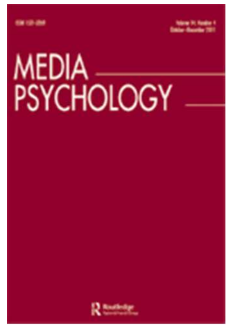

How Immersive is Enough? A Meta-Analysis of the Effect of Immersive Technology on User Presence

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Abstract

The concept of presence, or "being there", is a frequently emphasized factor in immersive mediated environments. It is often assumed that greater levels of immersive quality elicit higher levels of presence, in turn enhancing the effectiveness of a mediated experience. To investigate this assumption the current meta-analysis synthesizes decades of empirical research examining the effect of immersive system technology on user experiences of presence. Aggregating 82 effect sizes from 61 studies, it finds that technological immersion has a medium-sized effect on presence. Additionally, results show that increased levels of user-tracking and wider fields of view of visual displays are significantly more impactful than improvements to most other immersive system features, including stereoscopy and quality of visual content. These findings are discussed in light of theoretical accounts of the presence construct as well as practical implications for design.

Key words: presence, immersion, meta-analysis, virtual reality, mediated environments

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Mediated Environments, Presence, and Immersion

Even though Ivan Sutherland (1965) published his seminal essay *The Ultimate Display* almost fifty years ago, the technology that is able to produce a "looking glass into the mathematical wonderland" has only become widely available in the past few years (see Blascovich & Bailenson, 2011, for a historical account). Sutherland's first head-mounted display was nicknamed "The Sword of Damocles". It was so large and bulky it had to be bolted into the ceiling and users expressed fears of bodily harm if the ceiling mount happened to break while they wore it. Times have changed, and the technology required to achieve this "looking glass" is becoming cheaper and less cumbersome. However, as we transition into an era in which people are designing systems that immerse students, corporate collaborators, tourists, movie-goers, and video-game players into digital media experiences which look, sound, feel, and smell just like real ones, it is critical to understand how technology affects experience. The purpose of this paper is to examine the degree of correlation between *immersion*—defined as a technological quality of media – and *presence*—defined as the psychological experience of "being there."

The concept of presence, or a sense of "being there," is a frequently emphasized factor when discussing mediated environments. The assumption that achieving presence should be a goal of the design of virtual environments (VEs) pervades both applied and academic work. An increased sense of presence is often thought to magnify user effects (e.g., the extent to which user responses to virtual stimuli and virtual interactions resemble parallel responses to "real world" counterparts) and, in turn, to increase the effectiveness of mediated environment applications (e.g., the practical use of such environments as tools for entertainment, learning, training, or therapy; Slater & Wilbur, 1997; Nunez & Blake, 2001; Price & Anderson, 2006; Tamborini & Skalski, 2006; Tamborini & Bowman, 2010).

Over the last twenty years researchers have defined and explicated the concept of presence in a number of different ways (e.g., Heeter, 1992; Steuer, 1992; Slater & Wilbur, 1997; Lombard & Ditton, 1997; Witmer & Singer, 1998; McMahan, 2003; Lee, 2004a). The flagship journal of the field studying presence in virtual reality is aptly titled *Presence: Teleoperators and Virtual Environments*. The first volume of *Presence* was published in 1992, and contains work by some of the pioneers who still remain active leaders in the field, for example, Frank Biocca, Carrie Heeter, Jack Loomis, Sandy Pentland, and Thad Starner, to name a few. The articles across this issue offered an early attempt to provide theory and methods that describe the mental processes that occur when one gets psychologically drawn into a virtual world, focusing on the experience of occupying a virtual space. Biocca (1997) was one of first to hone in on particular elements of presence, with Lee (2004a) later providing a more detailed explication, introducing the concepts of social presence and self-presence, distinct from the more traditional spatial emphasis.

Notably, in their conceptualization of presence, Slater and Wilbur (1997) distinguish it from another related concept – immersion. Slater and Wilbur suggest that presence in a VE is inherently a quality of the user's psychology, representing the extent to which an individual experiences the virtual setting as the one in which they are consciously present. On the other hand, immersion can be regarded as a quality of the system's technology, an objective measure of the extent to which the system presents a vivid virtual environment while shutting out physical reality. By this account, the technological level of immersion afforded by the VE system facilitates the level of psychological presence. This relationship has implications, then, for how one might operationally design for increased presence.

Slater and Wilbur note that a system is more likely to be immersive – or to shut out physical reality – if it (1) offers high fidelity simulations through multiple sensory modalities, (2) finely maps a user's virtual bodily actions to their physical body's counterparts, and (3) removes the participant from the external world through self-contained plots and narratives. Such features are thought to make the interface of the system more transparent, permitting the user to then become psychologically engaged in the virtual task at hand rather than attending to the input mechanisms themselves. That is, the more immersive the system, the more likely an individual will feel present within the mediated environment and the more likely that the virtual setting will dominate over physical reality in determining user responses. But, psychologically, there are a number of mechanisms which guide how a user comes to experience an immersive mediated environment as a space in which they are physically present.

The Formation of Presence

A number of prominent presence scholars have put forth a theoretical model outlining the psychological process by which presence is experienced (Wirth, et al., 2007). The model understands the formation of presence as a two-step process. First, the user must perceive the mediated environment as a plausible space. This requires the user to construct a *spatial situational model* (SSM), a mental model of the simulated space communicated by the system. In constructing the SSM, users draw heavily on spatial cues, by which they organize the sensory information presented into a plausible spatial structure. However, simply perceiving the mediated environment as a space does not alone result in spatial presence. Second, the user must also then experience his or herself as being located within that perceived space. Only then is spatial presence achieved. It is in light of this process that Wirth and colleagues define presence as "a binary experience, during which perceived self-location and, in most cases, perceived action possibilities are connected to a mediated spatial environment, and mental capacities are bound by the mediated environment instead of reality (p.497)." With this definition in mind, the model describes presence as a two-dimensional construct, comprised of 1) a sense of self-location and 2) perceived possibilities to act.

Wirth et al. (2007) note specific media features that may assist with each step of the formation process –both constructing the spatial mental representation of the mediated space and then experiencing self-location within that space. Many of the spatial cues used in constructing the SSM are linked to the visual modality, including static monocular cues (e.g., occlusion, visual field, texture effects), dynamic monocular cues (e.g., motion parallax), and binocular cues (e.g., stereoscopy). Additionally, the mediated environment will more likely be perceived as a plausible space if these cues are both rich in quality and have a logical consistency. Regarding the second step, media factors are also thought to influence the user's ability to perceive this mediated space as their primary spatial reference frame rather than that of the real world. Indeed, as noted by Balakrishnan and Sundar (2011), this model suggests that the user's perception of both self-location and possible actions is at least partially defined by the affordances of the mediated environment. Specifically, Wirth et al. (2007) suggest that users will more likely perceive themselves as located within a mediated environment if 1) stimuli are congruent across modalities, 2) attention is persistently engaged, 3) stimuli are realistic, and 4) the users are permitted to perform actions and receive well-calibrated feedback. These conditions that are thought to promote spatial presence closely align with those Slater and Wilbur cite as influential on a system's immersive quality.

How Immersive is Enough?: Quantifying the Benefits of Immersive Quality

Again, the rationale provided by Slater and Wilbur would suggest that systems of higher immersive quality may elicit greater psychological presence and, in turn, generate stronger effects across a number of secondary user measures, including performance on various tasks (Bowman & McMahan, 2007; Slater, Linakis, Usoh, & Kooper, 1996). As such, we might conclude that a designer seeking to maximize the applied effectiveness of a VE simulation should construct the most advanced, technologically immersive system possible. Processors with faster update rates; tracking devices with finer scales and less cumbersome instruments; head mounted displays (HMDs) with wider fields of view (FOV); stereoscopic visuals and surround-sound; avatars with photo-realistic faces, expressions and clothing – the inclusion of these features could be expected to cause matching gains in a user's performance on virtual tasks. In terms of the two-step model, this equates to more consistent and rich spatial cues leading to a stronger SSM and a greater likelihood that the user perceives himself as located within the mediated environment.

Inclusion of all of the above features can, however, also come with certain costs. First there is the very real financial expense, as such features can cost a considerable amount of money – money that may seem wasted when new technologies come out an increasingly short time later, with finer tracking, faster update rates, or wider fields of view. Second, there is the pragmatic issue of usability – high immersion hardware often correlates with greater cumbersomeness and calibration requirements, for both the user (e.g., heavy equipment, placement of body markers) and the researcher or technician (e.g., acquiring and arranging dedicated spaces). As such, the theoretically driven push for the most advanced system is often balanced by practical restriction (Bowman & McMahan, 2007). Individuals constructing virtual environments and wishing to get the biggest "bang for their buck" may find themselves asking, "How immersive is enough?" In other words, how much benefit does the newer or additional technology really add to their VE's effectiveness?

The literature on VEs does not readily provide a straightforward answer to the questions posed above. A number of studies have empirically demonstrated a positive relationship between immersion and various performance measures, including search ability (Pausch, Proffitt, & Williams, 1997), recall (Lin, Duh, Parker, Abi-Rached, & Furness, 2002), and spatial judgments (Slater, Linakis, Usoh, & Kooper, 1996). However, there are indeed also cases that fail to find a positive relationship between immersion and performance (e.g., Narayan, Waugh, Zhang, Bafna, & Bowman, 2005; McMahan, Gorton, Gresock, McConnell, & Bowman, 2006; Polys, Kim, & Bowman, 2006). Again, the underlying assumption is that immersion begets presence, which in turn begets performance gains. Considering this process in which immersive quality indirectly influences performance, Slater and colleagues (1996) suggested that immersion's effect on performance is indeed due to relative increases in experienced presence, but they also noted that this effect should only be expected for virtual tasks in which more "natural" reactions and behavior are advantageous. This proposed moderation may explain some of the varied results in the literature. Such a theoretical framework is similar to that offered by Bowman and McMahan (2007), who suggest that multiple "immersion component" technologies independently influence a variety of potential "immersion benefits," including presence, which in turn independently influence application effectiveness and performance.

In sum, the existing literature as a whole does not clearly provide a picture of the relative impact of different immersive technologies on presence and performance. Some studies find statistically significant effects while others do not. Further, when an effect *is* observed, its magnitude may vary across different studies or different dependent measures: with presence in particular scholars have noted that self-report measures do not always align with behavioral measures (Slater 2004; Bailenson, Swinth, Hoyt, Persky, Dimov, & Blascovich, 2005). Simply put, a basic review of the existing literature does not itself permit researchers to confidently conclude that newer, faster, multi-modal immersive systems are always significantly more effective than older, slower, simpler ones.

Taking a Meta-Analytic Approach

Again, a review of the literature on immersion, its direct effects on presence, and its indirect effects on performance indicates there to be some variety in the effects observed, in the particular immersive components examined, and in the designs through which they were investigated. In such a situation, a formal meta-analysis can lend insight into the general direction and size of any actual effect. Indeed, the procedures comprising a meta-analysis can help to "address the challenges introduced by the existence of multiple answers to a given question" (Rosenthal & DiMatteo, 2001, p.61). The quantitative steps for combining results across a corpus of studies not only permit researchers to gain a more gestalt estimate of the effect in question, but can also provide insights into inconsistencies through the discovery of potential moderators and mediators (Rosenthal & DiMatteo, 2001; Rosenthal, 1991). Such an analysis would permit researchers a more nuanced characterization of the effects of immersive technology components, allowing us to tease out the relative added value of a given feature. In other words, by compiling the various operationalizations of immersion and their observed effects, a meta-analysis can better inform researchers and others investing in VEs as to what technology is enough for their particular projects and for optimizing return on investment.

Further, if particular technologies are found to lead to stronger effects than others, this process may lend theoretical insight into the formation of presence.

For the purpose of our meta-analysis, we intended to gauge the overall effect of immersion on presence. That is, in Bowman & McMahan's terms, we seek to see how various components technologies influence one particular immersion benefit, presence. Further, we have conducted multiple, separate meta-analyses for individual immersive system components (e.g., FOV, tracking level, stereoscopy) in order to help identify which immersive features are particularly effective in leading to the formation of presence.

Method

Selection of Candidate Studies

The first step of a meta-analysis is defining the variables of interest, both independent and dependent (Rosenthal & DiMatteo, 2001). Candidate studies for this meta-analysis needed to include the manipulation of a VE system's level of immersion and the subsequent measure of presence experienced by users. However, for theoretical and practical purposes we restricted the definitions of these variables in a few ways.

Operationalizations of presence. First, in operationally defining presence, for the sake of internal validity we decided that this initial analysis should be restricted to studies in which presence was measured through self-report. Other measures sometimes used include body vection, physiological arousal, and memory tests. However, the meaning of many of these measures is open to debate. For example, regarding vection posture, leaning forward can be construed as feeling present and engaged, but leaning back could similarly indicate feeling present and surprised. Additionally, if a user is feeling more present, there are plausible arguments for why he or she should be able to remember both more and fewer details on a memory recall test. Therefore, although there is compelling reason to suspect the most promising measures of presence are not self-report (e.g., Slater, 2004; Bailenson, Aharoni, Beall, Guadagno, Dimov, & Blascovich, 2004), an initial assimilation of the behavioral, cognitive, and physiological measures were too disparate to meet the standards of a meta-analysis which combines "like" dependent variables (Rosenthal & DiMatteo, 2001).

Additionally, this meta-analysis is focused on the form of presence that the majority of research has been centered on, and which Lee (2004a) later explicated as spatial presence: the superordinate feeling of being located within a virtual space. Indeed, there are simply too few studies in the existing literature that empirically examine the effect of particular immersive features on social and self presence for conducting independent meta-analyses regarding these related concepts. To this end, when compiling studies we looked for questionnaire items that generally asked about being in a space rather than being with other people (social presence or co-presence) or about self-identifying as a virtual representation or extension within the mediated space (self presence or body transfer).

Further, many presence questionnaires include subscales measuring other concepts alongside spatial presence that we deemed not appropriate for this meta-analysis. For instance, some studies measured engagement or involvement, but these have been considered separate concepts for the purpose of this analysis (a user can feel spatially present in a VE designed to be boring without feeling engaged in it or cognitively involved). Finally, many questionnaires include items regarding emotion, affect, or arousal. These items were not included in the analysis, as valenced responses and alterations in arousal may be moderated by presence but are not direct measures of a sense of "being there." With these restrictions of dependent self-report measures in mind, we then adhered to a very specific decision tree when reading through candidate studies: 1) if "presence" (or the synonymously used terms "general", "spatial", or "physical" presence) or "immersion" were reported as stand-alone measures, they were used; if more than one was reported, their effect sizes were aggregated (see details below); 2) if only a composite "presence" score was reported (comprised of subscales for engagement, involvement, affect, or other related but distinct concepts), then we were forced to rely on that measure ; 3) if subscales were reported, we carefully reviewed the exact questions and decided whether or not to include them.

Operationalizations of immersion. In operationally defining manipulations of immersion, we were guided by the operationalizations of presence-inducing system factors suggested by the SSM framework (Wirth et al., 2007) and corroborated with lists of immersive feature categories found in the literature (Bowman & McMahan, 2007). In addition to this top-down process, we were also guided bottom-up by the most common, modal operationalizations found in the literature. Together, this led to a definition of "immersive" that largely emphasizes system configurations or specifications as opposed to aspects of the mediated content itself, such as narrative (Rampoldi-Hnilo, Kind, Devries, Tait, & Besecker 1997), game elements (Song, Kim, Tenzek, & Lee, 2009), violence (Ivory and Kalyanaraman, 2007; Nowak, Krcmar, & Farrar, 2006) or emotional tone (Baños, Botella, Alcañiz, Liaño, Guerrero, & Rey, 2004; Grassi, Giaggioli, & Riva, 2008). This resulted in the following list of immersive features to be examined through meta-analysis:

Tracking level. Tracking level refers to the number and types of degrees of freedom (DOF) with which a user is tracked by an immersive system. Manipulations of this feature include the quality of the input method (e.g., more natural movement tracking vs. abstract controller input). It also refers to studies that have manipulated the relative (e.g., number of

DOF tracked) or absolute (e.g., capacity to take action within the mediated environment vs. simply observing the stimulus) level of tracking in order to measure its influence on feelings of presence.

Stereoscopic vision. Studies investigating this feature manipulated whether a given system provided users with monoscopic or stereoscopic visuals.

Image quality. This composite variable considers a number of elements that influence the general quality, realism, and fidelity of visuals provided by a mediated environment. Manipulations of this feature include high vs. standard definition resolution, flicker rates, lighting types, texture mapping quality, and general level of detail or overall realism.

Field of view. This refers to the relative field of the user's total view within which the environment's visuals extend. This feature is commonly manipulated through blinders or the screen size of a head-mounted display (HMD). It is worth noting that, for the purpose of our analyses, this variable also includes studies in which television or computer screen sizes were manipulated yet screen resolution and viewing distance were held constant (in effect actually altering the relative field of view of the user).

Sound quality. A number of studies have investigated how the relative presence of sound may influence user ratings of presence. Manipulations of this feature include the presence or absence of all sound, ambient sound, diegetic sound, or spatialized sound, as well as the number of sound channels used.

Display type. This feature refers to the form in which a mediated environment is displayed (e.g., HMD, projection screen, PC monitor). In some cases this variable confounds others (e.g., field of view, image quality). However, we separately examined it as an independent variable in instances when not confounded with other features.

Update rate. Studies in this category empirically examined how the rate at which the virtual environment is rendered may influence user presence.

User perspective. This feature refers to the manipulation of perspective – 1st-person (from the eyes of the user) vs. 3rd-person (over the shoulder or behind the user's representation or avatar) – through which the user views the mediated environment.

Overall high vs. low. Finally, this category applies to studies in which multiple features were manipulated across conditions, thereby producing operational confounds, preventing the teasing apart of the relative contribution of a given feature. For example, a study which compares presence experienced while using an HMD with head-tracking to that experienced while using a desktop PC without any such tracking falls into this category. However, note, in that same example, if the HMD condition did not include head-tracking such a study would instead be considered a manipulation of display type, as discussed above.

In sum, this meta-analysis includes studies that investigated the manipulation of at least one immersive system feature (as operationalized by corroborating literature) and included a self-reported measure of spatial (general, physical) presence.

Search procedures. After defining the variables of interest, the second formal step of a meta-analysis according to Rosenthal and DiMatteo (2001) is to systematically collect the relevant studies. To do this, we reviewed the full journal archives for *Presence: Teleoperators and Virtual Environments* and *CyberPsychology & Behavior*. We also reviewed the full conference proceedings of the *International Society for Presence Researchers (ISPR)* and the *IEEE Virtual Reality* annual conference. From this initial list of studies, we then back-referenced through their citations, finding additional research reports from the proceedings of annual conferences for the *Association for Computing Machinery (ACM)* and the ACM *Special Interest*

Group on Graphics and Interactive Techniques (SIGGRAPH), as well as articles from various journals related to human-computer interaction, human factors design, communication science, and unpublished manuscripts. Additionally, Google Scholar searches were completed for "presence" and key terms related to immersive systems (e.g., "stereoscopy", "field of view"). A similar search was completed on the Temple University ISPR Telepresence Literature *RefShare* database. A special call for relevant papers was also posted on the ISPR homepage. Finally, publication bias is inherently a concern when conducting a meta-analysis, as non-significant effect sizes are commonly not reported or published. In an attempt to pursue unpublished work, authors were emailed with direct requests for any unpublished relevant studies.

If a candidate study did not include the required details for calculating an effect size, direct emails were sent to authors. In total, after multiple attempts to contact authors for all studies requiring additional information, we accumulated 61 studies with enough details to include in our analysis, providing 82 separate effect sizes for manipulations of immersive quality.

Statistical Analysis and Procedures

The random effects model meta-analysis was conducted using the procedures described by Rosenthal and DiMatteo (2001) and, particularly in computing tests of heterogeneity, those detailed by Hunter and Schmidt (1990). These procedures were conducted for the full sample of studies as a whole as well as individually for each immersive feature category.

Effect size calculations and combination. In order to combine the results of the total pool of studies, an effect size was first computed for each study. Some studies included multiple experiments or independently tested multiple immersive features; in such cases each effect size was treated as a separate entry into the current meta-analysis. We standardized all effect sizes to the common metric of the correlation coefficient (r), as this is one of the more versatile effect size metrics available – not only is the correlation coefficient widely used, its practical importance is more easily interpreted than that of the alternative Cohen's *d* or Hedge's *g* (Rosenthal & DiMatteo, 2001).

Correlation coefficients were mainly derived from the group means and standard deviations on a given dependent variable measure. In instances where these statistics were reported across multiple groups (for instance, within a 2x2 design, offering 2 separate conditions that included the variable of interest), these statistics were aggregated with pooled variances. When means and standard deviations were not reported, the correlation coefficient was derived from *t* values or *F* values in which the numerator included only one degree of freedom (Rosenthal & DiMatteo, 2001). If a given study included multiple effect sizes of interest (e.g., multiple measures of spatial, general, or physical presence) these values were aggregated into a single effect size. To do this, the correlation coefficients for each measure were standardized through a Fisher Z transformation and averaged, with that average value then transformed back into a single correlation coefficient for the study.

Once a single correlation coefficient (r) was computed for each study manipulation, each was run through a Fisher Z transformation. Each transformed score (z) was then weighted by its respective study's sample size. Specifically, they were weighted by the inverse variance, *N-3*, where *N* is the number of paired observations of the different levels of the independent variable in that study (Lipsey & Wilson, 2001). Note – when different conditions included unequal numbers of observations, the higher value was used. Each of these weighted, transformed scores ("z-weighted") was than averaged into a single overall z score ("overall z"), which was then converted back into a single overall correlation coefficient ("overall r"). This value represented the overall effect size. This process was repeated multiple times – once to combine all studies included in the sample, and then an additional time for each of the individual immersive features listed above (that is, once for all tracking level studies, once for all stereoscopy studies, and so on). This allowed us to observe the overall effect of immersion as a whole on spatial presence, as well as to independently compare the relative effect of each immersive feature.

Interpretation of overall effect size. By Cohen's (1988) conventions a correlation coefficient of .10 can be interpreted as a relatively small effect size, with an *r* of .30 being considered a medium effect size, and an *r* of .50 or more being a relatively large effect size. With this framework, the relative size of the influence of one immersive feature on user presence can be compared to that of another. Of course, coupled with this loose rule of thumb should be consideration of the practical significance of the effect: features yielding small effect sizes may be noteworthy, particularly in cases where the implementation of features providing larger effect sizes are constrained by cost of other factors.

In addition to this convention, the extent to which effect sizes significantly differ from one another may be formally tested as outlined by Cohen and Cohen (1983). By this procedure, two independent correlation coefficients and their respective sample sizes can be converted to a z score using a Fisher transformation. The value and direction of the z score provide a measure of whether the first effect size is significantly larger or smaller than the other. To this end, the overall effect sizes for the various immersive features can be compared each other, allowing direct comparisons of their relative impact on user presence.

Tests of heterogeneity. Finally, each overall effect size (one for the full pool of studies, plus another for each individual immersive feature category) was subjected to a test of heterogeneity (Hunter & Schmidt, 1990). This chi-square test provides a measure of the heterogeneity of variance in correlation coefficients across the studies included in the sample. A significant result indicates that the variance is not due completely to sampling error and that there may be potential moderators within the sample. In such an event, potential moderating variables were then independently investigated. Hunter and Schmidt (1990) alternatively note what is known as the "75% rule", which asserts that if 75% or more of the variance across correlation coefficients can be attributed to corrected artifacts, including sampling error, then the remaining 25% is likely due to uncorrected artifacts rather than any moderating variables. Both chi-square tests of heterogeneity and calculations of the percent of variance attributable to sampling error are provided in the analysis below.

Results

Summary of Sample

In addition to their correlation coefficients, Table 1 includes additional descriptive information for all studies included in the sample. This allowed the researchers to not only categorize studies by the particular immersive feature each examined (which were then subjected to independent meta-analyses), but to also track values for potential variables that may moderate the effect sizes observed (e.g., year conducted, social science vs. engineering discipline). Additional notes for a given study, such as which exact levels of an immersive feature were compared or which dependent measures of a given study were included in the analysis, are also indicated. Finally, Figure 1 presents a forest plot of all the studies included in our sample, displaying their individual effect sizes within 95% confidence intervals.

Meta-Analytic Results – Effect Sizes for Full Sample and Individual Immersive Features

Conventional interpretation of effect sizes. The results of the initial meta-analyses – one combining all studies in the sample and then additional analyses for each immersion feature category – are presented in Table 2. Overall, immersive features as a whole had a medium sized effect on spatial presence (r = .310), fitting the causal relationship typically assumed to exist. However, a more nuanced understanding of this result was offered by independently examining the relative effect size of each immersive feature.

A number of the independent features included particularly small sample sizes (*K* in Table 2), such as update rate, agency, display type and user perspective. In turn, it may be especially risky to draw general conclusions about these features. However, we might more safely remark upon the observed effect sizes for some of the features for which larger samples were obtained. Indeed, as seen in Table 2, certain features appear to influence presence more than others. For instance, stereoscopy – a commonly implemented feature in many immersive environment systems – offered a relatively modest influence on presence (r = .225). Similarly, overall "high" vs. "low" manipulations of the immersive level of the system used (e.g., HMD with headtracking compared to a desktop display, CAVE simulation with motion tracking vs. PC with keyboard and mouse inputs) had a small impact on presence experienced (r = .269). Image quality – herein including manipulations of visual detail, quality, and overall levels of realism – also provided a small effect on presence (r = .157). Studies manipulating the relative presence or absence of sound provided a small to nearly medium sized effect on user presence (r = .293).

By comparison, other features produced effect sizes above the overall average. Studies that manipulated the field of view provided to the user had a medium effect size (r = .341). In addition, tracking level – including any studies in which the number of degrees of freedom of user inputs was manipulated – provided a medium to large effect size (r = .445). The nature of the effect of tracking level on presence was then further examined by calculating the correlation coefficients for particular subgroups of tracking studies. Specifically, in order to examine the relative impact of direct mapping, an effect size was calculated for studies whose manipulations compared natural versus more abstract tracking of user inputs (r = .409). Additionally, a number of studies compared conditions in which users had no control over navigation through the mediated environment to conditions in which some control was afforded (labeled "Some vs. None" in Table 2), while other studies compared conditions in which relatively many vs. relatively few degrees of freedom were tracked (labeled "Many vs. Some" in Table 2). While "Some vs. None" studies yielded a small to nearly medium effect size (r = .281), the "Many vs. Some" studies provided a particularly large effect on presence (r = .748). Finally, update rate also had a large impact on user presence (r = .534), though again, the representativeness of this measure may be dubious in light of a small sample size (only three studies).

Formal comparison of effect sizes. Again, Fisher Z transformations were employed to also provide formal tests of whether the effects of two given immersive features were significantly different from one another. Table 3 lists the z scores and their respective significance levels for each comparison. Most notably, the effect of tracking level on user presence was found to be significantly larger than that of nearly all other immersive features (with the one exception being the effect of update rate, which again, may be questionable in light of its small sample size). Field of view also generally provided a relatively strong effect, one that was significantly larger than that of display type, image quality, and stereoscopy. Finally, the impact of image quality on presence was particularly low in comparison to that of other features, with an effect size that was significantly smaller than that of tracking level, update rate, field of view, stereoscopy, and overall high versus low manipulations.

Tests of Heterogeneity of Effect Sizes and Moderator Analysis

Heterogeneity tests were then conducted after the initial meta-analyses. A test was performed both for the overall sample as well as each of the subsamples clustered by immersive feature. A significant chi square statistic suggests that the correlation between immersion and presence varied across studies to such an extent that it cannot be attributed to sampling error alone. When this is the case, potential moderating variables across the sample need to then be examined.

As noted in Table 2, the overall sample of all immersion studies was significantly heterogeneous ($p < .001$). Additionally, this variance could not be accounted for through different operationalizations of immersion, as the vast majority of all individual immersive feature subsamples also contained a significant level of heterogeneity. The only exceptions were update rate (a subsample comprised of three studies) and user perspective (with only one study contained in this sample, there was no variance between correlations requiring accounting).

These tests were followed by a search for potential moderators that could help account for variance between correlations. Various potential moderators between the studies were examined, including the study and participant geographic location and whether or not the study was conducted by social scientists or sourced from the engineering literature on immersion. Though these moderators helped account for some of the heterogeneity in correlations between immersion features and reported levels of presence, they could still not fully account for the variance in effect sizes across studies. However, these results are not surprising considering the relatively small number of studies comprising any particular level of the moderating variables tested.

Discussion

The relationship between the immersive quality of a mediated environment and the level of presence experienced by the user has been a topic of considerable theoretical discussion and empirical investigation. This pursuit is often predicated on an assumed chain of causal relationships – specifically, that greater system immersion begets greater user presence, which in turn enhances the applied effectiveness of the mediated environment, across domains including healthcare and rehabilitation (Riva, 2002; Kalyanaraman, Penn, Ivory, & Judge, 2010), learning and formal education (Monahan, McArdle, & Bertolotto, 2008; Reeves, Cummings, Scarborough, & Read, 2010), and persuasion and commercial advertising (Grigorovici, 2003; Ahn & Bailenson, 2011), to name a few.

In light of an empirical literature containing varied operationalizations of immersion, varied operationalizations of presence, and varied results, this study employed a meta-analytic approach to examine the overall effect of immersion of presence. Specifically, it explored how some of the most commonly employed and theoretically interesting immersive features contributed to user reports of spatial presence. Overall, immersion was found to have a conventionally medium sized effect on presence, while individual immersive features were found to vary in their effect sizes.

The relative effects of a few individual immersive features are of particular note, both for the variance observed in their respective influence on presence as well as their practical implications. Two features in particular were found to have a relatively larger effect on spatial presence – tracking level and field of view. Discounting update rate (which was also found to have a large effect size, though based on a small sample of studies), tracking level and field of view have a much stronger impact on user presence compared to most other features, including the commonly manipulated and upgraded features of stereoscopy and image quality and resolution. In other words, all else equal, given a fixed budget for designing an immersive system, a designer of mediated environments might be best advised to focus on tracking level and field of view rather than stereoscopic visuals or higher quality visual stimuli.

However, beyond practical considerations for system designers, the finding that particular immersive features provide greater gains than others in terms of user presence also offers some interesting theoretical implications. Indeed, these results may offer some compelling evidence for the formation of presence as outlined by the spatial situational model framework proposed by Wirth et al. (2007). Again, this framework suggests that presence is achieved through a two-step formative process, in which the user first constructs a spatialized mental model of the mediated environment (e.g., ascertains that the environment is a space) and then comes to accept this mediated environment over grounded reality as his or her primary frame of self-reference (e.g., ascertains that he or she is situated within that space). Completing this second step is thought to result in the experience of spatial presence, a two-dimensional construct construed in terms of perceived self-location and perceived possibilities to act within the environment at hand. That is to say, presence and its formation, as conceived by this framework, are premised on being able to tell where you are in a space. Supporting this, in empirically testing this framework Balakrishnan and Sundar, (2011) found the ability to navigate oneself through the mediated environment was key to experiencing presence.

General trends in virtual reality research and design align with this perspective, as the majority of the field is focused on aspects of sight and sound – senses responsible for gauging relative position in a large environmental space (Blascovich & Bailenson, 2011). To this extent, some of the most commonly investigated features, as iterated by the sample of studies acquired here, pertain to stereoscopic vision and overall improvement of visuals (in terms of resolution, detail, realism and the like). What's particularly interesting, however, is that despite the prominence of these component features of immersive systems, they apparently contribute relatively weakly to user presence when compared to other features like field of view and tracking level.

One approach to understanding this distinction is to consider the extent to which each of these variables make a unique contribution to the user's sense of presence. Stereoscopy provides the user with depth of perception similar to that found in non-mediated reality. However, the extent to which human beings rely on stereoscopy is by no means universal, as it is known to vary from person to person (Torii, Okada, Ukai, Wolffsohn, & Gilmartin, 2008). What's more, environments, both mediated and real, provide users with various alternative spatial cues that can be relied on for depth, self-location, and navigation through the environment – ranging from object occlusion to motion parallax.

Image quality, as well, may not be particularly crucial to one's ability to construct a spatial model or self-locate. Surprisingly low thresholds of detail and realism have been found to often be more than enough to enable object identification and a sense of depth. Reeves and Nass (1996) found fidelity of visuals have no impact on user attention, recognition, or subjective experience, suggesting that people may not even notice when technology improves visual quality. Indeed, as Hochberg (1962, p.30) noted, "Perfect physical fidelity is impossible and would not be of psychological interest if achieved, but perfect *functional* fidelity…is completely achievable and is of considerable psychological interest." Functionally, most viewers are able to negotiate the spatial cues of low fidelity visuals, easily linking an image to what it is supposed to represent. This capacity may be attributed to innate properties of human perception, thereby removing the onus of fidelity from the media message itself (Lee, 2004b).

Bearing in mind the two-step model of presence formation, the concept of functional fidelity may be particularly appropriate in discerning not only why stereoscopy or image quality have a relatively smaller effect on presence than other features, but also why tracking level and field of view have a greater impact. The ability to interpret spatial cues so as to construct a spatial situational model is only the first step of the process; not only is physical fidelity not needed, but even if afforded through stereoscopy, improved resolution and the like, it will primarily only assist users in completing the first step of the formative process – construing the mediated environment as a spatial situation. In turn, other, different immersive features may be much more important to the second step – perceiving oneself as being located with that space and having the possibilities to take action in or navigate through it. Tracking level, for instance, might be much more important in regards to this step of presence formation. Systems that more finely track and incorporate multiple, natural user inputs – that is, track more degrees of freedom – likely provide users with a better sense of self-location, navigation, and action possibilities than do those with improved depth perception or visual realism. Further, the observed impact of field of view on user presence also makes sense in light of this approach. When the mediated field of view encompasses a fuller proportion of the user's natural field of view, it may be easier to experience oneself as located within that virtual space as opposed to external reality.

In generalizing these findings to the design and implementation of immersive systems, it should be kept in mind that these findings apply to presence as it is most generally conceptualized, what Lee (2004a) construes as "spatial" presence. These results may not carry over to designing mediated experiences for eliciting feelings of self presence or social presence. For example, the situational model users must construct to experience social presence may depend far less on spatial cues and far more on issues of communication channels. If so, immersive system features are perhaps not the independent variables of concern when looking at social presence; rather, multi-modality, synchronous versus asynchronous communication, familiarity, and manipulations of artificial intelligence of agents and social actors may be more relevant variables to consider.

Further, particular restrictions should be considered when applying the findings yielded in this meta-analysis. Again, in examining the relationship between immersive system quality and user presence we relied on self-report measures. This conservative operationalization was for the sake of conceptual parity, as required by a meta-analysis. However, additional summative analyses, whether quantitative or qualitative in nature, are needed to similarly examine any overall trends in behavioral measures of presence (such as vection or physiological activity). Similarly, operationalizations of immersion were restricted to the most common, modal features manipulated in the literature. As a result some potentially interesting manipulations of immersion are not considered here. Though sight- and sound-related features are the most pervasive, newly emerging forms of immersive technology – including haptic or even olfactory features – may become more common in coming years. If so, a meta-analytic review of their relative contributions would be beneficial in the future.[1]

Other future efforts could also investigate potential moderators of the relationship between immersion and presence. The variance in effect sizes across studies was here found to be significantly heterogeneous. The different operationalizations of immersion failed to fully account for this heterogeneity, as did some proposed moderating variables tracked here. Whereas the moderator analysis of a meta-analysis simply attempts to account for variance ad

[1] Our literature review identified a few relevant studies in which haptic or tactile immersive features were manipulated and self-reported levels of presence were gathered, but sufficient statistics for inclusion in the current meta-analysis could not be obtained.

hoc, future studies could intentionally isolate and empirically manipulate potential moderators of interest in a more controlled, experimental fashion.

In *Virtually There* (2001), virtual reality pioneer Jaron Lanier outlined his vision of a world in which mediated reality would one day be capable of substituting many of the physically located elements of business, travel, and everyday interpersonal experiences. The long line of empirical work on presence, including the studies comprising the current analysis, have helped serve to fulfill this vision: after decades of research, development, implementation, and testing, immersive technologies are advancing to the point that such a world is near. What we find here, in a meta-analysis of those efforts, is that certain immersive system features may be more important than others in achieving the sense of "being there" that ultimately drives the promise of such technology. Future designs might therefore focus on such features – particularly tracking level and field of view - to better ensure that users process virtual environments as actual spaces in which they feel physically present.

References

Ahn, S. J. (2011). *Embodied experiences in immersive virtual environments: Effects on pro-environmental attitude and behavior*. Unpublished doctoral dissertation. Stanford University. Palo Alto, CA.

Ahn, S. J., & Bailenson, J. N. (2011). Self-endorsing versus other-endorsing in virtual environments. *Journal of Advertising*, *40*(2), 93-106.

André, C. R., Embrechts, J. J., Verly, J. G., Rébillat, M., & Katz, B. F. (2012, June). Sound for 3D cinema and the sense of presence. In *Proceedings of the 18th International Conference on Auditory Display.*

Axelsson, A. S., Abelin, Å., Heldal, I., Schroeder, R., & Wideström, J. (2001). Cubes in the cube: A comparison of a puzzle-solving task in a virtual and a real environment. *CyberPsychology & Behavior*, *4*(2), 279-286.

Aymerich-Franch, L. (2010). Presence and emotions in playing a group game in a virtual environment: the influence of body participation. *Cyberpsychology, Behavior, and Social Networking*, *13*(6), 649-654.

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. *Proceedings of the International Society for Presence Research Annual Conference*, October 13 - 15, Valencia, Spain.

Bailenson, J. N., Swinth, K., Hoyt, C., Persky, S., Dimov, A., & Blascovich, J. (2005). The independent and interactive effects of embodied-agent appearance and behavior on self-report, cognitive, and behavioral markers of copresence in immersive virtual environments. *Presence: Teleoperators and Virtual Environments*, *14*(4), 379-393.

Balakrishnan, B., & Sundar, S. S. (2011). Where am I? How can I get there? Impact of navigability and narrative transportation on spatial presence. *Human–Computer Interaction*, *26*(3), 161-204.

Baños, R. M., Botella, C., Alcañiz, M., Liaño, V., Guerrero, B., & Rey, B. (2004). Immersion and emotion: their impact on the sense of presence. *CyberPsychology & Behavior*, *7*(6), 734-741.

Baños, R. M., Botella, C., Rubio, I., Quero, S., Garcia-Palacios, A., & Alcaniz, M. (2008). Presence and emotions in virtual environments: The influence of stereoscopy. *CyberPsychology & Behavior*, *11*(1), 1-8.

Barfield, W., & Hendrix, C. (1995). The effect of update rate on the sense of presence within virtual environments. *Virtual Reality*, *1*(1), 3-15.

Biocca, F. (1997, August). The cyborg's dilemma: Embodiment in virtual environments. In *Cognitive Technology, 1997.'Humanizing the Information Age'. Proceedings., Second International Conference on* (pp. 12-26). IEEE.

Blascovich, J., & Bailenson, J. N. (2001). Infinite reality: Avatars, eternal life, new worlds, and the dawn of the virtual revolution. New York: HarperCollins.

Botella, C., Rey, A., Perpiñá, C., Baños, R., Alcaniz, M., Garcia-Palacios, A., Villa, H., & Alozano, J. (1999). Differences on presence and reality judgment using a high impact workstation and a PC workstation. *CyberPsychology & Behavior, 2*(1), 49-52.

Bowman, D. A., & McMahan, R. P. (2007). Virtual reality: how much immersion is enough? *IEEE Computer*, *40*(7), 36-43.

Bracken, C. C. (2005). Presence and image quality: The case of high-definition television. *Media Psychology*, *7*(2), 191-205.

Bracken, C. C. & Botta, R. A. (2002). Presence and television: Form versus Content. *Proceedings of the International Society for Presence Research Annual Conference*, October 9-11, Porto, Portugal.

Bracken, C.C. & Skalski, P. (2009). Telepresence and video games: The impact of image quality. *PsychNology Journal, 7*(1), 101-112.

Broek, P. (2008). *To game or not to game: Examining differences in presence, arousal and intended aggression after playing or observing a violent videogame*. Unpublished manuscript. Department of Psychology, University of Twente, Netherlands..

Bystrom, K. E., & Barfield, W. (1999). Collaborative task performance for learning using a virtual environment. *Presence: Teleoperators and Virtual Environments*, *8*(4), 435-448.

Çiflikli, B., İşler, V., Güdükbay, U. (2010). Increasing the sense of presence in a simulation environment using image generators based on visual attention. Presence: Teleoperators and Virtual Environments, 19(6), 557-568.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciencies*. Routledge.

Cohen, J., & Cohen, P. (1983). Applied multiple regression/correlation analysis for the behavioral sciences. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

De Kort, Y. A. W., Meijnders, A. L., Sponselee, A. A. G., & IJsselsteijn, W. A. (2006). What's wrong with virtual trees? Restoring from stress in a mediated environment. *Journal of Environmental Psychology*, *26*(4), 309-320.

Dinh, H. Q., Walker, N., Hodges, L. F., Song, C., & Kobayashi, A. (1999, March). Evaluating the importance of multi-sensory input on memory and the sense of presence in virtual environments. In *Virtual Reality, 1999. Proceedings., IEEE* (pp. 222-228). IEEE.

Duh, H. B. L., Lin, J. J. W., Kenyon, R.V., Parker, D. E., & Furness, T. A. (2002). Effects of characteristics of image quality in an immersive environment. *Presence: Teleoperators and Virtual Environments, 11*(3), 324-332.

Felnhofer, A., Heinzle, A.-K. & Kothgassner, O.D. (2013). Game experience and behavior in young women: A comparison of interface technologies. Proceedings of the Usability Day XI.

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

Freeman, J., Avons, S. E., Meddis, R., Pearson, D. E., & IJsselsteijn, W. (2000). Using behavioral realism to estimate presence: A study of the utility of postural responses to motion stimuli. *Presence: Teleoperators and Virtual Environments*, *9*(2), 149-164.

Gamito, L., & Anastácio, M. (2006). Presence: head mounted display vs. translucid screen. *Annual Review of CyberTherapy and Telemedicine*, 111.

Gandy, M., Catrambone, R., MacIntyre, B., Alvarez, C., Eiriksdottir, E., Hilimire, M., Davidson, B., & McLaughlin, A. C. (2010, October). Experiences with an AR evaluation test bed: Presence, performance, and physiological measurement. In *Mixed and Augmented Reality (ISMAR), 2010 9th IEEE International Symposium on* (pp. 127-136). IEEE.

Gorini, A., Capideville, C. S., De Leo, G., Mantovani, F., & Riva, G. (2011). The role of immersion and narrative in mediated presence: The virtual hospital experience. *Cyberpsychology, Behavior, and Social Networking*, *14*(3), 99-105.

Grassi, A., Giaggioli, A., & Riva, G. (2008). The influence of media content and media form in sense of presence: A preliminary study. *Proceedings of the International Society for Presence Research Annual Conference,* Padova, Italy.

Grigorovici, D. (2003). Persuasive effects of presence in immersive virtual environments. In G. Riva, F. Davide, & W. IJsselsteijn (Eds.), *Being there: Concepts,effects and measurement of presence in synthetic environments.* Amsterdam: Ios Press

Häkkinen, J., Vuori, T., & Paakka, M. (2002, October). Postural stability and sickness symptoms after HMD use. In *Proc. Of IEEE International Conference on Systems, Man and Cybernetics*.

Heeter, C. (1992). Being there: The subjective experience of presence. *Presence: Teleoperators and virtual environments*, *1*(2), 262-271.

Hendrix, C., & Barfield, W. (1996a). Presence within virtual environments as a function of visual display parameters. *Presence: Teleoperators and Virtual Environments*, *5*(3), 274-289.

Hendrix, C., & Barfield, W. (1996). The sense of presence within auditory virtual environments. *Presence: Teleoperators and Virtual Environments*, *5*(3), 290-301.

Hochberg, J. (1962). The psychophysics of pictorial perception. *Audiovisual Communication Review*, *10*(5), 22-54.

Hou, J., Nam, Y., Peng, W., & Lee, K. M. (2012). Effects of screen size, viewing angle, and players' immersion tendencies on game experience. *Computers in Human Behavior*, *28*(2), 617-623.

Hunter, J. E., & Schmidt, F. L. (1990).Methods of meta-analysis: Correcting error and bias in research findings. Newbury Park, CA: Sage.

IJsselsteijn, W., de Ridder, H., Freeman, J., Avons, S. E., & Bouwhuis, D. (2001). Effects of stereoscopic presentation, image motion, and screen size on subjective and objective corroborative measures of presence. *Presence: Teleoperators and virtual environments*, *10*(3), 298-311.

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*(3), 532-555.

Jeong, E. J., Biocca, F. A., & Bohil, C. J. (2009). Advertising effects through violent virtual experience - Presence, arousal, brand memory and attitude in 3D violent games. *Proceedings of the International Society for Presence Research Annual Conference,* November 11-13, Los Angeles, California, USA.

Jeong, E. J., Biocca, F. A., & Bohil, C. J. (2008). Effects of representational realism in 3D violent games. *Proceedings of the International Society for Presence Research Annual Conference,* October 16-18, Padua, Italy.

Juan, M. C., & Pérez, D. (2009). Comparison of the Levels of Presence and Anxiety in an Acrophobic Environment Viewed via HMD or CAVE. *Presence: Teleoperators and Virtual Environments*, *18*(3), 232-248.

Kallinen, K., Salminen, M., Ravaja, N., Kedzior, R., & Saaksjarvi, M. (2007). Presence and emotion in computer game players during 1st person vs. 3rd person playing view: Evidence from self-report, eye-tracking, and facial muscle activity data. *Proceedings of the International Society for Presence Research Annual Conference,* October 25-27, Barcelona, Spain.

Kalyanaraman, S., Penn, D. L., Ivory, J. D., & Judge, A. (2010). The virtual doppelganger: Effects of a virtual reality simulator on perceptions of schizophrenia. *The Journal of Nervous and Mental Disease*, *198*(6), 437-443.

Kim, T., & Biocca, F. (1997). Telepresence via television: Two dimensions of telepresence may have different connections to memory and persuasion. *Journal of Computer-Mediated Communication, 3*(2).

Kim, K. J., & Sundar, S. S. (2013). Can interface features affect aggression resulting from violent video game play? An examination of realistic controller and large screen size. *Cyberpsychology, Behavior, and Social Networking*, *16*(5), 329-334.

Krijn, M., Emmelkamp, P. M., Biemond, R., de Wilde de Ligny, C., Schuemie, M. J., & van der Mast, C. A. (2004). Treatment of acrophobia in virtual reality: The role of immersion and presence. *Behaviour Research and Therapy*, *42*(2), 229-239.

Lanier, J. (2001). Virtually there. *Scientific American*, *284*(4), 66-75.

Larsson, P., Västfjäll, D., Olsson, P., & Kleiner, M. (2007). When what you hear is what you see: Presence and auditory-visual integration in virtual environments. *Proceedings of the International Society for Presence Research Annual Conference,* October 25-27, Barcelona, Spain.

Larsson, P., Västfjäll, D., & Kleiner, M. (2001). The actor-observer effect in virtual reality presentations. *CyberPsychology & Behavior*, *4*(2), 239-246.

Lee, K. M. (2004a). Presence, explicated. *Communication Theory*, *14*(1), 27-50.

Lee, K. M. (2004b). Why presence occurs: Evolutionary psychology, media equation, and presence. *Presence: Teleoperators and Virtual Environments*, *13*(4), 494-505.

Lee, K. M., Park, N., Jin, S., & Kang, S. (2005). Effects of narrative on feelings of presence in computer-game playing. Paper presented at the annual meeting of the *International Communication Association*, New York, NY.

Lee, H., & Chung, D. (2013). Influence of Gaming Display and Controller on Perceived Characteristics, Perceived Interactivity, Presence, and Discomfort. In *Human-Computer Interaction. Applications and Services* (pp. 258-265). Springer Berlin Heidelberg.

Ling, Y. Brinkman, W.P., Negs, H.T., Qu, C., & Heynderickx, I. (2012). Effects of stereoscopic viewing on presence, anxiety and cybersickness in a virtual reality environment for public speaking. *Presence: Teleoperators and Virtual Environments, 21*(3), 254-267.

Lombard, M., & Ditton, T. (1997). At the heart of it all: The concept of presence. *Journal of Computer‐Mediated Communication*, *3*(2).

Lombard, M., & Ditton, T. B. (2000). Measuring presence: A literature-based approach to the development of a standardized paper-and-pencil instrument. *Proceedings of the International Society for Presence Research Annual Conference*, Delft, Netherlands.

Lombard, M., Reich, R. D., Grabe, M. E., Bracken, C. C., & Ditton, T. B. (2000). Presence and television. *Human Communication Research*, *26*(1), 75-98.

Lott, A., Bisson, E., Lajoie, Y., McComas, J., & Sveistrup, H. (2003). The effect of two types of virtual reality on voluntary center of pressure displacement. *Cyberpsychology & behavior*, *6*(5), 477-485.

Lo Priore, C., Castelnuovo, G., Liccione, D., & Liccione, D. (2003). Experience with V-STORE: considerations on presence in virtual environments for effective neuropsychological rehabilitation of executive functions. *CyberPsychology & Behavior*, *6*(3), 281-287.

McMahan, A. (2003). Immersion, engagement, and presence: A method for analyzing 3-D video games. In M.J.P. Wolf & P. Bernard (Eds.) *The Video Game Theory Reader* (pp.67-86). New York: Routledge.

McMahan, R. P., Gorton, D., Gresock, J., McConnell, W., & Bowman, D. A. (2006, November). Separating the effects of level of immersion and 3D interaction techniques. In *Proceedings of the ACM symposium on Virtual Reality Software and Technology* (pp. 108-111). ACM.

McGloin, R., Farrar, K. M., & Krcmar, M. (2011). The impact of controller naturalness on spatial presence, gamer enjoyment, and perceived realism in a tennis simulation video game. *Presence: Teleoperators and Virtual Environments*, *20*(4), 309-324.

Monahan, T., McArdle, G., & Bertolotto, M. (2008). Virtual reality for collaborative e-learning. *Computers & Education*, *50*(4), 1339-1353.

Morina, N., Beuving, J., Deiman, A., Kampmann, I.L., Brinkman, W-P., Hartanto, D., & Emmelkamp, P.M.G. (2012). Social virtual environments for the treatment of social phobia: Using different virtual reality displays. *CyberPsychology & CyberTherapy Conference 17*.

Muhlbach, L., Bocker, M., & Prussog, A. (1995). Telepresence in videocommunications: A study on stereoscopy and individual eye contact. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *37*(2), 290-305.

Narayan, M., Waugh, L., Zhang, X., Bafna, P., & Bowman, D. (2005, November). Quantifying the benefits of immersion for collaboration in virtual environments. In *Proceedings of the ACM symposium on Virtual reality software and technology* (pp. 78-81). ACM.

Nordahl, R. (2005). Self-induced footsteps sounds in virtual reality: Latency, recognition, quality and presence. *Proceedings of the International Society for Presence Research Annual Conference*, September 21-23, London, U.K.

Nowak, K. L., Krcmar, M., & Farrar, K. M. (2006, August). Examining the relationship between violent video games, presence, and aggression. *Proceedings of the International Society for Presence Research Annual Conference,* Cleveland, Ohio.

Nunez, D. (2007). Effects of non-diegetic information on presence: A content manipulation experiment. *Proceedings of the International Society for Presence Research Annual Conference*, Barcelona, Spain.

Nunez, D., & Blake, E. (2001, November). Cognitive presence as a unified concept of virtual reality effectiveness. In *Proceedings of the 1st international conference on Computer graphics, virtual reality and visualisation* (pp. 115-118). ACM.

Pausch, R., Proffitt, D., & Williams, G. (1997). Quantifying immersion in virtual reality. *Proceedings from the ACM SIGGRAPH Annual Conference, Computer Graphics*, 13–18. ACM Press/Addison-Wesley Publishing Co..

Peer, A., Pongrac, H., & Buss, M. (2010). Influence of varied human movement control on task performance and feeling of telepresence. *Presence: Teleoperators and Virtual Environments*, *19*(5), 463-481.

Persky, S., & Blascovich, J. (2008). Immersive virtual video game play and presence: Influences on aggressive feelings and behavior. *Presence: Teleoperators and Virtual Environments*, *17*(1), 57-72.

Polys, N. F., Kim, S., & Bowman, D. A. (2007). Effects of information layout, screen size, and field of view on user performance in information□rich virtual environments. *Computer Animation and Virtual Worlds*, *18*(1), 19-38.

Price, M., & Anderson, P. (2007). The role of presence in virtual reality exposure therapy. *Journal of anxiety disorders*, *21*(5), 742-751.

Prothero, J. D., & Hoffman, H. G. (1995). Widening the field-of-view increases the sense of presence in immersive virtual environments. *Human Interface Technology Laboratory Technical Report TR-95*, *2*.

Rajae-Joordens, R., Langendijk, E., Wilinski, P., & Heynderickx, I. (2005, December). Added value of a multi-view auto-stereoscopic 3D display in gaming applications. In *Proc Int Disp Workshop*.

Rand, D., Kizony, R., Feintuch, U., Katz, N., Josman, N., & Weiss, P. L. T. (2005). Comparison of two VR platforms for rehabilitation: video capture versus HMD. *Presence: Teleoperators and Virtual Environments*, *14*(2), 147-160.

Rampoldi-Hnilo, L. A., Kind, K., Devries, J., Tait, K., & Besecker, K. (1997). The presence of presence: The influence of narrative on the perception of presence in virtual environments. *Unpublished Manuscript. East Lansing, MI*.

Regenbrecht, H., & Schubert, T.E. (2002). Real and illusory interactions enhance presence in virtual environments. *Presence: Teleoperators and virtual environments*, *11*(4), 425-434.

Reeves, B., Cummings, J.J., Scarborough, J., & Read, J.L. (2010). Government uses for games and virtual worlds: Optimizing choices for citizens and government workers in the areas of energy efficiency, educational assessment, work productivity, safety and health, and quality of information exchanges. White House Office of Science and Technology Policy's *Occasional Papers in Science and Technology Policy* series.

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

Riva, G. (2002). Virtual reality for health care: the status of research. *Cyberpsychology & Behavior*, *5*(3), 219-225.

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*(1), 59-82.

Sallnäs, E. L. (2005). Effects of communication mode on social presence, virtual presence, and performance in collaborative virtual environments. *Presence: Teleoperators and Virtual Environments*, *14*(4), 434-449.

Schlindwein, L. F. M., Hounsell, M. D. S., & Kemczinski, A. (2013). A comparative study on aspects that influence the sense of presence in virtual environments. *Revista Brasileira de Computação Aplicada*, *5*(1), 113-125.

Seay, A. F., Krum, D. M., Hodges, L., & Ribarsky, W. (2001, March). Simulator sickness and presence in a high FOV virtual environment. In *Virtual Reality, 2001. Proceedings. IEEE* (pp. 299-300). IEEE.

Shim, W., & Kim, G. J. (2003). Designing for presence and performance: The case of the virtual fish tank. *Presence: Teleoperators and Virtual Environments*, *12*(4), 374-386.

Skalski, P., Tamborini, R., Shelton, A., Buncher, M., & Lindmark, P. (2011). Mapping the road to fun: Natural video game controllers, presence, and game enjoyment. *New Media & Society*, *13*(2), 224-242.

Skalski, P., & Whitbred, R. (2010). Image versus Sound: A Comparison of Formal Feature Effects on Presence and Video Game Enjoyment. *PsychNology Journal*, *8*(1), 67-84.

Slater, M. (2004). How colorful was your day? Why questionnaires cannot assess presence in virtual environments. *Presence: Teleoperators and Virtual Environments*, *13*(4), 484-493.

Slater, M., Linakis, V., Usoh, M., & Kooper, R. (1996, July). Immersion, presence, and performance in virtual environments: An experiment with tri-dimensional chess. In *ACM Virtual Reality Software and Technology (VRST)* (pp. 163-172).

Slater, M., & Wilbur, S. (1997). A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. *Presence: Teleoperators and virtual environments*, *6*(6), 603-616.

Snow, M. P., & Williges, R. C. (1998). Empirical models based on free-modulus magnitude estimation of perceived presence in virtual environments. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *40*(3), 386-402.

Song, H., Kim, J., Tenzek, K. E., & Lee, K. M. (2010, June). The Effects of Competition on Intrinsic Motivation in Exergames and the Conditional Indirect Effects of Presence. In *annual conference of the International Communication Association, Singapore*.

Steuer, J. (1992). Defining virtual reality: Dimensions determining telepresence. *Journal of communication*, *42*(4), 73-93.

Sutherland, I., 1965. The ultimate display. Information Processing 1965: *Proceedings of the IFIP Congress 65*, 2,. Washington, DC: Spartan Books, pp. 506-508

Swinth, K. R., & Blascovich, J. (2001). Conformity to group norms in an immersive virtual environment. Paper presented at the annual meeting of the *American Psychological Society* (APS).

Takatalo, J., Kawai, T., Kaistinen, J., Nyman, G., & Häkkinen, J. (2011). User experience in 3D stereoscopic games. *Media Psychology*, *14*(4), 387-414.

Takatalo, J., Häkkinen, J., Komulainen, J., Särkelä, H., & Nyman, G. (2006, September). The impact of the display type and content to a game adaptation. In *Proceedings of the 8th* *conference on Human-Computer Interaction with Mobile Devices and Services* (pp. 17-20). ACM.

Tamborini, R., & Bowman, N. D. (2010). Presence in video games. In Bracken, C.C. & Skalski, P. (Eds.) *Immersed in media: Telepresence in everyday life*, 87-109.

Tamborini, R., & Skalski, P. (2006). The role of presence in the experience of electronic games. In Vorderer, P. & Bryant, J. (Eds.) *Playing video games: Motives, responses, and consequences*, 225-240.

Torii, M., Okada, Y., Ukai, K., Wolffsohn, J. S., & Gilmartin, B. (2008). Dynamic measurement of accommodative responses while viewing stereoscopic images. *Journal of Modern Optics*, *55*(4-5), 557-567.

Welch, R. B., Blackmon, T. T., Liu, A., Mellers, B. A., & Stark, L. W. (1996). The effects of pictorial realism, delay of visual feedback, and observer interactivity on the subjective sense of presence. *Presence: Teleoperators and Virtual Environments*, *5*(3), 263-273.

Williams, K. D. (2013). The Effects of Video Game Controls on Hostility, Identification, and Presence. *Mass Communication and Society*, *16*(1), 26-48.

Wilson, D. B. (2001). *Practical meta-analysis* (Vol. 49). Sage.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and virtual environments*, *7*(3), 225-240.

TABLE 1
Descriptive Summary of Sample Studies

Independent Variable and Study	*Date*	*r*	*N*	*Presence Measurement*	*Location*	*Domain*	*Additional Notes*
Update Rate							
Barfield & Hendrix	1995	.395	13	Custom (6 items)	US	Engineering	5 Hz vs. 25 Hz
Gandy et al.	2010	.106	8	PQ (modified)	US	Social Science	60 fps vs. 15 fps
Snow & Williges	1998	.691	12	magnitude estimate	US	Engineering	16 Hz vs. 8 Hz
Tracking Level							
Ahn	2011	.008	101		US	Social Science	Self-move vs. other-move
Aymerich-Franch	2009	.000	56	SUS questionnaire (modified)	Australia	Social Science	body-tracking vs. joystick
Balakrishnan & Sundar	2011	.832	240	MEC-SPQ (5 select items)	US	Social Science	High vs. low steering control
Broek	2008	.318	180	SAM presence scale	Netherlands	Social Science	Active vs. passive
Bystrom & Barfield	1999	-.271	20	Custom (based on Barfield & Hendrix)	US	Engineering	Head-tracking & mouse vs. neither
Fox et al.	2009	.233	69	Custom (10-item composite)	US	Social Science	Change vs. no-change in avatar
Hendrix & Barfield (Exp. 2)	1996	.425	12	Custom (2 items)	US	Engineering	Head-tracking vs. none
Kim & Sundar	2013	.932	80	ITC-SOPI (spatial presence subscale)	Korea	Social Science	gun replica controller vs. traditional controller
Lee & Chung	2013	.464	64	Custom (spatial involvement subscale)	Korea	Social Science	PS Move (motion tracking) vs. PS3 controller
McGloin et al.	2011	.138	195	Perceived Spatial Presence (based on Skalski et al., 2011)	US	Social Science	Wiimote (motion tracking) vs. PS3 controller
Nordahl	2005	.566	19	SVUP (Presence items only)	Denmark	Engineering	Hear own footsteps vs. no audio
Regenbrecht & Schubert	2002	.320	56	IPQ	Germany	Social Science	Move freely vs. watched prerecorded sequence
Seay et al.	2001	.266	156	PQ	US	Engineering	Driving vs. watching
Snow & Williges	1998	.750	12	magnitude estimate	US	Engineering	headtracking vs. none
Welch et al.	1996	.651	20	Custom (100-point scale comparison)	US	Engineering	Active vs. passive exposure
Williams	2013	.154	72	Based on Lee et al. (2005) questionnaire	US	Social Science	Wiimote + nunchuk vs. traditional controller
Display Type							
Lott et al.	2003	-.239	18	PQ	Canada	Engineering	HMD vs. flat screen

Takatalo et al.	2006	.249	120	PIFF² (physical presence subscale)	Finland	Social Science	Near-eye display vs. external monitor
Field of View							
Bracken & Botta	2002	-.059	291	Custom	US	Social Science	65-inch vs. 32-inch screen
De Kort et al.	2006	.119	80	ITC-SOPI (spatial presence subscale)	Netherlands	Social Science	35° vs. 15°
Hendrix & Barfield (Exp. 3)	1996	.697	12	Custom (2 items)	US	Engineering	GFOV (90 vs. 10)
Hou et al.	2012	.322	30	4 items based on Kim & Biocca's (1997) Physical Presence scale	US	Social Science	81' screen (76°) vs. 12' screen (18°)
IJsselsteijn et al.	2001	.305	24	Visual analog rating scale	UK	Engineering	50° vs. 28° (resolution and distance kept identical)
Kim & Sundar	2013	.976	80	ITC-SOPI (spatial presence subscale)	Korea	Social Science	42" vs. 27" monitor
Lombard et al.	2000	.198	65	Custom	US	Social Science	46-inch vs. 12-inch screen (resolution and distance kept identical)
Prothero & Hoffman	1995	.243	38	Custom (5-item composite)	US	Engineering	unmasked screen (105°) vs. visual scene masking (60°)
Schlindwein et al.	2013	.269	30	SUS	Brazil	Engineering	50° vs. 20°
Seay et al.	2001	.296	156	PQ	US	Engineering	180° vs. 60°
Shim & Kim	2003	.256	23	PQ (modified)	Korea	Engineering	180° vs. 120°
Snow & Williges	1998	.992	12	magnitude estimate	US	Engineering	High (48x36) vs. Low (24x18)
Image Quality							
Bracken & Botta	2002	.085	291	Custom	US	Social Science	High vs. standard definition
Bracken & Skalski	2009	.305	50	Lombard & Ditton (2000) 3-item questionnaire	US	Social Science	High vs. standard definition
Bracken	2005	.211	95	Lombard & Ditton (2000) 3-item questionnaire	US	Social Science	High vs. standard definition
Çiflikli et al.	2010	.530	20	PQ	Turkey	Engineering	High vs. low flickering
Dinh et al.	1999	-.003	256	Custom (100-point scale and 13-item composite)	US	Engineering	localized lighting & high res. textures vs. ambient lighting & lower res. textures
Skalski & Whitbred	2010	.121	74	TPI (spatial presence subscale)	US	Social Science	High vs. standard definition
Snow & Williges (Exp. 2)	1998	.336	12	magnitude estimate	US	Engineering	Texture mapping on vs. off
Snow & Williges (Exp. 3)	1998	.156	12	magnitude estimate	US	Engineering	High vs. low environmental detail
Welch et al.	1996	.808	20	Custom (100-point scale comparison)	US	Engineering	High vs. low pictorial realism

Stereoscopy							
Baños et al.	2008	-.076	40	ITC-SOPI (spatial presence subscale); SUS	Spain	Social Science	Stereoscopic vs. monoscopic
Freeman et al.	2000	.652	24	Visual analog rating scale	UK	Social Science	Stereoscopic vs. monoscopic
Hendrix & Barfield (Exp. 1)	1996	.377	12	Custom (2 items)	US	Engineering	Stereoscopic vs. monoscopic
IJsselsteijn et al.	2001	.478	24	Visual analog rating scale	UK	Engineering	Stereoscopic vs. monoscopic
Ling et al.	2012	.078	88	IPQ; SUS	Netherlands	Engineering	Stereoscopic vs. monoscopic
Muhlbach et al.	1995	.103	32	Custom (4 spatial presence items)	Germany	Engineering	Stereoscopic vs. monoscopic
Rajae-Joordens et al.	2005	.532	20	Presence and Engagement Questionnaire (Häkkinen et al., 2004)	Netherlands	Engineering	3D vs. 2D game mode
Schlindwein et al.	2013	.225	33	SUS	Brazil	Engineering	Stereoscopic vs. monoscopic
Snow & Williges	1998	.378	12	magnitude estimate	US	Engineering	Stereoscopic vs. monoscopic
Takatalo et al.	2011	.041	60	PIFF^2 (physical presence subscale)	Finland	Social Science	High stereo vs. 2D mono
Sound							
André et al.	2012	-.212	22	TPI (spatial presence subscale)		Engineering	Wave field synthesis vs. stereo
Dinh et al.	1999	.273	256	Custom (100-point scale and 13-item composite)	US	Engineering	Ambient vs. no ambient sound
Hendrix & Barfield (Exp. 1)	1996b	.322	16	Custom (2 items)	US	Engineering	Spatialized sound vs. no sound
Hendrix & Barfield (Exp. 2)	1996b	.468	16	Custom (2 items)	US	Engineering	Spatialized vs. non-spatialized sound
Jeong et al.	2008	.007	80	ITC-SOPI (physical presence subscale)	US	Social Science	Screams vs. no screams
Jeong et al.	2009	.158	60	ITC-SOPI (physical presence subscale)	US	Social Science	Screams vs. no screams
Larsson et al.	2007	.790	30	SVUP (presence subscale); Custom (100-point scale)	Sweden	Engineering	Sound vs. no sound
Poeschl et al.	2013	.366	66	SUS	Germany	Engineering	Spatialized sound vs. no sound
Skalski & Whitbred	2010	.304	74	TPI (spatial presence subscale)	US	Social Science	5.1 (surround) vs. 2 channel (Dolby stereo)
Snow & Williges	1998	.833	12	magnitude estimate	US	Engineering	Sound on vs. off
User Perspective							
Kallinen et al.	2007	.172	50	MEC-SPQ	Sweden	Engineering	1st vs. 3rd person video game views
High vs. Low Immersion							
Ahn	2011	.167	101	ITC-SOPI (11 items)	US	Social Science	HMD w/ tracking vs. desktop

Axelsson et al.	2001	.633	44	Custom (3 items)	Sweden	Social Science	CAVE-type system vs. desktop
Baños et al.	2004	.013	40	ITC-SOPI (spatial presence subscale)	Spain	Social Science	HMD with tracking vs. desktop
Botella et al.	1999	.207	69	Reality Judgment Questionnaire ("Sense of presence" item")	Spain	Social Science	"high impact workstation" vs. PC, lower quality HMD, lower quality graphics card, and 2D mouse
Felnhofer et al.	2013*	-.118	52	PQ	Austria	Social Science	HMD with tracking and stereo display vs. flat screen
Gamito et al.	2006	.186	69	SUS	Portugal	Social Science	HMD w/ tracking vs. translucid screen
Gorini et al.	2011	.473	84	UCL; ITC-SOPI (spatial presence subscale)	Italy	Social Science	High (HMD, motion tracker, 640x480 res) vs. Low (external monitor, 1600x1200 res)
Juan & Pérez	2009	.578	25	SUS (modified)	Spain	Engineering	CAVE vs. HMD w/ tracking
Krijn et al.	2004	.486	25	IPQ	Netherlands	Social Science	CAVE (with greater update rate and wider FOV, vs. HMD
Larsson et al.	2001	.481	32	SVUP (Presence subscale)	Sweden	Engineering	Actor(drive, headtracking, stereo, HMD) vs. Observer (projection, mono)
Lo Priore	2003	.244	12	ITC-SOPI (spatial presence subscale)	Italy	Social Science	HMD with tracking vs. flat screen w/ joystick
Morina et al.	2012	.566	43	IPQ	Netherlands	Engineering	HMD with tracking vs. projection
Peer et al.	2010	-.114	16	Custom (single item measuring Immersiveness)	Germany	Engineering	HMD (w/ head tracking) vs. Stereo Projection
Persky & Blascovich (Exp. 1)	2008	.401	62	8-item scale (from Swinth & Blascovich, 2001)	US	Social Science	IVETP vs. DTP
Persky & Blascovich (Exp. 2)	2008	.360	127	8-item scale (from Swinth & Blascovich, 2001)	US	Social Science	IVETP vs. DTP
Rand et al.(Exp. 1)	2005	-.291	80	PQ	Israel	Engineering	GX+HMD vs. GX+monitor
Sallnäs (Exp. 1)	2005	.000	40	PQ (subset)	Sweden	Social Science	audio vs. video + audio conference
Sallnäs (Exp. 2)	2005	.523	20	PQ (subset)	Sweden	Social Science	audio vs. video + audio conference

TABLE 2
Initial Meta-Analysis Results for Overall Immersion and Individual Immersive Features

Independent Variable	*K*	*r (weighted)*	*95% Confidence Interval*	*N*	*X^2*	*Variance Attributable to Sampling Error (%)*
Immersion (all studies)	82	.310	.309 to .310	5172	1663.65*	14
Update Rate	3	.534	.534 to .535	33	4.298	100
Tracking Level	17	.445	.445 to .446	1362	244.700*	6
Natural vs. abstract mapping	5	.409	.408 to .410	467	85.187*	5
“Many vs. Some”	3	.748	.747 to .749	306	21.565*	0
“Some vs. None”	10	.281	.281 to .282	645	189.786*	27
Display Type	2	.149	.148 to .150	138	61.028*	67
Field of View	12	.341	.340 to ..342	841	426.924*	4
Image Quality	9	.157	.156 to .157	830	245.337*	36
Stereoscopy	10	.225	.224 to .226	345	162.400*	59
Sound	10	.293	.292 to .293	632	185.334*	25
User Perspective	1	.172	.171 to .173	50	N/A	N/A
High vs. Low	18	.269	.269 to .270	941	309.076*	44

* $p < .001$.

TABLE 3
Comparison of Differences in Effect Sizes for Individual Immersive Features

	Update Rate	Tracking Level	Display Type	Field of View	Image Quality	Stereoscopy	Sound	User Perspective	High vs. Low
Update Rate *r = .534, N = 33*	—								
Tracking Level *r = .445, N =1362*	-.64	—							
Display Type *r = .149, N = 138*	-2.21**	-3.63***	—						
Field of View *r = .341, N =841*	-1.30	-2.79**	2.21**	—					
Image Quality *r =.157, N =830*	-2.36**	-7.25***	.09	-4.02***	—				
Stereoscopy *r = .221, N = 345*	-1.93*	-4.11***	.78	-1.97**	1.10	—			
Sound *r = .293, N = 632*	-1.58	-3.66***	1.60	-1.02	2.71**	1.08	—		
User Perspective *r = .172, N = 50*	-1.81*	-2.05**	.14	-1.21	.10	-.36	-.85	—	
High vs. Low *r = .269, N = 941*	-1.73*	-4.76***	1.37	-1.67*	2.47**	.74	-.50	.68	—

* $p < .1$
** $p < .05$
*** $p < .001$

Formal comparison of the extent to which the effect sizes of given immersive features are significantly different are listed above. Each value represents a *Z* score computed using the correlation coefficient and sample size of each feature. The effect of tracking level is significantly greater than that of all other features with the exception of update rate. The effect of update rate is generally stronger than most, though it is derived from a very small sample of 3 studies. Field of view provides a larger effect than all features other than tracking level, update rate, and user perspective (the latter of which is also based on a particularly small sample). Finally, the effect of image quality is seen to be significantly lower than that of most other immersive features, including tracking level, update rate, field of view, sound, and high vs. low manipulations of overall immersiveness.

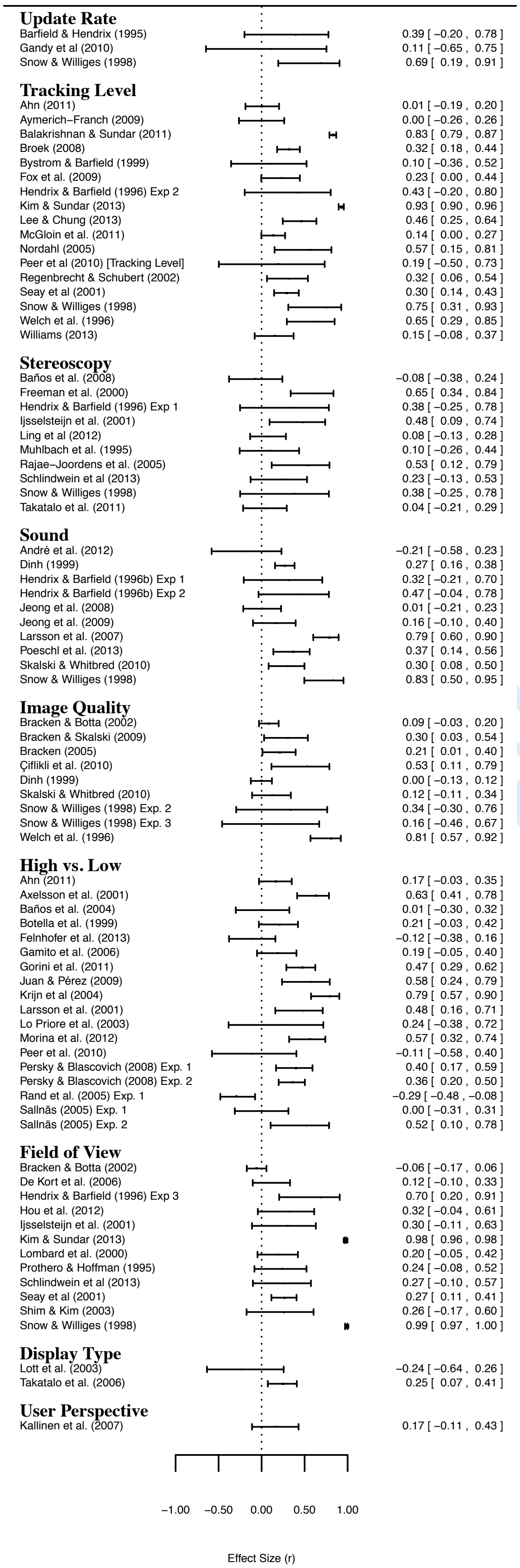

Figure 1. Forest plot displaying effect sizes and 95% confidence intervals of the influence of immersion on user presence. Studies are clustered by type of immersive feature manipulated. Effect sizes and their respective confidence intervals are represented by squares and bordering lines. Effect sizes to the right of the dotted line are positive.