Avatars Versus Agents: A Meta-Analysis Quantifying the Effect of Agency on Social Influence

Jesse Fox

The Ohio State University

Sun Joo (Grace) Ahn

University of Georgia

Joris H. Janssen

Philips Research

Leo Yeykelis

Stanford University

Kathryn Y. Segovia

Stanford University

Jeremy N. Bailenson

Stanford University

Running head: META-ANALYSIS: AVATARS VS. AGENTS

Corresponding author's contact information:
Jesse Fox
3084 Derby Hall
154 North Oval Mall
The Ohio State University
Columbus, OH 43210-1339
Fax: (614) 292-2055
Phone: (650) 391-8984
fox.775@osu.edu

Jesse Fox (Ph.D., Stanford University) is an Assistant Professor in the School of Communication at The Ohio State University with an interest in communication technologies. **Sun Joo (Grace) Ahn** (Ph.D., Stanford University) is an Assistant Professor in the Grady College of Journalism and Mass Communication at University of Georgia with an interest in digital media and persuasion. **Joris H. Janssen** (Ph.D., Eindhoven University of Technology) is a Research Scientist at Philips Research with an interest in affective computing and persuasive technology. **Leo Yeykelis** (B.A., Stanford University) is a Ph.D. candidate at Stanford University with an interest in human-computer interaction. **Kathryn Y. Segovia** (Ph.D., Stanford University) is a student at Stanford University with an interest in research at the intersection of law and social psychology. **Jeremy N. Bailenson** (Ph.D., Northwestern University) is an Associate Professor at Stanford University and the founding director of the Virtual Human Interaction Lab with an interest in immersive virtual environments.

ABSTRACT

Existing research has investigated whether virtual representations perceived to be controlled by humans (i.e., avatars) or those perceived to be controlled by computer algorithms (i.e., agents) are more influential. A meta-analysis (*N* = 32) examined the model of social influence in virtual environments (Blascovich, 2002) and investigated whether agents and avatars in virtual environments elicit different levels of social influence. Results indicated that perceived avatars produced stronger responses than perceived agents. Level of immersion (desktop vs. fully immersive), dependent variable type (subjective vs. objective), task type (competitive vs. cooperative vs. neutral), and actual control of the representation (human vs. computer) were examined as moderators. An interaction effect revealed that studies conducted on a desktop that used objective measures showed a stronger effect for agency than those that were conducted on a desktop but used subjective measures. Competitive and cooperative tasks showed greater agency effects than neutral tasks. Studies in which both conditions were actually human-controlled showed greater agency effects than studies in which both conditions were actually computer-controlled. We discuss theoretical and design implications for human-computer interaction and computer-mediated communication.

Keywords: avatars, computer agents, virtual representations, virtual environments, social influence

CONTENTS

1. INTRODUCTION

Virtual representations of people in computer-mediated interactions can be categorized as *avatars* or *agents*. Avatars are distinguished from agents by the element of control: avatars are controlled by humans, whereas agents are controlled by computer algorithms. Hence, interaction with an avatar qualifies as computer-mediated communication (CMC) whereas interaction with an agent qualifies as human-computer interaction (HCI; Morkes, Kernal, & Nass, 1999).

The difference in the locus of control gives avatars and agents distinctive features. Agents are useful for digital media because once an agent is built, it can be replicated easily and nearly infinitely across various platforms. Unlike a human-controlled avatar, an agent does not need to sleep, does not get bored, and does not require a paycheck. In many situations, an agent may be preferable. At this point, however, some theorizing and research has indicated that agents are not as persuasive as avatars (e.g., Blascovich, 2002), which has major implications for HCI design.

According to this research, the effectiveness of persuasive virtual representations may depend on how they are perceived by users. Even assuming that an agent functions objectively as well as an avatar does, there may be fundamental differences in how people react to a computer-controlled agent as opposed to a human-controlled avatar. Because of existing schemata regarding computers, agents may be seen as mechanical or depersonalized, whereas avatars may be perceived more like people because humans control them. From the user's perspective, it may be that the mere *perception* of human interaction affects whether a virtual representation is successful at influencing the user. That is, regardless of any actual difference in the performance of agents and avatars, if users believe they are interacting with a human (instead of a machine), they may be more susceptible to social influence (Lim & Reeves, 2010; Okita, Bailenson, & Schwartz, 2008). Given that virtual representations are becoming increasingly common in education, health, marketing, and other persuasive contexts (Blascovich & Bailenson, 2011), it is important to identify whether there is a difference in how agents and avatars are perceived and how they differ in their abilities to exert social influence.

In this meta-analysis we sought to determine whether perceived agency of a virtual representation affected social influence. Using the model of social influence in virtual environments (Blascovich, 2002; Blascovich, Loomis, Beall, Swinth, Hoyt, & Bailenson, 2002) as a framework, we examined whether avatars yield greater social influence than agents. If avatars and agents are perceived as equally influential, then those designing and implementing HCI interfaces can select whichever is more convenient, efficient, or inexpensive. If the model of social influence in virtual environments is supported, however, HCI designers and researchers would have to carefully consider the costs and benefits of using agents instead of avatars.

To enrich the analyses and application of the findings, we also included relevant moderators. First, we examined whether differences existed between immersive (i.e., hardware that perceptually surrounds users and responds to their natural movements) and desktop environments. We also investigated the strength of these responses based on whether objective (behavioral) or subjective (self-report) dependent variables were employed. Task type may be another important factor, so we compared competitive, cooperative, and neutral simulations. Because these studies manipulated perceived control (i.e., whether the participant thought they were interacting with a person or a computer), we also examined actual control (i.e., whether the participant was actually interacting with a person or a computer). These moderators will add further insight into how the agency of virtual representations affects their social influence.

2. VIRTUAL REPRESENTATIONS: FORM AND FUNCTION

Virtual representations include avatars, agents, and hybrids that feature some aspects of computer and human control. Avatars often represent people in Internet chat, video games, social networking sites, virtual worlds, and other mediated contexts (Blascovich & Bailenson, 2011). Agents tend to appear as interactive characters in video games and virtual worlds or provide a social interface in realms such as online customer service (Bickmore & Cassell, 2005; Cassell, Sullivan, Prevost, & Churchill, 2000). Avatar-agent hybrids also exist, capitalizing on the strengths of programmable features and algorithms while still guided by a human controller (Benford, Bowers, Fahlén, Greenhalgh, & Snowdon, 1997; Gerhard, Moore, & Hobbs, 2001). With such broad applications, virtual representations serve many purposes and are often multi-functional within a given context (Fox, Arena, & Bailenson, 2009). They often serve as conduits for verbal and nonverbal communication (Bente, Rüggenberg, Krämer, & Eschenburg, 2008; Gratch, Rickel, André, Cassell, Petajan, & Badler, 2002). Compared to other symbolic representations of people (e.g., names), avatars and agents are able to behave in a human-like manner (Blascovich et al., 2002), giving them unique capabilities to influence users.

As such, virtual representations are often employed as a method of influence. They may function as interpersonal sources or as demonstrative models to inform or persuade a user. For example, they have been used to increase exercise behavior by illustrating weight loss on a self-resembling avatar (Fox & Bailenson, 2009); persuade people to assist in a scavenger hunt using sequential request techniques (Eastwick & Gardner, 2009); promote learning and trust among students (J.-E. R. Lee et al., 2007); encourage environmental behaviors (Ahn, Fox, Dale, & Avant, in press); and create brand preference by affiliating a particular brand with a self-representation (Ahn & Bailenson, 2011). Agents and avatars have also been incorporated in studies of health monitoring (Skalski & Tamborini, 2007), speech learning (D’Mello, Graesser,

& King, 2010), attitudes toward women (Fox, Bailenson, & Tricase, 2013), and memories (Segovia & Bailenson, 2009). This research has demonstrated that, like human interactions, social interactions with agents and avatars can be used to modify users' attitudes and behaviors. In many studies, however, agency of these virtual representations is not clarified or manipulated.

Different traits of virtual representations may determine their effectiveness as persuasive tools. Agents and avatars can vary along many dimensions. For example, when representations appear more human-like in form (i.e., anthropomorphic), users may develop social expectations for subsequent interactions (Nowak & Biocca, 2003). Representations that demonstrate high behavioral realism, including interactivity and situational appropriateness, may facilitate more natural interactions (Blascovich et al., 2002; Gratch et al., 2002). There may be a downside to realism, however; Mori (1970) hypothesized the uncanny valley, suggesting that technologies may reach a point of human likeness that makes users uncomfortable. Recent research by Tinwell and colleagues (2011) has elaborated features of highly realistic human-like virtual representations that evoke negative reactions.

These different aspects of representations may influence the impact of a representation and whether or not users are likely to categorize and perceive it as a computer or a human. Users often react to virtual representations similarly to how they would react to people in the physical world on a psychological, physiological, and behavioral level (Cassell et al., 2000; Eastwick & Gardner, 2009; Fox et al., 2013; Gong & Nass, 2007; Hoyt, Blascovich, & Swinth, 2003). Thus, it is important to determine whether variables such as agency affect how people respond to virtual representations and how influential virtual representations are.

3. THEORETICAL EXPLANATIONS

Allport (1985) suggested that human actions and psychological experiences are shaped by the actual, imagined, and implied presence of others; that is, people behave in accordance with some degree of *social influence* (Heider, 1958; Zajonc, 1965). Social influence has been broadly defined to include changes in an individual's cognitions, attitudes, physiological responses, and behaviors resulting from the belief that another person is present (Allport, 1985; Cialdini, 2008) and the attributions made about that person (Heider, 1958). Social influence may operate through a number of mechanisms, such as social norms (perceived common practices, the violation of which may yield social punishment), conformity (shifting one's attitude or behavior to match another's), compliance (acquiescing to a request or desired behavior), and identification (being persuaded by a liked or similar other; Cialdini, 2008; Kelman, 1961).

Media technologies add a new dynamic to the process of social influence. Agents and avatars, although they are digital, mediated representations, symbolize the presence of another entity (either computer or human). Because of their anthropomorphic nature, users make attributions about these representations similar to those they make about humans (Blascovich et al., 2002). Thus, there are two ways that social influence may play out. If people make similar attributions and do not distinguish a computer-controlled agent from a human-controlled avatar, both will yield *social presence*, or the perception that another individual is in the environment (Lombard & Ditton, 1997). In this case, social influence would be constant across conditions. If people make different attributions and distinguish between the two, we expect that a human-controlled avatar would elicit more presence than a computer-controlled agent and social influence would be stronger in situations where an avatar was present as opposed to an agent.

Other potential mechanisms that may explain the effect of agency on social influence are the processes of identification and social categorization. Identification occurs when a person feels similar to the influential entity based on perceived similarity in background, goals, demographics, or other traits (Kelman, 1961). When perceiving virtual representations, people may identify more with an avatar because of its humanness. Alternatively, other cues of similarity may override perceived agency, and whether or not the entity is human or computer-controlled may be less important in determining influence. For example, photorealistic virtual selves (i.e., virtual doppelgängers) influenced exercise behaviors when they were controlled by a computer as well as when they were controlled by a human (Fox & Bailenson, 2009).

Social categorization may also occur, wherein others are evaluated based on salient indicators of group membership and then categorized accordingly (Tajfel & Turner, 1979). Agents would be considered a member of an outgroup, whereas avatars would be included in the same category as the human self. As a fellow ingroup member, the avatar would then be more influential than an outgroup member (Tajfel & Turner, 1979). It is possible that other features of representations or the nature of the interaction make other social categories salient, however, so it is not certain that ingroup and outgroup perceptions will be based solely on perceived agency.

One perspective argues that people do not make such distinctions between humans and computers. According to the computers as social actors framework (CASA, derived from the media equation), humans are not evolved to differentiate (Nass & Moon, 2000). Instead, humans behave “mindlessly” and interact with computers in a “fundamentally social and natural” way (Reeves & Nass, 1996, p. 5). If a computer demonstrates social behavior, people do not exert the cognitive effort to determine how to react to a social machine; rather, they respond to computers in a manner similar to how they would respond to people (E.-J. Lee, 2010; Nass & Moon, 2000).

Although CASA has been extensively applied to understanding how people respond to devices and systems as a whole within physical environments (e.g., Nass, Fogg, & Moon, 1996;

Nass, Moon, & Green, 1997), considerably less research has examined its relevance for examining representations within virtual environments (although see Appel, von der Pütten, Krämer, & Gratch, 2012; von der Pütten, Krämer, Gratch, & Kang, 2010). In contrast, the model of social influence in virtual environments was developed specifically considering the effects of virtual representations and the affordances of virtual environments (Blascovich, 2002; Blascovich et al., 2002). This model suggests that users process and make attributions to a virtual representation based on whether they believe it is being controlled by a computer or by another person. Perceived agency is important because it affects the degree of social presence an individual feels and thus the likelihood of influence occurring; Blascovich et al. posit that computers (agents) elicit less social presence than humans (avatars). According to the model, when greater social presence is experienced with a virtual representation, more social influence will occur because users will perceive and interact with the representation as they would with a real person. The feeling of social presence and the resulting social influence may be enhanced by several factors, including the richness of sensory information provided, the behavioral realism of the interactant, and the self-relevance of the interaction (Blascovich et al., 2002).

Several studies have indicated support for the model of social influence in virtual environments. Bailenson, Blascovich, Beall, and Loomis (2003) found that participants maintained greater personal space with an allegedly human-controlled avatar than with a computer-controlled agent. In another study, Hoyt and colleagues (2003) asked participants to complete learned or novel tasks in the presence of two avatars, in the presence of two agents, or alone. When participants were told that the virtual human observers were avatars, participants' performance on novel tasks suffered. Completing the task in front of agents did not impact performance. The results from the avatar condition mirror studies wherein the presence of humans inhibited task performance, but agents showed no such effects. In light of the model and supporting research, we anticipate that:

H1: Avatars will yield greater influence than agents.

Results from other studies, however, find no differences between avatars and agents or find that agents yield stronger influence (e.g., Nowak & Biocca, 2003; Williams & Clippinger, 2002; Zadro, Williams, & Richardson, 2004). Given the mixed findings, a meta-analysis seemed a prudent method to identify any consistencies across the literature. Additionally, because these studies span several domains (e.g., learning, ostracism, and aggression), employ different hardware setups (e.g., video games, desktop-based virtual worlds, and fully immersive virtual environments), and use different outcome variables (e.g., self-report questionnaires, behaviors, and physiological measures), several moderators were also investigated.

4. VARIABLES OF INTEREST

We chose to examine several moderating variables that were of interest in regards to theory, design, and future avenues of research on agency. We selected variables that could be consistently identified across studies in the sample and accurately coded based on the information provided in the description of the method.

4.1 Level of Immersion

The model of social influence in virtual environments suggests that if a user is interacting with a more perceptually realistic representation, the differences between avatars and agents will be minimized. In other words, if an agent is high in realism, then the user is influenced less by the fact that it is controlled by a computer than if an agent is unrealistic.

Given that fully immersive environments allow participants to move in a natural manner and mimic the depth and motion cues of the physical environment, agents and avatars encountered within them may be considered more realistic than those observed in a two-dimensional desktop environment. Indeed, previous research has indicated that stimuli presented in three-dimensional immersive environments may be more compelling and influential than those presented in typical two-dimensional desktop environments (Bailenson, Patel, Nielsen, Bajcsy, Jung, & Kurillo, 2008; Persky & Blascovich, 2007). Thus, this model would predict greater differences between avatars and agents in desktop environments as opposed to fully immersive environments, where realism would make agency less of a factor.

H2: Studies conducted in immersive virtual environments will demonstrate smaller differences in the effects of agency than studies conducted in desktop environments.

4.2 Type of Measure

The dependent variables included in these studies can be categorized as subjective or objective measures. Subjective measures are those that are self-reported and rely on the participant to provide accurate assessments of their experiences. Thus, these measures may be less reliable because they are subject to participants' biases. Objective measures include behavioral data collected by the experimenter or other devices (e.g., motion trackers).

Among HCI scholars, there is particular concern about the differences in subjective and objective measures in virtual environments (Slater, 2004). For practical purposes, it is important for researchers studying agency to determine whether some measures are more sensitive than others for identifying differences in social influence. For example, Bailenson and colleagues (2004) demonstrated that behavioral measures could be sensitive enough to pick up responses to digital representations, such as personal distance, that self-reports could not. In a meta-analysis on realism, however, Yee, Bailenson, and Rickertson (2007) found that effect sizes were greater for subjective measures than objective measures. Given the mixed findings, we ask:

RQ1: Will agency effects on social influence vary between objective variables and subjective variables?

4.3 Task Type

The type of task completed in the VE may also affect the levels of social influence elicited by different agents of control. Several of the included studies used gaming tasks to test agency effects (e.g., Eastin, 2006; Ravaja, 2009; Williams & Clippinger, 2002). Within these gaming tasks, users are asked to compete or cooperate with an avatar (i.e., another player) or a computer agent to achieve a goal. Competitive or cooperative tasks are likely to differ from neutral scenarios on variables such as physiological response, aggression, or perceptions of the agent/avatar. In competitive tasks, users may feel that more is at stake when playing against another person as opposed to a computer because of the potential social consequences (e.g., bragging rights or sharing the defeat/victory among a wider social circle; Weibel, Wissmath, Habegger, Steiner, & Groner, 2008). Additionally, competition may encourage users to categorize their competitors as outgroup members (which may augment an agent's outgroup status as a computer), whereas cooperation encourages users to categorize their collaborators as ingroup members (which may discount an agent's outgroup status; Tajfel & Turner, 1973). Thus, we would expect competitive tasks to show a greater difference than cooperative tasks.

Having a goal to accomplish in competitive and cooperative tasks likely bolsters the self-relevance of the task because the outcome is contingent on the user's performance (moreso in the competitive task than the cooperative task, as the cooperative task relies on the performance of other collaborators as well). The model of social influence in virtual environments states that the higher the self-relevance of the task, the more agency matters (Blascovich et al., 2002). That is, if the task is high in self-relevance, the model predicts that avatars will be much more influential than agents, and the observed effect size for this difference would be larger. Thus, we predict:

H3: Competitive tasks will show the greatest differences in agency, followed by cooperative tasks, and neutral tasks will show the smallest differences in agency.

4.4 Actual Control

Blascovich et al. (2002) argue that perceived control of a representation drives social influence. From a methodological and design standpoint, however, it is also important to consider actual control. If actual control has no impact, it may be sufficient for designers to focus on convincing people about perceived control and rely on agents. It may be, however, that despite awareness that they are interacting with a human or computer, users are perceiving other cues of agency that affect levels of social influence. For example, if a user is told they are interacting with another person, but the other person is actually a computer and “behaving” in a very sterile or programmed way that evokes a computer controller, this may lead to diminished social presence and thus less social influence. Given that researchers who study agency typically have both the agent and avatar conditions controlled by the same entity for purposes of experimental control, it is important to determine if actual control affects social influence as these researchers’ findings may need to be appropriately qualified and interpreted.

RQ2: Will actual control moderate the effect of perceived control on social influence?

4.5 Time

Technological platforms have evolved rapidly in the past two decades, from chunky, pixelated, stiffly animated depictions to highly lifelike, fluid, and interactive digital representations. It is possible that this evolution has yielded some fundamental differences in the depictions and thus perceptions of avatars and agents. Ivory and Kalyanaraman (2007) found that technologically advanced video games led to greater involvement, presence, and physiological arousal than less sophisticated games. Virtual environments are becoming increasingly compelling and representations are demonstrating greater behavioral realism as relevant technologies evolve (Blascovich et al., 2002). Thus, we examined whether time was a significant factor and whether it should be included as a covariate in the analyses.

5. META-ANALYSIS

Given the mixed findings observed in the literature review, a meta-analysis was proposed to draw some general insights about responses to agents and avatars. Meta-analysis is a method by which the data from several studies can be aggregated to create an overarching picture of what exists in the literature on a given topic (Hunter, Schmidt, & Jackson, 1982; Preiss & Allen, 1995; Rosenthal & DiMatteo, 2001). Meta-analysis helps overcome a downfall of significance testing by accumulating related results, so that even small or nonsignificant effects are included. Collecting and combining data also allows for the investigation of potential mediator and moderator variables across a larger data set (Rosenthal & DiMatteo, 2001).

6. METHOD

6.1 Study Selection

In the first round of study selection, we searched bibliographic indices relating to the fields of virtual reality, communication, psychology, and video gaming. The databases used included ScienceDirect, Google Scholar, Google Keyword, PsycInfo, PsycArticles, ISI Web of Knowledge, EBSCO Academic Search Complete, Computers & Applied Sciences Complete, Computer Source, Proquest Dissertations & Theses, and websites of individual faculty or laboratories providing lists of publications. In this initial pass, the following search terms were used: virtual world*, digital world*, virtual environment*, digital environment*, video game*, avatar*, embodied agen*, virtual agen*, computer agen*, virtual human*, virtual representation*, computer control*, human control*, computer opponent, social influence model, media equation, and computers as social actors. Once an appropriate paper was identified, we searched its references for potentially related papers and also reverse searched to see which papers had cited this paper. We advertised on relevant listservs and contacted individual researchers in several disciplines (e.g., computer science, psychology, communication, education) we thought might have or know of relevant work. These articles were skimmed to determine whether they reported a study that measured social influence (i.e., one in which participants were led to believe that another entity was present, and changes in an individual's cognitions, attitudes, physiological responses, and behaviors were measured and compared based on this presence). Following the suggestion of Preiss and Allen (1995), both published and unpublished papers were included. This initial literature review yielded 119 studies.

6.2 Study Criteria

The next step was to filter out studies that did not adhere to the requirements for inclusion in the meta-analysis. Three criteria were established. 1) The studies' dependent variables (DVs) had to be quantitative measures of social influence (e.g., presence or affect ratings, physiological measures, or interpersonal distance). Purely descriptive studies involving open-ended self-reports or observational studies without quantitative coding schemes or dependent variables were removed. 2) Furthermore, studies needed to have a visual representation of the avatar and agent. This representation could range from a video of a virtual hand played on a desktop computer to full-bodied ball-tossing virtual humans in an immersive environment; however, treatments without a visual representation (for example, a voice recording or a text passage that asked one to imagine a scenario) were excluded because we were interested in evaluating immersive virtual environments (i.e., digitally rendered virtual spaces using hardware that perceptually surrounds users and responds to their natural movements) as a moderator, and it was difficult to ascertain what constituted an IVE for non-visual sensory representations. To note, we did not identify any studies that manipulated agency without a visual representation; rather, these studies manipulated other variables, such as realism or anthropomorphism (e.g., studies of synthesized speech that examined how human-like a voice sounded such as Gong & Nass, 2007). 3) Finally, studies that did not explicitly manipulate agency were removed. Experimental instructions were required to inform participants explicitly that the virtual representation was controlled by a human in one condition compared to another condition wherein participants were told the virtual representation was controlled by a computer. This process left 36 studies.

In the third and final round, we made an inventory of the selected studies and their reported statistics. Minimally required statistics were means, standard deviations, and *n*s per condition, or *t* values or *F* values with degrees of freedom, or *r* values, or Cohen's *d* values. For papers that did not report the minimal statistics needed for a formal meta-analysis, we individually contacted the lead or corresponding authors to gather those statistics. The only case for which we were not able to obtain information was the Eastin and Griffiths (2006) studies, for which we assumed equal *n*s across conditions. In the end, 32 studies provided enough data to be included in the formal meta-analysis. These studies can be viewed in Figure 1.

[Insert Figure 1 about here]

Of these 32 studies, the average year of publication was 2007.13 (SD = 3.30) with a median of 2006. The average sample size within each study was 71 participants (SD = 44.80). Twenty studies were conducted in the U.S., five in Europe, four in Singapore, two in Australia, and one in Canada. Desktop equipment was used for 21 studies and 11 studies were conducted using immersive virtual environments. Sixteen studies involved gaming tasks and 16 studies involved non-gaming tasks. Four studies featured a cooperative task, 11 studies were competitive, and one study had cooperative and competitive conditions which were separated when analyzing cooperation vs. competition and joined otherwise. In seven of the gaming studies, an actual human controlled the virtual representations, whereas in all but one of the 16 non-gaming studies the virtual representations were controlled by computers.

6.3 Effect Size Calculations

We compiled a datasheet with all of the studies and their dependent variables. For each DV, measures were coded for the method of collection as either objective or subjective. *Objective* measures consisted of interaction behavior (e.g., gaze or interpersonal distance); cognitive markers, such as memory; and physiological responses, such as heart rate or skin conductance. *Subjective* measures included self-report measures assessing the participant's affective state, experience of presence, or attitudes toward the agent or avatar. Next, means, standard deviations, t-values, p-values, and number of participants were included where available. If there was more than one condition representing a level of agency (e.g., if an avatar was controlled by a friend in one condition, but a stranger in another), we combined them using averages weighted by the respective n.

We calculated effect sizes based on the seminal work by Rosenthal and DiMatteo (2001). The effect size r is a measure of the impact that a manipulation has on a dependent variable. The squared value, r^2, shows the amount of variance in the dependent measure that can be accounted for by the manipulation. For example, an r^2 of .15 means that 15% of the variance in the dependent measure can be explained by the relevant manipulation (e.g., level of agency). For each DV, we calculated an effect size r value based on the t value and the degrees of freedom. If the *t* value was not reported, means, standard deviations, and the number of cases in each condition were used to derive the *t* value and subsequently the *r* value.

In cases where statistics to calculate the *r* value were missing, we coded two values for *r*. Following Rosenthal (1991), first we coded *r* as zero (*zero-coded*). This process avoids inflated results due to publication bias of significant effects and is an effective, albeit conservative, method of ensuring inclusion of the wide range of findings. Additionally, following Sherry (2001), we calculated a less conservative estimate using the maximum non-significant effect size (*max-coded*), which allowed us to account for all of the studies. The maximum non-significant effect size is based on the sample size of the study and gives the *r* value at the boundary of significance. The true effect size of a non-significant DV is somewhere between zero and the maximum non-significant effect size. In the results, we report aggregates for both approaches.

The sign of the *r* value signifies the direction of the effect. We ensured that the *r* value was positive in cases where the avatar condition yielded stronger responses on the DV than the agent condition. The *r* value was negative if the agent condition yielded stronger responses on the DV than the avatar condition.

The surveyed studies reported more than one DV of social influence. Because the types of DVs differed considerably, including emotional and affective responses, presence ratings, behavioral effects, and physiological indices, we conducted an analysis with DV as the unit of analysis. Doing so allowed us to include these diverse effects without ignoring the variance caused by the wide range of DV types. Furthermore, we could investigate the effect of DV type as a moderator of effect size. We also conducted analyses using study as the unit of analysis, which enabled us to confirm our DV level results and check for possible violations of assumptions of independence in the DV level analysis. No violations were observed.

6.4 Statistical Analyses

All of the calculated *r* values were weighted by sample size to ensure that studies with more participants were given stronger weight (Hunter et al., 1982). Subsequently, weighted *r* values were transformed to Fisher's *Z* values. According to Rosenthal and DiMatteo (2001), Fisher's *Z* transformation must be performed on *r* values because the *r* distribution does not follow a normal distribution. After aggregation, the averaged Fisher's *Z* values were transformed back to *r* values. Only *r* values are reported in the Results section. Figure 1 contains the *r* and weighted *r* values for every DV from each study.

First, the grand mean and variance of *r* was calculated. The first source of variance around the mean *r* is sampling error variance (Hunter et al., 1982). If, after subtraction of the sampling error variance, there is still unexplained variance left, there may be moderator variables that can account for this variance. Our subsequent steps in the analysis then focused on testing the moderator variables we coded in the datasheet through categorical or regression analyses.

Finally, we assessed the *n*-*r* correlation. Because studies tend to report only significant effects, and effects are more likely to be significant with larger samples, a negative correlation between *n* and *r* is often found in meta-analyses (Levine, Asada, & Carpenter, 2009). The *n*-*r* correlation can be interpreted as evidence of publication bias in a sample of studies, although it is more sensitive in certain conditions. The purpose of the *n*-*r* correlation is not to invalidate the meta-analysis, but rather provide an indication of the generalizability of the findings.

7. RESULTS

In addition to using zero-coded and max-coded data based on missing *r* values, we weighted the *r* values by the size of the *N* of each study. In the end, we had four sets of effect sizes: zero-coded unweighted *r*'s, zero-coded weighted *r*'s, max-coded unweighted *r*'s, and max-coded weighted *r*'s. We ran all analyses for each set.

First, we examined whether there was an overall effect of agency in which avatars were more influential than agents (H1). We computed Fisher's *Z* values from the *r* values of each DV and submitted all sets of Fisher's *Z* values to a one-sample *t*-test to see if they differed from zero. For all sets, we found a significant overall effect of agency such that avatars were more influential than agents. H1 was supported. All inferential statistics and means are reported in Figure 2. Conducting the analyses over the average effect size per study instead of over the effect size for all DVs also gave significant overall effects for all sets of *r*'s. See Figure 3.

[Insert Figures 2 & 3 about here.]

We were also interested in possible factors that influenced the effect sizes. Following Hunter et al. (1982), we first subtracted the sampling error variance from the total variance. The resulting variance was greater than zero for each of the four sets of *r* values. Hence, there were likely to be moderator variables to explain part of the variance in the data.

Then, we tested the effect of Year of Publication on the effect of agency. We regressed Year on the four sets of *r* values and found a significant effects for all sets ($p < .01$), as can be viewed in Figure 4. The regression coefficients B and β for Year were negative for all sets, indicating that the effect size of agents versus avatars became smaller over time. To make sure findings in subsequent analyses were not driven by Year of Publication as a possible confounding factor, we controlled for Year of Publication by including it as a covariate. H1 was again supported; avatars were found to be more influential than agents.

[Insert Figure 4 about here.]

Subsequently, we examined the effects of Immersion and DV type by submitting the Fisher's *Z* values of each of the four sets to an ANOVA with these as between-DV factors. We expected desktop environments to show greater differences in agency than immersive environments (H2) and wanted to determine if there were differences between subjective and objective dependent variables. Year of Publication was controlled for by including it as a covariate. Neither the main effect for Immersion nor the main effect for DV type was significant, but results showed significant effects for the interaction between Immersion and DV type for the max-coded sets (see Figure 5). Figure 6 shows means and SEs. Pairwise comparisons with Bonferroni corrections showed that the *r* value was significantly higher in the Desktop-Objective condition than in the Desktop-Subjective condition with $p < .05$ for the max-coded set and $p = .07$ for the weighted max-coded set. No other significant differences were found.

[Insert Figures 5 & 6 about here.]

Next, we investigated the effect of Task Type on agency. We anticipated that agency effects would be greatest in competitive environments, followed by cooperative environments and then neutral environments (H3). We submitted the Fisher's *Z* values of all four sets to an ANOVA with Task Type as a between-DV factor and Year of Publication as a covariate. We found a significant effect of Task Type for the unweighted sets and the weighted zero-coded set, as can be viewed in Figure 7. Pairwise comparisons using Bonferroni corrections revealed that for the unweighted sets, *r* values were higher in both gaming tasks compared to the non-gaming tasks ($p < .05$). Cooperative and competitive gaming did not significantly differ. The same pattern was found for the weighted zero-coded set, although this was only marginally significant ($p < .10$). A similar pattern was found for the weighted max-coded set, although this was not significant. H3 was partially supported. Means and SEs are depicted in Figure 8.

[Insert Figures 7 & 8 about here.]

Furthermore, we also tested whether Actual Control (by a computer or human; RQ2) of the virtual representation made any difference on the effect of the perceived control. We submitted the Fisher's *Z* values of all four sets to an ANOVA with Actual Control as a between-DV factor and Year of Publication as a covariate. The results showed a significant effect for all four sets. Effects when actual control was done by humans were larger than when actual control was done by computers. See Figures 9 and 10 for descriptive and inferential statistics.

[Insert Figures 9 & 10 about here.]

Finally, we investigated the *n*-*r* correlation as a measure of publication bias. We correlated the *n* of each study with the average *r* of both the zero-coded and max-coded set of that study. Results indicated significant negative correlations between *n* and *r* in the zero-coded set ($r = -.37$, $p < .05$) as well as the max coded set ($r = -.42$, $p < .05$). These findings indicate it is likely that some studies were not uncovered in our analysis.

8. DISCUSSION

8.1 Summary of Findings

Results of our meta-analysis largely supported our hypotheses regarding the effects of agency on social influence. Most importantly, results supported H1 that avatars are more influential than agents in social interactions. Several moderators were involved in this relationship. In testing H2 and RQ1, we found the interaction between using a desktop system to present virtual representations and measuring the influence with objective measures (vs. subjective measures) was the most effective in detecting differences in how avatars and agents influence people. Thus, H2 was supported with objective, but not subjective, measures. The effect of agency is amplified within competitive and cooperative rather than neutral tasks, partially supporting H3. Finally, addressing RQ2, actual control moderated the effect of agency: social influence between avatars and agents was greater when the virtual representation was controlled by a human rather than a computer.

8.2 Theoretical Implications

One of the most central findings from this meta-analysis supports Blascovich's (2002) model: when people perceived their virtual interactants to be human-controlled avatars, social influence was significantly stronger than when they thought they were interacting with computer-controlled agents. Users appear to make distinct attributions (Heider, 1958) in terms of whether a virtual entity is controlled by a human or a computer. Despite the acceleration of technological advancement, there is still nothing quite like the (perceived) human touch. This finding also implies that much of the classical research on social influence may carry over into virtual worlds as long as the user perceives the controller of the virtual representation to be human. Our findings also suggest, however, that this social influence and its measurement are conditioned by several moderating variables.

The meta-analysis revealed that in immersive environments, objective measures revealed greater differences for agency than subjective measures. Due to their realism, immersive environments may evoke different reactions in the body than the mind. Going forward, researchers should identify different ways to probe cognitive processing of agency (e.g., through fMRI; Assaf et al., 2009). Alternatively, it is possible that users perceive and make attributions regarding avatars and agents differently when behaving naturally in the moment than they do when asked to reflect upon the interaction later, which may explain some variation (Heider, 1958; Takayama, 2012).

Another moderator was task type. Our analysis revealed that in the unweighted half of our datasets, experiments conducted using competitive or cooperative tasks obtained higher agency effects compared to those with neutral, non-gaming ones. It is interesting that competition and cooperation did not differ; perhaps the inclusion of a social goal made agency more important than in a neutral task. Goals may heighten the experience of self-relevance, which may magnify agency effects on social influence (Blascovich et al., 2002).

8.3 Implications for HCI Research and Design

The findings of this study provide insight for the design of both research studies and applied interfaces. Our results imply that the first goal for a researcher or designer seeking to persuade an audience via a virtual representation may be to convince them that they are interacting with a real person rather than an algorithm. We also recommend straightforward instructions or cues regarding the agency of virtual representations. By leaving the identity of a virtual representation undefined, results may vary significantly based on whether individual participants perceive the representation to be human-controlled or computer-controlled.

The actual control of representations is also important for researchers and designers to consider. Our analysis revealed that differences in agency perceptions are magnified in situations where humans controlled the stimulus in both conditions as opposed to when a computer controlled both. This suggests researchers and designers need to be mindful of differences inherent in computer-controlled versus human-controlled stimuli.

We also identified differences in agency based on whether studies employed subjective or objective measures. In this light, we encourage researchers and interface testers to adopt multiple methods as commonly used subjective measures (e.g., self-report survey items) may not capture the entire spectrum of attitudinal or behavioral changes resulting from treatments.

The findings also provide suggestions for applied interface design. Although humans often anthropomorphize representations (Kiesler, Powers, Fussell, & Torrey, 2008), our findings indicate that the perception of human control in these interactions—not just human-like appearance—may be crucial for compliance. Thus, designs may focus on humanizing virtual agents in persuasive contexts to maximize the potential for influence. Current findings would be particularly applicable in persuasive contexts that directly lead to our wellbeing, such as healthcare. For example, HCI scholars have recently explored the possibility of using agents in the diagnosis of depression (Gratch et al., 2013). Our findings suggest that for providing further healthcare solutions following diagnosis, avatars would be more effective than agents as patients are more likely to comply with advice given by avatars.

Additionally, in computer-mediated situations wherein a human is interacting through a virtual representation, designers may need to reinforce human agency by enabling natural speech (D'Mello et al., 2010), nonverbal behaviors (Bente et al., 2008), emotions (Gratch et al., 2002), flexibility (Fan, McNeese, & Yen, 2010), context consideration (Bellotti & Edwards, 2001), and other markers of humanness. Indeed, with ever-evolving AI technology, our conscious and subconscious Turing tests may become more or less sophisticated. For designers, it becomes increasingly necessary to identify what communicative and design features are processed and categorized as human and which are processed and categorized as computerized. With the growth in use of virtual agents as communicators, users may become skeptical that they are, indeed, interacting with a human. Designers must enable humanness by avoiding highly scripted behaviors, personalizing and tailoring details of the interaction, and even affording disfluencies such as interruptions (McFarlane & Latorella, 2002).

Another promising goal would be to investigate how an optimal hybrid can be constructed for different contexts (Fan et al., 2010). For instance, Chase and colleagues (2009) discuss using a hybrid virtual representative that blends the properties of avatars and agents to serve as a teaching agent. If avatars can exert greater social influence on individuals compared to agents as confirmed by our current study, and agents offer greater controllability and are cheaper to operate and manage, hybrids may be able implement the best of both worlds.

8.4 Limitations and Future Directions

Because the method of meta-analysis relies on the original researchers' execution and reporting of the study, we were limited in the number of moderators we could examine. For example, too few studies collected data on variables such as perceived anthropomorphism or behavioral realism of the representations for us to conduct meaningful analysis. To hone the social influence model's explanatory power, it is essential to parse out other mediators and moderators of agency effects. How users process and make attributions when interacting with human versus computer controllers would lend great insight to the model. The role of behavioral realism (including physical realism) is another key component meriting future investigation, particularly given the model's anticipated effects have a steady slope and do not account for the uncanny valley phenomenon (Mori, 1970). Another possibility suggested by Blascovich et al. (2002) is that self-relevance of the realm of influence may moderate the effect. For example, the model anticipates greater effects of agency if users were interacting with a virtual representation about personal health issues than a health issue they feel is irrelevant to them. Going forward, researchers should examine these processes and variables to clarify the model.

Additionally, the majority of authors did not report system features that may provide useful details for designers, and thus we were unable to examine these features in our analyses. A variety of features of virtual environments (e.g., screen size, quality of graphics, rendering rate, field of view) have been found to affect user experience (Bracken & Skalski, 2010), which may affect social influence processes. Future research should manipulate specific features of environments to determine how they may influence or interact with perceptions of agency.

Also, this meta-analysis categorized measurement methods into objective or subjective measures, but there are other approaches to distinguishing measurement methods. For instance, rather than categorizing these measures as subjective or objective, future analyses could examine implicit versus explicit response variables. Another distinction that may be of interest is automatic (i.e., responses that participants cannot control, such as reflexes) as opposed to deliberate (i.e., those that participants can think about, such as self-reports) responses. These classifications may lend greater insight as to how people consciously and subconsciously process and evaluate interactions with agents and avatars.

Methodologically, the results of meta-analyses are seldom unqualified (Rosenthal & DiMatteo, 2001). This study cannot avoid the general criticisms of meta-analyses, such as the aggregation of different methods and research designs. For instance, many desktop-based studies included in this analysis used physiological measures, whereas none of the studies conducted in immersive environments used them, likely due to the complications of using both sets of equipment simultaneously. It may be that some particular detail of the desktop-physiological pairing (e.g., physiological measures are more accurate when participants are stationary) led to a more sensitive measure of agency effects.

Another limitation, which is also prevalent in the vast majority of meta-analyses as noted by Levine et al. (2009), is the negative correlation between the number of participants and the *r* values, which may indicate a bias of reporting and publishing only significant results. It is worth noting, however, that this meta-analysis also met the conditions in which Levine et al. suggested that negative medium or large correlations would most likely be identified. Namely, this study included fewer than 100 studies and included experimental studies with smaller sample sizes, thus strongly influencing the *n* in the calculation. Although we gave our best effort at being exhaustive in our literature review and attempted to maximize our coverage of the literature by including unpublished studies we identified, it is probable that we did not completely overcome the “file drawer” problem faced by this method.

9. CONCLUSION

This study revealed that agency is an important factor to consider when examining social influence in mediated interactions. Although we focused on virtual representations, our results may apply to how individuals make attributions of and respond to different entities outside of virtual environments as well. Managing an individual’s perceptions about the origin of a message may be essential to successful persuasion. A recipient may be unconvinced by a personalized letter if it appears to have computer rather than human origins. A customer who calls a help line may not be persuaded by a computer-generated response or even a real human’s response if it sounds too scripted and computer-like. Our results imply that when influence is the desired outcome, it is important for people to perceive that they are interacting with another person.

In sum, the current findings shed light on the processes that occur when humans interact with different types of virtual representations. As both industry and academia continue to embrace and encourage the use of virtual environments, avatars and agents will continue to play more important roles as social interactants within the mediated world. Thus, researchers should acknowledge that the mere perception of humanity in a digital representation can be powerful enough to amplify social responses within virtual environments.

NOTES

Support. This work was partially supported by NSF grant 0966838 to Co-PI Jeremy Bailenson.

Authors' Present Addresses. Jesse Fox, School of Communication, The Ohio State University, Columbus, OH 43210-1339. Email: fox.775@osu.edu. Sun Joo (Grace) Ahn, Grady College of Journalism & Mass Communication, University of Georgia, Athens, GA 30602-3018. Email: sjahn@uga.edu. Joris H. Janssen, Philips Research, High Tech Campus 34, 5656AE Eindhoven, The Netherlands. Email: joris.h.janssen@philips.com. Leo Yeykelis, Department of Communication, Stanford University, 450 Serra Mall, Stanford ,CA 94035. Email: yeyleo@stanford.edu. Kathryn Y. Segovia, Department of Communication, Stanford University, 450 Serra Mall, Stanford, CA 94035. Email: kathrynyr@gmail.com. Jeremy Bailenson, Department of Communication, Stanford University, 450 Serra Mall, Stanford, CA 94035. Email: bailenson@stanford.edu.

References

Ahn, S. J., & Bailenson, J. N. (2011). Self-endorsing versus other-endorsing in virtual environments: The effect on brand preference. *Journal of Advertising, 40,* 93-106. doi: 10.2753/JOA0091-3367400207

Ahn, S. J., Fox, J., Dale, K. R., & Avant, J. A. (in press). Framing virtual experiences: Effects on environmental efficacy and behavior over time. *Communication Research*.

Allport, G. (1985). The historical background of social psychology. In G. Lindzey & E. Aronson (Eds.), *Handbook of social psychology*, 3rd ed. (pp. 1-46). New York: Random House.

Appel, J., von der Pütten, A., Krämer, N. C., & Gratch, J. (2012). Does humanity matter? Analyzing the importance of social cues and the perceived agency of a computer system for the emergence of social reactions during human-computer interaction. *Advances in Human-Computer Interaction,* article ID 324694, 1-10. doi: 10.1155/2012/324694

Arena, D. A., Schwartz, D. L., & Bailenson, J. N. (2009). Effects of social belief on spatial learning in virtual reality. Paper presented at the Games, Learning, & Society Conference 5.0, Madison, WI. doi: 10.1016/S0166-4328(98)00019-9

Assaf, M., Kahn, I., Pearlson, G. D., Johnson, M. R., Yeshurun, Y., Calhoun, V. D., & Hendler, T. (2009). Brain activity dissociates mentalization from motivation during an interpersonal competitive game. *Brain Imaging & Behavior, 3*, 24-37. doi: 10.1007/s11682-008-9047-y

Bailenson, J. N., Aharoni, E., Beall, A. C., Guadagno, R. E., Dimov, A., & Blascovich, J. (2004). Comparing behavioral and self-report measures of embodied agents' social presence in immersive virtual environments. Paper presented at the 7th Annual International Workshop on PRESENCE, Valencia, Spain. doi: 10.1027/1864-1105.21.3.95

Blascovich, J., & Bailenson, J. N. (2011). *Infinite reality: Avatars, eternal life, new worlds, and the dawn of the virtual revolution.* New York: HarperCollins. doi: 10.1162/105474605774785235

Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. (2003). Interpersonal distance in immersive virtual environments. *Personality & Social Psychology Bulletin, 29*, 819-833. doi: 10.1177/0146167203029007002

Bailenson, J. N., Patel, K., Nielsen, A., Bajcsy, R., Jung, S., & Kurillo, G. (2008). The effect of interactivity on learning physical actions in virtual reality. *Media Psychology*, *11*, 354-376. doi: 10.1177/0146167203029007002

Belloti, V., & Edwards, K. (2001). Intelligibility and accountability: Human considerations in context-aware systems. *Human-Computer Interaction*, *16*, 193-212. doi: 10.1207/S15327051HCI16234_05

Benford, S., Bowers, J., Fahlén, L. E., Greenhalgh, C., & Snowdon, D. (1997). Embodiments, avatars, clones, and agents for multi-user, multi-sensory virtual worlds. *Multimedia Systems*, *5*(2), 93-104. doi: 10.1007/s005300050045

Bente, G., Rüggenberg, S., Krämer, N. C., & Eschenburg, F. (2008). Avatar-mediated networking: Increasing social presence and interpersonal trust in net-based collaborations. *Human Communication Research*, *34*, 287-318. doi: 10.1002/ab.20279

Bickmore, T., & Cassell, J. (2005). Social dialogue with embodied conversational agents. In J. C. J. Kuppevelt, L. Dybkjaer, & N. O. Bernson (Eds.), *Advances in natural multimodal dialogue systems* (pp. 1-32). New York: Springer.

Blascovich, J. (2002). Social influence within immersive virtual environments. In R. Schroeder (Ed.), *The social life of avatars: Presence and interaction in shared virtual environments* (pp. 127-145). London: Springer-Verlag. doi: 10.1162/105474603322761270

Blascovich, J., Loomis, J., Beall, A. C., Swinth, K. R., Hoyt, C. L., & Bailenson, J. N. (2002). Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry*, *13*, 103-124. doi: 10.1207/S15327965PLI1302_01

Bracken, C. C., & Skalski, P. D. (2010). *Immersed in media: Telepresence in everyday life*. New York: Routledge.

Cassell, J., Sullivan, J., Prevost, S., & Churchill, E. F. (Eds.) (2000). *Embodied conversational agents.* New York: Cambridge University Press.

Cialdini, R. B. (2008). *Influence: Science and practice* (5th ed.) Boston: Allyn & Bacon.

Chase, C. C., Chin, D. B., Oppezzo, M. A., & Schwartz, D. L. (2009). Teachable agents and the protégé effect: Increasing the efforts towards learning. *Journal of Science Education & Technology*, *18*, 334-352. doi: 10.1007/s10956-009-9180-4

D'Mello, S. K., Graesser, A., & King, B. (2010). Toward spoken human-computer tutorial dialogues. *Human-Computer Interaction*, *25*, 289-323. doi: 10/1080/07370024.2010.499850

Eastin, M. S. (2006). Video game violence and the female game player: Self and opponent gender effects on presence and aggressive thoughts. *Human Communication Research, 31,* 351-372. doi: 10.1007/s10956-009-9180-4

Eastin, M. S., & Griffiths, R. P. (2006). Beyond the shooter game: Examining presence and hostile outcomes among male game players. *Communication Research, 33,* 448-466. doi: 10.1111/j.1468-2958.2006.00279

Eastwick, P. W., & Gardner, W. L. (2009). Is it a game? Evidence for social influence in the virtual world. *Social Influence*, *4,* 18-32. doi: 10.1177/0093650206293249

Fan, X., McNeese, M., & Yen, J. (2010). NDM-based cognitive agents for supporting decision-making teams. *Human-Computer Interaction*, *25,* 195-234. doi: 10.1080/07370020903586720

Fox, J., Arena, D., & Bailenson, J. N. (2009). Virtual reality: A survival guide for the social scientist. *Journal of Media Psychology*, *21*(3), 95-113. doi: 10.1080/15534510802254087

Fox, J., & Bailenson, J. N. (2009). Virtual self-modeling: The effects of vicarious reinforcement and identification on exercise behaviors. *Media Psychology*, *12,* 1-25. doi: 10.1027/1864-1105.21.3.95

Fox, J., Bailenson, J. N., & Tricase, L. (2013). The embodiment of sexualized virtual selves: The Proteus effect and experiences of self-objectification via avatars. *Computers in Human Behavior*, *29*, 930-938. doi: 10.1016/j.chb.2012.12.027

Gajadhar, B. J., de Kort, Y. A. W., & Ijsselsteijn, W. A. (2008). Shared fun is doubled fun: Player enjoyment as a function of social setting. In P. Markopoulos, et al. (Eds.), *Proceedings of the 3rd International Conference on Fun and Games* (pp. 106-117). Berlin: Springer-Verlag. doi: 10.1007/s11199-009-9599-3

Gajadhar, B. J., Nap, H. H., de Kort, Y. A. W., & Ijsselsteijn, W. A. (2010). Out of sight, out of mind: Co-player effects on seniors' player experience. In V. Vanden Abeele, B. Zaman, M. Obrist, & W. A. Ijsselsteijn (Eds.), *Proceedings of the 3rd International Conference on Fun and Games* (pp. 74-83). New York: ACM. doi: 10.1007/978-3-540-88322-7_11

Gerhard, M., Moore, D. J., & Hobbs, D. J. (2001, January). Continuous presence in collaborative virtual environments: Towards a hybrid avatar-agent model for user representation. In

Intelligent Virtual Agents (pp. 137-155). Berlin, Germany: Springer.

Gong, L., & Nass, C. (2007). When a talking-face computer agent is half-human and half-humanoid: Human identity and consistency preference. *Human Communication Research, 33,* 163-193. doi: 10.1080/15213260801906489

Gratch, J., Morency, P., Scherer, S., Stratou, G., Boberg, J., Koenig, S., Adamson, T., & Rizzo, A. (2013). User-state sensing for virtual health agents and telehealth applications. *Studies in Health Technology and Informatics, 184,* 151-157. doi: 10.3233/978-1-61499-209-7-151

Gratch, J., Rickel, J., André, E., Cassell, J., Petajan, E., & Badler, N. (2002). Creating interactive virtual humans: Some assembly required. *IEEE Intelligent Systems, 17*(4), 54-63. doi: 10.1111/j.1468-2958.2007.00295.x

Guadagno, R. E., Blascovich, J., Bailenson, J. N., & McCall, C. (2007). Virtual humans and persuasion: The effects of agency and behavioral realism. *Media Psychology, 10,* 1-22. doi: 10.1109/MIS.2002.1024753

Guadagno, R. E., Swinth, K. R., & Blascovich, J. (2011). Social evaluations of embodied agents and avatars. *Computers in Human Behavior*, *27*, 2380-2385. doi: 10.1016/j.chb.2011.07.017

Heider, F. (1958). *The psychology of interpersonal relations*. New York: Wiley.

Hoyt, C. L., Blascovich, J., & Swinth, K. R. (2003). Social inhibition in virtual environments. *PRESENCE: Teleoperators & Virtual Environments*, *12,* 183-195. doi: 10.1080/15213260701300865

Hunter, J. E., Schmidt, F. L., & Jackson, G. B. (1982). *Meta-analysis: Cumulating research findings across studies*. Beverly Hills, CA: Sage. doi:

10.1162/105474603321640932

Ivory, J. D., & Kalyanaraman, S. (2007). The effects of technological advancement and violent content in video games on players' feelings of presence, involvement, physiological arousal, and aggression. *Journal of Communication, 57,* 532-555. doi: 10.1111/j.1460-2466.2007.00356.x

Kelman, H. C. (1961). Processes of opinion change. *Public Opinion Quarterly, 25*, 57-78. doi: 10.2307/2746461

Kiesler, S., Powers, A., Fussell, S. R., & Torrey, C. (2008). Anthropomorphic interactions with a robot and robot-like agent. *Social Cognition, 26,* 169-181. doi: 10.1521/soco.2008.26.2.169

Lee, E.-J. (2010). What triggers social responses to flattering computers? Experimental tests of anthropormorphism and mindlessness explanations. *Communication Research, 37,* 191-214. doi: 10.1111/j.1460-2466.2008.00386.x

Lee, J.-E. R., Nass, C., Brave, S. B., Morishima, Y., Nakajima, H., & Yamada, R. (2007). The case for caring colearners: The effects of a computer-mediated colearner agent on trust and learning. *Journal of Communication, 57,* 183-204. doi: 10.1177/0093650209356389

Levine, T. R., Asada, K. J., & Carpenter, C. (2009). Sample sizes and effect sizes are negatively correlated in meta-analyses: Evidence and implications of a publication bias against nonsignificant findings. *Communication Monographs, 76,* 286-302. doi: 10.1111/j.1468-2885.2004.tb00302.x

Lim, S., & Reeves, B. (2010). Computer agents versus avatars: Responses to interactive game characters controlled by a computer or other player. *International Journal of Human-Computer Studies, 68,* 57-68. doi: 10.1080/03637750903074685

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer-Mediated Communication, 3*(2), available at http://jcmc.indiana.edu/vol3/issue2/lombard.html. doi: 10.1016/j.ijhcs.2009.09.008

Mandryk, R. L., Inkpen, K. M., & Calvert, T. W. (2006). Using psychophysiological techniques to measure user experience with entertainment technologies. *Behaviour & Information Technology, 25,* 141-158. doi: 10.1080/01449290500331156

McFarlane, D. C., & Latorella, K. A. (2002). The scope and importance of human interruption in human-computer interaction design. *Human-Computer Interaction, 17,* 1-61. doi: 10.1207/S15327051HCI1701_1

Merritt, T., & McGee, K. (2012, May). Protecting artificial team-mates: more seems like less. In *Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems* (pp. 2793-2802). ACM.

Merritt, T., McGee, K., Chuah, T. L., & Ong, C. (2011, June). Choosing human team-mates: perceived identity as a moderator of player preference and enjoyment. In *Proceedings of the 6th International Conference on Foundations of Digital Games* (pp. 196-203). ACM.

Merritt, T., Ong, C., Chuah, T. L., & McGee, K. (2011, January). Did you notice? Artificial team-mates take risks for players. In *Intelligent Virtual Agents* (pp. 338-349). Berlin, Germany: Springer.

Mori, M. (1970). The uncanny valley. *Energy, 7*(4), 33-35.

Morkes, J., Kernal, H. K., & Nass, C. (1999). Effects of humor in task-oriented human-computer interaction and computer-mediated communication: A direct test of SRCT theory. *Human-Computer Interaction, 14,* 395-435. doi: 10.1207/S15327051hci1404_2

Nass, C., Fogg, B. J., & Moon, Y. (1996). Can computers be teammates? *International Journal* *of Human-Computer Studies, 45,* 669-678. doi: 10.1080/01449290500331156

Nass, C., & Moon, Y. (2000). Machines and mindlessness: Social responses to computers. *Journal of Social Issues, 56,* 81-103. doi: 10.1006/ijhc.1996.0073

Nass, C., Moon, Y., & Green, N. (1997). Are computers gender-neutral? Gender stereotypic responses to computers. *Journal of Applied Social Psychology, 27,* 864-876. doi: 10.1111/0022-4537.00153

Nowak, K. (2004). The influence of anthropomorphism and agency on social judgment in virtual environments. *Journal of Computer-Mediated Communication, 9*(2), available at http://jcmc.indiana.edu/vol9/issue2/nowak.html. doi: 10.1111/j.1468-2958.1993.tb00311.x

Nowak, K. L., & Biocca, F. (2003). The effect of the agency and anthropomorphism on users' sense of telepresence, copresence, and social presence in virtual environments. *PRESENCE: Teleoperators & Virtual Environments, 12,* 481-494. doi: 10.1111/j.1083-6101.2004.tb00284.x

Okita, S. Y., Bailenson, J. N., & Schwartz, D. L. (2008). The mere belief in social interaction improves learning. In S. Barab, K. Hay, & D. Hickey (Eds.), *Proceedings of the 8th International Conference for the Learning Sciences* (p. 132-139). Mahwah, NJ: Erlbaum. doi: 10.1111/j.1083-6101.2006.tb00308.x

Ong, C., McGee, K., & Chuah, T. L. (2012, November). Closing the human-AI team-mate gap: how changes to displayed information impact player behavior towards computer teammates. In *Proceedings of the 24th Australian Computer-Human Interaction Conference* (pp. 433-439). ACM.

Persky, S., & Blascovich, J. (2007). Immersive virtual environments versus traditional platforms:

Effects of violent and nonviolent video game playing. *Media Psychology, 10,* 135-156. doi: 10.1080/15213260701301236

Preiss, R. W., & Allen, M. (1995). Understanding and using meta-analysis. *Evaluation & the Health Professions, 18,* 315-335. doi: 10.1080/15213260701301236

Ravaja, N. (2009). The psychophysiology of digital gaming: The effect of a non co-located opponent. *Media Psychology, 12,* 268-294. doi: 10.1177/016327879501800306

Ravaja, N., Saari, T., Turpeinen, M., Laarni, J., Salminen, M., & Kivikangas, M. (2006). Spatial presence and emotions during video game playing: Does it matter with whom you play? *PRESENCE: Teleoperators & Virtual Environments, 15,* 381-392. doi: 10.1080/15213260903052240

Reeves, B., & Nass, C. (1996). *The media equation: How people treat computers, television, and new media like real people and places.* New York: Cambridge.

Rosenthal, R. (1991). Meta-analysis: A review. *Psychosomatic Medicine, 53,* 247-271.

Rosenthal, R., & DiMatteo, M. R. (2001). Meta-analysis: Recent developments in quantitative methods for literature reviews. *Annual Review of Psychology, 52,* 59-82. doi: 10.1146/annurev.psych.52.1.59

Segovia, K. Y. & Bailenson, J. N. (2009). Virtually true: Children's acquisition of false memories in virtual reality. *Media Psychology, 12,* 371-393. doi: 10.1080/15213260903287267

Segovia, K. Y., & Bailenson, J. N. (unpublished paper). *Virtual first impressions and their persistence in the physical world.*

Sherry, J. L. (2001). The effects of violent video games on aggression: A meta-analysis. *Human Communication Research, 27,* 409-431. doi: 10.1111/j.1468-

2958.2001.tb00787.x

Skalski, P., & Tamborini, R. (2007). The role of social presence in interactive agent-based persuasion. *Media Psychology, 10,* 385-413. doi: 10.1080/15213260701533102

Slater, M. (2004). How colorful was your day? Why questionnaires cannot assess presence in virtual environments. *PRESENCE: Teleoperators & Virtual Environments, 13,* 484-493. doi: 10.1162/1054746041944849

Staiano, A. E., & Calvert, S. L. (2011). Wii tennis play for low-income African American adolescents' energy expenditure. *Cyberpsychology: Journal of Psychosocial Research on Cyberspace, 1*, n.p.

Swinth, K. R., & Blascovich, J. (2001, June). Conformity to group norms in an immersive virtual environment. Paper presented at the Annual Meeting of the American Psychological Society, Toronto, ON.

Tajfel, H., & Turner, J. (1979). An integrative theory of intergroup conflict. In W. Austin & S. Worchel (Eds.), *The social psychology of intergroup relations* (pp. 33-47). Monterey, CA: Brooks/Cole.

Takayama, L. (2012). Perspectives on agency: Interacting with and through personal robots. In M. Zacarias & J. V. Oliveira (Eds.), *Human-computer interaction: The agency perspective* (pp. 111-132). Berlin: Springer-Verlag.

Tinwell, A., Grimshaw, M., & Abdel-Nabi, D. (2011). Effect of emotion and articulation of speech on the uncanny valley in virtual characters. In *Affective computing & intelligent interaction* (pp. 557-566). Berlin, Germany: Springer.

von der Pütten, A. M., Krämer, N. C., Gratch, J., & Kang, S.-H. (2010). "It doesn't matter what you are!" Explaining social effects of agents and avatars. *Computers in*

Human Behavior, 26, 1641-1650. doi: 10.1016/j.chb.2010.06.012

Weibel, D., Wissmath, B., Habegger, S., Steiner, Y., & Groner, R. (2008). Playing online games against computer vs. human-controlled opponents. *Computers in Human Behavior, 24,* 2274-2291. doi: 10.1016/j.chb.2007.11.002

Williams, R. B., & Clippinger, C. A. (2002). Aggression, competition and computer games: Computer and human opponents. *Computers in Human Behavior, 18,* 495-506. doi: 10.1016/S0747-5632(02)00009-2

Yee, N., Bailenson, J. N., & Rickertsen, K. (2007, April). A meta-analysis of the impact of the inclusion and realism of human-like faces on user experiences in interfaces. In *Proceedings of the SIGCHI conference on Human Factors in Computing Systems* (pp. 1-10). ACM.

Zadro, L., Williams, K. D., & Richardson, R. (2004). How low can you go? Ostracism by a computer is sufficient to lower self-reported levels of belonging, control, self-esteem, and meaningful existence. *Journal of Experimental Social Psychology, 40,* 560-567. doi: 10.1016/j.jesp.2003.11.006

Zajonc, R. B. (1965). Social facilitation. *Science, 149*, 269-274.

FIGURE CAPTIONS

Figure 1. *Effect sizes of dependent variables*

Figure 2. *Inferential and descriptive statistics for the one sample t-tests for each set of r values per DV*

Figure 3. *Inferential and descriptive statistics for the one sample t-tests for each set of r values per study*

Figure 4. *Unstandardized (B) and standardized (β) coefficients, F-values, and* R^2 *values for the regression of Year of Publication on each of the four sets of r values*

Figure 5. *Inferential statistics for ANOVAs of Immersion × DV Type for each set of r values per DV*

Figure 6. *Means (SEs) for Level of Immersion (Desktop / Immersive) × DV type (Subjective / Objective) for each set of r values per DV evaluated at Year = 2007.9.*

Figure 7. *Inferential statistics for ANOVAs of Task Type for each set of r values per DV with Year of Publication as covariate*

Figure 8. *Means (SEs) for Task Type (Competitive gaming / Cooperative gaming / Non-gaming) for each set of r values per DV*

Figure 9. *Inferential statistics for ANOVAs of Actual Control for each set of r values per DV with Year of Publication as covariate*

Figure 10. *Means (SEs) for Actual Control (Human / Computer) for each set of r values per DV*

Figure 1

Effect sizes of dependent variables[1,2]

Desktop	Objective	Subjective	Immersive	Objective	Subjective
Appel, von der Pütten, Krämer, Gratch, 2012 (N = 90)			**Arena, Schwartz, & Bailenson, 2009** (N = 92)		
Person perception factor 1		r = .02, r_w = .02	Time	r = .16, r_w = .22	
Person perception factor 2		r = .02, r_w = .03	**Bailenson, Blascovich, Beall, & Loomis, 2003** (N = 80)		
Person perception factor 3		r = .17, r_w = .23	Personal space	r = .08, r_w = .09	
Empathy		r = .10, r_w = .14	Social presence		r = .22*, r_w = .25*
Mutual awareness		r = .00, r_w = .00	Affect ratings		r = .22*, r_w = .25*
Mutual understanding		r = .16, r_w = .21	Memory	r = .26, r_w = .30	
Attention allocation		r = .15, r_w = .20	**Bailenson, Blascovich, Beall, & Loomis, 2003** (N = 80)		
Behavioral interdependency		r = .00, r_w = .00	Distancing behavior	r = -.30, r_w = -.34	
Social presence		r = .32, r_w = .42	Social presence		r = .43, r_w = .48
Feelings and self-efficiency		r = .19, r_w = .25	Affect ratings		r = .22*, r_w = .25*
Rapport and connection		r = -.05, r_w = -.07	Emotional reaction questionnaire		r = .22*, r_w = .25*
Attention allocation		r = .004, r_w = .005	**Guadagno, Blascovich, Bailenson, & McCall, 2007** (N = 174)		
Embodiment		r = -.07, r_w = -.10	Behavioral realism rating		r = .17, r_w = .41
Number of words	r = -.17, r_w = -.23		Attitude change		r = .15*, r_w = .37*
Speech disfluencies	r = .03, r_w = .04		Trait ratings		r = -.02, r_w = -.05
Self-disclosure	r = .05, r_w = .07		Social presence		r = .19, r_w = .46
Eastin, 2006 (N = 75)			**Guadagno, Swinth, Blascovich, 2011** (N = 38)		
Presence		r = -.13, r_w = -.14	Counselor empathy rating		r = .30, r_w = .17
Aggressive thoughts		r = .33, r_w = .35	**Hoyt, Blascovich, & Swinth, 2003** (N = 39)		
Eastin, 2006 (N = 81)			Copresence		r = .77, r_w = .50
Presence		r = -.04, r_w = -.04	Task performance (all tasks)	r = .36, r_w = .20	

[1] Asterisk (*) signifies the maximum coded values (in place of the zero-coded unreported values)

[2] r_w signifies a weighted r value

Aggressive thoughts	$r = .22$, $r_w = .25$
Eastin & Griffiths, 2006 ($N = 219$)	
Hostile expectation (behaviors)	$r = -.02$, $r_w = -.08$
Hostile expectation (thoughts)	$r = .01$, $r_w = .04$
Hostile expectation (feelings)	$r = -.004$, $r_w = -.01$
Presence	$r = .10$, $r_w = .31$
Gajadhar, de Kort, & Ijsselsteijn, 2008 ($N = 42$)	
PI social presence scale	$r = .32$, $r_w = .19$
BE social presence scale	$r = .21$, $r_w = .12$
GEQ positive	$r = .23$, $r_w = .13$
GEQ competence	$r = .15$, $r_w = .09$
GEQ challenge	$r = .10$, $r_w = .06$
GEQ frustration	$r = .31^*$, $r_w = .18^*$
Anger	$r = .31^*$, $r_w = .18^*$
Verbal aggression	$r = .31^*$, $r_w = .18^*$
Hostility	$r = .31^*$, $r_w = .18^*$
Physical aggression	$r = .31^*$, $r_w = .18^*$
Gajadhar, Nap, de Kort, & Ijsselsteijn, 2010 ($N = 20$)	
Empathy	$r = .24$, $r_w = .06$
Engagement	$r = .07$, $r_w = .02$
Jealousy	$r = .18$, $r_w = .05$
Positive affect	$r = .20$, $r_w = .05$
Competence	$r = .00$, $r_w = .00$
Challenge	$r = .07$, $r_w = .02$
Frustration	$r = -.01$, $r_w = .00$
Boredom	$r = .27$, $r_w = .07$
Immersion	$r = .16$, $r_w = .04$
Flow	$r = .10$, $r_w = .03$
Revised flow	$r = .13$, $r_w = .03$
PID	$r = .00$, $r_w = .00$
Lim & Reeves, 2010 ($N = 34$)	
Skin conductance response (SCR)	$r = .75$, $r_w = .42$
Phasic SCR frequency	$r = .48$, $r_w = .24$
Task performance (novel tasks)	$r = .61$, $r_w = .36$
Okita, Bailenson, & Schwartz, 2008 ($N = 35$)	
Posttest score	$r = .33$ $r_w = .16$
SCL	$r = .18$, $r_w = .09$
Segovia & Bailenson, in preparation ($N = 34$)	
Likeability rating	$r = -.02$, $r_w = -.01$
Status rating	$r = .28$, $r_w = .13$
Hot sauce weight (grams)	$r = .26$, $r_w = .12$
Swinth & Blascovich, 2001 ($N = 64$)	
Amount bet	$r = .31$, $r_w = .29$
von der Pütten, Krämer, Gratch & Kang, 2010 ($N = 83$)	
Mutual awareness	$r = .22^*$, $r_w = .28^*$
Mutual understanding	$r = .22^*$, $r_w = .28^*$
Behavioral independence	$r = .22^*$, $r_w = .28^*$
Empathy	$r = .22^*$, $r_w = .28^*$
Attention allocation	$r = .22^*$, $r_w = .28^*$
Bailenson presence scale	$r = .22^*$, $r_w = .28^*$
Weibel, Wissmath, Habegger, Steiner, & Groner, 2008 ($N = 70$)	
Presence	$r = .40$, $r_w = .40$
Flow	$r = .29$, $r_w = .29$
Enjoyment	$r = .30$, $r_w = .30$

Heart rate	$r = .87$, $r_w = .55$	
Tonic Skin Conduction Change	$r = .43$, $r_w = .21$	
Valence		$r = .71$, $r_w = .39$
Presence		$r = .70$, $r_w = .38$
Likeability		$r = .62$, $r_w = .32$
Mandryk, Inkpen, & Calvert, 2006 ($N = 10$)		
Boring		$r = -.32$, $r_w = -.03$
Challenging		$r = .15$, $r_w = .02$
Easy		$r = -.13$, $r_w = -.01$
Engaging		$r = .42$, $r_w = .05$
Exciting		$r = .50$, $r_w = .06$
Frustrating		$r = -.16$, $r_w = -.02$
Fun		$r = .46$, $r_w = .05$
GSR	$r = .11$, $r_w = .01$	
EMG	$r = .48$, $r_w = .05$	
Heart rate	$r = .49$, $r_w = .06$	
Respiration rate	$r = .35$, $r_w = .04$	
Respiration amplitude	$r = .55$, $r_w = .06$	
Merritt, McGee, Chuah, & Ong, 2011 ($N = 40$)		
Highest level achieved	$r = .13$, $r_w = .08$	
Deaths of participant	$r = .02$, $r_w = .01$	
Deaths of team mate	$r = .19$, $r_w = .12$	
Yell events by participant	$r = .02$, $r_w = .01$	
Enjoyment		$r = .14$, $r_w = .08$
Perceived cooperation		$r = .25$, $r_w = .15$
Merritt, Ong, Chuah, & McGee, 2011 ($N = 40$)		
Highest level achieved	$r = .31$*, $r_w = .19$*	
Deaths of participant	$r = .31$*, $r_w = .19$*	
Deaths of team mate	$r = .31$*, $r_w = .19$*	
Yell events by participant	$r = .31$*, $r_w = .19$*	
Signaling frequency	$r = .02$, $r_w = .01$	
Perception of risk		$r = .20$, $r_w = .12$
Perception of cooperation		$r = .25$, $r_w = .15$
Merritt & McGee, 2012 ($N = 32$)		

Highest level achieved	$r = .14$, $r_w = .06$	
No. of first touch events	$r = .05$, $r_w = .02$	
Deaths of participant	$r = .05$, $r_w = .02$	
Deaths of team mate	$r = .07$, $r_w = .03$	
Yell events by participant	$r = .15$, $r_w = .07$	
Adaptive performance of team mate		$r = .63$, $r_w = .34$
Helpfulness of team mate		$r = .36$, $r_w = .17$
Understanding of team mate		$r = .45$, $r_w = .22$
Personal pressure to win		$r = .69$, $r_w = .38$
Nowak, 2004 ($N = 134$)		
Social attraction		$r = .03$, $r_w = .05$
Credibility		$r = .08$, $r_w = .16$
Uncertainty		$r = -.14$, $r_w = -.28$
Nowak & Biocca, 2003 ($N = 134$)		
Other's copresence		$r = -.03$, $r_w = -.05$
Self-report copresence		$r = .05$, $r_w = .11$
Social presence		$r = -.08$, $r_w = -.15$
Telepresence		$r = -.06$, $r_w = -.12$
Ong, McGee, & Chuah, 2012 ($N = 73$)		
Save frequency	$r = .20$, $r_w = .23$	
Consideration of team goals		$r = .23$*, $r_w = .26$*
Importance of survival of the team mate		$r = .23$*, $r_w = .26$*
Challenges for the team mate		$r = .23$*, $r_w = .26$*
Emotional difficulty		$r = .51$, $r_w = .56$
Goals of the team		$r = .23$*, $r_w = .26$*
Ravaja, 2009 ($N = 23$)		
Valence		$r = .17$, $r_w = .06$
Arousal		$r = .17$, $r_w = .06$
Spatial presence		$r = .11$, $r_w = .03$
Engagement		$r = .18$, $r_w = .05$
Zygomaticus Major	$r = .14$, $r_w = .04$	
Corrugator Supercilii	$r = -.24$, $r_w = -.07$	
Orbicularis Oculi	$r = .33$, $r_w = .10$	
SCL	$r = .07$, $r_w = .02$	

Cardiac IBI	r = .12, r_w = .04	
Ravaja et al., 2006 (N = 99)		
Higher anticipated threat		r = .44, r_w = .59
Post-game challenge rating		r = .32, r_w = .44
Spatial presence		r = .37, r_w = .51
Engagement		r = .60, r_w = .76
Positive emotional response		r = .66, r_w = .81
Self-reported arousal		r = .20*, r_w = .28*
Heart rate (cardiac IBIs)	r = .68, r_w = .83	
Zygomaticus Major EMG activity	r = .84, r_w = .94	
Corrugator Supercilli EMG activity	r = .87, r_w = .96	
Orbicularis Oculi EMG activity	r = .93, r_w = .98	
Staiano & Calvert, 2011 (N = 69)		
Caloric expenditure	r = .29, r_w = .31	
von der Pütten, Krämer, Gratch, & Kang, 2010 (N = 83)		
Total number of words	r = .18*, r_w = .22*	
Negative low dominance		r = .25, r_w = .30
Negative high dominance		r = .18*, r_w = .22*
Positive high dominance		r = .18*, r_w = .22*
Feelings and self-efficiency		r = .18*, r_w = .22*
Rapport and connection		r = .18*, r_w = .22*
Evaluation of listener		r = .18*, r_w = .22*
Attention allocation		r = .18*, r_w = .22*
Williams & Clippinger, 2002 (N = 54)		
Aggression score		r = .51, r_w = .40
Zadro, Williams, & Richardson, 2004 (N = 62)		
Self-reported levels of needs		r = .25*, r_w = .22*
Mood		r = .25*, r_w = .22*
Ancillary variables		r = .25*, r_w = .22*
Anger at being ostracized		r = .27, r_w = .24
Zadro, Williams, & Richardson, 2004 (N = 71)		
Self-reported levels of needs		r = .18, r_w = .18
Meaningful existence		r = .23, r_w = .23
Mood		r = .23*, r_w = .24*

Ancillary variables	r = .23*, r_w = .24*
Anger at being ostracized	r = .37, r_w = .38

Figure 2

Inferential and descriptive statistics for the one sample t-tests for each set of r values per DV

Set of *r* values	*M*	95% CI	*t*(170)	Cohen's *d*
unweighted, zero-coded	.22	[.18, .26]	10.18*	0.78
unweighted, max-coded	.27	[.23, .31]	13.65*	1.04
weighted, zero-coded	.19	[.14, .24]	7.29*	0.56
weighted, max-coded	.24	[.20, .29]	9.77*	0.75

* $p < .001$

Figure 3

Inferential and descriptive statistics for the one sample t-tests for each set of r values per study

Set of *r* values	*M*	95% CI	*t*(31)	Cohen's *d*
unweighted, zero-coded	.22	[.15, .29]	6.46*	1.14
unweighted, max-coded	.26	[.20, .32]	8.58*	1.52
weighted, zero-coded	.18	[.12, .24]	5.99*	1.06
weighted, max-coded	.22	[.17, .28]	7.68*	1.36

* $p < .001$

Figure 4

Unstandardized (B) and standardized (β) coefficients, F-values, and R^2 values for the regression of Year of Publication on each of the four sets of r values

Set of *r* values	B year	β year	*F*(1,169)	R^2
unweighted, zero-coded	-0.02	- 0.22	8.26*	.05
unweighted, max-coded	-0.02	-0.22	8.28*	.05
weighted, zero-coded	-0.03	-0.21	8.02*	.05
weighted, max-coded	-0.03	-0.22	8.29*	.05

* $p < .01$

Figure 5

Inferential statistics for ANOVAs of Immersion × DV Type for each set of r values per DV

Set of *r* values	Factor	*F*(1, 166)	partial η^2
unweighted, zero-coded	Year	13.66**	.08
	Immersion	3.33†	.02
	DV Type	2.65	.02
	Immersion × DV Type	1.86	.01
unweighted, max-coded	Year	13.27**	.07
	Immersion	3.21†	.02
	DV Type	0.64	.00
	Immersion × DV Type	4.81*	.03
weighted, zero-coded	Year	11.50**	.07
	Immersion	1.67	.01
	DV Type	1.55	.01
	Immersion × DV Type	1.38	.01
weighted, max-coded	Year	10.39**	.06
	Immersion	0.74	.00
	DV Type	0.04	.00
	Immersion × DV Type	3.82†	.02

† $p < .10$; * $p < .05$; ** $p < .01$

Figure 6

Means (SEs) for Level of Immersion (Desktop / Immersive) × DV type (Subjective / Objective) for each set of r values per DV evaluated at Year = 2007.9

	Desktop		Immersive	
Set of *r* values	Subj (*n* = 101)	Obj (*n* = 38)	Subj (*n* = 24)	Obj (*n* = 8)
unweighted, zero-coded	.19 (.03)	.36 (.05)	.16 (.06)	.17 (.10)
unweighted, max-coded	.24 (.02)	.39 (.04)	.25 (.05)	.18 (.09)
weighted, zero-coded	.15 (.03)	.33 (.06)	.14 (.07)	.15 (.03)
weighted, max-coded	.20 (.03)	.35 (.05)	.28 (.07)	.15 (.12)

Figure 7

Inferential statistics for ANOVAs of Task Type for each set of r values per DV with Year of Publication as covariate

Set of *r* values	Factor	$F(1,163)$	partial η^2
unweighted, zero-coded	Task Type	8.86**	.10
	Year	11.75**	.07
unweighted, max-coded	Task Type	7.01**	.08
	Year	13.86**	.08
weighted, zero-coded	Task Type	2.64†	.03
	Year	6.49*	.04
weighted, max-coded	Task Type	0.69	.01
	Year	6.50*	.04

† $p < .10$; * $p < .05$; ** $p < .01$

Figure 8

Means (SEs) for Task Type (Competitive gaming / Cooperative gaming / Non-gaming) for each set of r values per DV

Set of *r* values	Competitive gaming (*n* = 66)	Cooperative gaming (*n* = 29)	Non-gaming (*n* = 69)
unweighted, zero-coded	.26 (.03)	.27 (.05)	.10 (.03)
unweighted, max-coded	.29 (.03)	.34 (.05)	.17 (.03)
weighted, zero-coded	.24 (.04)	.21 (.07)	.11 (.04)
weighted, max-coded	.26 (.04)	.26 (.07)	.20 (.04)

Figure 9

Inferential statistics for ANOVAs of Actual Control for each set of r values per DV with Year of Publication as covariate

Set of *r* values	Factor	*F*(1,163)	partial η^2
unweighted, zero-coded	Actual control	10.41**	.06
	Year	5.10*	.03
unweighted, max-coded	Actual control	10.25**	.06
	Year	5.13*	.03
weighted, zero-coded	Actual control	7.30**	.04
	Year	5.27*	.03
weighted, max-coded	Actual control	4.87*	.03
	Year	5.85*	.03

* $p < .05$; ** $p < .01$

Figure 10

Means (SEs) for Actual Control (Human / Computer) for each set of r values per DV

Set of *r* values	Human (n = 44)	Agent (n = 127)
unweighted, zero-coded	.33 (.04)	.18 (.02)
unweighted, max-coded	.37 (.04)	.24 (.02)
weighted, zero-coded	.30 (.05)	.15 (.03)
weighted, max-coded	.33 (.05)	.21 (.03)