Agents of Spatial Influence: Designing incidental interactions with arrangements and gestures

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ABSTRACT

Humans are implicitly affected by spatial arrangements. From the round table leading us to egalitarian discussions to room partitions that attempt to isolate us, the ways interiors are arranged, divided, instrumented, and outfitted affects our interactions in space. Machines in our environment, meanwhile, may interact with us using explicit gestures. They affect our behavior and perception by using human-like metaphors to communicate with us, giving us an impression of recognition, disagreement, or understanding.

How do implicit and overt influences work together to shape human behavior when first meeting interactive agents in public spaces? We used a paradigm where both forms of influences are embodied: an locomotive and reactive chair. The way chairs are arranged in a room can signal the purpose of the space, and unexpected chair movements can signal their purpose and agency.

We investigated implicit influences by using eyetracking to study perceptual attention of humans in scenes with different arrangements of chairs. We studied overt gestures using human feedback on videos of chair-human interactions. We then placed humans incidentally in a space of unexpectedly interacting chairs in VR, where both arrangement and interactive gestures of chairs affect perception. We found that implicit spatial and explicit gestural factors of chair robots interact with each other in human free-form exploration of a virtual room. This demonstrates a prototyping strategy using hypothetical situations and fine controls that are difficult to realize in real life.

BACKGROUND

Space affects the way we perceive and behave. In terms of perception, the presence of windows in visual representations of space affects the social aesthetics and mood of the viewers (Kaye, 1982). In terms of behavior, the way offices are partitioned can promote differing levels of perseverance (Roberts, et al, 2019). Even human creativity and productivity are linked to how free or confined people feel within space of movable walls (Taher, 2008).

Spatial influence can be studied using seating arrangements. In one study, subjects are asked to evaluate individual-oriented vs family-oriented vacation advertising. The way subjects sit around a room in an angular or a circular seating arrangement imperceptibly affects how persuasive these different endorsements became (Zhu & Argo, 2013). Other work finds that corner-table seating arrangements produces greater subject interaction than opposite-facing and side-by-side facing seating (Sommer, 1959).

The first way we communicate with others is often with nonverbal cues like posture, facial expression, and gestures. People given the opportunity to evaluate the gestures of robotic agents, tend to prefer gestures most like their own (Luo et al, 2013), much like unconscious gesture mimicking during human conversations. Previous work has also examined which robotic lamp and micromachine gestures elicit human compassion and understanding by creating a story of a troupe of robots which perform when the audience is not looking (LC, 2019). This work begins to probe the type of robotic furniture gestures that are best at eliciting human empathy, gestures like turning away in shyness and up-down movements for agreement (Figure 1). In a study with a mechanical ottoman footstool, a furniture robot was able to get people to rest their feet on it, as well as understand a cue for getting the feet off as an up and down gesture (Sirkin et al, 2015). Finally a chair robot was able to get people to move out of the way after using overt gestures like moving forward-backward or side-by-side (Knight et al, 2017).

Figure 1: Machines that use gestures to interact with humans. A shy lamp that looks away when humans approach (upper left; LC, 2019). A set of performance micromachines that enact Shakespeare's *Romeo and Juliet* when audience is not watching (upper right; LC, 2019). A surveillance camera that follows your face to project it on a face sculpture (lower left; LC et al, 2019). Chair robots that roam in space, making locomotive gestures like "you go first" and "follow me" (lower right, Knight et al, 2017).

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FRAMEWORK

To bring both implicit and overt/explicit influences on human perception and action into one theoretical understanding, we propose an environment support model for incidental human-robot interaction (Figure 2). We study chair robots in incidental encounters because they sit at an intersection between being arranged in space, but also endowed with gestural capabilities using locomotion and movement. The model suggests that unsuspecting humans interact with machines with gestural capabilities (like lamps, surveillance cameras) interactively with cues. The agent also aligns with the environment to shape human behavior subconsciously. Such space design affects humans implicitly via arrangement (like furniture placement).

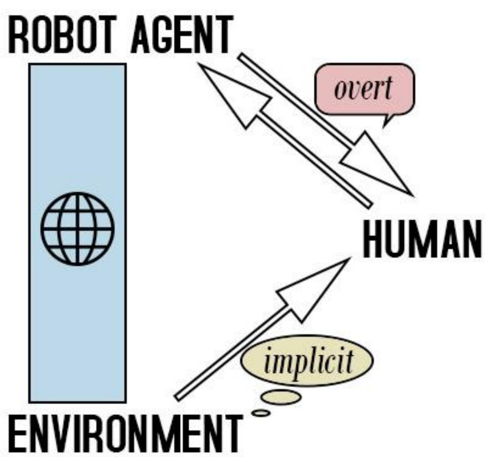

Figure 2: Environment support model for human-robot interaction. Humans find themselves in public in the presence of robots, which are expected to behave with social norms. The robot agent interacts using overt/explicit gestures, but also communicates with or changes the environment to effect implicit influences on the human. In the context of chair robots, they change the environment by moving themselves into different alignments, causing perceptual changes leading to new behaviors.

STUDY: SPATIAL INFLUENCE

To investigate how space affects human perceptual attention, we ran an experiment utilizing eyetracking to gauge how different arrangements of chairs in a scene affects where people are gazing.

Methodology

We presented photos of the same view of a room containing a TV and table but with different chair arrangements either in a circle, semi-circle, or aligned toward the wall. Gaze of 8 students from Northeastern University were tracked using a Tobii X2 30Hz eye tracker. Subjects were asked to fixate on a cross before presentation of stimulus. They are asked to score (1 to 5) how pleasant the scene depicted is to divert suspicion. Each stimulus was presented for 5 seconds after a 5 second fixation, in random order. The TV and table areas were drawn as areas of interest (AOI), and the percent time spent in the AOIs are calculated, allowing us to draw gaze heat maps.

Results and Discussion

Figure 3 shows the concentration of gaze on the TV when chairs are aligned, and on the table when the chairs are arranged in a circle. To assess if the time spent gazing is affected by location of gaze (AOI) and the way chairs were placed, we ran a 2-way ANOVA with aligned, semi-circular, and circular config conditions. Results show significant interaction aoi:config (F=6.698, df=2, p=0.00299), and no significance on aoi nor config by itself (Figure 4). The biggest differences come when the chairs are aligned (lower left).

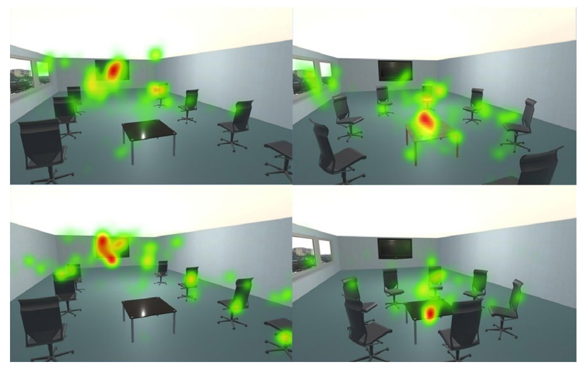

Figure 3: Example heat maps of grouped gaze activity during the course of 5 second stimulus presentation. Regular aligned config (upper left). Table-emphasized circular config (upper right). Window-less aligned condition (lower left). High chair density circular config (lower right).

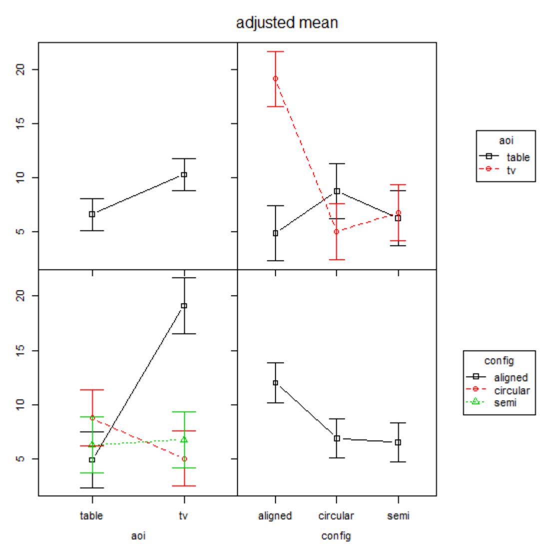

Figure 4: Interaction plot of percent time spent as a factor of aoi (TV, table) and config (aligned, circular, semi-circular). There’s a gaze preference for TV when the chairs are aligned, and for table when the chairs are in a circular arrangement.

Posthoc comparison (Tukey) reveals a significant difference between tv:aligned vs. table:aligned (p=0.0040745), showing that subjects are more likely to look at the TV if the chairs in two rows are facing the wall containing the TV. The tv:circular vs. tv:aligned comparison is also significant (p=0.0045019), showing a difference in the way gaze is directed towards the TV when chairs are arranged in a circle around the table as opposed to aligned towards the wall.

This shows that without knowledge of the robotic nature of the chairs, human gaze attention is directed by chair arrangement to targets that symbolize functions of a room. Chairs aligned facing the wall imply a context for presentation or focus. Chairs arranged in a circle around table shift to discussion, meeting, and socialization.

STUDY: AGENT GESTURES

To investigate which particular overt gestures undertaken by chair robots best communicate to unsuspecting humans about goals and intentions of locomotive agents in an incidental encounter, we created videos of human-chair interactions and used crowd-sourced human data survey to see how people perceive different chair gestures.

Methodology

We designed a set of gestures that involve people interacting with one chair that has agency, or with multiple chairs that work with or against each other. Example one-to-one gestures include "Follow Me" where the chair moves forward in space in the direction it wants the person to go, "I Understand" where the chair moves back and forth to signal agreement, and "I am on a Mission" where the chair doesn't stop for anyone. Multi-chair interactions are in Figure 5.

We made green-screen recordings of the interactions with student actors. One actor wore a green suit to play the role of the chairs making gestures, while two actors served as human participants. A chroma key is used to convert green-screen content to a background image of the wall. Videos are shown to human workers on Amazon Mechanical Turk. Participants are asked to rate for each video under: "Chair was responsive to the person" (Responsive), "Relationship between chair and the person in the scene is satisfactory" (Relationship), "This chair is very expressive" (Expressive), and "The person in the scene is affected by the chair's presence" (Affected). Answers to qualitative questions like "Describe what you saw" and "What's the chair's intent?" are coded by two independent raters whose correspondence is tested using Cohen's kappa.

Results and Discussion

To see how ratings vary with the question asked and interaction shown, we ran a 2-way ANOVA using Interaction*Question as explainers, and found Interaction, Question, and Interaction:Question to be significant ($p < 0.05$). Posthoc test (Tukey) reveals Expressive-Affected, Responsive-Expressive, and Responsive-Relationship to be significantly different, but that Responsive and Affected ratings are not significantly different (p=0.6014), indicating that whether chair serves as agent of change or subject of change by the person does not affect ratings about its expressiveness and relationship with a person.

This study shows that people's perception of whether chairs are expressively affecting humans is linked to whether chairs are responsive to humans. This underlies the idea that chairs and humans affect each other in feedback loops, so that agency from one side is reflected in agency in the other, as they mutually influence each other.

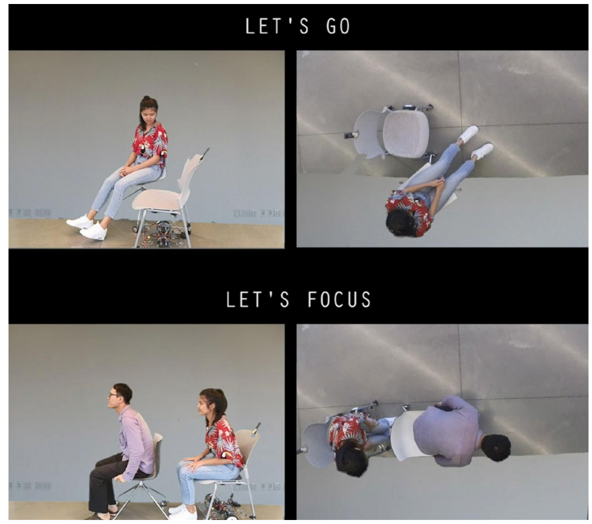

Figure 5: Examples multi-chair multi-person interactions that influence behavior. Amazon mTurk studies used videos on the left side. "Let's Go" a moving chair urges a human to get out of her seat and walk. "Let's Focus" two chairs arrange themselves to make two humans look at the content in front of them.

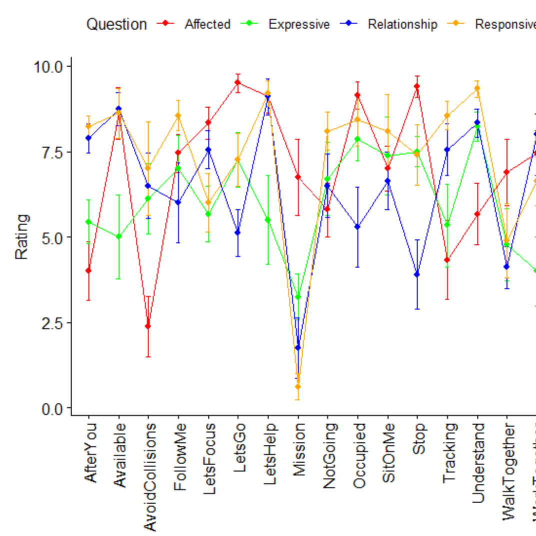

Figure 6: Human ratings on questions of Affected "the person in the scene is affected by the chair's presence, " Expressive "this chair is very expressive," Relationship "relationship between chair and the person in the scene is satisfactory," and Responsive "chair was responsive to the person" for each of the videos of chair-human interactions.

STUDY: 3D IMMSERSIVE PROTOTYPES

The two previous results beg the question of whether we can create prototypes of chairs in space that both rearrange themselves to affect us implicitly, and also make gestures that communicate with us their intentions directly. Can we prototype these interactions in VR without building all these chairs with proper mechanical controls?

Methodology

We created a set of possible chair arrangements in VR and picked two for further analysis, the fully aligned and circularly assigned configurations. We chose to focus on the "look at" gesture, where the chairs suddenly orient themselves towards the viewer continuously, and see how that interaction differs between chair arrangements. We created two scenes that arrange the chairs 1. aligned towards the sliding doors behind where the viewer starts in VR, and 2. around a circle about the center of the room near the viewer (Figure 7).

Intermittently during the experience, the chairs will switch to "look at" orientation and focus the front towards the viewer, at which point she will be surprised by the incidental encounter. We tested 9 students from Parsons School of Design and Cornell Tech in each condition. Subjects moved around in VR for 30 seconds before the first "look at" maneuver. After two minutes, we surveyed their experience with questions like "how stunned are you when the chairs looked at you," and "what purpose do you think the room serves."

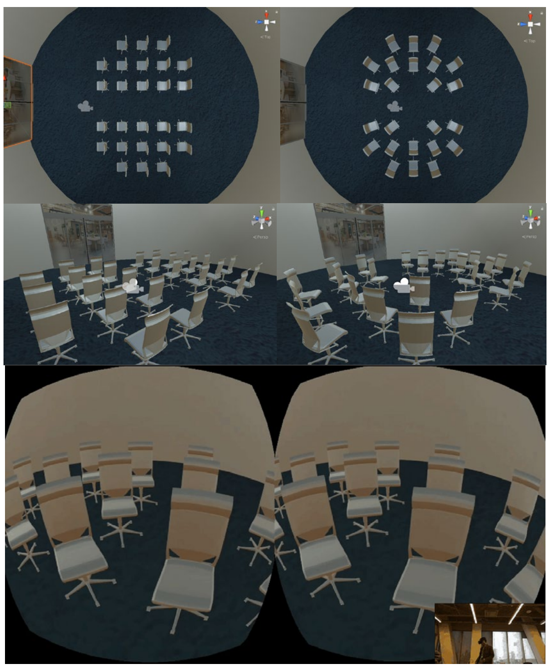

Figure 7: Starting chair arrangements in a VR scene for an experiment looking at reactions of viewers to sudden change into "look at" the viewer orientations. Chairs aligned towards the door where the viewer starts in VR (left), chairs aligned towards the center in a circle (right). A point in the VR experience when the chairs all look towards the viewer (bottom). Wherever the viewer moves, the chairs follow around with their front side until the "look at" situation is turned off.

Results and Discussion

Ratings of the viewer to questions of expressiveness, responsiveness, and "how stunned are you" were analyzed with the configuration condition (aligned vs. circular) in a 2-way ANOVA. Configuration was significant ($p = 0.0426$), and post-hoc test (Tukey HSD) also found only significance in aligned vs. circular conditions. Thus audiences are more stunned by the "look at" gesture employed by the chairs when they are initially in an aligned position towards the door rather than in a circular position around the center of the room. Viewers assigned the room such functions as "meeting room" or "place of lecture" when given the aligned condition, and as "a waiting area" or "place of discussion" in the circular condition.

Unlike the video prototypes, in VR we can test hypotheses regarding chairs' interactions with us arranged in space. Unlike the space design study, in VR we can examine gestural efficacy through activity in the objects themselves. VR prototypes thus serve the best of both worlds, allowing us to evaluate both chair arrangements that affect audience response, and trigger machine gestures that occur.

Together these studies in spatial influence, agent gestures, and 3D interactive immersive prototypes show the capability of machines to affect human perception and behavior both in the way it is arranged in space and in the interactions they maintain with us. They foretell a future where interactive furniture embedded in environments can shape our attention and behavior for the better by using spatial and gestural cues that optimally affect human capabilities.

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