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Perception while watching movies: Effects of physical screen size and scene type

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Abstract. Over the last decade, television screens and display monitors have increased in size considerably, but has this improved our televisual experience? Our working hypothesis was that the audiences adopt a general strategy that "bigger is better." However, as our visual perceptions do not tap directly into basic retinal image properties such as retinal image size (C. A. Burbeck, 1987), we wondered whether object size itself might be an important factor. To test this, we needed a task that would tap into the subjective experiences of participants watching a movie on different-sized displays with the same retinal subtense. Our participants used a line bisection task to self-report their level of "presence" (i.e., their involvement with the movie) at several target locations that were probed in a 45-min section of the movie "*The Good, The Bad, and The Ugly*." Measures of pupil dilation and reaction time to the probes were also obtained. In Experiment 1, we found that subjective ratings of presence increased with physical screen size, supporting our hypothesis. Face scenes also produced higher presence scores than landscape scenes for both screen sizes. In Experiment 2, reaction time and pupil dilation results showed the same trends as the presence ratings and pupil dilation correlated with presence ratings, providing some validation of the method. Overall, the results suggest that real-time measures of subjective presence might be a valuable tool for measuring audience experience for different types of (i) display and (ii) audiovisual material.

Keywords: presence, immersion, movie, pupil dilation, cinema, screen size.

1 Introduction

1.1 "Bigger is better," but what do we mean by bigger?

The recent growth in the size of visual displays for both home cinema and the working environment (e.g., Robertson et al., 2005) suggests that the popular notion "bigger is better" is correct (Silvera, Josephs, & Giesler, 2002). But is it? Do larger displays improve our visual experience, or are manufacturers simply tapping into our belief that this must be so?

One might argue that it is obvious that larger displays are better because they will produce larger retinal images, but there are several problems with this argument. First, it might be that people view larger displays from greater distances, thereby negating the retinal image effects. Second, one might apply a counter argument that by expanding the retinal image, much of the image detail falls outside of the fovea, whereby it suffers from the poor spatial resolution of the visual system. Third, visual illusions such as Shepard's tables suggest that our conscious visual experiences do not tap into basic retinal image properties such as retinal image size, anyways—a view supported by formal experiments using sine wave gratings (Burbeck, 1987).

The issues above prompt numerous research questions, many of which are beyond the scope of the present study. Here, we limit ourselves to investigating the effects of display size while keeping retinal image size (visual angle) constant. With this approach, we can be sure that any experimental

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effects that we find can be attributed to the perception of object size and are not an effect (spurious or otherwise) of varying the number of retinal receptors involved.

Given the commercial popularity of large screen displays, one would expect to find a large body of research on this topic; however, it appears that rather little properly controlled research has been done. A promising start was made by Hatada, Sakata, and Kusaka (1980), who found that subjective reports of the "sensation of reality" increased with the physical size of a display both when visual angle covaried with the display size and when it was fixed. However, in that study, it appears that luminance covaried with projection area and that might have influenced the subjective ratings. Similarly, Tan (2004) confirmed the benefits of physically larger displays with fixed retinal image size for several performance tasks. Tan (2004) also recognized the need to control for possible luminance effects. However, this was done by adjusting the luminance of each display according to subjective criteria and so it is not possible to rule out luminance differences as a factor in that study. Here, we solved this problem by using the zoom lens of a projector to control display size and decreased the luminance in our "small" condition using a neutral density filter to scale the luminance in proportion to the change in size.

1.2 "Bigger is better," but what do we mean by better?

In visual psychophysics, the term "better" usually pertains to an improvement in performance in a visual task. This type of approach was used by Tan (2004) as shown above, but in that study, the interest was in the use of visual displays as part of the man–machine interface, where task performance measures are central to the investigation (Robertson et al., 2005). In contrast, our interest in the study here was with the depth of engagement that audiences have with audiovisual imagery. The concept of "presence" (Lombard & Ditton, 1997; Wirth et al., 2007) has been developed in the computer graphics literature as a way to describe this (Sheridan, 1992, 1994). High levels of presence mean that in some sense, perceivers feel that they are "in the situation" being depicted, whereas low levels of presence indicate that perceivers feel they are merely observing events unfolding on a display. Aiming to achieve high levels of presence has been important in virtual reality, in virtual worlds, and in gaming (e.g., Biocca, 1997; Skalski, Tamborini, Shelton, Buncher, & Lindmark, 2011). Therefore, in the study here, we might say that the movie experience is "better" if participants experience greater presence.

One of the difficulties in measuring presence is that it is usually assessed by questionnaire after the viewing experience has finished (e.g., Skalski et al., 2011). This means that the information needs to be held in memory for a considerable period before a response is made and that moment-to-moment variations in presence during the viewing experience cannot readily be determined (Slater, 2004). Instead, we wanted to measure presence in real-time, with the ultimate goal (which we only edge toward here) of understanding the factors that cause presence to wax and wane throughout the televisual experience. We did this using a line bisection task (Ijsselstein, de Ridder, Freeman, Avons, & Bowhuis, 2001) where participants were prompted to provide a series of marks to indicate their level of presence in the movie (see Methods section for details).

1.3 Corroborative measures

One of the arguments leveled against presence ratings is their inherent subjectivity. For example, the experimenter cannot know for sure that the response marks on the gauge lines are true measures of presence. It is possible that not knowing what "presence" is, or how to gauge it, participants would respond in whatever other way they could. To try and deal with this, indirect measures have been developed that might be expected to relate to presence. One possibility is to measure the process of looking during the testing period (Hirose, Kennedy, & Tatler, 2010). Such measures give us an important insight into the uptake of visual information, but they are less revealing about the perceptual consequences of the patterns of eye movements and it is not clear that how these could be related to the subjective responses of the participants. Physiological measures, such as skin conductance, electroencephalogram (EEG), and pupil dilation (Kahneman, 1973), are probably more profitable because there is a possibility that these one-dimensional measures might map onto our one-dimensional presence ratings. Furthermore, pupil dilation has been used previously to evaluate perceptual load in visual tasks (Porter, Troscianko, & Gilchrist, 2007). Another possibility is to measure reaction time (RT). This is commonly used to indicate the degree of difficulty in exiting from the current process to make a response. So in our case, we might expect RTs to be longer when participants are more deeply involved (more present) with the audiovisual material. Therefore, in addition to our presence scores, we also measured RTs and pupil dilation.

1.4 Choice of audiovisual material

We have already mentioned that we are interested in measuring responses to movies, but why? There are several reasons for this. Our initial interest was with how effectively audiovisual displays can invoke presence. But a problem with many of the studies on presence is that they are not very good at generating high levels of presence—viewing a depiction of a student's study in virtual reality (VR) goggles is unlikely to set the pulse racing (e.g., Jurnet, Beciu, & Maldanado, 2005). This is a paradox of presence research and is presumably a consequence of the fact that cognitive scientists who design the experiments are not necessarily skilful at making displays that are interesting to watch. Instead, our approach was to use audiovisual material that is known to achieve high levels of presence, precisely because that is what it was produced for. Movies fit the bill, and much is known about their composition (Cutting, DeLong, & Brunwick, 2011; Cutting, DeLong, & Nothelefer, 2010; Mital, Smith, Hill, & Henderson, 2011; Smith, 2010). They consist of a coherent narrative divided into visual shots that have durations in the order of several seconds. The soundtrack usually "glues" the visually disparate shots, together forming a whole, which keeps the perceiver engaged. Clearly, movies are familiar stimuli and ones that can provide an enjoyable experience. Although there is a wealth of cinemetric data about their composition (e.g., Cutting et al., 2010; Cutting et al., 2011; Salt, 1992), there is much less work on the effects that movies have on the viewer (e.g., Smith, Levin, & Cutting, 2012). One study has reported that momentary subjective presence ratings provide a valid measure of arousal when watching video sequences (Freeman, Avons, Pearson, & IJsselstein, 1999), suggesting that this technique holds promise for the task of assessing the effect of viewing parameters. IJsselstein et al. (2001) studied the level of subjective presence when viewing a 100-s movie filmed from the bonnet (hood) of a moving rally car and obtained measures of presence immediately after viewing. They found a significant effect of a combined variation in retinal image size and display size.

Neither of the studies above used a full-length feature film as a stimulus but showing a movie presents difficulties. The viewing experience is likely to be much altered if the movie has been seen before, so a possible solution is to show an old, obscure movie. However, fashions in movies change and so an old movie may not produce high values of presence in a modern audience. A potential solution to this problem presented itself with the work of Hasson, Nir, Levy, Furmann, & Malach (2004). Their experiment involved presenting participants with the movie "*The Good, The Bad, and The Ugly*" (Leone, 1966) while measuring cerebral blood flow using fMRI. A correlational analysis identified those portions of the movie that led to a high activation in the same brain area across participants. Thus, for example, scenes depicting faces led to a strong activation of the "face area" in the fusiform gyrus (FFA) and scenes related to navigation around landscapes and buildings activated the parahippocampal place area (PPA). The results of this study therefore allowed us to identify scenes that lead to high levels of activation of particular brain areas with the hope that this would be relevant to our presence task.

Hasson et al. (2004) showed the first 45 mins of the movie to their audience, so we decided to do the same. We chose 16 moments in the film that coincided with the highest degrees of activation of either the FFA or the PPA regions reported by Hasson et al. (2004) and arranged for auditory and/or visual cues to prompt participants to estimate their subjective presence at those moments. We were thus able to present a complex, dynamic, multimodal stimulus while at the same time, being confident that the probed moments produced particular patterns of cortical neural excitation. Finally, this approach also introduced "scene type" as an additional factor into our experiment. We had no specific hypothesis about whether faces or landscapes would produce the higher presence scores, but previous work hints that this might be an important factor (Cutting et al., 2010; Cutting et al., 2011; Hasson et al., 2004; Magliano & Zacks, 2011; Mantovani, 1995).

2 Overview

Several of the studies reviewed above (Freeman et al., 1999; Hatada et al., 1980; IJsselstein et al., 2001; Tan, 2004) suggest that presence might be a valuable measure and that we might expect to find effects of screen size, but these issues are not yet decided. Advancing them is important though because if we were to find that large screen displays produce greater levels of presence, then this might go some way toward explaining the current popularity of large screen televisions. Therefore, the aim of these experiments was to find out whether the presence (i.e., immersion) can be estimated by participants on a moment-to-moment basis and whether presence depends on (a) the type of scene being viewed in the movie and (b) the physical size of the display. To reiterate, we chose to study the effect of physical size while keeping the retinal size constant, because it could easily be argued that a larger retinal angle stimulates more retinal receptors. In that case, greater presence scores might be associated with this larger neural signature, whether consciously recognized or not. Keeping the retinal size of the screen constant therefore provides a more conservative measure of the effect of physical screen size. Our hypothesis was that the larger physical display would nonetheless invoke a greater sense of presence owing to the high-level influences from the general belief that bigger is better, or more engaging (Silvera et al., 2002). We tested this hypothesis in Experiment 1. In Experiment 2, we extended the study to include measures of RT and pupil dilation.

We should also consider the design of the experiment. A repeated-measures design appears the simplest. However, we were concerned that watching the same movie more than once would diminish the immersive effects that we were trying to measure. A between-subjects design avoids this problem and has the additional benefit that participants are kept blind to the screen size variable.

Our study here is preliminary, but its outcome suggests that our general technique (on-line assessment of presence using a line bisection task) could also be used to study the psychological effects of other display variables such as color, stereo depth, compression technique, and so forth.

3 Experiment 1: Screen size and presence

3.1 Methods

Forty participants took part. The design was between-subjects, so there were 20 participants in the “big” screen condition (13F, 7M, age range 20–34 years, $M = 21.55$, $SD = 2.98$) and 20 in the “small” screen condition, (13F, 7M, age range 20–23 years, $M = 20.95$, $SD = 0.87$). Participants were tested individually. None of the participants had seen the movie before, and informal discussions after the experiment indicated that they found the movie gripping and not dated (partly because it is a costume drama).

The movie was projected onto a screen using a Sony video projector (model CX20 XGA) with a resolution of 1,024 (h) by 768 (*v*) pixels. In both conditions, the image subtended 32.9° angle (h) by 24.7° angle (*v*). This was achieved by having two sizes of screen and two viewing distances. In the “big condition, the viewing distance was 2.61 m and the physical image size was 1.5 m 3 1.125 m. In the “small condition, the viewing distance was 1.55 m and the physical image size was 0.89 m 3 0.668 m.

The image size was adjusted using the zoom control on the projector lens. The local luminance of the “small” condition was reduced to that of the “big” condition by the insertion of a 0.5 log unit neutral density filter (metal-coated glass, made by Optical Electrical Coatings, Totnes, Devon). The mean luminance in both conditions was 13 cd/m^2.

The presence ratings were obtained by illuminating a bright LED above the screen for 1 s; participants used a pen to bisect a black line presented one per page in a response book to indicate their level of presence immediately after the light went on. Each line was 9.8 cm in length. The instructions to each participant were as follows:

You should make a mark on the line to indicate how “present” you feel in the movie just before the light came on. If you feel completely “in the story,” then your mark should be at the far right of the line. If you feel that you are viewing the movie, then place your mark on the far left of the line.

Participants were asked whether these instructions required clarification. None asked for further clarification.

The first 45 mins of the film “*The Good, The Bad, and The Ugly*” were shown to each participant. Sound was provided by small loudspeakers set to a constant, comfortable listening level.

Presence ratings were obtained at a total of 16 points in time identified by Hasson et al. (2004) as giving maximal activation of the “face” FFA area (8 points) and the “place” PPA area (8 points). The “face” probe points were at the following times in the movie (measured from the start): 189070, 219320, 279200, 289570, 309330, 319280, 329240, and 429420. The “place” probe points were at the following points in the movie: 229240, 249090, 259150, 269330, 299090, 309560, 319280, and 339060. The face scenes contained close-ups of faces in a mix of indoor and outdoor scenes, some well-lit and some dimly lit. The landscape scenes were mainly long shots, and informal observation suggested that like the face scenes, they were similarly mixed in terms of their range of contrast and luminance. (We address this formally in the analysis of Experiment 2.) The line bisections in the booklets were measured by a single experimenter using a ruler and converted into percentage of the total line length giving the presence rating per subject.

3.2 Results: bigger is "better" for faces and for landscapes

We had no particular hypothesis about the face and landscape results but chose to analyze them separately to see if the presence ratings varied across these very different stimuli. Figure 1 shows these ratings for the "face" and "place" conditions across the two different screen sizes.

A two-factor mixed ANOVA showed a main effect of screen size ($F(1, 38) = 30.49$, $p < .001$) and a main effect of scene type [$F(1, 38) = 19.31$, $p < .001$]. Presence ratings increased with screen size for faces ($M = 66.02$, $SD = 3.19$ vs. $M = 47.76$, $SD = 5.36$) and for landscapes ($M = 60.48$, $SD = 3.19$ vs. $M = 39.66$, $SD = 3.53$), and face scenes produced higher presence ratings than landscape scenes. There was no significant interaction ($F(1, 38) = 0.68$, $p = .42$). Notably, the subjective benefit (in terms of presence rating) of increasing the screen size was approximately the same for both types of scene.

4 Experiment 2: Presence, reaction times, and pupil dilation

4.1 Introduction

The main aim of our second experiment was to introduce the measures of RT and pupil size and to investigate whether these correlated with the presence scores.

4.2 Methods

Thirty participants took part with 15 participants in the "big" screen condition (11F, 4M, aged 19–23, $M = 20.73$, $SD = 1.1$) and 15 in the "small" screen condition, (10F, 5M, aged 20–24, $M = 20.93$, $SD = 1.1$). Participants were tested individually. None of the participants had seen the movie before.

The methods while viewing the movie were similar to those of Experiment 1, with the same viewing distances, angles, luminance levels, and video projector. The aim was to repeat Experiment 1 while obtaining data on the size of the pupil and RT to an auditory beep. Reaction time was measured using a timed button press signaled by an auditory beep that replaced the light-emitting diode (LED) from the previous experiment. Instead of playing the sound through loudspeakers, small portable headphones

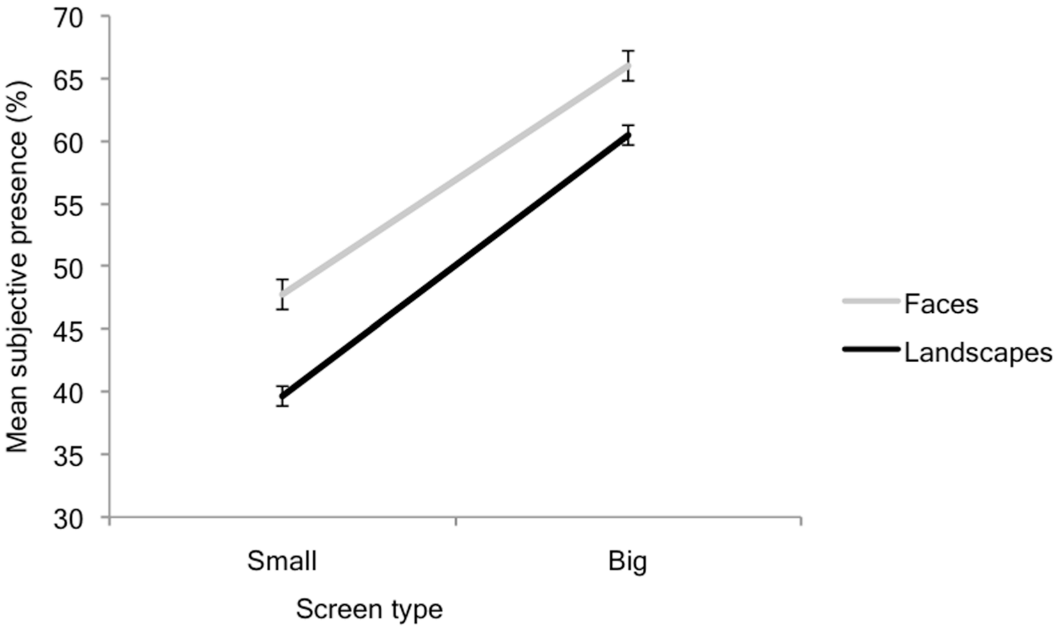

Figure 1. Mean presence scores from Experiment 1. Error bars show ±1SE.

were used at a comfortable listening level, which was kept constant throughout the experiment. The presence rating was made immediately after the RT task.

The pupilometer was a custom-built model, described in greater detail in Porter et al. (2007). It used infrared illumination to sample the image of each eye at 50 Hz and used software to identify the pupil in each frame and deliver a value of the pupil diameter. The stimulus beeps were recorded on one data channel, allowing synchronization between the recorded pupil data and the movie. Baseline pupil diameter was obtained while viewing a gray blank screen at mean luminance before and after the 30-min recording period, for each participant. Pupil data were cleaned of blinks in the way described by Porter et al. (2007), by removing data differing by more than two standard deviations (plus four nearest frames) and filling the gap with linearly interpolated values. This was done for each eye separately, and the eye with fewer missing data was used for the analysis. The data for each trial consisted of the pupil diameter for 2 s before the onset of the beep. The reported pupil diameter was the difference between the diameter before each beep and the mean baseline value.

Presence ratings were obtained in exactly the same way as in Experiment 1.

4.3 Results: faces are more important than landscapes

Figure 2 shows the mean rated presence scores from Experiment 2. Although the trend was identical to that from Experiment 1, a two-factor mixed ANOVA showed that the screen size effect was not significant ($F(1, 28) = 1.644$, $p = .21$) for either faces ($M = 55.25$, $SD = 6.96$ vs. $M = 50.18$, $SD = 5.05$) or landscapes ($M = 51.73$, $SD = 3.43$ vs. $M = 47.07$, $SD = 5.92$), but that there was a highly significant main effect of scene type ($F(1, 28) = 7.320$, $p = .01$). In addition, there was no significant interaction between scene type and screen type ($F(1, 28) = 0.027$, $p = .870$). The failure to replicate the size effect from Experiment 1 was surprising, and we will return to this in the General Discussion section. The presence ratings were lower in the second experiment (in the "big" condition the mean from Experiment 1 was 63.63 ($SD = 10.96$) whereas it dropped to 53.49 ($SD = 10.00$) in Experiment 2; ($F(1, 26) = 29.78$, $p < .01$).

Figure 3 shows the mean RT results. A mixed ANOVA showed a significant effect of scene type (faces vs. landscapes; $F(1, 28) = 7.221$, $p = .012$) for the "big" screen condition ($M = 1.735$, $SD = 0.19$ vs. 1.66, $SD = 0.14$) and the "small" screen condition ($M = 1.65$, $SD = 0.16$ vs. $M = 1.58$, $SD = 0.07$). The effect of screen size was not significant ($F(1, 28) = 0.561$, $p = .561$) and there was no significant interaction between scene type and screen size ($F(1, 28) = 0.096$, $p = .934$).

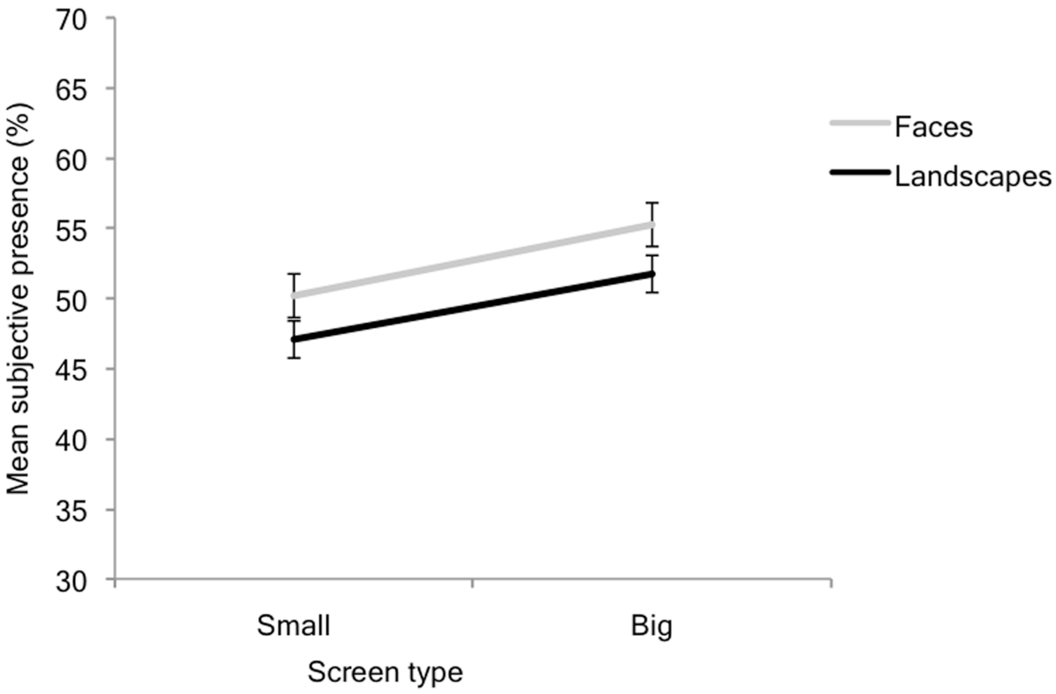

Figure 2. Mean presence scores from Experiment 2. Error bars show ±1SE.

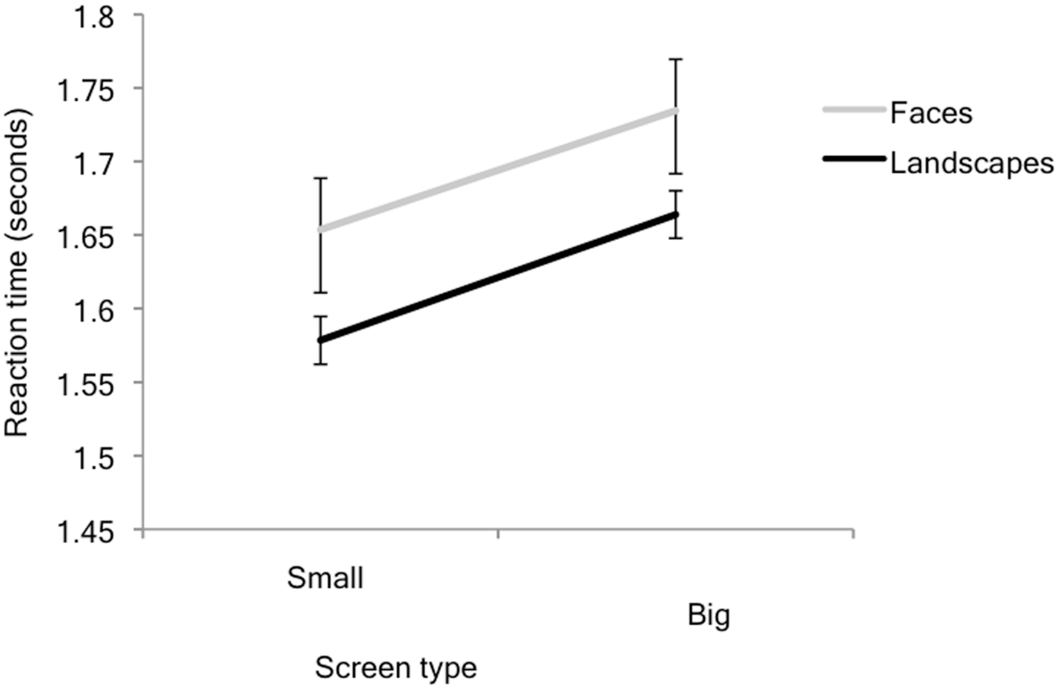

Figure 3. Mean reaction time results from Experiment 2. Error bars show ±1SE.

Figure 4 shows the pupil dilation results. There was a highly significant main effect of scene type (*F*(1, 28) = 20.538, *p* < .001)) with face scenes resulting in a larger pupil than landscape scenes for the “small” screen condition (*M* = 0.25 mm, *SD* = 0.54 vs. *M* = 0.03 mm, *SD* = 0.54) and for the “big” screen condition (*M* = 0.34, *SD* = 0.56 vs. *M* = 0.16. *SD* = 0.60). The main effect of screen size was not significant (*F*(1, 28) = 1.036, *p* = .318), and there was no significant interaction between scene type and screen size (*F*(1, 28) = 0.205, *p* = .318).

The analyses above provide a compelling case that in some sense, our participants found that the face scenes are more important than the landscape scenes: the presence scores were higher, RTs were slower (implying that the faces were more engaging), and pupil dilation was greater. As one of the primary motivating factors behind this study was our interest in presence, we wondered whether presence correlated with either of the other measures, as the general trend of our results implies. There was no significant correlation between RT and presence, *r*(28) = .252, *p* = .195; two-tailed, but the correlation between the presence scores and pupil dilation (Figure 5) was highly significant (*r*(28) = .488, *p* = .008; two-tailed).

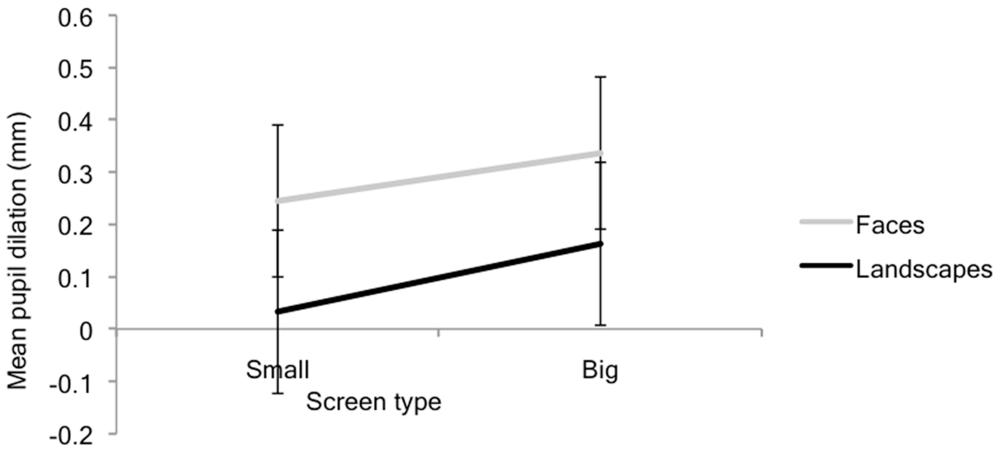

Figure 4. Mean pupil dilations from Experiment 2. Results are compared with pre-film baselines. Error bars show ±1SE.

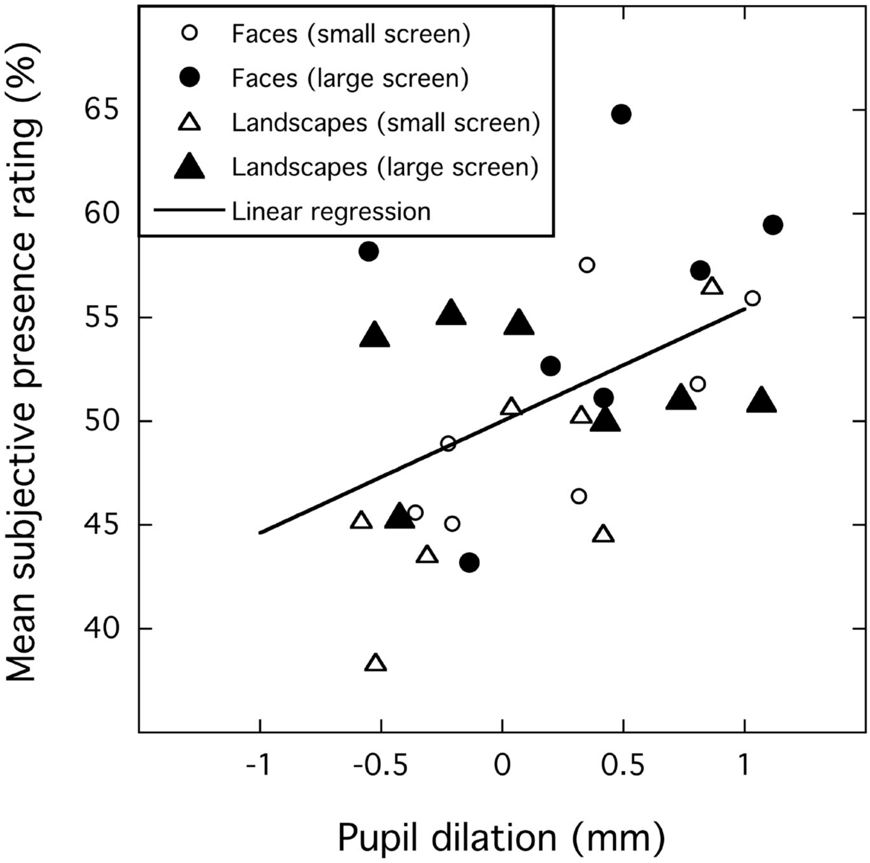

Figure 5. Subjective presence response (%) vs. pupil dilation (mm) for the results from Experiment 2. The solid line is the result of linear regression and has a slope of 5.4.

However, we were concerned about a possible intervening variable in the analysis above. It is possible that the dilation effects were related to the luminance levels at the relevant points in the movie and that this might be responsible for the correlation with the presence scores. We used a photometer (Minolta CS-100) to measure the relation between pixel value and luminance for each of the three color channels and from this we established the average luminance in a 30-s window prior to each probe point in the experiment (i.e., we computed the average luminance over space and time in the 30-s window for each test scene). We found that this did correlate with pupil diameter and was highly significant ($r(28) = .848$, $p < .001$: two-tailed). We then removed the complicating factor of luminance by conducting a partial correlation between presence scores and pupil dilation. This was highly significant ($r(28) = .505$, $p = .007$; two-tailed) and provides a formal confirmation of a link between our subjective measure of presence and the objective measure of pupil size.

4.4 Comparison with results from Experiment 1

Some aspects of the presence ratings were in reasonably close agreement with those from the first experiment: faces were rated higher than landscapes and there was no hint of an interaction between scene type and screen size (the lines in Figure 2 are nearly parallel). The reaction time and pupil dilation results were qualitatively similar to each other—hinting at the possibility of common underlying processes—although to our surprise, there was no significant effect of screen size for presence, pupil dilation, or RT, even though all three sets of results were in the same direction as the screen size effect from Experiment 1.

5 General discussion

One of our main aims was to find out whether we could use a simple measure of presence to learn about our subjective experiences while we are watching a movie. We concentrated on studying the effects of two independent variables: screen size and scene type. Both of these could reasonably be expected to affect the degree of immersion in a movie. This is exactly what we found in Experiment 1: Subjective presence was greater for face scenes than for landscapes and it increased with screen size when retinal angle, resolution, and local luminance were kept constant. We discuss possible explanations for this below, but first we address the failure to replicate the screen size effect in Experiment 2. As noted above, the presence ratings were lower overall in the second experiment than in the first. In the first experiment, the only task was to use a pen to write marks on a line to indicate subjective presence when prompted by an LED. In the second experiment, the LED prompt was replaced by an auditory beep, participants wore head-mounted eye-tracking equipment and headphones and they also performed an RT task. It is possible that these differences led to greater levels of distraction in the second experiment, putting a ceiling on the level of immersion that was available to the participants. Whether, these, individual differences between our participant groups, the smaller group sizes, or some combination of these and possibly other factors are responsible for the loss of the size effect in Experiment 2 is not clear. Therefore, we advise that the following discussion of the size effect be treated with some caution.

5.1 Why do presence ratings increase with screen size?

If we had varied visual angle as well as or instead of screen size, then one might argue that we should expect presence to increase as the display approaches the size of the visual field, since as the projection of the movie would dominate the visual input. In that case, it is easy to see that one might feel "in the movie." However, for the screen size variable, we chose to keep the angular subtense of the screen constant, varying only the physical size of the screen. This approach was conservative: if we were to find an effect of screen size, it could not be due to a greater spread of activation from the bottom-up drive of retinotopic mechanisms but must involve more complex higher level processes. This is exactly what we found in Experiment 1, suggesting that our perception of screen (object) size itself influences our involvement with the movie. Thus, a high-level account of these results might posit that larger displays are generally more impressive and therefore more engaging. Of course, it should come as no surprise that object size is an important visual measure. After all, it is not retinal images but the properties of distal stimuli that we are rightly interested in, and our perceptions of these are derived from the influences of various perceptual constancies, including size constancy. Evidence from fMRI (Murray, Boyaci, & Kersten, 2006) has shown that the spread of activation across the retinotopic V1 increases with an increase in perceived size, even when retinal size is constant. Exactly why this occurs is still not clear (e.g., it could involve effects of attention (Moradi, Buracas, & Buxton, 2012) or adjustments to contrast gain control (DeAngelis, Anzai, Ohzawa, & Freeman, 1995)) but it does show that the perception of physical object size, traditionally associated with high-level processes, can assert its influence at the very earliest stages of cortical visual processing, presumably through feedback. Thus, a more mechanistic account of our results might appeal to the greater engagement of the neuronal substrate that might be produced by physically larger objects.

5.2 Why do faces produce higher ratings of presence than landscapes and what do presence ratings measure?

We found a scene-type effect for presence ratings in Experiment 1 and for all three of our measures (presence, RT, and pupil dilation) in Experiment 2. Although we had no initial hypothesis for why this might be so, a plausible account is that the face scenes invited social engagement from our participants. However, whether our presence ratings were misdirected to this cue, or whether the putative prime for social engagement had a genuine influence on presence, is not clear. In fact, this highlights the general difficulty of using subjective measures in experiments of this kind: it is possible that shifts in the demand characteristics of the task mean that what is measured is not what the experiment was intended to measure (IJsselstein et al., 2001). Nevertheless, the consistency of our presence results across experiments and also its positive correlation with the objective measure of pupil dilation point to its merit. (The only setbacks were the failure for the size effects to reach significance in Experiment 2 and the lack of a correlation between presence ratings and RTs; see below.) We are confident that we have tapped into a measure with consistent properties, but we cannot claim to have pinned down its precise meaning at this stage. But perhaps this is not as worrisome as it seems. Our presence measure has face validity, it correlates with a physiological measure and it seems very likely to have a strong relation with a viewer's positive reaction to the movie experience. Perhaps this is sufficient to be of value.

Another possible explanation for why faces and landscapes produced different presence ratings was suggested to us by an anonymous reviewer as follows. Most movie scenes begin and end with landscape shots whereas close-up face shots tend to be placed in the more central parts of the scene (Cutting et al., 2010; Cutting et al., 2011). Therefore, it could be that our presence scores are measuring narrative differences rather than differences in image content per se (Magliano & Zacks, 2011). Further work would be needed to disentangle these factors.

5.3 Why did reaction time not correlate with presence?

In Experiment 2, the pattern of results was the same for all three of our measures (presence, RTs, and pupil dilation) but although presence correlated with pupil dilation, it did not correlate with RT. These results might imply that our presence scores are not measuring a dimension for which processing time is relevant, but on this, we advise caution. As noted above, the presence scores were fairly low in Experiment 2 (compared with Experiment 1), but that they also have a fairly narrow spread. It is possible that the RT measure was simply not sensitive enough to tap into the small variation in presence scores that were available in Experiment 2. On this line of thinking, it would be argued that pupil dilation is a more sensitive measure than RTs. Similar findings have been reported before (Porter et al., 2007).

5.4 Online presence ratings: a method for tapping real-time movie experiences

In practical terms, our results suggest that subjective measures of presence may provide a valuable tool in assessing the user experience of various displays. Viewing a stimulus that gives high degrees of immersion, such as a movie, allows an assessment of the impact of screen parameters such as size and, perhaps, others such as color and "3D"—all of which are seeing major technological developments at the present time. Of course, the presence estimation technique also reveals a strong dependence on the content of the movie, as revealed by the scene-type effects found here. This may allow an empirical assessment of many technical aspects of movie production, such as the effects of editing and changes to the narrative content. To our knowledge, no use has been made of empirical presence data in movie production. Further work is needed to take this measure into this area, which is interesting for both scientific and practical reasons. However, we have made a start by showing that a simple technique—ratings of subjective presence by observers while watching a movie—can provide valuable information about our experience of the movie.

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