Small group formations of virtual characters using a 3D game engine

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ABSTRACT
When small groups of people gather in public places, they often form free standing conversational groups. Understanding how to generate realistic looking groups of virtual characters forms an important basis for media and entertainment applications that feature groups of agents, ranging from computer games to movies. This research paper investigates the physical proximity to virtual characters and the perceived comfort for the subjects who wears a designated virtual reality headset and presented static groups with varying circular formations while instructed to move towards them until at a comfortable distance.

The results yielded that test subjects tend to feel more welcome to groups of that are closer together and facing towards the subject. Subjects that were presented to groups forming a closed group felt on average less welcome to said group.

Author Keywords
Virtual Reality, F-formations, Virtual Characters, 3D Game Engine, HMD, User Evaluation

INTRODUCTION
The study of pedestrian group formations, interactions and the perception of such groups have been the subject to a lot of research and study during recent years [1]. Simulations and models of different crowd behaviours are today often applied to a wide set of disciplines ranging from transportation research, architectural design, social science, safety and civil engineering and entertainment [1, 2, 4]. In cinema and in the gaming industry the need for generating animated realistic looking crowds, with interactive and immersive human-like behaviour, have become more and more important [4]. In some recent open-world games such as The Witcher: The Wild Hunt, Horizon Zero Dawn and The Assassin's Creed Series the goal of the game designers was to provide an immersive experience based on crowd game-play.

This research paper will focus on people's perception of static small group formations in a virtual 3D environment [6]. By limiting the varying parameters to agent orientation and arc length the authors want to measure the feeling of being welcomed to a group.

THEORY
It should come as no surprise to most people that there are a lot of physiological and social factors which comprise the formation and movement of people [1, 3, 5] . When two pedestrians meet they together form a small, free conversational group. A social hierarchy between the group members are established and the relationships within the group, the so called intra-relations, will shift the groups collected attention and attitude [1]. At the same time the group inter-relations, i.e. relationship between groups will do the same. If a group grows, then naturally their relations will change and their collected influence, both within and outside the group, will shift. In a crowd, where there are several groups and pedestrians comprising it, both static and in movement, the complexity grows exponentially.

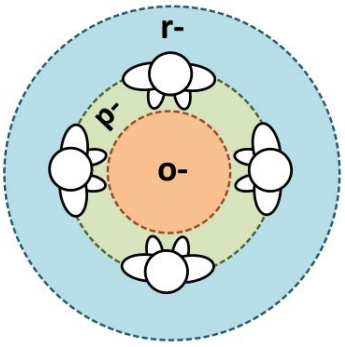


Figure 1.

In smaller static group formations, a general model has been created called F-formations [4] where the participating members take on one of four arrangements i.e. circular-,

vis-a-vis-, L- and side-by-side arrangement. All these arrangements take into consideration the subconscious human behaviour of organizing into social spaces i.e. o-space, p-space and r-space *(fig. 1)* O-space is the empty space surrounded by the people involved in a social interaction. All the participants look into it and no external people are allowed inside it. P-space is a narrow strip surrounding the o-space which contains the participants. R-space is the area beyond the p-space and represents the outside of the group.

METHOD

In order to collect perceptual data about small group formations in a virtual 3D environment, a testing application was developed in the game engine Unity. The application was designed to generate different types of circular group formations using a set of predefined parameters, such as group member count, group size (i.e inter-group distance), group arc and member orientation in a neutral office environment. In a pre-study test with three subjects the last two parameters were identified as having more perceptual impact than the first, and thus were chosen to be tested in the real study while the other parameters were kept static for the duration of the test. The value for the group member count was set to three, and the group size was set to 0.8m (the distance from each actor to the middle of the circular group formation).

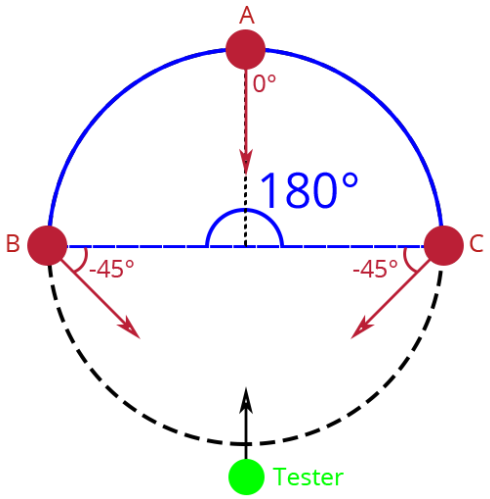


Figure 2 displays the placement logic of the group generation algorithm. The blue angle indicates group arc, the red angle displaying the agent orientation.

The group generation algorithm would take the group parameters and place agents in the corners of the circular group with respect of the group arc (displayed in red in figure 2). These agents were rotated to face the origin of the group circle as a standard and then rotated either towards the approaching tester or away from them depending on the group scenario. The middle agent (agent A in figure 2) always faced the approaching tester.

After the group generation algorithm was completed, a total of 20 different variable combinations were produced to be tested within the user evaluation study to be able to identify interesting perceptual combinations of group formations. These combinations were repeated three times each to collect an average of each combination.

The user evaluation test was done in virtual reality setting using the Oculus Rift VR Head Mounted Display (HMD). The test starts with the subject operating a controller to first move towards the group, stopping where the subject feels comfortable in relation to the group. When the subject has determined their position, he or she will say aloud on a scale from one to five, how welcome they feel to the group presented. One being very unwelcome and five representing very welcome.

The 60 total group formations scenarios were presented randomized to each test subject using a latin square[7] randomization selection to ensure that similarly looking scenarios not repeating consecutively. Thus, in each scenario the group arc and the orientation varied. Since the study is a perceptual one, the subjects need to get a different order to ensure there is no bias in the scenario selection.

After the evaluation study the subjects answered a short survey regarding the test to get qualitative feedback of how some group formations changed their perception of the group.

RESULT

Testing was performed with ten different test subjects whereas five were male and five were female in order to receive even and equal data. The Anova two-factor with replication test follows:

SUMMARY	Distance	Welcomed	Duration
Female			
Count	100	100	100
Sum	148.03	328.67	819.02
Average	1.48	3.29	8.19
Variance	0.60	1.16	39.83
Male			
Count	100	100	100
Sum	129.05	336.67	731.29
Average	1.29	3.37	7.31
Variance	0.51	1.21	4.77
Total			
Count	200	200	200
Sum	277.08	665.33	1550.31
Average	1.39	3.33	7.75
Variance	0.56	1.18	22.38

Variation	*SS*	*df*	*MS*	*F*	*p*	*F crit*
Sample	16.24	1	16.24	2.03	0.16	3.86
Columns	4258.4	2	2129.2	265.73	0.00	3.01
Interaction	24.36	2	12.18	1.52	0.22	3.01

- **Distance** implies distance from the subject to the group origo in meters.
- **Welcomed** regards as “welcomeness factor”, on a scale between one to five of how welcome the subject feels to each group.
- **Duration** is the duration in seconds for each scene on average.

The statistical summary reveals distinguishable data regarding the female and the male groups of the test. In general, male test subjects on average stood 19 centimeters closer to the groups presented during the test. Males also felt on average more welcome to all groups presented (3.37 versus female 3.29 welcomeness factor)..

Welcomeness factor throughout all the test subjects revealed to average at 3.33, with a distance of 1.39 meters and an average testing session in VR of 7 minutes and 45 seconds.

In general, the p-value shows that the results are not statistically significant (if $p>0.05$).

Orientation	Arc Degree	Distance	Welcomed	Duration
20	260	1.66	2.1	6.2
−12.5	260	1.47	2.5	12.3
50	140	1.03	2.6	8.4
40	180	1.09	2.7	7.2
30	220	1.21	2.8	7.7
−110	260	2.22	3.0	6.5
−90	220	2.04	3	8.0
−45	260	1.74	3.2	8.4
0	220	1.31	3.3	7.8
−50	140	1.33	3.4	6.7
−77.5	260	1.90	3.4	7.8
25	140	1.77	3.5	7.0
−70	180	0.80	3.5	8.1
12.5	180	1.08	3.5	8.1
−60	220	1.60	3.7	6.8
−30	220	1.48	3.7	7.1
−15	180	1.11	3.9	6.7
0	140	0.84	4.2	7.6
−25	140	0.87	4.3	8.9
−42.5	180	1.15	4.3	7.6

- **Orientation** refers to the individual orientation in degrees of agents B and C as shown in figure 2.
- **Arc Degree** refers to the angle colored blue in figure 2. It is the angle between agent B and C. 140 degrees means that the three agents stand close to each other. 260 degrees have the three agents form an almost full circle.
- **Distance** again implies average distance in meters from the test subjects to the group origo.
- **Welcomed** regards as “welcomeness factor”.
- **Duration** is the duration in seconds for each scene on average.

This table above is the direct result of average data from all test subjects. The table is sorted in ascending order by the “welcome factor”. Using the diagram presented in the method, having an arc degree of 180 and -42.5 degrees yields an average of 4.3 welcomeness to this group. This

group stands in a half-circular formation with every single agent turned towards the player.

Contrary to this result, the group with the least amount of welcomeness is one with an arc degree of 260 and 20 degrees orientation on the agents. This practically translates to a full circle group with agent B and C looking towards agent A. Illustration of these two scenes can be seen in figure 3.

Figure 3. Test scene with the most welcoming group (left) and the least welcoming group (right).

Following is a table of average results of group the different group arcs and further correlations:

Arc Degree	Distance	Duration	Welcomed
140	1.17	7.71	3.59
180	1.05	7.55	3.59
220	1.53	7.50	3.29
260	1.80	8.24	2.84

The table above is a correlation of the results of all test subjects.

Correlating the test data shows that when agents form a group and stand close to each other (having a low arc degree), give a relatively low distance of 1.17 meters and a high welcomeness factor of 3.59.

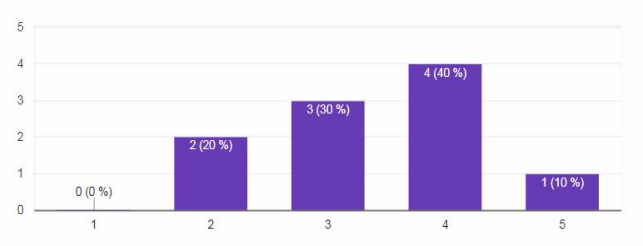
Contrary to when the agents form a more circular group with an arc degree of 260, the test subjects tend to stand further from the group origo on average (1.8 meters). This group also indicates a lower average of 2.84 welcomeness factor.

Post-test questionnaire

After the testing scenes were finished, the test subjects were encouraged to answer a short questionnaire that consisted of four questions.

1) *"How realistic did you feel that the group formations were?"*

Figure 4



This question had a scale of one to five, where one was very unrealistic and five very realistic (fig. 4)

2) "Do you believe that the realism of the group formations could affect your choice of distance from the group in the test? Motivate!"

Most of the consensus within the test subjects answers was that it indeed could affect their choice of distance. One particular answer mentioned that if the agents would be animated and move, their respective actions could be a determining factor in the choice of distance by the test subject.

3) *"Was there anything you noticed standing out in the test?"*.

In general, a few test subjects brought up the man in the blue suit that felt unwelcoming and came across as an agent with authority that may have felt more intimidating than other agents.

The last question was for general feedback of the test.

DISCUSSION

The testing scenes were done in Virtual Reality allowing test subjects to relate to their real life experience of group formations. For most individuals meeting others, group formations happen instinctively where orientation, group formation and distance become a habit. Due to Virtual Reality, the test subjects therefore feel more used to the scenes and the variables of the group formation compared to a two-dimensional screen. The power of the virtual reality headset is that it conveys a more in-depth experience compared to a computer screen.

This study has a few important points that may or may not have an impact on the result;

None of the agents had any animations nor did any agent turn their head to follow the subject's movement or

positioning. In addition to this, none of the agents had any animated faces. Occasionally, the test subjects naturally mentioned this during the testing session. The reason for not implementing this is that if every test scenario has agents that look toward you, the test result may be skewed. If the agents would always turn their heads toward the test subject, they would emanate a higher sense of welcomeness to the subjects. Furthermore the generated agents had a gender which might affect the subjects overall perception of the group formation.

Throughout the testing and going through the results, there has been a trend where the orientation of the agents themselves has been a defining factor for the test subjects results. An example of this are scenes where the agents themselves form a group in a circle (An arc degree of 260). The test subject tend to answer a higher value of welcomeness, juxtaposed to where the agents form less of a group themselves and the test subjects answers a lower value.

During the scenes as mentioned in the results, the subject was allowed to move their position to a distance where they feel comfortable standing. The distance was recorded in every test scene and the trend suggests that the distance from the group is highly dependant on the group arc. The distances on average varies between 1.17 to 1.80 meters from the group center. An arc degree of 140 yielded an average of 1.17 meters from the group center. However, an arc degree of 260 showed that subjects on average walk up to 1.80 meters from the group center. A trend we noticed therefore is that if a group is formed like a circle, the test subject tends to feel more outside the group formation and therefore may be obstructed by the agents with their backs towards the subject. However, when the arc degree is 140 and the agents are closer together, there is more space in front of the group formation. The subject therefore feels much more welcome and positions themselves closer to the group.

The result that the testing has yielded does have an impact of small group formation design in related fields. An example of a field is computer game design where the game designer wants to deliver a specific feeling of welcomeness to a player. Slight changes to orientation and placement of characters suddenly becomes important parts to the whole game experience. It's also worth noting if one prefers to use a different camera than the first person view. Changing the camera placement or having movement may skew the perception of a group, hence designing a small group formation may give a different experience than intended.

CONCLUSION

Throughout this project, some trends have been interesting and important to realize when looking at the results. Much of the data suggests other possibilities of future research such as gender difference within groups, psychological influence and agent impression differences depending on animations or facial expressions for example.

The data shows that most of the openness of groups follows a clear path as to how a group is formed. Further research may be required to see how it correlates to how groups in real life forms naturally in order to determine the importance of specific agent rotation and group arcs. However, in order to get more precise group formation data, altering the number of agents in a group would be a good path to follow.

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