# The Influence of Size in Augmented Reality Telepresence Avatars

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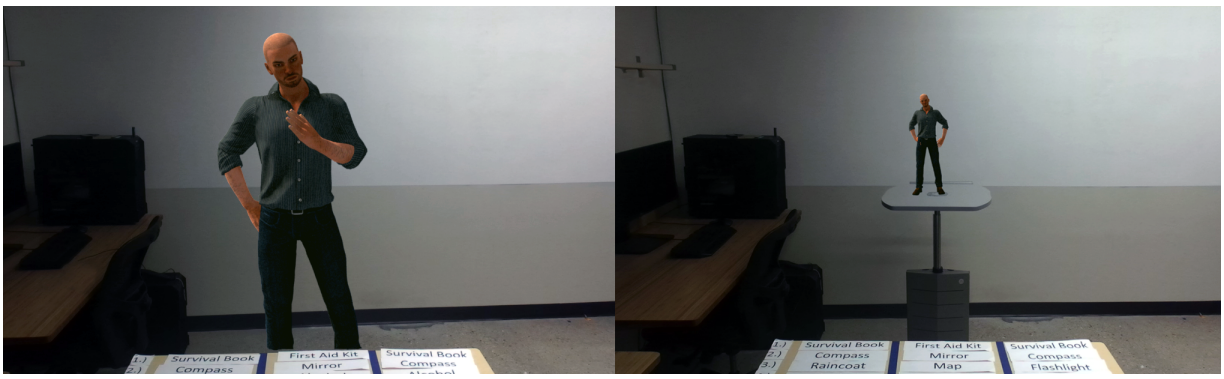


Figure 1: First person views of the AR telepresence avatars: (Left) appearance and placement of the equal-sized avatar; (Right) appearance and placement of the small-sized avatar.

## Abstract

In this work, we explore how advances in augmented reality technologies are creating a new design space for long-distance telepresence communication through virtual avatars. Studies have shown that the relative size of a speaker has a significant impact on many aspects of human communication including perceived dominance and persuasiveness. Our system synchronizes the body pose of a remote user with a realistic, virtual human avatar visible to a local user wearing an augmented reality head-mounted display. We conducted a two-by-two (relative system size: equivalent vs. small; leader vs. follower), between participants study ($N$ = 40) to investigate the effect of avatar size on the interactions between remote and local user. We found the equal-sized avatars to be significantly more influential than the small-sized avatars and that the small avatars commanded significantly less attention than the equal-sized avatars. Additionally, we found the assigned leadership role to significantly impact participant subjective satisfaction of the task outcome.

**Keywords:** Avatars, augmented reality; mixed reality; avatar-mediated communication; human-avatar interaction; avatar telepresence systems; avatar size; scenario-based design; team role;

**Index Terms:**

Human-centered computing—HCI—Interaction paradigms—Mixed / augmented reality Human-centered computing—HCI—Interaction paradigms—Virtual reality Human-centered computing—HCI—Interaction paradigms—Web-based interaction Human-centered computing—HCI—Interaction paradigms—Collaborative interaction Human-centered computing—HCI—HCI design and evaluation methods—User studies Human-centered computing—HCI—HCI design and evaluation methods—Laboratory experiments Human-centered computing—Interaction design—Interaction design process and methods—Scenario-based design

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## 1 Introduction

Modern families and companies have become more geographically distributed, and as a result, people have increasingly turned to technology as a substitute or alternative to travel, using video- and teleconferencing to maintain social connections and effectively collaborate. As improvements have been made in telecommunication technologies, new channels, such as augmented reality (AR), virtual reality (VR), and robotics have become viable alternatives to pure voice or video calls. With these alternative channels of communication come greater flexibility when it comes to how users present themselves and the variety of ways that they can alter their appearance.

Recent advances in VR and AR have allowed users to project 3D virtual avatars of themselves in both virtual [21] and real world environments [13]. Just as in standard teleconferencing, remote users can communicate with local users in AR while embodied by these virtual avatars, giving the local user the sense that the remote user is occupying the same physical space. However, the virtual nature of these telepresence avatars allows users to alter their appearance at a whim such as changing their clothes, hair, or even body.

One dimension of a person's physical appearance that has been extensively studied in the field of psychology is height and the effects it has on perceptions and behaviors. Human height has been shown to be positively correlated with perceived poise, self-assurance, composure, relaxation, expressiveness, and persuasiveness [1, 7], as well as improving workplace success [12], judgments of a person's attractiveness [16, 28], and perceptions of trustworthiness and credibility [20, 30].

Although height is fixed in real-life, remote users in VR or AR can easily change the size of their AR telepresence avatars, leveraging the inherent benefits that height can bring in real-world interactions. For example, prior work has explored the use of avatars with adaptive size and redirected gaze/gestures in improving mixed-reality collaboration [23]. This potential for users to shape their mediated-communications by positively or negatively altering aspects of their virtual embodiments might have effects on interactions and relationships in a number of contexts, especially in those with clearly defined roles of leaders and followers. For example, in a corporate setting a manager could increase subordinate productivity, agree-

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Figure 2: The AR telepresence avatar.

ment, and obedience by altering the size of his or her avatar. In an educational setting a teacher could demand greater attention and authority over distance-learning students and possibly increase pupil performance and information retention.

Although the promise of being able to manipulate one's appearance may have many benefits, how these manipulations might affect the local user's perceptions of the remote user, particularly in situations where levels of dominance may differ between users, are still not fully understood. Therefore, we are interested in how changes to the dimensions of a remote user's appearance—namely size—transfer from face-to-face interactions to new mediums of telepresence communication—such as AR—in collaborative leader/follower contexts.

In this paper we explore how the size of an AR telepresence avatar impacts remote user dominance and influence in the context of collaboration where differences in role exist.

## 2 Background

### 2.1 Height in Human-Human Interaction

Psychology research in human-human communication has shown that height has a profound impact on human treatment and perceptions by others [12, 18]. More specifically, taller people are associated with being more dominant, relaxed, composed, expressive, dramatic, persuasive, poised, self-assured, having more leadership qualities, and exhibiting less self-censorship [1, 7]. Interestingly, the impact of height in human communication is a temporary effect and in long-term interactions the effect of height diminishes [17]. Additionally, research has shown that remote users utilizing videoconferencing technology are more influential when the user perceives themselves as taller than the other caller [11].

Although height and size are not equivalent, the two terms share a correlation, such that if an object or person becomes taller, then their size is also likely to have increased. Additional research is required to know if findings related to height in human-human interactions hold true for human-avatar interactions as well.

### 2.2 Size in Human-Robot Interaction

Prior work in the field of human-robot interaction (HRI) has found that robot size has a significant impact on human preconceptions and interactions with robots. In a study performed by Walters et al. it was found that short robots are viewed as less conscientious than taller robots [31]. Studies have also reported that humans are less willing to interact with a smaller robot due to the increased effort of bending over [22].

Telepresence robots have also been an area of study in the HRI community for many years. Rae et al. discovered that when robot telepresence systems are shorter than the local users and the remote operator was in a leadership role, the local user found the remote operator to be less persuasive [25]. These telepresence robots have many similar capabilities as AR telepresence avatars, such as remote user embodiment and enhanced remote user presence; however, there are many differences as well including the fact that telepresence robots can directly interact with the physical environment whereas AR avatars cannot. Although prior work on human-robot telepresence interactions may inform how AR telepresence avatar appearance affects local user interactions and preconceptions, whether these findings transfer to an AR context requires further study.

### 2.3 Appearance in Human-Avatar Interaction

Previous research regarding avatar design has explored how avatar appearance can influence human-avatar interactions.

This work has demonstrated that human-avatar interactions can be affected by the morphology of the avatar. Mull et al. showed that the form of the avatar (i.e., human, animal, hybrid, etc.) can influence their perceived credibility and attractiveness [20]. In addition, the face of an avatar can have a significant effect on trust. Walfl et al. were able to increase sales in an online store by altering the width-to-height ratio of an avatar and increasing shopper trust [30].

Other appearance traits such as gender, attractiveness, and age have also been shown to be influential in human-avatar interactions. Studies have found that male subjects are more easily persuaded by female avatars, and female subjects were more easily persuaded by male avatars [33]. In addition, avatar age and attractiveness can impact how persuasive the avatar is. Holzewarth et al. found younger, attractive avatars to be a more effective sales agent at moderate levels of product involvement, while an older "expert" avatar is a more effective sales agent at high levels of product involvement [10].

Digital mimicry (e.g., copying a user's face onto an avatar or copying a user's gestures) has also been shown to impact communication between user and avatar. Bailenson et al. found that an avatar with a "team face," (made by combining features of a social group) receives more attention than avatars that do not share appearances with a group [26].

Finally, research has found that remote users communicating via virtual reality had increased influence when they perceived themselves to be taller than the person with whom they were interacting [32]. However, there have found to be trade-offs when adjusting the size of AR telepresence avatars, for research has shown that unrealistically small avatars may hold some advantages over life-sized avatars in AR remote collaboration. Small-sized avatars are able to be dynamically and diversely integrated within the local user's environment (e.g., the avatar can be resized and placed on a work table, desk, etc.) and have also shown to have an improved social presence when fixed within the user's field of view [23]. Due to these benefits, small-sized avatars may be more suitable for certain AR remote collaboration scenarios.

Although much of this work has explored the effects of height or appearance in contexts of equal relationships or those where levels of dominance differ, how generalizable these findings are to interactions in AR has yet to be studied.

### 2.4 Leadership Roles in Communication

Although research in human communication has shown that the roles assigned to individuals in a group may drastically alter behavior in terms of perceived authority, dominance, and aggression [34], further investigation is needed to understand how this may affect

people's perceptions of other humans when their communication is mediated by an AR telepresence avatar system. Our study seeks to understand the extent to which the effects of size observed in human-human communication and human-robot interaction settings generalize to avatar-mediated communication. In particular, we look at how size may serve to undermine or support a user's role when a disparity exists between the user's physical and assigned levels of authority. This understanding will provide design guidelines for future development of AR avatar communication products and promote longer, more natural interactions between geographically distributed people.

## 3 Hypotheses

Based on this body of prior work, we hypothesized that the AR telepresence avatar's size relative to the local user would support or undermine the local user's feelings of authority when interacting with an operator under different leader-follower authority structures:

*Hypothesis I:* When interacting with a remote user that is using the small-sized avatar, local users who were assigned the leader role would exhibit the most dominance.
*Hypothesis II:* When interacting with an remote user that is using the equal-sized avatar, local users who were assigned the follower role would exhibit the least dominance.
*Hypothesis III:* Local users interacting with the small-sized avatar would exhibit more dominance than local users interacting with the equal-sized avatar, regardless of assigned role.

## 4 Design & Implementation

To explore the impact that AR telepresence avatar size has on interactions, we designed our own avatar system for use in a controlled laboratory experiment.

### 4.1 Design

When designing the appearance and features of the avatar, our main objective was to simulate a regular in-person human interaction as closely as possible to establish a baseline of how AR telepresence avatar size affects human-avatar interactions. To do so, we outlined several requirements for our avatar system to meet.

First, the avatar's general appearance was designed to resemble a life-like human. Although the avatar could take any shape or form we desired, our avatar was to look realistic to stay true to our goal of simulating normal in-person communication. This requirement of realism not only applied to the avatar's general appearance, but to its motion as well. The avatar must have a rigged skeleton and an appropriate number of joints to allow for mimicking natural human movement.

The avatar was also to embody the natural motion and body language of its user. Previous work has shown that human dominance and submissiveness in social interactions are greatly impacted by natural non-verbal communication [29]. In addition to supporting communication, capturing the natural body language of the user may also help prevent our avatar from falling into the "uncanny valley," which is the unsettled feeling people experience when interacting with visual simulations that closely resemble humans, but are not convincingly realistic [19]. Therefore, it was of great importance to ensure the avatar captured the non-verbal cues of its user as accurately as possible.

Finally, the avatar was to look generic. We wanted to exclude any abnormal features from the avatar design (e.g., tattoos, uncommon hair styles, irregular clothing, etc.) that may have the potential to intimidate or embolden local users and create confounds.

These design guidelines were made to help us reduce potential confounding variables, allow us to isolate the effect of avatar size, and match our expectations for how these systems would behave in practice, such as in remote teaching or work contexts.


Figure 3: The HTC Vive HMD with ZED Mini AR stereo video pass-through camera.

### 4.2 Implementation

Once our requirements had been identified, we selected a human 3D model that met our design specifications (see Figure 2). The appearance of the model was that of a young-adult Caucasian male, which was chosen to faintly resemble that of the experiment confederate (refer to Section §5). This model included with it a fully-rigged skeleton with programmatically adjustable joints.

To capture the movements and body language of the avatar's remote user, we utilized a Microsoft Kinect v2 motion sensor. This sensor is able to perform real-time body tracking of up to 25 individual joints. The joint rotations we synced with the virtual avatar were: hip (center, left and right), spine, neck, clavicles, shoulders, elbows, hands, knees, and feet. In addition to capturing the user's body movements, we implemented real-time lip syncing software to animate the avatar's mouth, mimicking the natural mouth movements made by the remote user to increase the avatar's realism.

After implementing our AR telepresence avatar model and capabilities, we then selected our medium for viewing the avatar. The current state of augmented reality technology provides for viewing the virtual imagery with many different hardware paradigms (e.g., tablets, monitors, head-mounted-displays (HMDs), etc.). We opted to use an AR HMD to view and interact with the AR avatar. Using AR HMDs represents a fundamentally different type of interaction than either traditional 2D displays, static/remote AR displays, or AR displays on mobile devices/tablets, as AR HMD designs provide stereoscopic depth, do not require gaze shifts between the device and the real world [9], enable free user movement in the environment, and can support hands-free operation. It is for these reasons that we argue that an AR HMD would be best suited for naturally integrating into human social settings.

The AR HMD we used for this study was a HTC Vive virtual reality HMD with a ZED Mini stereo video pass-through camera installed on its outward-facing side (see Figure 3). In this configuration, the imagery captured by the pass-through cameras is fed to each of the user's eyes, allowing the user to "see-through" the HMD, which simulates an optical see-through AR HMD like the Microsoft HoloLens. For this experiement, the ZED Mini camera was set to feed $2560 \times 720$ resolution images to each eye at a rate of 60 frames per second. A stereo video pass-through camera was selected for the multiple advantages: the technology holds over many current consumer-grade AR devices, a wider field of view ($110° \times 60°$), and improved rendering of virtual object occlusions created by the real world environment with a depth range of $0.15 - 12m$.

We used the game engine Unity for developing and deploying our application due to its rich set of MR developer tools and native

support for the HTC Vive, ZED Mini, and Kinect v2. To achieve long-distance communication between local user and avatar remote user, we utilized two instances of Unity: the local instance that ran the AR HMD application and displayed the AR telepresence avatar and the distal instance that used the Kinect to track and send avatar remote user joint angles to the local instance.

## 5 Experiment

We conducted a $2 \times 2$ between-participants experiment to evaluate how avatar size (equal vs. small) and assigned leadership role (leader vs. follower) affected the local user's feelings of authority when interacting with a telepresence AR avatar. Participants (the local users) completed a series of tasks with a confederate embodied as a virtual avatar. The confederate was a 28-year-old male who controlled the avatar from a remote location. The avatar in this experiment was either scaled to a relative size equal to that of the participant or scaled to a static small size of $0.5m$ tall. The same confederate was used for all trials and followed a pre-scripted dialogue. Note that this experiment design was inspired by the study run by Rae et al. in which the height of a telepresence robot was evaluated for dominance and persuasion [25].

### 5.1 Tasks

During the study the participant completed two joint tasks with the confederate that evaluate different aspects of negotiation: the Desert Survival Task and the Ultimatum Task.

#### 5.1.1 Desert Survival Task

The first task was a modified version of the Desert Survival Problem [14]. The problem takes the form of a hypothetical situation where a plane has crashed in the desert with the only survivors being the participant and confederate. The participant was asked to rank nine salvaged items in terms of their importance to the participant's own survival. The item list was altered from the original Desert Survival Problem to ensure each item was easily recognizable and relevant to a present-day survival situation [25]. The list of items consisted of an air map of the area, survival book titled "Edible Animals of the Desert," duct tape, first aid kit, cosmetic mirror, flashlight, compass, flask of vodka, and a raincoat. A second ranking of the items was algorithmically generated based on the participant's submitted list of item ranks and assigned to the confederate as their own item rankings. This generated list ensured that the confederate's rankings were consistently different from the participant (i.e., the participant's item ranked 1$^{st}$ is assigned as the confederate's item ranked 3$^{rd}$, the participant's item ranked 2$^{nd}$ is assigned as the confederate's item ranked 6$^{th}$, etc.). The participant and confederate were then asked to discuss the differences in each others' ranked item lists and come to a consensus to form a new final list of ranked items. In order to keep interactions consistent across all participants, the confederate made one scripted argument for each survival item being higher or lower and then accepted what the participant suggested as a final ranking.

This task was chosen due to its ability to measure agreement between two parties. In this study, the participant's initial ranked item list was used as a baseline measurement of agreement to compare against the final combined list and evaluate how much influence the confederate and their rankings had over the participant. Additionally this task has been evaluated for both reliability and validity and has been utilized in many previous mediated communication studies (e.g., [11, 24, 25]).

#### 5.1.2 Ultimatum Task

The second task was the Ultimatum Task [5]. This task consisted of four independent rounds where a pool of $100 was to be split between participant and confederate. Either the participant proposed a split of the money in the pool and the confederate had the option of accepting or rejecting the split, or vice versa depending on the participant's preassigned role as leader or follower. If the split was accepted, then the money would be shared accordingly, but if the split was rejected, then neither person received any of the money. The participant designated the split in the first and third rounds and the confederate proposed the split in the second and fourth rounds. As in previous work [32], the confederate accepted any proposals where he received more than $10 out of the $100. During the second round, the confederate always proposed a 50/50 split, and in the fourth round, the confederate offered a 75/25 split ($75 going to the confederate).

The Ultimatum Task is a negotiation-based economics exercise that we chose due to its ability to study perceptions of dominance. As with the first task, it has been evaluated for both reliability and validity and has been utilized in previous mediated communication studies (e.g., [5, 25]).

### 5.2 Procedure

The study took approximately 45 minutes and participants were compensated $10. Once participants had signed a consent form, they were provided with the instructions of both tasks and told their partner will be another participant located on the other side of campus who would be calling in remotely. The participant was also informed that either they or the confederate were assigned the role of leader, and explicitly told "the leader is responsible for ensuring the tasks are completed appropriately and within the allotted time." If assigned to the equal-sized avatar, the participant's height was measured to appropriately set the avatar's relative size. The participant was standing at all times during the experiment.

Participants were then positioned at a table and provided with 3 minutes to create their initial ranked list of items for the Desert Survival Task. Due to the difficulty of reading small text while wearing the AR HMD, the items to be ranked took the form of large paper cutouts with the item's name printed in 100pt font. The desk had rows labeled $1-9$ allowing the participant to set and adjust their rankings by physically moving the paper printouts. Additionally, the desk had three columns that the participant used to record their ranks, the confederates ranks, and the final unified list. Upon completion of the initial ranked item list, the algorithmically generated rankings were secretly created and sent to the confederate. The avatar was then either positioned on the opposite side of the table on the floor for the equal-size condition or on a raised platform for the small-size condition (see Figure 1) . In the small-size condition, the raised platform was utilized to ensure the avatar was eye-level with the participant to help minimize the potential confounding effect of elevation, which previous studies have shown to impact perceptions of dominance [27]. The participant was then fitted with the AR HMD and introduced to the confederate. The AR HMD's built-in speakers and microphone allowed for two-way voice communication between participant and confederate. The confederate was able to see the participant from the avatar's point of view through cameras placed in the experiment room. The participant and the confederate were then told they would have 12 minutes to discuss and to reach a consensus on a set of final rankings (see Figure 4). To further ensure the participant knew their leadership role, the confederate would explicitly confirm with the participant who the leader was prior to beginning the first task by asking "You're the leader, right?" or "I'm the leader, right?" (depending on assigned roles) and began the task only after a correct affirmation was received from the participant.

After the discussion period was completed and a consensus list had been created, the experimenter instructed the participant and the confederate on the Ultimatum Task, which was then performed. Upon completion of the final task, the confederate was told to log off and the experimenter administered the post-experiment questionnaire.

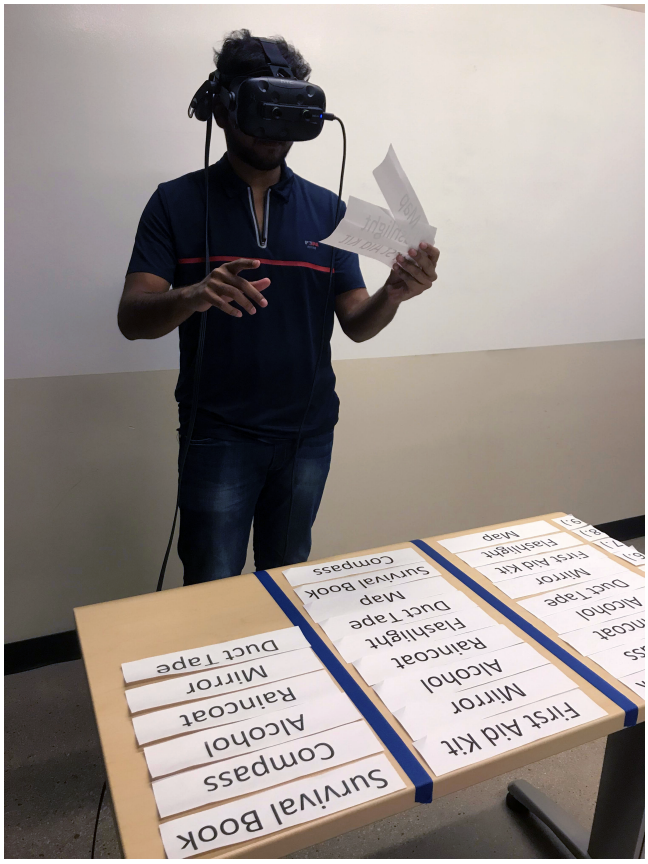


Figure 4: Local user participant performing the Desert Survival Task with the confederate remote user.

### 5.3 Measures & Analysis

#### 5.3.1 Task Measures

In the Desert Survival Task, we measured the compliance of the participant using the difference between the confederate's initial scores and the final consensus rankings. The confederate's initial rankings were calculated to be consistently distant from the participant's; therefore, the difference between the initial rankings of the participant and those of the confederate were consistent across trials. Thus, the difference between the final consensus ranking and the confederate's initial ranking measured how much influence the confederate had on the participant. A larger difference meant that the participant was less persuaded by the confederate's arguments, whereas a smaller difference indicated that the confederate's arguments had more of an impact. Additionally, time to complete the task was also measured.

In the Ultimatum Task, we used three measures: the initial split proposed by the participant in the first round, the split proposed by the participant in the third round, and whether or not the participant accepted the unfair 75/25 split proposed by the confederate in the last round.

#### 5.3.2 Subjective Measures

The Interpersonal Dominance Scale [2] was used to measure perceived dominance along five dimensions: poise, persuasion, conversational control, panache, and self-assurance. The scale is comprised of 32 statements on perceptions of the other person (e.g., "the other person is more of a follower than a leader;" "the other person did more talking than listening"). Participants expressed their agreement with each statement using a seven-point rating scale.

The Subjective Value in Negotiation Tasks Scale [4] was used to to measure the participants' feelings about the tasks. These questions were divided along four dimensions with three to five questions per dimension: feelings about the instrumental outcome of the task, feelings about the self, feelings about the process, and feelings about the relationship.

Additionally, we had all participants evaluate perceived usability using the System Usability Scale (SUS), an industry standard ten-item attitude survey. SUS scores below 68 are considered below average, scores above 68 are considered above average, and scores above 80.3 are considered in the top 10th percentile.

We also constructed a custom scale from 7-point Likert-style questionnaire items to measure the participant's general attitude towards the confederate (e.g., "my partner was helpful," "I liked working with my partner," and "my partner was friendly").

Finally, qualitative feedback was also obtained through open-ended questions posed to each participant as part of the concluding questionnaire to describe their experiences as well as what they did and didn't like about interacting with the virtual avatar.

#### 5.3.3 Behavioral Measures

We also recorded first-person and third-person video to analyze behavioral patterns in participant actions. Two coders annotated video data from each interaction based on when participants were visually focused on the AR avatar. Data was divided evenly between coders, with an overlap of 15% of the data coded by both. Inter-rater reliability analysis revealed substantial agreement between raters (Cohen's $\kappa = .92$) [15]. This coding enabled us to calculate the percentage of time the participant spent visually focused on the avatar during the Desert Survival Task to evaluate the attention commanded by the avatars across conditions. To account for the equal-sized avatar's size being larger than the small-sized avatar and it being more likely that the participant coincidentally looked at a part of the avatar, time was only recorded when the participant focused on the avatar's head.

#### 5.3.4 Other Measures

Following the questionnaires, we administered a manipulation check. To determine whether the manipulation of avatar size was successful, we asked participants what the avatar's proportional size was relative to their own with a drop-down answer field ranging from $10\% - 200\%$. We also collected demographic information which included gender, participant height, age, occupation, and experience with AR HMDs.

#### 5.3.5 Analysis

We analyzed data from all measures using a two-way Analysis of Variance (ANOVA) with experimental condition (avatar size and participant leadership role) as fixed effects. The only exception being the analysis of accepting the unfair (75/25) proposal by the confederate in the Ultimatum Task where a Pearson's Chi-squared test was used to determine any effects of size or team role. Post-hoc tests used Tukey's Honestly Significant Difference (HSD) to control for Type I errors.

### 5.4 Participants

We recruited a total of 41 participants (25 males and 16 females) from a university campus to take part in our IRB-approved study. One participant was sitting during the experiment, so to remove the confounding factor of differing elevation between local user and remote user avatar, his data was excluded from analysis. This left us with data from 40 participants (10 in each condition). Average participant age was 22.6 (SD = 6.06), with a range of 18-56. On a seven-point scale, participants reported a moderate familiarity with AR HMDs (M = 3.53, SD = 2.24), indicating the growing popularity of such technology.

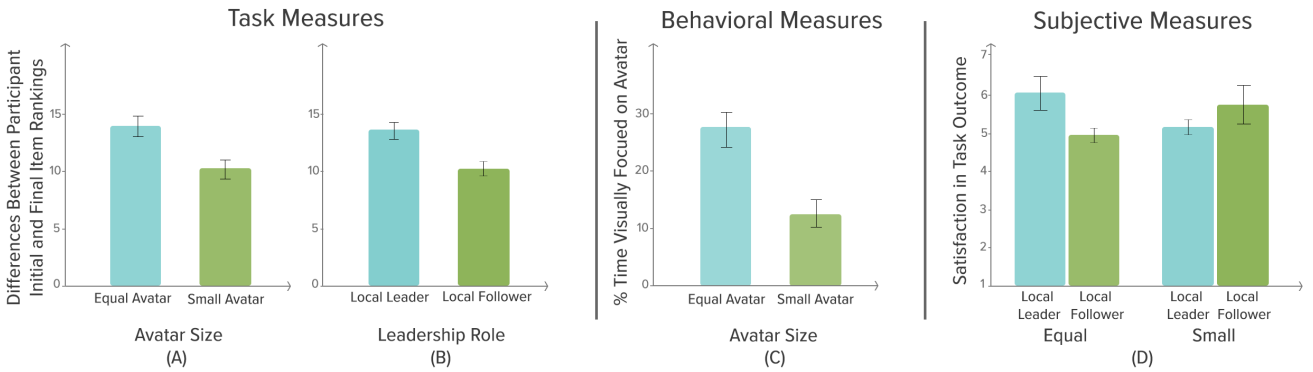


Figure 5: Results showing significant effects of the relative size of the AR telepresence avatar and assigned role on task (left), behavioral (middle), and subjective (right) outcomes.

## 6 Results

The analysis of the data from the manipulation check question showed that participants were able to distinguish between the different sizes of the AR telepresence avatar, $F(1,38) = 114.2, p < .0001$, with the small avatar being consistently labeled as proportionally smaller than the equal-sized avatar.

### 6.1 Hypothesis I & II

Based on prior research, Hypothesis 1 posited that when interacting with a remote user that was using a smaller AR telepresence avatar, local participants who were assigned the leadership role would exhibit the most dominance. On the other hand, Hypothesis II postulated that when interacting with a remote user that was using an equal-sized AR telepresence avatar, local participants who were assigned a follower role would exhibit the least dominance. Our results showed no support for either hypothesis; in fact, we observed partial support of the opposite effect in which local participants assigned the follower role showed more dominant behavior. We found a significant main effect of assigned leadership role on the number of differences between participant initial rankings and the final consensus list rankings in the Desert Survival Task, $F(1,38) = 7.33, p = .01$.

Participants assigned the leader role were more influenced by the confederate when creating the consensus item rankings ($M = 13.9, SD = 4.17$) than participants assigned the follower role ($M = 10.4, SD = 4.41$) (see Figure 5-B). Additionally, we found a significant interaction effect between the size of the avatar and assigned role on feelings about the instrumental outcome of the task (measure from the Subjective Value in Negotiating Tasks Scale), $F(1,38) = 7.34, p = .01$. Tukey's HSD revealed that assigned role impacted perceptions of outcome satisfaction in the case of interacting with the equal-sized avatar, yet not when the remote user was communicating with a small avatar. The participants interacting with the equal-sized avatar were significantly more satisfied with the task outcome ($p = .05$) when assigned the leader role ($M = 6.08, SD = .47$) than those assigned the follower role ($M = 4.95, SD = 1.28$) (see Figure 5-D).

### 6.2 Hypothesis III

Hypothesis III predicted that local participants interacting with a remote user that was using a smaller telepresence avatar would exhibit more dominance, regardless of their assigned role, than those who interacted with a remote user that was using an equal-sized telepresence avatar. Our results showed support for this hypothesis. We found a significant main effect of assigned avatar size on the number of differences between participant initial rankings and the final consensus list rankings in the Desert Survival Task, $F(1,38) = 7.33, p = .01$.

Participants interacting with the equal-sized avatar were more influenced by the confederate when creating the consensus item rankings ($M = 13.9, SD = 4.56$) than participants interacting with the equal-sized avatar ($M = 10.4, SD = 4.24$) (see Figure 5-A). Also we found a significant main effect of percentage of time visually focused on the avatar during the Desert Survival Task, $F(1,38) = 9.52, p = .003$. The equal-sized avatar commanded more attention from the participants ($M = 27\%, SD = 16.4\%$) than the small-sized avatar ($M = 12.2\%, SD = 14\%$) (see Figure 5-C).

### 6.3 Remaining Measures

We found no significant effects of the size of the avatar or assigned role in the Ultimatum Task on what the participant chose as a split in their first or second proposals or on whether or not the participant chose to accept the unfair split in the last round of the task. Additionally, no significant effects of Desert Survival Task completion time were found.

Finally, no significant results were found when analyzing the Interpersonal Dominance Scale, the SUS, or our custom scale evaluating the participant's general attitude towards the confederate.

## 7 Discussion

We found the equal-sized avatars to be significantly more influential than the small-sized avatars and the small avatars commanded significantly less attention than the equal-sized avatar. Additionally, we found the local users assigned a leadership role were less influenced by the AR telepresence avatars and that participant subjective satisfaction of the task outcome was higher when the local user was assigned a leadership role than when assigned a follower role, but only in the case of the equal-sized avatar condition. The results relating to avatar size aligned with our hypothesis, yet the results relating to assigned leadership role were contrary to our expectations.

### 7.1 Effect of Size

In our results, we found the equal-sized avatar to be significantly more influential than the small-sized avatar in the Desert Survival Task. We also found that the small avatar commanded significantly less attention than the equal-sized avatar. When analyzing the qualitative data from our free-response question, which asked if the final consensus list in the desert survival task had more or less of their initial rankings and why, every participant responded by saying shifts were due to logical points brought up by the remote user. Not a single participant felt as though the interaction was unfair or that they were strong-armed into agreement.

Our two findings relating to avatar size may be explained by a general dislike of the smaller avatar design by participants. These negative feelings participants held towards the small avatar design might have manifested themselves in how willing participants were to listen to the remote user's opinions. Additionally, the small-sized avatar commanding less influence and attention could be explained by participants perceiving the smaller size as having a reduced presence and, in turn, be considered less engaging than the equivalently-sized avatar. Responses to our open-ended questions help support this conclusion. When asked what they disliked about the avatar design (never referencing size in any question), some participants who interacted with the small avatar stated:

**P01 [Small - Follower]:** "The avatar was not large enough... to make it feel like a person was present. Thus I did not typically feel the need to speak to the avatar directly ... the avatar was instead very small compared to myself and felt like the presence it created was minuscule."
**P03 [Small - Leader]:** "[I want] the option to change the size of the avatar. Probably bring a more clear eye to eye interaction...I think I was more influenced by his voice than by looking at the avatar"
**P09 [Small - Leader]:** "[Interacting] wasn't really necessary, I found myself focusing on his voice more than the avatar."
**P15 [Small - Follower]:** "[The avatar] felt unnecessary, and the tasks could have been done in person. The avatar was not noticed because I was not looking at it. I guess it could be removed."
**P26 [Small - Follower]:** "Size of the avatar could be much better...if the actual size of the avatar was bigger, it would've been more engaging and interactive. It seemed that the avatar had some sort of facial gestures going on, but I couldn't see because it was very small."
**P33 [Small - Follower]:** "I disliked that the size was small."

One participant went as far as to say the small avatar was like talking to a toy or a doll.

**P19 [Small - Follower]:** "The size ratio was different, so felt like I was talking to a toy figure/doll"

This shift from viewing the avatar as a person to as an animated, non-human object is an interesting insight as to how AR avatar size can manipulate the perspective of local users into viewing the human avatar controlled by a human remote user as non-human. As seen in Mull et al's. work, when users view avatars as human-hybrids or non-human, preconceptions about the avatar change [20]. In this case, viewing the remote user as child's plaything might have greatly impacted the influence the remote user had over the local user and the attention they received.

It is important to note that not a single participant in the equal-sized condition had a negative comment regarding the avatar size when asked the same questions (instead the recurring complaint was how heavy the AR HMD was).

While analyzing the free-response questions, we came across an interesting trend regarding user expectations of the avatar's appearance. We asked "What did you expect the augmented reality avatar to be like and how did your expectations compare with reality?" and found that participants assigned to the small avatar conditions were far more likely to have mismatch. Many participants were surprised that the avatar size was small:

**P04 [Small - Follower]:** "I expected it to be closer to my size."
**P09 [Small - Leader]:** "I expected it to be life-size."
**P15 [Small - Follower]:** "I thought it would be larger."
**P18 [Small - Follower]:** "I thought the avatar would appear nearly life-size, or at least just the upper half of the body that would be life-size."
**P26 [Small - Follower]:** "I was wishing the avatar to be as big as me"
**P27 [Small - Leader]:** "I thought that the avatar would be more of my size and that I'd be able to see him more clearly. I couldn't make out the face , and I expected that I would be able to see the body parts in more detail."
**P36 [Small - Leader]:** "[I expected it to be] much bigger than what I saw."

This difference in expectations (usually negative in connotation) vocalized by local users with the small avatar was not echoed by local users interacting with the equal-sized avatar. Only one participant in the equal-sized conditions said the "life-sized" avatar was unexpected, although they expressed positivity about the surprise.

**P05 [Regular - Leader]:** "I didn't expect it to be life-size so that was cool."

It is possible this misalignment of expectations also fed into why the small avatar was less influential and less attention grabbing than the equal-sized design. This insight might help to inform developers of AR avatars because attempting to meet user expectations plays a central role in design formulation.

### 7.2 Effect of Role

In addition to the effect avatar size played on remote user dominance, we found the participants assigned to the leader role were significantly more influenced by the remote user, which was opposite of our expectations. We found no insights that explained this result in the survey responses provided by participants. To help explain why followers may have resisted the influence of remote users more strongly, we surveyed psychology literature regarding leader-follower interactions and follower resistance.

Collinson et al. state that follower resistance is a way for followers to construct alternative, more positive identities to those provided or prescribed [3]. Additionally, Foucault et al. assert that power invariably produces resistance especially in the guise of micro acts of local defiance and that the construction and protection of self is an important motivator for follower resistance [6]. Finally, Haslem et al. state leadership depends on group members sharing a consensual social identity, that leaders can play a fundamental part in constructing this shared identity, and the very possibility of leadership depends upon the existence or creation of a shared group identity [8]. It is possible that the superficial assignment of a leadership role, assigned at the beginning and confirmed once by the confederate, and very short interaction time span, was insufficient for developing this shared identity, resulting in followers more actively resisting the leader.

Another hypothesis to explain the influence the remote user followers had on the leader-assigned participants is the definition of leader provided by the researcher at the beginning of the experiment. When participants were told that "the leader is responsible for ensuring the tasks were completed appropriately and within the allotted time" it may have primed participant leaders to artificially yield to the confederate's opinion in order to reach a consensus faster and finish the task within the time limit.

There also was a significant interaction effect found relating to participant subjective satisfaction of the task outcome. We found that satisfaction was higher when the local user was assigned a leadership role than when assigned a follower role, yet this was not the case in the small avatar conditions. We postulate that in the equal-avatar cases, the local user leaders felt accomplished for leading the team to a successful conclusion of both tasks; meanwhile, when leaders interacted with a remote user using a small avatar, they felt as if the remote user was more dependent on the local user. This could have made the local user feel resentment towards the remote user as there was a negative exchange of social capital from having to represent or support the person when they were small vs. it being a collaboration between equals when the confederate was normal size. We see potential support for this theory in the

comments made by participants, who described wanting an "eye-to-eye" interaction when communicating with the small avatar and described the manifestation of the remote user as "minuscule."

### 7.3 Design Implications

The effects that avatar size and leadership role have on human-avatar interactions are of particular importance in contexts where the AR telepresence avatar remote user's ability to exert authority are critical to the success of the interaction. For example, in businesses where employers are to stay in contact with remote employees, in interactions where negotiation is a key factor, in educational settings where the teacher is using an AR telepresence avatar to teach while maintaining control of the classroom, and in medical settings where doctors are prescribing treatment plans for patients that must be followed. As a result, those designing AR telepresence avatar systems should be aware of who the potential users of the system are and what their roles may be. For example, an equal-sized avatar is important if there is a hierarchical relationship that requires dominance. Finally, more research is required to better understand the relationship between remote user influence and leader-follower roles in human-avatar interactions.

### 7.4 Limitations & Future Work

The study we performed demonstrated the effect AR telepresence avatar size had on local users; however, it is not without practical and theoretical limitations that may decrease the generalizability of our results.

First, the lack of support for our hypotheses in the Ultimatum Task may have stemmed from positioning it after the Desert Survival Task. In previous studies [5, 32], the Ultimatum Task was an independent exercise. Asking the participant to interact with the confederate in a negotiation that requires consensus prior to engaging in the Ultimatum Task might have established a cooperative relationship between the local and the operator, leading to a tendency toward fairness and compromise. To support this theory, the vast majority of participants offered $50/50$ splits during this task, and when asked in the post-survey for reasoning of the proposed the splits, 12.5% of participants cited the relationship built in the Desert Survival Task.

Second, the definition of leader we provided to participants may have influenced their behavior when assigned the leader role. These participants may have been more willing to cave to the opinions of the confederate in order to finish the task in a timely manner. Future studies might explore leader-follower relationships in more depth by examining alternate definitions of the leader role, such as "being responsible for ensuring the optimum outcome for each task" rather than our focus on the leader being responsible for completing the tasks in the allotted time period.

Additionally, our current avatar system utilizes a pre-made 3D model of a human with a rigged skeleton that we synced with the body tracking of a Kinect motion sensor. Although the majority of participants in the post-experiment survey described the motions of the avatar as helpful, beneficial, and enhancing the interaction with natural body language, a few participants described the movements of the avatar as "stiff." Future work might explore using real-time 3D scans of remote operators. These real-time scans would allow for the remote user to project his or her actual appearance as an AR avatar as well as perfectly matching the remote operator's movements.

Another avenue of potential research would be that of pairing the condition of telepresence avatar size with appearance traits that have been previously shown to impact human-avatar communication, such as attractiveness [10], form [20], or avatar gender [33]. The possible interaction effects of such combinations could further inform AR telepresence avatar design.

Further studies in this domain may increase the generalizability of our results by examining how the short-term effects of size may evolve over time, how previous contact with the remote user may mediate the local user's reaction to the size of the avatar, and how allowing the remote user to adjust his or her avatar size mid-interaction may change the local user's perceptions.

## 8 Conclusion

Many aspects of physical appearance have been shown to change how an individual is perceived, judged, and treated by others. Prior findings have shown to that these changes to perception hold true in human-human, human-robot, and human-avatar interactions. As AR technology becomes more mainstream and is integrated into telepresence systems, it is important to understand how the size of AR telepresence avatars impacts interactions between local and remote users.

In our study, we assigned the role of either leader or a follower to participants and explored how manipulating the size of the telepresence avatar to be equal-sized or small-sized reinforced or undermined his or her authority. We found the equal-sized avatars to be significantly more influential than the small-sized avatars and that the small avatars commanded significantly less attention than the equal-sized avatars. We also found that local users assigned to the role of leader were less influenced by the AR telepresence avatars and had higher subjective satisfaction of the task outcome, but only in the case in the equal-sized avatar conditions. While the results presented in this paper are limited to short-term interactions, they provide evidence that the size of avatars may shape interactions between local and remote users and help inform the design of current and future AR telepresence avatar systems.


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