Making Sense of Group Interaction in an Ambient Intelligent Environment for Physical Play

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ABSTRACT

This paper presents the results of a study on group interaction with a prototype known as socio-ec(h)o. socio-ec(h)o explores the design of sensing and display, user modeling, and interaction in an embedded interaction system utilizing a game structure. Our study involved the playing of our prototype system by thirty-six (36) participants grouped into teams of four (4). Our aim was to determine heuristics that we could use to further design the interaction and user model approaches for group and embodied interaction systems. We analyzed group interaction and performance based on factors of team *cohesion* and *goal focus*. We found that with our system, these factors alone could not explain performance. However, when *transitions* in the degrees of each factor, i.e. high, medium or low are considered, a clearer picture for performance emerges. The significance of the results is that they describe recognizable factors for positive group interaction.

Author Keywords

Groups, responsive environment, play, embodiment, ambient display, games

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

socio-ec(h)o is a prototype environment for group play that explores design and use issues of ambient intelligent systems. Ambient intelligence computing is the embedding of computer technologies and sensors in architectural environments that combined with artificial intelligence, respond to and *reason* about human actions and behaviors within the environment. Our broader research with socio-ec(h)o is focused on several related issues including sensing and display, user modeling, and interaction models. The overall research goal is to understand how to support groups of participants as they learn to manipulate an ambient intelligent space. The research questions are numerous in a project of this nature and yet immersive and embodied interaction does not lend itself to reducible variables that can be measured independently. Given this, our initial aim is to provide a broad, yet particular set of heuristics that help describe and make sense of group interaction in these environments.

The contribution of this paper is that we describe two factors, *cohesion* and *goal focus* as descriptors to analyze group interaction. We further detail how *transitions* between the degrees of each factor, i.e. high, medium, low help explain the performances of groups in an embodied interaction system. The value of our study is that it reports on responsive environments in which actions are deeply physical, i.e. embodied, visual, aural, and tactile, as well as verbal.

We chose to design our prototype as a game since game structures are suitable for this type of research. Games provide a sufficiently open framework to study a range of interactions that are both embodied and intellectual, yet are sufficiently constrained in regards to goals and rules and so provide commonality and identifiable design factors (i.e. the rules). In socio-ec(h)o, the aim is for a team of four players to progress through multiple game levels. Each level is completed when all the players achieve a certain combination of body movements and positions. At the beginning of each level, players are presented with a word puzzle as a clue in discovering the desired body states. The levels are represented by changes in the environment in light and audio. The levels are progressively more challenging in terms of body states.

In our complete study, we conducted an experiment involving fifty-six (56) participants divided into teams of four. The experiment included a two-hour session of playing in the socio-ec(h)o environment. The teams were divided into two groups that each followed a different protocol. In this paper we only report on one of the protocols and groups of thirty-six (36) participants. We also have chosen to focus our analysis on data from two critical levels of the game rather than all the levels.

The paper provides an overview of related research, a description of our prototype and study. We then devote the remainder of the paper to discussing the results, analysis of our study and future research issues to pursue.

RELATED RESEARCH

We will briefly describe our previous research related to this project and then present an overview of research into frameworks for tangible and embedded interaction and previous embodied and ambient intelligent prototypes. In [19] we discuss a method for constructing group parameters from individual parameters with real-time motion capture data; and a model for mapping the trajectory of participant's actions in order to determine an *intensity* level used to manage the experience flow of the game; as well as design strategies for representing intensity via an audio and visual display. We refer readers who would like further technical details on our prototype to this paper. In [5] we explore the use of an intensity scale for audio display.

Tangible and Embedded Interaction Frameworks

Over the years various frameworks have been proposed to better define tangible user interfaces and embedded interaction. Holmquist and others [8] proposed defining concepts of containers, tools, and tokens. Ullmer and Ishii proposed a framework known as the Token+Constraint System [17] that highlighted the integration of representation and control in tangible user interfaces. Shaer and others have extended Ullner and Ishii's work to propose their Token and Constraints (TAC) paradigm [15].

Fishkin's taxonomy [7] is noteworthy for its embodied approach. It is a two-dimensional space across the axes of *embodiment* and *metaphor*. Djajadiningrat argues for a "perceptual-motor-centered" approach to tangible interfaces [4]. He argues for a "direct approach" for its "sensory richness and action-potential" of the objects to carry meaning through interaction.

Hornecker and Buur [9] address the interweaving of embodied and social aspects with the interaction experience of tangible interaction in a framework that offers design guidelines along four themes of *tangible manipulation*, *spatial interaction*, *embodied facilitation,* and e*xpressive representation.*

While each of these frameworks make a valuable contribution to the epistemological discussions on tangible and embedded computing, none at this point provide an adequate analytical foundation for embedded and embodied group interaction. For example, in [18] we explored the limits of TUI frameworks at the convergence of tangibility and embodiment. While Hornecker and Buur's guidelines are a useful starting point, they are simply too high level and not sufficiently granular for our purposes.

Group Interaction in Game and Play Environments

Recent projects have investigated the play space of responsive environments and tangible computing utilizing sensors, audio, and visual displays. For example, Andersen [1], and Ferris and Bannon [6] engage children in exploratory play and emergent learning through sensor-augmented objects and audio display. Andersen's work reveals how theatrical settings provide an *emotional framework* that scaffolds the qualitative experience of the interaction. Ferris and Bannon's work make clear that a combination of simple feedback and control lead children to widely explore and discover a responsive environment.

In the *Nautilus* project, Strömberg and her colleagues employ bodily and spatial user interfaces as a way of allowing players to use their natural body movements and to interact with each other in a group game within a virtual game space [16]. Strömberg observed in physical and team games such as soccer or dodge ball that players coordinate their physical movements and rely heavily on communication to be successful.

In relation to the above research, socio-ec(h)o builds on the theatrical, simple and physical interaction models in order to develop a game structure approach that lies between exploratory play and a structured game for adults within an ambient intelligent environment. In addition, we extend the notion of a game structure to an interaction model for the physical environment rather than a virtual game space. We also build on the idea that actions, play and learning are linked in such physical environments.

THE PROTOTYPE & DESIGN MOTIVATIONS

The prototype involves interaction of multiple participants (four at one time) in a cooperative puzzle game that is solved by coordinated physical actions of the group. The environment is responsive to the participants' actions through ambient audio and light (see Figure 1).

Description of the prototype

The short scenario of the socio-ec(h)o environment below is excerpted from a previous paper [19]:

Madison, Corey, Elias and Trevor have just completed the first level of socio-ec(h)o. They discovered that each of them had to be low to the ground, still, practically on all fours. Once they had done that, the space became bathed in warm yellow light and filled with a wellspring sound of resonating cymbals. Minutes earlier, the space was very dim – almost pitch black until their eyes adjusted. A quiet soundscape of "electronic crickets" enveloped them. They discussed and tried out many possibilities to solving the word puzzle: "Opposites: Lo and behold." At Corey's urging, the four grouped together on the edge of the space and systematically sent a player at a time to the opposite side in order to gauge any change in the environment.

Figure 1 Participants playing level 5 of socio-ec(h)o

Nothing changed. Madison, without communicating to anyone realized the obvious clue of "Lo" or "low". She lowered herself to a crouching position. The space immediately glowed red and became brighter. The audio changed into a rising chorus of cymbals – not loud but progressively more pronounced. Corey and Trevor stopped talking and looked around at the changing space. Madison, after a pause began to say "Get down! Get down!" Elias stooped down immediately and the space became even brighter. Corey and Trevor dropped down in unison and the space soon became bathed in a warm yellow light like daylight. The audio reverberated in the space. A loud cheer of recognition came from the group, "Aaaaahhh! We got it!"

The game consists of six levels that require the group to achieve specific body states and goals. The *body states* are the body movements and positions that players must discover in order to complete a level. *Goal*s are the changes in the environment players are aiming to achieve. The goals are implicit and have to be discovered during the game. Each level has a beginning quality of light and audio. As the players progress toward achieving the right body state, the environment incrementally shifts toward the goal state of the environment (see Figure 1). For example, as depicted in the scenario, when Madison lowered herself, the environment gradually shifted toward the goal of creating day. As each of the other three players followed Madison, the environment responded to movements of each player.

The levels were designed to enable the players to gradually acquire *generic skills* to manipulate the environment. The aim was that a generic skill acquired at lower level is required in order to discover the more complex body states at higher levels. *Goals* allowed us to design an implied progressive narrative. We intended for this approach to provide a sense of coherency across the levels, and to loosely map increased challenge to the reward of a more complex display.

The physical environment consists of a circumscribed circular space (the area in which we can detect motion), immersive 8-channel audio, theatrical lighting, and three video projection surfaces.

Design Motivations

In approaching the design of our ambient intelligent environment we were clearly inspired by play and games. We followed the principles of simple rules and goals with a great degree of variation in how the goals are achieved. For example, consider the game of soccer, in which within a set of simple rules there are a myriad of ways to score a goal. Fans of soccer often refer to the creative playmaking in a wonderful goal. In fact, it is the very combination of limited simple rules and almost limitless paths to the same goal that establishes a creative space that can make a game so appealing. From the perspective of the design of the interaction model and system, we realized it was important to decide where not to specify interaction and system functionality. In many respects, we learned to *off-load* formalized interaction among participants to the situated dynamics of people *mundanely* interacting, i.e. people will communicate together in whatever form possible given the resources in the environment without the need of formalizing communication modes. In addition, the system does not need to encode or sense actions or behaviors that are not relevant to the required body-state at a given level, i.e. no response from the system is a perceived response. We employed simplicity with the aim of creating rich and complex responses. For example, limiting sensing actions to whole body positions and movements rather than gestures, opened gestures up to unique, particular and complex communication between participants. Ignoring or not encoding large parts of the embodied action supported a wide range of exploration of body movements. In other words, our approach was not to overwhelm the interaction by over determining the experience.

At the same time we are looking for clear descriptors and factors upon which we can base refinements and future design, and validation of our design strategy.

THE STUDY AND RESULTS

Description of the study

In our complete study, each of the participants completed Keirsey's Temperament Sorter[1] to identify his or her personality type. We utilized the results to organize people into team configurations that resulted in 56 participants being chosen from which a cohort of 36 participants is reported on in this paper. The other cohort of 20 participants followed a different protocol aimed at studying the explicit support of players during game play (these results have yet to be published). The sample of 36 included 11 females and 25 males where 30 were 18-24 years old, 5 were 25-34, and 1 was 35-49. This produced 9 teams of 4 players.

The Keirsey temperament designations were pursued in order to develop a baseline metric for our group user model. As it turned out we found virtually no significance between

[1] See http://www.keirsey.com

our results and temperaments. We discuss this in detail in another paper currently in review that cautions against the use of Keirsey temperaments as a compositional approach to user models or group interaction. In this paper, we focus on an alternate explanation of observed commonalities and as such make no further reference to Keirsey temperaments.

Each session began with a warm-up that introduced the concept of puzzles solved through physical action that was helped by implicit responses. The warm-up was a modification of the child's game of "hot-cold." Participants were also played a range of sonic cues and rewards in order to adjust their perceptual hearing to our sound ecologies. Each team of four played the first four levels without any intervention from the research team. After a short break the last two levels were played. A time limit of 15 (fifteen) minutes was given for completing these last levels.

The evaluation was performed with the socio-ec(h)o prototype in our 'black-box' lab environment. The sessions were videotaped and audio recorded. In addition, each participant wore a wireless microphone to record conversations. Following the sessions each participant completed a questionnaire.

Data Types

The data analyzed included video coding of the sessions that used a scheme that we developed based on levels of *cohesion* and *goal focus*, log data from the system that mapped the game state and player actions represented as *intensity*, and transcripts of the verbal communications between players. We also compared our groupings against the questionnaire data.

Coding Scheme and Transcripts

Each session was recorded with three cameras providing sufficient data to code group actions and behaviors. Our coding scheme was based on two main factors: *cohesion* and *goal focus*. The combination of these factors in a two-dimensional matrix show the degree of descriptive capacity, see figure 2. Two researchers independently coded the videos and later negotiated the differences to reach a consensus.

Cohesion can be described as the extent to which players appear to be acting as a team (all members coordinating together) – whether that is working on a game solution, playing, thinking, or talking to each other. Cohesiveness is a measure of team dynamics and does not necessarily reflect their focus on the game but only whether they are acting in unison as a team. We analyzed different degrees of *cohesion*:

- *Low*, players are not together as a group or they are temporarily fragmented. They are not communicating or are individually exploring;
- *Medium*, players are in the process of becoming a group or are regrouping. Players are negotiating roles and establishing leadership or consensus;
- *High,* players constitute an established team. They make several agreements and are coordinated in their movements or are communicating with each other about strategy and solving the puzzles.

Cohesion is a common construct in group studies, referring to the affinity an individual feels toward a group [2] and is demonstrated by a high commitment to the solidarity of the group [12]. Cohesion is often studied in an organizational context dating back to Seashore [14], and more recently it has been applied to virtual teams [13].

Goal focus can be described as the extent to which players appear to be or are attempting to "play the game" the way they understand it. Game activity is not dependent on whether players are working as a team or not. In addition, game activity does not necessarily only mean that players are actively playing, i.e. in our case moving. If players are still because they believe the game requires them to be still, then they are "playing the game." We analyzed different degrees of *goal focus*:

- *Low*, players are not involved in playing the game. They are resting, or are distracted, or engaged in activities not related to the game;
- *Medium*, players are in the process playing the game. They are experimenting with different actions, and communicating with each other about or reflecting on the effects of their actions;
- *High,* players are actively and consciously playing the game and attempting to solve the puzzle at hand. This is reflected in concerted efforts and good communication related to their performance in the game. Many ideas are shared on actions for solving the puzzle.

Malone and Lepper [11] consider games to be intrinsic motivators for learning that suggests an internal state of mind however a sense of focus or concentration is evident.

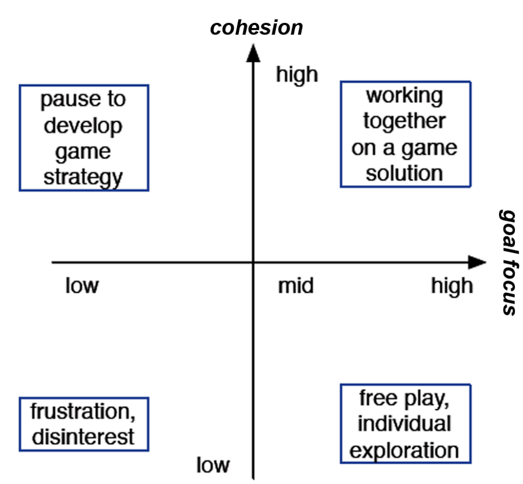

Figure 2 Matrix showing the descriptive capacity of the two factors *cohesion* and *goal focus*

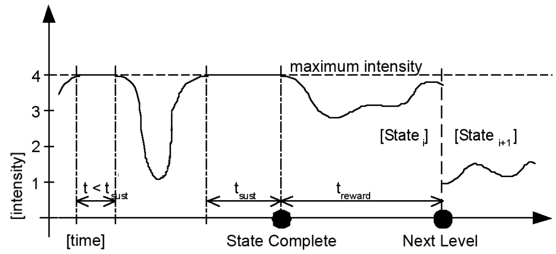

Figure 3 Representation of the intensity levels in response to game play modeled by the reasoning engine

Huizinga referred to play as invoking a magic circle, a liminal space for games [10] that extends the perceptible concentration to a sense of intense focus that is almost separate from the everyday world. This idea has best been captured by psychologist Csikszentmihalyi's notion of *flow*, which is a high level of engagement, risk and challenge found in play and ritualized in sport [3].

Intensity Scale

A component of our system is a reasoning engine that manages the game state of the interaction. The model for this includes mapping the trajectory of the body states to participant's actions in order to determine the *intensity* level, or proximity to the desired body state. For example the sensing system sends data on predefined parameters such as velocity and body positions. Based on these basic parameters the reasoning engine infers higher-level behaviors for the user group such as high-fast-moving group, middle-low-stationary group, etc. The *intensity* is computed based on heuristics applied in response to the current state of the game and the inferred behaviors of the teams.

The *intensity* is measured from 0 to 4 with 4 representing the maximal intensity or state completion. The *intensity* is reflected in the ambient display of the system, thus when the intensity reaches value 4, the participant hears the cue sound indicating that they achieved the body states required by the current level. In addition, we felt that the overall shifts in intensities toward and away from the goal could be represented in the ambient display in a gradient effect in real-time in order to support player actions in the environment and awareness of the game state. It should be noted that the ability to sustain *intensity* levels are also monitored, typically a 4 second duration is required to complete the state, see figure 3. The reasoning engine provided a log of intensity values. This allowed us to precisely analyze the game state (players' actions) and the state of the environment (ambient display).

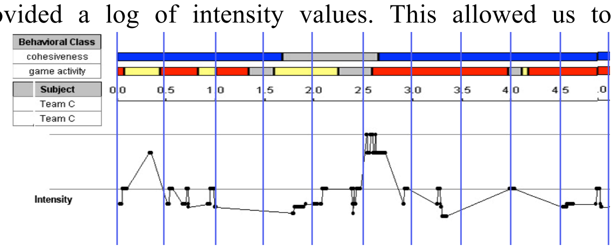

Figure 4 Comparative timeline analysis of *intensity*, transtions, and duration

Questionnaire

The questionnaire was comprised of twenty-five questions including Likert scale and semi-structured answers. The questionnaire was structured in four parts with questions on the perceptions how the system facilitated or constrained goals; the social and physical resources of the players, system and environment; the role of internal and external elements in the learning and cognitive transformations; and how the activity and understanding of the system changed over the course of the two hours. Participants completed the questionnaire immediately after the sessions.

Analysis

Our analysis looked at the different levels of *cohesiveness* and *goal focus* over duration to determine a *density* value in percentages:

$$density = \frac{factor(\text{min})}{duration(\text{min})}$$

We looked for combinations of *density* values of the different degrees (high, medium, low) of the two *factors* (*cohesion, goal focus*) and compared these to team performance or *duration* of the game level. Additionally, we correlated the different degrees of *cohesion* and *goal focus* factors with team performance (duration) using the Pearson correlation coefficients. The Pearson correlation coefficients measure the degree and the direction of the linear relation between two variables. That is, how much are changes in one of the variables related to changes in the other variables. Correlation can be used to estimate the extent to which teams' performance, *cohesion* and *goal focus* factors were related. Lastly, we compared the video coding results with the *intensity* data from the logs, see figure 4. Based on these comparisons we can isolate key events that we can further examine through transcripts and videos.

Results

Our results discuss correlations between high degrees of the two factors, the role of transitions, and players' perceptions. Tables 1 through 4 show correlations between *cohesion* and *goal focus*. Note that in each table, column numbers refer to the same values as rows, for example in table 1, row 7 and column 2 shows a significant correlation of .871 between the medium degree of *cohesion* and completion time.

One might expect that a team that showed high *density* values of both *cohesion* and *goal focus* factors would lead to a fast performance in the game. Indeed, we found that Team H held density values of 93% for *goal focus* and 97% for *cohesion* in level 4 and completed the level in less than a minute. However, Team D had significantly more modest *density* values for level 4, 63% for *goal focus* and 67% for *cohesion* yet were able to complete the level in just under a

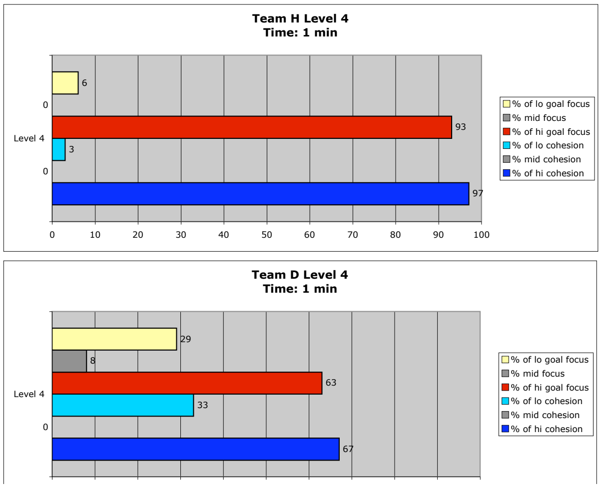

Figure 5 Bar graphs showing that high density values of high *cohesiveness* and high *goal focus* do not correlate to fast completion as in the example of teams H and D.

minute, see the comparison in figure 5. To further the point, a team like Team C, which had a *density* value for *goal focus* of 66% and *cohesion* of 89% required over 39 minutes to complete the levels.

High level of cohesion and goal focus does not necessarily lead to good performance:

Statistically, we found no significant correlations between high degrees of *cohesion* or *goal focus* factors and team performance in game level 3 (see Table 1). We had virtually the same results for game level 4 see Table 2. However, Table 1 shows a significant correlation between *Medium* degree of *cohesion* and performance (.871). Table 2 shows a strong correlation between *Medium* degrees of *cohesion* and *goal focus* and performance (.892; .927). This led us to examine the role of transitions, where factors change in degrees such as a team shifts from a *high* degree of *cohesion* to *medium* degree of *cohesion*.

Transitions as an influencing factor

We found that transitions from different levels of *coherence* and *goal focus* held statistical significance when compared against performance throughout level 3 of the game except for transitions to high *cohesion*, see row 9 in Table 3, and significance in transitions from all degrees of both factors in level 4 of the game except for transitions to low *cohesion*, see row 9 in Table 4.

Players Perceptions

We examined the relationship between players' perception of the helpfulness of the system and their performance. No correlation was found, thus fast players did not necessarily believe the system to be more helpful than slow players. However, there was a significant relationship between players on teams who completed the most levels and their perception of the support of the system. This suggests that the more "skilled" players (those who could complete the

Level 3	1	2	3	4	5	6
1. High degree of cohesion	-	-	-	-	-	-
2. Medium degree of cohesion	.577	-	-	-	-	-
3. Low degree of cohesion	-.355	.828 **	-	-	-	-
4. High degree of goal focus	-.346	-.609	.284	-	-	-
5. Medium degree of goal focus	.303	.799 **	-.511	.743*	-	-
6. Low degree of game focus	.158	-.010	.172	-.651	-.023	-
7. Whether or not completion time is < 5min	.494	**.871***	-.743	-.439	.651	-.012

* Correlation is significant at 0.05 (2-tailed),
** Correlation is significant at 0.01 (2-tailed).

Table 1. Correlations in Level 3

Level 4	1	2	3	4	5	6
1. High degree of cohesion	-	-	-	-	-	-
2. Medium degree of cohesion	.837**	-	-	-	-	-
3. Low degree of cohesion	-.785*	.358	-	-	-	-
4. High degree of goal focus	.854**	.834**	-.566	-	-	-
5. Medium degree of goal focus	-.785*	.926**	.370	.882**	-	-
6. Low degree of goal focus	-.590	.450	.586	.816**	.486	-
7. Whether or not completion time is < 5min	-.037	**.892****	-.334	-.647	**.927****	.297

* Correlation is significant at 0.05 (2-tailed)
** Correlation is significant at 0.01 (2-tailed)

Table 2. Correlations in Level 4

higher levels) perceived the system to be more helpful. The overall rating of the system was quite good, for example on the question of how helpful the system was the median score was 4.0 (SD 1.02) on a scale of 1-5 (5 high).

Level 3	1	2	3	4	5	6	7	8
1. Total transitions game focus	-	-	-	-	-	-	-	-
2. Transitions to low game focus	.985 **	-	-	-	-	-	-	-
3. Transitions to medium game focus	.854 **	.771 *	-	-	-	-	-	-
4. Transitions to high game focus	.947 **	.963 **	.649	-	-	-	-	-
5. Total transitions cohesion	.860 **	.823 **	.848 **	.744 *	-	-	-	-
6. Transitions to low cohesion	.818 **	.839 **	.670 *	.770 *	.923 **	-	-	-
7. Transitions to medium cohesion	.883 **	.838 **	.889 **	.754 *	.994 **	.893 **	-	-
8. Transitions to high cohesion	.820 **	.775 *	.825 **	.703 *	.995 **	.906 **	.984 **	-
9. Completion time	**.939** **	**.960** **	**.732** *	**.916** **	**.688** *	**.687** *	**.725** *	.625

* Correlation is significant at 0.05 (2-tailed)

** Correlation is significant at 0.01 (2-tailed)

Table 3. Correlations between transitions and duration in level 3

Level 4	1	2	3	4	5	6	7	8
1. Total transitions game focus	-	-	-	-	-	-	-	-
2. Transitions to low game focus	.989 **	-	-	-	-	-	-	-
3. Transitions to medium game focus	.958 **	.911 **	-	-	-	-	-	-
4. Transitions to high game focus	.971 **	.987 **	.863 **	-	-	-	-	-
5. Total transitions cohesion	.897 **	.842 **	.980 **	.769 *	-	-	-	-
6. Transitions to low cohesion	.778 *	.690 *	.922 **	.613	.964 **	-	-	-
7. Transitions to medium cohesion	.897 **	.841 **	.978 **	.770 *	.999 **	.966 **	-	-
8. Transitions to high cohesion	.942 **	.913 **	.976 **	.845 **	.977 **	.888 **	.972 **	-
9. Completion time	**.950** **	**.971** **	**.831** **	**.988** **	**.722** *	.553	**.717** *	**.817** **

* Correlation is significant at 0.05 (2-tailed)

** Correlation is significant at 0.01 (2-tailed)

Table 4. Correlations between transitions and duration in level 4

DISCUSSION

We expected a clearer pattern of what makes players successful and where breakdowns occur. For example, we expected correlations between *high* degrees of *cohesion* and *goal focus*. In our analysis, the results point to three possible patterns of engagement with our system yet only one pattern that leads to better game performance:

- *Get it right:* Certain teams were simply very good. They demonstrated an understanding of the game that the players were able to carry across levels. For example Team H was consistently quick and their initial ideas for what might work in the game tended to be correct.
- *Luck:* Some teams were simply lucky in certain levels. The players were not engaged yet accidentally they formed a correct body state leading them toward a solution however they may not know how they got there. For example, in some cases the degree of *cohesion* and *goal focus* was modest yet the *intensity* was high.
- *Banging their heads against the wall*: Some teams displayed extraordinary persistence by consistently having high degrees of *cohesion* and *goal focus* yet equally consistent in their inability to find a correct path for a solution.

Enabling skilled players is a part of any game as is luck, yet the third pattern is a distinct problem with the prototype. One possibility is that we designed an approach that exclusively looks for positive patterns to support, i.e. as players find a correct path the system provides positive support by increasing the *intensity* of the ambient display. A design change would be to include a *negative intensity* response in the ambient display that would warn players they are going in the wrong direction.

Transitions were a better indicator of performance, at least in terms of speed. In other words, teams that made fewer transitions, i.e. shifting between different degrees of either *cohesion* or *goal focus*, completed levels faster. This is clearly illustrated in figure 6 showing the affect of transitions on duration. Here teams that take longer have a greater number of transitions, for example the marginally longer time of Team C in comparison to Team B can be accounted for by the slightly more transitions in degrees of *cohesion.*

In our preliminary examination, we found that transitions allow players to strategize, analyze the system's response,

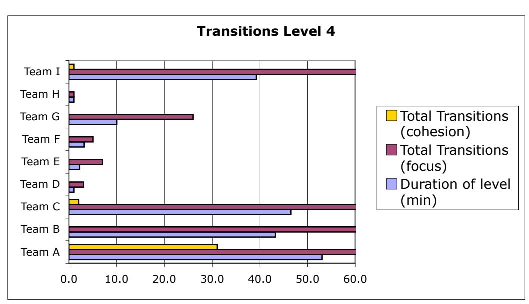

Figure 6 Graph comparing number of transitions per team for *cohesion* and *goal focus* in comparison to duration

and to communicate, in that order. It is clear that fewer transitions may help a team to perform faster but that does not mean that no transitions are an optimal pattern.

Our future research will focus on a detailed analysis of the video and transcripts to better understand what occurs during the transitions and how better to support these activities in terms of design. This next phase of research will rely on analyzing the rich qualitative data we have, based on the questionnaires, video, and audio. Further, we expect the embodiment aspect of our prototype to yield a multi-modal description of what occurs during transitions that are particular to tangible and embedded systems. While these preliminary findings do not fully make the case of generalization, we do believe that our future findings will have general applicability to ambient intelligent systems.

We analyzed only levels 3 and 4 of the six (6) levels of the game. The amount of data across all levels is substantial. We aimed to find patterns in these two critical levels first. Levels 1 and 2 are in large part learning levels. Nevertheless, our future work will look at the full cycle of the game with an eye toward the cumulative patterns such as skill acquisition and team dynamics. For example, a pattern of more effective strategizing and less analysis of the system's response as the levels progress suggest players clearly learn as they play.

CONCLUSION

We have provided an overview of related research, described our prototype, and experimental study. We concluded by discussing the results, analysis of our study and future research issues to pursue. The contribution of this paper is that we describe two factors, *cohesion* and *goal focus* as descriptors for analysis of group interaction. We detail how *transitions* between the degrees of each factor help explain the performances of groups in an embodied interaction system.

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