

Understanding the Effect of Diminished Reality Screen Filters

Eneas Holanda Arrais
eneasharra85@gmail.com
Simon Fraser University
Vancouver, Canada

David Lindlbauer
davidlindlbauer@cmu.edu
Carnegie Mellon University
Pittsburgh, USA

Alex Noh
alex_noh_2@sfu.ca
Simon Fraser University
Vancouver, Canada

Wolfgang Stuerzlinger
w.s@sfu.ca
Simon Fraser University
Vancouver, Canada



(a) Active screens: dynamic video content on surrounding displays creates a visually distracting environment.



(b) DR screen filters replace dynamic screen content with static alternatives.

Figure 1: DR screen filters can mediate a multi-screen environment by replacing dynamic screen content with static or aesthetic alternatives. Our study evaluates where this intervention reduces perceived distraction and where it does not.

Abstract

Screens in shared environments produce dynamic, attention-capturing stimuli that can distract users from primary activities. Diminished Reality (DR) screen filtering offers a plausible way to mediate such content by visually blocking or replacing it. However, less is known about whether this intervention reduces distraction across different task contexts. We simulated five DR screen filters (BLOCK, DIM, WALLPAPER, REPLACE, and FREEZE) in VR and evaluated them in two user studies across three task types: a 3D puzzle assembly, a Stroop color-naming task, and a structured conversation. No comparable differences in perceived distraction or task performance were detected during the visually anchored tasks (puzzle assembly, Stroop). However, the BLOCK filter significantly reduced self-reported distraction (Cohen's $d = 0.80$) during the conversation task, and qualitative interview data supported this finding. These mixed results show the bounded utility of DR screen filtering. Visual blocking helped reduce perceived distraction during conversation, but did not produce general benefits across the tasks we tested. Participants preferred static aesthetic filters, especially WALLPAPER, for single screens and used simple blackout most often in multi-screen

scenarios. They favored static over dynamic filters and valued user control over filtering.

CCS Concepts

• **Human-centered computing** → **Empirical studies in HCI**; *Virtual reality*; *Mixed / augmented reality*; *User studies*.

Keywords

Diminished Reality, Virtual Reality, Mixed Reality, Cognitive Load, Visual Clutter, Human-Computer Interaction

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1 Introduction

Digital screens in shared environments produce visual stimuli designed to capture and hold attention. In offices, cafes, and public venues, screens can become a persistent source of distraction that users cannot directly control. Diminished Reality (DR), first introduced by Steve Mann [24], offers one way to mediate such content. DR refers to altering human perception of reality by concealing, replacing, or removing real-world objects (Figure 2). Because the modification is applied within the wearer's own view, DR can suppress a shared display without changing what other people see.



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Situated within the Extended Reality (XR) spectrum, DR has often been explored for reducing visual clutter in the user’s environment.

DR has been applied across a wide range of domains, including decluttering [5], driving [21, 33], gaming [16, 34], accessibility [30, 41], and others [32, 35, 37]. Most of this work addresses technical implementation challenges. A recent systematic review found that nearly half of DR papers do not include an evaluation with users [9]. Thus, how users experience DR systems, when these interventions help, and what forms they prefer all remain largely underexplored.

Previous research has explored user perception of DR prototypes for decluttering physical environments [7] and for blocking physical advertisements in outdoor settings [15]. Dynamic screen content, screen imagery that changes over time, such as video, is a related but distinct target. Screens are prevalent in many shared spaces, produce continuously changing visual stimuli, and often present content designed to attract and sustain attention. In the specific case of dynamic screen content, it is tempting to assume that visually blocking distracting content should reduce distraction. However, less is known about whether DR screen filtering actually reduces perceived distraction and cognitive load, or improves task performance across different activities.

Yet, whether screen content actually interferes with ongoing tasks depends not only on the screen but on what the user is doing. Research in attention science has established that susceptibility to environmental distraction varies with the demands of the user’s primary task [18, 19, 23]. Tasks that continuously engage visual attention may suppress peripheral stimuli, while cognitively demanding tasks that do not engage visual attention may leave users more exposed to attentional capture. This motivates evaluating DR screen filtering across different task contexts. Visual blocking may provide little relief when the primary activity already limits processing of peripheral stimuli, and it may matter more when the activity leaves visual attention less constrained.

An initial empirical evaluation is needed to understand where DR screen filtering appears useful, where it does not, and what kinds of filters users prefer.

To investigate these questions, we simulated five DR screen filters (BLOCK, DIM, WALLPAPER, REPLACE, and FREEZE) within a VR environment and conducted two user studies across three task types: a 3D puzzle assembly, a Stroop color-naming task, and a structured conversation task. We measured task performance, perceived distraction, and cognitive load, and also gathered qualitative data on user preferences and envisioned applications.

1.1 Research Questions

Our goal is to understand how users perceive and experience DR screen filters and where this screen-mediation technique appears useful. We address two research questions:

- (1) How does DR screen filtering affect perceived distraction, cognitive load, and task performance across different task contexts?
- (2) How do users perceive different DR screen filter designs, and how do preferences shift across contexts?

Prior work on XR attentional interventions suggests that subjective experience often changes more clearly than objective task

performance [6, 8, 16, 29, 31]. We therefore treated perceived distraction and cognitive load as central outcomes, while also measuring task performance where available. We evaluated DR screen filtering across three activity contexts and compared the outcomes measured within each.

This paper makes two contributions:

- (1) An empirical evaluation of DR screen filtering for dynamic screen content across three task contexts. Participants reported lower perceived distraction with BLOCK during conversation, whereas we detected no differences in the measured puzzle or Stroop performance outcomes.
- (2) A comparison of filter evaluations. WALLPAPER received the highest mean post-training ranking, whereas BLOCK was used by the largest number of participants during the five-screen task. Participants also favored static over dynamic filters and valued control over which screens were filtered.

2 Related Work

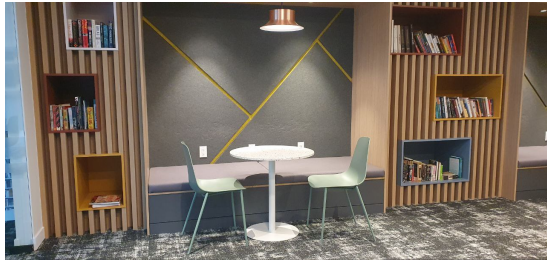
Mann [24] introduced Diminished Reality, removing or altering elements of the physical world, as a part of his mediated reality framework. To illustrate the concept, Mann described using mediated reality to suppress real-world colors while preserving highlighted elements. A refined variant rendered the physical environment behind an AR workspace in grayscale so that users remained peripherally aware of their surroundings without being distracted. Mann and Fung [25] subsequently explored an “eye-tap” device for mediating reality, extending DR to filtering offensive, sensitive, or unwanted media such as advertisements. They framed DR as a real-world parallel to web browser extensions that hide or block specific content.

Current DR systems typically involve three steps: capturing the background, detecting the region of interest (ROI), and generating a modified view. Approaches include inpainting, observation, alteration, and replacement [28].

2.1 DR for Attention and Distraction Management

Susceptibility to environmental distraction varies with the demands of the primary task. Lavie’s perceptual load theory [18, 19] proposes that when a task saturates visual processing capacity, task-irrelevant stimuli are suppressed before they can compete for attention. More recent work argues that the critical variable is not exhausted perceptual capacity itself, but the degree to which a task engages visual attention [23].

Sustained-attention tasks require continued focus on task-relevant stimuli over time. When this focus is visual, it can narrow the attentional spotlight and reduce processing of surrounding stimuli [23]. Working-memory tasks require information to be held or manipulated. When these demands do not occupy visual attention, users may have fewer resources to suppress distractors. For DR screen filtering, this literature suggests that dynamic screens may matter more in some activity contexts than others. We use this work as an interpretive lens rather than as a theory that our study directly tests.



(a) Original image.



(b) Plant added through Augmented Reality.



(c) Table and chair removed through Diminished Reality (DR).

Figure 2: Illustrations exemplifying mediated reality interventions.

McLaughlin et al. [26] conducted two VR experiments evaluating DR as a cognitive aid during a working-memory-intensive assembly task. Participants held operation names in working memory while scanning a mismatch-labeled environment and monitoring a concurrent simulated emergency. DR consistently reduced subjective workload across both novice and expert populations, though performance improvements appeared only among novices. Their work shows that DR outcomes can depend on user expertise and outcome measures in an industrial distractor environment. Our work uses a similar VR testbed methodology but examines dynamic screen content rather than industrial distractors.

Motivated by evidence that the visible presence of a phone can reduce available cognitive capacity [40], Lee and Kim [20] used a HoloLens 2 to conceal a smartphone. This restored performance on working-memory tasks but produced no benefit in a sustained-attention task. However, their intervention targets device presence rather than screen content. Phones were powered off during testing, and the mechanism operates on the visible phone regardless of what appears on its display. Our work addresses the distinct case of dynamic screen content, where the content itself is the potential distractor.

DecluttAR [42] showed that diminishing physical desk clutter through grayscale, outline, and transparency modes improved concentration during arithmetic tasks. Hong et al. [13] extended this line of research by introducing Visual Noise Cancellation as the visual analogue of noise-cancelling headphones. Through participatory workshops, they found that users identified highly salient stimuli, including advertisement signs and notice boards, as primary sources of visual discomfort. Screen content was among the categories participants identified as disruptive. This suggests that dynamic screen content is a plausible target for DR, but prior work has not established how DR screen filtering affects perceived distraction, cognitive load, or task performance.

2.2 DR Preferences and User Experience

Cheng et al. [7] examined how users perceive DR and related mediated-reality effects across multiple scenarios, including clutter management, search assistance, privacy protection, and remote guidance. Their findings show that visualization choice (e.g., transparency, abstraction, or replacement) matters to users and should be treated as a design variable rather than a purely technical decision. However, their scenarios center on physical objects and static environments, leaving open whether these preferences translate to dynamic distractors such as screen content.

Katins et al. [15] examined DR visualization concepts for blocking physical outdoor advertisements. In an online survey comparing six strategies, replacing ads with artwork received the highest ratings, driven by hedonic motivation. Participants preferred manual control over automatic blocking, except for sexually suggestive content, where automatic blocking was strongly preferred. Their work targets physical billboards rather than dynamic screens.

Taken together, this work shows that users' responses to DR depend on the target content, visualization strategy, and degree of user control. However, less is known about DR screen filtering as a general intervention for dynamic screen content, especially when evaluated quantitatively across different task contexts. We extend this literature with a cross-task empirical comparison of wearer-side filtering for dynamic screen content across perceived distraction, cognitive load, and task performance outcomes.

3 Methods

We conducted two user studies to evaluate DR screen filtering for dynamic screen content. The formative study examined five filter designs—BLOCK, DIM, WALLPAPER, REPLACE, and FREEZE—and participants' use of these filters during a puzzle assembly task. The main study tested the BLOCK filter in two additional task contexts: a Stroop color-naming task and a structured conversation. We simulated these DR screen filters in VR, a method of prototyping XR interactions that is frequently used to overcome current technical limitations [6, 7, 10, 12, 22, 36]. We chose full VR rather than real-world DR or a hybrid setup with physical tasks and virtual screens because VR provides the most controlled environment. A physical or hybrid setup would require a fully reliable real-world DR implementation that includes accurate and 100% stable alignment of the virtual filters with physical screens, something that current AR headsets do not deliver.

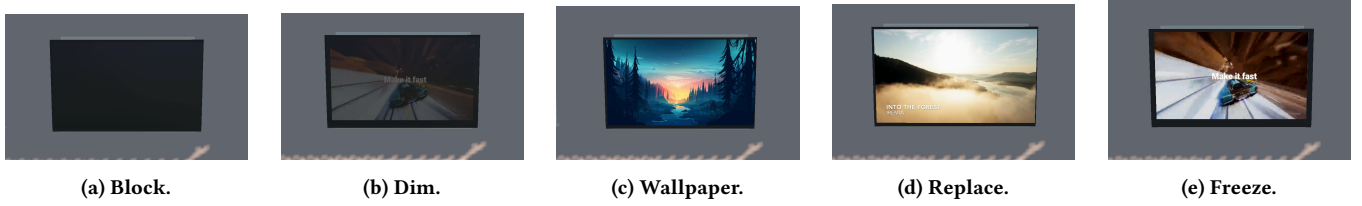


Figure 3: Screenshots illustrating the appearance of the different filter options used in the experiments.

We followed a mixed-methods approach [14], with quantitative analysis as the primary method and analysis of semi-structured interviews and questionnaires as support. We used a repeated-measures design described in more detail in each study’s section.

The study protocol was approved by the authors’ institutional Research Ethics Board before data collection. Participants provided informed consent, including separate consent for audio and screen recording, and all study data were stored under de-identified participant IDs.

3.1 Apparatus

We created our prototypes in Unity [39] with an Oculus Quest 2 VR head-mounted display (HMD). Task-relevant actions and dependent measures were logged into a CSV file. Questionnaires were administered through SurveyMonkey [27], and interview audio was recorded with OBS Studio [1].

3.2 DR Screen Filters

We implemented five filter options as rectangular overlays placed in front of the screen elements. We chose this replacement approach because it is robust and feasible with current technology.

By default, all filters were inactive. When participants could select filters, they pointed the controller at a screen, pressed the grip button, and selected an option from a tooltip menu via the trigger button. We designed the following filters to explore the space of potential replacements (Figure 3):

- **BLOCK (A)** renders an opaque dark gray box, making the screen appear to be turned off and blocking all content.
- **DIM (B)** renders a semi-transparent gray box that reduces brightness and contrast (and thus saliency) while preserving screen content.
- **WALLPAPER (C)** renders a static, aesthetically pleasing image over the screen.
- **REPLACE (D)** renders an alternative video, a slow-moving nature scene, in place of the original screen content.
- **FREEZE (E)** captures the current frame and displays it as a static image, removing motion and simulating a paused state.

4 Formative Study: Filter Design Preferences

This formative study had two goals: to investigate user preferences for our five DR screen filter designs and to provide observations about filter use during a visually and manually demanding puzzle task in VR. The preference and usage data are the primary outcomes of this study. Eighteen participants completed filter use training

followed by the main puzzle assembly task under three conditions: no screens, screens, and screens with user-selected filters.

4.1 Study Design

4.1.1 Puzzle Blocks. The primary task required participants to assemble five blocks in a target combination. The blocks were 3D objects that could be grabbed and connected by releasing two proximal blocks. The puzzle tasks always used the same five blocks, but in different configurations. There were 13 puzzle tasks: one was always used for training, and the other 12 were selected randomly without replacement for the experimental tasks. During the experiment, participants were seated in an office chair. In VR, they saw a virtual desk with a freely manipulable target model behind it (Figure 4) and had to assemble the five puzzle blocks in the same pattern. The puzzle task required continuous engagement of visual attention as participants had to visually search for blocks, track spatial positions during manipulation, and compare their assembly against the target model throughout each trial.

Participants could see the number of correct connections on a panel in the virtual environment. Once they completed the puzzle, they pressed a “proceed” button, and the system respawned the pieces for the next task.

The training phase familiarized participants with the puzzle controls and all five filters. In a single-screen environment, participants completed the same sample puzzle once with each filter active. No measures were recorded during training.



Figure 4: View of the scenario for the puzzle block experiment. The puzzle target is visible just below the center screen, while the five pieces the user has to assemble are currently placed somewhere close to the bottom left screen.

4.1.2 DR Distractor Task. The study included three counterbalanced conditions: no screens, screens active, and screens with user-selected filters. We used five screens to create a screen-dense setting by filling the central and peripheral parts of the participant's field of view in the VR headset.

In the two conditions with screens, five videos were played on different screens around the participant (see Figure 4). We selected popular YouTube videos from different categories that could generally be perceived as distracting: Animals, Advertisements, Awesome Moments, Trick Shots, and Fails. The selected videos were roughly 15 minutes long and were all compilations of shorts, with each short being around 5 seconds. The associated abrupt transitions served as additional distractions, as previous research has shown that shifts in motion are particularly effective in capturing attention [2]. In all tasks, the distractor videos were presented without audio. During the main study's conversation task, participants thus only heard the experimenter's live speech.

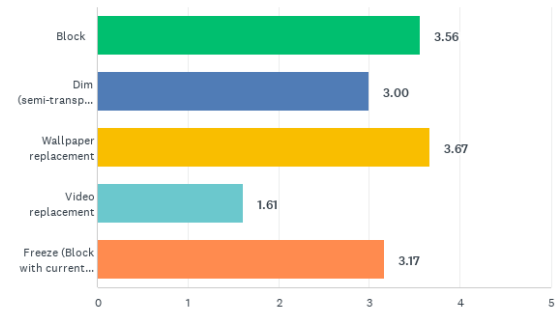
The order of the conditions was counterbalanced across participants using balanced Latin squares. The dependent variables were the time to complete each puzzle task and the number of interactions. Puzzle time was measured from the first grab of any block until participants pressed the proceed button, and each grab-and-release of a puzzle piece counted as one interaction.

4.1.3 Procedure. Participants completed a demographic questionnaire, then a training phase where they experienced each filter, and subsequently ranked them from most to least preferred, rating each on perceived usefulness and comfort. Participants completed 12 experimental puzzles total (4 per condition). A semi-structured interview then asked about filter opinions and potential everyday uses for DR. In the experimental phase, participants completed a simplified NASA TLX after each experimental condition. A final interview gathered reflections on the three conditions and participants' home and work screen environments.

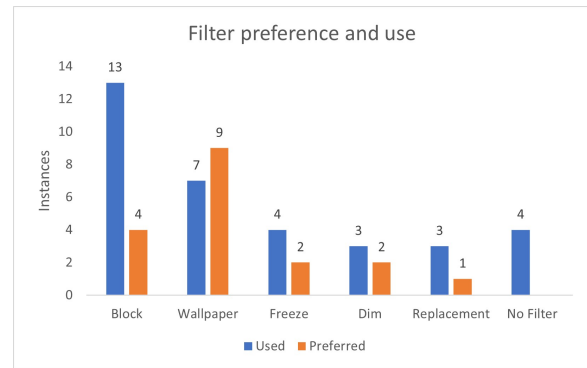
4.1.4 Participants. Eighteen participants took part (nine male, nine female). Age information was collected in categorical bands. Most were aged 25 to 29 ($N = 8$) or 30 to 34 ($N = 5$). Data regarding their vision was not collected. The study took around one hour, and all participants were compensated with 15 Canadian dollars.

4.2 Results

4.2.1 Filter Preferences and Usage. Participants favored the WALLPAPER filter ($M = 3.67$), followed by BLOCK ($M = 3.56$), FREEZE ($M = 3.17$), DIM ($M = 3.00$), and REPLACEMENT ($M = 1.61$) (Figure 5a). No inferential statistics were performed on these rankings because this phase of the study was formative and was primarily aimed at identifying which filter types to investigate further and understanding participants' reasoning behind their choices. Comfort and usefulness ratings followed the same ordering. Participants consistently identified WALLPAPER as the preferred option because it makes the screen static while providing a pleasant visual. Participants liked static images generally ("It's easier to pay attention to something when the images are frozen or not so bright," P6) and appreciated WALLPAPER's calming aesthetics ("I like the idea of a static image that is pleasant to look at," P8).



(a) Stated preference rankings after training (1 = least preferred, 5 = most preferred).



(b) Observed filter use during the five-screen experimental task (blue) and the number of participants who ranked each filter as their most preferred option after single-screen training (orange). Usage counts are non-exclusive because participants could apply multiple filters or none; preference counts are exclusive and apply only to the five filter options.

Figure 5: Stated preference (top) versus actual usage (bottom). Wallpaper ranked highest in preference, but Block was used most frequently. The shift follows the move from single-screen training to the five-screen experimental task.

Actual filter usage during the experimental task diverged from stated preference (Figure 5b). Usage was non-exclusive, so a participant could apply different filters to different videos, switch between them, or apply none. We counted a participant as using a filter if they applied it to at least one screen at least once during the filter condition. Thirteen participants used the BLOCK filter, seven WALLPAPER, four used FREEZE, three DIM, and three used the REPLACEMENT filter. Four participants applied no filter at all. Among the 14 participants who used any filter, all but one used BLOCK. We interpret this divergence as a difference between preference in a single-screen setting and practical use in a multi-screen setting. Preference rankings were formed during training with one screen, but the experimental task included five simultaneous screens. When participants managed several screens at once, BLOCK's simplicity appeared to matter more than WALLPAPER's aesthetic appeal.

4.2.2 Envisioned Applications. Participants described contexts where DR screen filters would be useful, most commonly for focused work and studying in public environments ($N = 9$). One participant stated

“studying and also working, like when I had to focus on just my screen, and there are office situations where many people are walking around” (P11). Others mentioned blocking distractions during transit ($N = 4$) or blocking advertisements in public spaces ($N = 2$).

4.2.3 Task Performance. VR interaction difficulties, primarily due to the participants’ unfamiliarity with its controls and with the prototype’s block-connection physics, dominated task-time variance. Hand collisions, accidental connection breaks, and selection errors were frequent across all conditions, and a simple linear regression showed that interaction count predicted task time with $R^2 = 0.83$. We detected no significant differences in puzzle task time or number of interactions across conditions (Friedman test, $\chi^2 = .778$, $p = .678$), and NASA TLX ratings similarly showed no significant differences. Four of eighteen participants chose not to apply any filters, reporting that the screens were not bothering them while they were engaged in the assembly work. Many participants mentioned that they did not pay much attention to the filter options ($N = 6$) or that filters made no difference ($N = 4$). Under these task conditions, screen filtering produced no detectable performance or workload benefit in the puzzle task.

5 Main Study

5.1 Study Design

To follow up on the formative study, we evaluated DR screen filtering in two additional task contexts. The first was a Stroop task that required sustained visual attention. The second was a structured conversation that required little sustained visual attention. Both tasks used two conditions: active screens and screens blocked with the BLOCK filter. We used the BLOCK filter because the formative study showed that participants used it most often when managing five simultaneous screens, even though they preferred WALLPAPER during single-screen training.

We carried only BLOCK forward from the formative study because the majority, 13 of 18 participants, used it during the five-screen task, i.e., more than any other filter. The no-screen condition showed no detectable performance or workload advantage, so it was not carried into the main study. Participants did not select filters in the main study, and the BLOCK filter was applied to all screens in the blocked condition as it was the most utilized filter in the formative study. Although BLOCK was visually equivalent to turning the displays off from the participant’s perspective, it constitutes a DR operation because the visual change was applied within the wearer’s mediated view rather than to the displays themselves. In an applied scenario, this means that other people’s view of the screen would not be affected.

5.1.1 Stroop Task. We used a Stroop-inspired task in VR (Figure 6) [38], implemented similarly to Grandl et al. [11]. Participants were presented with a task cue (“WORD” or “COLOR”) and a target word displayed in a mismatched ink color. They selected among six colored floating panels via raycasting. All trials were incongruent, so participants had to resolve color-word conflict throughout the task. Participants completed 15 practice trials, then 120 experimental trials per condition (equal WORD/COLOR split, randomized order), with screens active or screens blocked with the BLOCK filter. Because all trials required resolving color-word conflict and selecting



Figure 6: The Stroop test panels and prompt. In this example, as the task cue is “WORD”, the correct answer is blue. With a task cue of “COLOR”, the user should select orange instead.

the correct response panel, we treated the Stroop task as a task that required sustained visual attention.

5.1.2 Conversation Task. Previous research has shown that maintaining a conversation demands a fixed cost of attention that can be affected by distractions [17]. We designed the conversation task to instantiate a common real-world scenario, such as talking with someone in a living room, café, or sports bar while background screens compete for attention. As in the Stroop task, participants completed the conversation under two DR conditions (screens active, screens blocked), counterbalanced across participants.

The task consisted of conversing with the experimenter for 5 minutes per condition. The experimenter drew from a list of 45 predefined questions on varied topics, generated with ChatGPT and refined to exclude sensitive subjects, and posed them one at a time in random order without repetition. Example questions included “What’s a hobby you enjoy doing on weekends?” and “If you could learn any new skill in an instant, what would it be?”; the complete list is provided in Appendix A. This procedure, similar to Kunar et al. [17], requires participants to plan responses on the spot [3], engaging executive and working-memory processes while requiring little sustained visual attention. The conversation task thus likely provided less of a visual anchor than the puzzle and Stroop tasks, leaving more opportunity for attention to shift toward nearby screens.

Across the formative study and the main study, the three tasks provided different contexts for evaluating DR screen filtering. The puzzle assembly task and the Stroop task both required continuous visual involvement with the task display, while the conversation task required relatively little sustained visual attention. The studies were not designed to parametrically test predictions from load theory. Instead, attention research motivated the selection of tasks that differed in how strongly they anchored visual attention, allowing us to evaluate where DR screen filtering appeared useful under controlled conditions.

5.1.3 Procedure. Participants completed the same demographic questionnaire as in the formative study. The main study always presented the Stroop task before the conversation task. Within each task, the order of the two screen conditions, screens active

and screens blocked with BLOCK, was counterbalanced across participants. Participants completed the Stroop task in both screen conditions, followed each time by a NASA TLX and two additional self-report items (perceived focus and self-rated performance). A semi-structured interview was then used to gather comparisons of the Stroop conditions. Participants then completed the conversation task in both screen conditions. After each condition, participants provided three closed-response, single-item seven-point ratings adapted from the naturalness, typicality, and distraction ratings used by Boiteau et al. [4]: agreement with “The conversation was natural” and “The questions were representative of a normal conversation” (1 = strongly disagree, 7 = strongly agree), and perceived distraction (“How distracted were you during the conversation?”, 1 = very focused, 7 = very distracted). A final interview gathered reflections on all conditions and potential DR applications.

5.1.4 Participants. We recruited a new set of participants for the main study. Sixteen participants took part (twelve female, four male). All reported normal or corrected-to-normal vision and no color vision deficiencies. Most were aged 18 to 24 ($N = 8$) or 25 to 29 ($N = 4$). Participants were compensated with 15 Canadian dollars. The study took around one hour to complete.

5.2 Results

5.2.1 Stroop Task. Most participants performed the task accurately, with all but two reaching at least 100 correct trials out of 120 in each condition. One participant answered only 65 of 120 correctly, slightly more than half, which suggested they did not understand the task. The experimenter recorded that this participant initially always selected the panel associated with the word regardless of the task cue and only later noticed the error. We excluded this participant from the response time and accuracy figures but retained their data for the TLX ratings, which reflect subjective experience independent of accuracy.

Across the remaining 15 participants, accuracy was high in both conditions, with means of 114.06 of 120 ($SD = 8.41$) in the screen condition and 112.69 ($SD = 13.15$) in the filter condition, and the difference was not significant.

For the response time analysis, we removed outlier trials beyond three times the interquartile range. After excluding the participant and these outliers, 3,596 of the 3,840 trials remained (6% removed). Mean response times were nearly identical between the filter condition ($M = 2.80s$, $SD = 1.44$) and the screen condition ($M = 2.94s$, $SD = 1.62$). A Wilcoxon signed-rank test indicated no significant difference ($Z = 1.079$, $p = .281$). The response times of roughly 2.8 seconds are slower than those typical of computerized Stroop tasks, likely because of the motor overhead of selecting panels with a VR controller rather than pure cognitive interference.

In an exploratory analysis of individual TLX subscales ($N = 16$), participants rated the filter condition slightly more favorably on nearly all subscales, though only the perceived success item reached significance: participants rated their success higher in the filter condition ($M = 5.25$) than in the screen condition ($M = 4.44$, $t(15) = 2.228$, $p < .05$, Cohen’s $d = 0.57$) (Figure 7). Given the number of comparisons, this result should be interpreted cautiously.

Qualitative responses were consistent with the null quantitative results. The most common response was that participants felt little

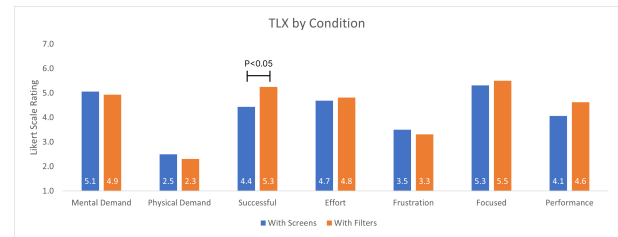


Figure 7: TLX results for the main study.

or no difference between conditions after an initial adjustment phase ($N = 9$): “I didn’t feel any difference. There was just some noise around, but I could just focus on the center of the screen where my tasks were” (P12). A subset of participants did identify the screens as distracting ($N = 7$), and a few reported that they only recognized how distracting the screens had been once they experienced the filter condition ($N = 3$). Two participants found the filters themselves distracting.

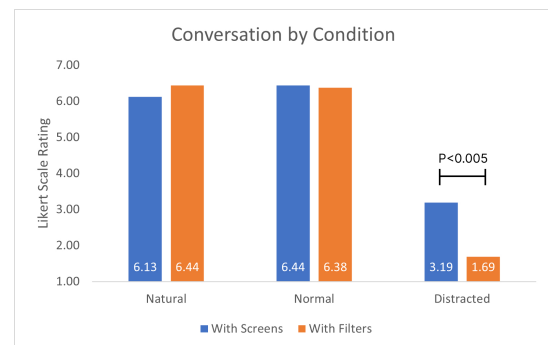


Figure 8: Conversation ratings by condition.

5.2.2 Conversation Task. Figure 8 shows the conversation ratings by condition. Participants reported greater perceived distraction with active screens ($M = 3.19$) than with BLOCK ($M = 1.69$); a paired-samples t -test indicated that this difference was significant ($t(15) = 3.223$, $p < .01$, Cohen’s $d = 0.80$). In the post-task interview, 9 of 16 participants also described greater distraction with active screens. Ratings of conversation naturalness ($M = 6.13$ vs. 6.44) and question representativeness ($M = 6.44$ vs. 6.38) were descriptively similar across the active-screen and BLOCK conditions, suggesting that the manipulation did not noticeably alter how natural or representative participants found the conversation.

In the screen condition, most participants ($N = 9$) reported negative reactions, mentioning that the screens distracted them or that they could not go as in-depth with their answers. Participants noted that this happened because they did not have a straightforward visual task, leaving them “free” to attend to the screens. One participant said, “When selecting some colors [Stroop test], I have something to do. Then I’ll just focus on what I’m doing, but while we make conversation, I’m just doing nothing. So I just focus on the TV. So yeah, it is definitely distracting” (P9).

Five participants expressed positive attitudes toward the filters, saying that the task felt more manageable and they could think more deeply before answering the questions. Two participants felt that the filter condition was worse for them because it felt too serious or because they did not know where to focus, so they kept looking around the environment.

Four participants felt that there was no difference between conditions, substantially fewer than for the Stroop task. The participants who reported no difference often stated that this is a situation they are used to in their daily lives: “I didn’t feel as distracted. Because, like, usually nowadays when people talk, they talk with an experience in front of you sometimes. It felt natural to me that the screens were present” (P10).

Taken together, the ratings and interview responses suggest lower perceived distraction with BLOCK during this structured conversation task.

6 Discussion

6.1 Bounded Utility of DR Screen Filtering

Across our two studies, DR screen filtering showed bounded utility. The BLOCK filter significantly reduced self-reported distraction during conversation ($d = 0.80$, $p < .01$), with convergent qualitative evidence. However, we detected no comparable benefits during the puzzle or Stroop tasks. These mixed results suggest that visual blocking alone does not guarantee benefit. Instead, the utility of DR screen filtering depends on task context, outcome measure, and the way users engage with surrounding screen content.

Participants’ comments were consistent with this interpretation. In the Stroop task, the majority (9 of 16) reported feeling no difference between conditions. For the conversation task, only four participants reported no difference. As one explained, the absence of a competing visual task during conversation left them free to attend to background screens in a way the Stroop task did not (P9, “When selecting some colors [Stroop test], I have something to do. Then I’ll just focus on what I’m doing, but while we make conversation, I’m just doing nothing. So I just focus on the TV.”)

One possible explanation is that screen filtering matters more when the primary task does not already anchor visual attention. Linnell and Caparos’s revision [23] suggests that tasks that continuously recruit visual attention can narrow the attentional spotlight and reduce processing of peripheral stimuli. Related work on load theory [18, 19] suggests that tasks that draw on working-memory resources may make active distractor suppression more difficult when distractors remain visible. The Stroop and puzzle tasks both required ongoing visual engagement with the task display. Conversation, by contrast, drew on working memory and response planning but did not require participants to continuously attend to a task-relevant visual target. This account is consistent with our results, but our study was not designed to test load theory directly.

Our findings are also compatible with prior DR and XR work showing that benefits can depend on task, user expertise, distractor type, and outcome measure. Lee and Kim [20] observed that AR concealment of a smartphone restored performance on working-memory tasks but produced no benefit on a sustained-attention task. McLaughlin et al. [26] found that DR reduced subjective workload during a VR assembly task, while performance benefits appeared

only among novices. These studies do not establish a general rule for DR effectiveness, but they support the need to evaluate DR interventions in relation to the specific activity and outcome measure.

6.2 Designing DR Screen Filters

Participants consistently preferred the WALLPAPER filter because it combined a static presentation with a pleasant visual. This preference is consistent with Katins et al. [15], who found that replacing outdoor advertisements with artwork outperformed blur, desaturation, and warning overlays, with hedonic motivation as the primary differentiator. The similar result in our formative study suggests that aesthetic replacement is worth further study for single-screen or low-effort filtering contexts. However, our usage data show that this preference did not directly translate to multi-screen use.

A different pattern emerged in the five-screen task. When participants filtered multiple screens, they used BLOCK most frequently despite ranking WALLPAPER slightly higher after training. This suggests that filter choice depends on the use context: aesthetic replacement was preferred for a single screen, whereas simple blocking was used most often when participants managed several screens. Thus, a single-screen evaluation might have missed this shift. Together, these findings suggest that, rather than optimize any one factor, filter selection should consider task context, screen number, interaction effort, and aesthetics, while preserving user control over which screens are filtered.

In both studies, participants consistently preferred static filters over dynamic ones. The REPLACEMENT filter, which displayed a slow-moving nature video, was ranked last. In these study contexts, participants treated motion in the replacement content as another possible source of distraction.

Participants reported satisfaction at being able to choose which screens to block and which to leave active. This preference for selective control, rather than an all-or-nothing filter, has practical implications for DR system design. Even as context-aware DR becomes technically feasible, preserving user control over what is filtered matters for how the system is received.

6.3 Implications

Our results suggest that DR screen filtering should be designed and evaluated as a context-sensitive screen-mediation technique. In tasks that heavily engaged visual attention, simple screen blocking produced no detectable benefits under our study conditions. During conversation, the same kind of blocking reduced perceived distraction. Future systems should therefore avoid assuming that visual blocking is generally beneficial. Contexts involving sustained conversation in screen-dense environments, such as meetings, collaborative work, or open-plan offices, are useful candidates for further evaluation.

Context-aware filters would require activity recognition, which introduces trade-offs. Mixed-initiative approaches, where the system suggests filters based on inferred context but the user can override them, may balance automation with the selective control that participants valued. Future work could also examine whether DR screen filters are useful for populations who experience difficulty inhibiting irrelevant visual stimuli, including individuals with

ADHD or sensory processing differences [30]. The present data do not address that question.

Across both studies, participants envisioned DR screen filtering for focused work in public spaces ($N = 9$ formative, $N = 5$ main), blocking billboards ($N = 2$ and $N = 5$), and hiding sensitive or disturbing content ($N = 5$ main study). The desire to block advertisements echoes the foundational DR vision of Mann and Fung [25]. It also aligns with Katins et al. [15], who found that participants wanted advertisement blocking to be manual rather than automatic, temporary, and sensitive to content type.

7 Limitations and Future Work

Several limitations bound the interpretation of these results.

We simulated DR screen filters in VR rather than implementing them in AR. This approach has precedent in prior XR work [6, 7, 10, 12, 22, 36], and VR provided the experimental control needed for an initial evaluation. However, differences in the field of view, visual fidelity, and optical see-through display characteristics could change how users experience screen filtering. Future work should test DR screen filters on AR or MR hardware, ideally with gaze-based or behavioral measures of distraction.

The tasks used in our studies, except for conversation, do not represent real-world activities. We chose them as they provide reliable measures of cognitive load and distraction. Yet, more representative tasks, such as reading or writing, could reveal different responses to DR filters. Our experiments also capture only short-term impressions. A longitudinal deployment study would be needed to understand how preferences and perceived benefits evolve. Further, our findings also apply most directly to short DR tasks involving nearby dynamic screens in VR, and might not generalize to other tasks, scenarios, or DR targets.

The within-participants design was transparent to participants, who were aware of the filter versus no-filter manipulation, creating a potential demand characteristics confound for self-report measures. A consistent pro-filter bias across all measures would be expected if participants were simply reporting what they thought we wanted to hear, but that pattern did not emerge.

The conversation distraction finding relies on a single self-report item. Because naturalness, representativeness, and distraction were each measured with one item, internal-consistency reliability could not be estimated. The distraction item directly captured participants' perceived distraction, and the qualitative interview data converged with the quantitative result, with 9 of 16 participants also reporting greater distraction in the active-screen condition. Future work should triangulate these reports with gaze measures, such as the number and duration of glances toward the screens or conversation partner, and speech measures, such as response latency, pause duration, speech rate, or disfluencies, to test whether perceived distraction corresponds to observable changes in visual attention or conversational behavior.

The main study tested only the BLOCK filter. Other filter designs may produce different benefits or trade-offs across task contexts. The formative study suggests that participants value aesthetic replacement and selective control, but it did not test these alternatives as fixed conditions in the Stroop or conversation tasks.

Our sample sizes ($N = 18$, $N = 16$) were not informed by a priori power analysis. The high variability in task performance measures could indicate that the studies might have been underpowered to detect small-to-medium behavioral effects. The null behavioral results should therefore be interpreted as an absence of evidence for large effects, not as evidence of absence. Future work should use a priori power analysis to appropriately size studies for the effect magnitudes suggested by this work. Both samples were concentrated among younger adults, and recruitment was not stratified by familiarity with ambient screens; the findings may therefore not generalize to other age groups or levels of habituation to screen-dense environments. Because age was collected in categorical bands in the formative study, exact minimum and maximum ages and the standard deviation could not be calculated.

Because the study was not designed to parametrically vary perceptual and working-memory load, the load-theoretic interpretation we offer should be treated as a plausible explanatory framework rather than a confirmed mechanism. Future work that systematically manipulates load dimensions would provide a more rigorous test of the boundary conditions for DR effectiveness.

VR itself imposes cognitive overhead for novice users, including unfamiliar controls and lower visual fidelity. This baseline overhead may have inflated the effective visual attentional engagement of all tasks, which, under our interpretive framework, would reduce the room for screen distractors to compete and could have contributed to the null behavioral results independently of the DR manipulation.

8 Conclusion

DR screen filtering had bounded utility in our studies. Regarding RQ1, participants reported lower distraction with BLOCK during conversation in the main study with convergent qualitative evidence, whereas the puzzle and Stroop tasks explored earlier showed no consistent differences in behavioral performance or workload. These results suggest that visual blocking alone does not guarantee benefit. DR screen filters should be evaluated in relation to the task context and outcome measure rather than assumed to reduce distraction whenever dynamic screens are present. Regarding RQ2, participants ranked WALLPAPER highest after single-screen training but used BLOCK most often when managing five screens. Across both studies, they favored static filters and selective control. Future work should validate these findings on AR or MR hardware, with tasks more representative of everyday work, behavioral measures of distraction, and longitudinal deployments that examine how preferences and perceived benefits shift with extended use.

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