategic contexts by connecting with the physical aspects of the bordering r-space (the player-free side), to step beyond the boundaries of the focussed encounter.

Sim-Suite’s virtual and physical spaces are very closely intertwined. This feature, together with immersive gameplay and the use of virtual artefacts, strongly influences the players’ spatial relationships. Tangible and embodied games offer a useful insight into how interpersonal dynamics in virtual space connect with physical space and perception.

6 Conclusion

Predictions based on Kendon’s F-formation framework were partially supported in that the most frequent winner (triangle) was one of the players who occupied a face-to-face play position. However, the other facing player (square) lost more games than the non-facing player (circle). This finding did not support our prediction made on the basis of the F-formation framework. The players' play-area preferences we observed appear to interact with F-formation position effects in complex ways.

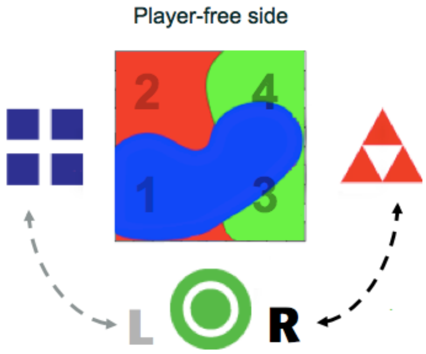

Figure 7: Summary of spatial play effects. The coloured fields indicate the tendency of token movement.

In Sim-Suite, the various o-space (game-board) regions vary widely in their strategic significance to each player. We have seen that several factors interact to affect game win/lose outcomes - these are F-formation player position, various o-spaces and perceptual-motor play biases. Further research is focussed on establishing these factors' relative strengths of influence - to identify which is the strongest influencing factor, which mediates a moderate effect and which have only weak effects.

In conclusion, our results indicate the importance of considering the interaction of several factors in embodied, collocated, multiplayer, blended physical and virtual gaming contexts. The factors include the lateral asymmetry in lower limb movement control and the players' spatial orientation with respect to each other and to the virtual game-space. With the recent advent of technologies such as virtual agents, augmented reality and wearables, blended contexts in which physical and virtual spaces are coextensive and will soon become ubiquitous. Designing game experiences that take into account spatial factors in blended contexts will therefore assume great importance. Designers could respond in different ways. One strategy would be to 'design out' player position advantages or disadvantages by changing the characteristics of particular game-space areas. Alternatively, future games could incorporate AI or machine learning approaches to analyse the spatial aspects of players' behaviour in real-time during gameplay so that in-game adjustments can be made. These could take the form of altering the sensitivity of a player's input system or re-configuring game-play elements 'on-the-fly' e.g. to encourage players to alter their positions relative to each other and/or the game-space. However designers choose to respond to player and game-space spatiality effects, the consideration of human spatial behaviour in blended contexts by the HCI community is likely to assume greater importance in the near future.

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