Exploring Diminished Reality for Attention Support: A Co-Design Study with Students with ADHD

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Abstract

Diminished Reality (DR) modifies or removes elements of the perceived environment. We explored DR for attention support through diary studies, interviews, and speculative co-design with 15 university students with ADHD. Participants described a persistent gap between intention and attention, and the use of externalization strategies that encounter fundamental limits in physical reality. In co-design, rather than reasoning from visual operations, participants articulated which properties of stimuli they needed to perceive versus filter, revealing cases where visual diminishment does not reliably map to attentional diminishment. We contribute rich descriptive data on the attentional challenges and DR preferences of students with ADHD, and propose Attentional Diminishment, a sensitizing concept that reframes DR for attention support from visual outcomes to attentional effects.

Keywords

Diminished Reality, ADHD, Accessibility, Attention, Augmented Reality, Extended Reality

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1 Introduction

Attention-Deficit/Hyperactivity Disorder (ADHD) affects an estimated 2-8% of university students worldwide [23], who face significantly elevated rates of academic failure, dropout, anxiety, and depression compared to neurotypical peers [5]. These outcomes reflect differences in executive function affecting inhibitory control, working memory, and arousal regulation. These differences manifest as unreliable selective attention, impacting the capacity to filter sensory input based on relevance to current goals [1, 7, 62]. For many individuals with ADHD, there is a persistent gap between intention and what actually captures attention. This gap reflects not failures of motivation but differences in the cognitive infrastructure supporting goal-directed behavior [14].

Researchers have proposed numerous digital interventions to support individuals with ADHD. These include wearable devices providing haptic or visual cues for self-regulation and time awareness [18, 57], gamified cognitive training applications targeting sustained attention and inhibitory control [32, 56], and neurofeedback systems using brain-computer interfaces to train attentional states [40]. These approaches commonly train cognition, structure tasks, or scaffold behavior, but leave the perceptual environment intact. Diminished Reality offers a distinct possibility: modulating what users perceive rather than how they act.

Diminished Reality (DR) systems modify, remove, or alter elements of the perceived environment [46], potentially offering finer-grained perceptual control unconstrained by physical reality. DR techniques, including blur, desaturation, removal, and replacement, have been applied to attention support with demonstrated efficacy [17, 39, 49], yet this work predominantly frames the technology through visual operations rather than attentional outcomes. For attention-support applications, where the goal is to modulate what captures attention rather than what is simply visible, this framing may obscure relevant design considerations.

Through diary studies, semi-structured interviews, and speculative co-design sessions with 15 university students with ADHD, we investigated attention challenges and management strategies in academic contexts and explored DR as a potential solution space. Co-design sessions were conducted without imposing operational vocabulary; instead, we invited participants to describe what they would change about their environments and why.

Our findings revealed participants' use of externalization, a well-documented strategy leveraging external structures to support cognitive processes that internal systems cannot reliably sustain [8], and the limitations of externalization when physical environments bundle properties that participants need separated. When reasoning about DR for attention support, participants articulated which properties of stimuli they needed to perceive versus filter, revealing cases where visual diminishment did not reliably map to attentional diminishment. We present Attentional Diminishment as a sensitizing concept that reframes DR for attention support from visual outcomes to attentional effects.

This paper contributes:

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- **Empirical findings** from exploratory research and speculative co-design with university students with ADHD, characterizing attention challenges in academic contexts and documenting how participants reasoned about and designed DR for attention support.
- **Attentional Diminishment**, a sensitizing concept that reframes DR for attention support from visual outcomes to attentional effects, raising questions about design and evaluation for attention-supporting DR and, more broadly, technologies for attention support.

2 Related Work

Our work sits at the intersection of research on attention and executive function in ADHD, theories of selective attention, practices of cognitive externalization, and prior work on Diminished Reality and adjacent fields.

2.1 Executive Function, Attention, and ADHD

ADHD is widely characterized through differences in executive function (EF), encompassing difficulties in regulating attention, behavior, and goal-directed action. Barkley's influential model frames ADHD as primarily involving differences in inhibition that cascade into challenges with working memory, self-regulation, and sustained attention [7, 8]. Sergeant's cognitive-energetic model offers a complementary perspective, highlighting dysregulation of arousal and activation as central to ADHD [53, 54]. In this model, attentional difficulties emerge particularly under conditions that challenge energetic regulation in two ways: by overstimulating environments that overwhelm regulatory capacity, and by understimulating environments that fail to maintain adequate activation for sustained attention.

These differences in executive functions manifest as challenges in selective attention, impacting the capacity to prioritize task-relevant stimuli while filtering those that are irrelevant to current goals. These frameworks inform our analysis of how participants experience and describe their attentional challenges, and how DR might address the specific mechanisms that underlie them.

2.2 Selective Attention and Load Theory

Selective attention is a process in which multiple stimuli compete for neural representation [20]. This competition is biased by both stimulus salience (exogenous, bottom-up) and task relevance (endogenous, top-down)[19]. Unattended information is not fully blocked but attenuated, remaining capable of capturing attention when conditions allow [60]. This is how one can be vaguely aware of others in a room and filter out irrelevant details, yet still react when someone approaches or speaks their name.

Load theory provides an account of when selective attention succeeds or fails. Lavie distinguishes perceptual load from cognitive load: high perceptual load exhausts early perceptual capacity and prevents distractor processing, whereas high cognitive load depletes working memory resources needed for top-down control, increasing distractibility [36, 37]. This framework is relevant to ADHD, where working memory limitations reduce the capacity to maintain task priorities and suppress distractions [48]. Forster and Lavie demonstrated that increasing perceptual load can reduce ADHD-related differences in distractibility by reducing distractor processing at early perceptual stages [24].

The load theory's distinction between perceptual and cognitive load offers a lens for understanding why different DR techniques may succeed or fail for attention support, and why filling visual space with task content might reduce distractibility rather than add distraction.

2.3 Externalization as a Cognitive Strategy

Externalization has long been recognized as a core strategy for supporting executive function, particularly in ADHD. Barkley characterizes externalization as the deliberate recruitment of environmental structures, including artifacts, spatial arrangements, social configurations, and constraints, to support cognitive processes that internal systems cannot reliably sustain [8]. Empirical research on ADHD documents a wide range of such strategies, including visual reminders, environmental selection, routines, social accountability through body doubling, and self-imposed constraints such as commitment devices [4, 15, 35].

2.4 Digital Self-Control and Pre-commitment

A substantial body of HCI research addresses digital self-control tools (DSCTs), apps, and browser extensions that help users align their actual device use with intended use [27, 43–45, 51]. Lyngs et al. analyzed 367 such tools, finding they predominantly employ block/removal strategies, self-tracking, goal-advancement, or reward/punishment mechanisms, often in combination [43]. These tools operationalize pre-commitment, a well-documented self-control strategy in which individuals constrain their future options to align with current intentions [4].

Empirical work has demonstrated the effectiveness of various DSCT interventions. For example, removing Facebook's newsfeed helped users stay on task, though some reported increased fear of missing out [45]. Design frictions, brief delays, or cognitive tasks before accessing distracting content, reduce impulsive app openings while preserving user agency [27].

This literature establishes a paradigm for technological support of self-control: frontloading decisions about what to restrict, then delegating enforcement to the system. Yet these tools constrain access and behavior while preserving awareness: users know the blocked content exists. This leaves perception itself as an underexplored site of intervention.

2.5 Diminished Reality and Adjacent Work

Diminished Reality (DR) refers to technologies that modify, remove, or alter elements of the perceived environment [46, 47]. Foundational definitions are relatively open. Mann describes DR as the capability to "deliberately diminish" visual perception [46], while Mori et al. define it as "a set of methodologies for concealing, eliminating, and seeing through objects" [55].

Current DR research typically operationalizes DR through visual techniques [55]. Common technique families include blur[17], dimming[63], desaturation[17], removal or inpainting (eliminating targets and reconstructing occluded background)[17, 49], scale reduction[52], and replacement (occluding targets with virtual content, sometimes termed substitution) [38, 39, 55].

Mori et al. identify replacement as a DR technique, discussing both full occlusion by a virtual element and "removal and then replacement methodology" where the target is first removed and then a virtual object is placed [55]. We use replacement to refer to any technique that replaces a physical target stimulus with a virtual stimulus, whether through full occlusion or removal followed by replacement. Replacement qualifies as DR because the target stimulus is diminished: its visibility is reduced or eliminated. The visual operation on the scene may be additive (virtual content is added), but the effect on the target is subtractive (concealed from view).

2.5.1 DR for Attention and Cognitive Support. DR and DR-adjacent techniques have increasingly been applied to attention and distraction management. Systems explicitly framed as DR have addressed reduction of drain on cognitive resources from the presence of smartphones [39], visual decluttering in work and mobile contexts [16, 49, 63], mitigation of content-irrelevant objects in Augmented Reality (AR) [31], and modulation of perceptual salience [21]. Other work pursues similar goals using different terminology: visual noise cancellation applies grayscale and blur to peripheral regions for concentration support [29, 33], and reduced-reality displays aim to influence comfort and cognitive load through perceptual modulation [52].

2.5.2 Selective Attenuation as Unarticulated Design Territory. What we refer to as selective attenuation appears in the literature without being conceptualized as a broader design territory [17, 59, 63]. Cheng et al. found that users preferred transparency with outline preservation over complete removal, as outlines maintained spatial awareness and assisted with collision avoidance, while filtering other visual properties [17]. Yet this is treated as a specific finding about outlines rather than an instance of a general design territory. Other contexts suggest different priorities, such as social presence, notification, and other non-visual properties of target stimuli. This design territory cuts across implementation categories and remains largely implicit in current DR discourse. Through selective attenuation, DR serves goals analogous to those of selective attention, prioritizing relevant stimulus properties while filtering irrelevant ones. Our work surfaces this territory through co-design with users for whom selective attention is a persistent challenge.

3 Method

Spiel et al.'s review of ADHD technology research in HCI found that the field is dominated by diagnosis-focused and intervention-focused systems that treat ADHD traits as deficits to be corrected toward neurotypical norms, with only a small fraction involving people with ADHD as stakeholders in the design process [58]. We designed a two-phase qualitative study that positions university students with ADHD as co-designers of potential DR interventions.

Phase 1 consisted of an asynchronous diary study capturing real-world distraction incidents. Phase 2 consisted of in-person workshops combining semi-structured interviews, speculative co-design, and scenario-based discussions about system preferences. This research received ethics approval from the University's Institutional Review Board. Participants gave their informed consent and, upon completion, were compensated with CAD $42.50 in the form of an Amazon gift card for their participation in both the workshop and the successful completion of the diary study.

3.1 Participants

We recruited 15 university students with ADHD through university mailing lists and social media. No member of the research team held any instructional, supervisory, or advisory relationship with any participant. Participants self-identified as having ADHD and completed the Adult ADHD Self-Report Scale (ASRS v1.1) for screening and symptom presentations [30]. Consistent with neurodiversity-affirming approaches that respect self-identification while using validated instruments to describe the sample, we did not require formal diagnosis.

Participants ranged in age from 18 to 30 years. Seven identified as women, five as men, and three as non-binary. The sample was predominantly East and Southeast Asian, with additional participants identifying as Middle Eastern, South Asian, and Caucasian. Fourteen participants scored in the High or Very High symptom severity range on the ASRS (M = 48.8, SD = 7.53). Twelve presented with the Combined subtype and three with the Predominantly Inattentive subtype. Thirteen participants reported limited or no prior experience with extended reality technologies. For a detailed description of the participant demographics, please refer to Table 1.

3.2 Phase 1: Diary Study

We employed an asynchronous diary study to capture distraction incidents as they occurred in participants' daily academic lives. Diary methods offer ecological validity that laboratory-based attention tasks cannot provide, capturing experiences in situ and reducing the recall bias inherent in retrospective interviews [10]. Participants were asked to submit at least one entry per day for a minimum of three days whenever they experienced difficulty completing a task due to environmental distractions.

Participants submitted entries through an online form (Microsoft Forms). Each submission was required to include a de-identified photograph of their environment, a description of the environment and distracting elements, information about the task they were attempting, an explanation of what was distracting and why, and what they would change to make the environment less distracting.

We collected 49 diary submissions across the 15 participants. These submissions served as empirical data about real-world distraction patterns and as elicitation material for subsequent sessions [28]. Using participant-generated artifacts to anchor interview discussion grounds speculative exploration in concrete, lived experiences rather than abstract hypotheticals, while giving participants interpretive authority over their own documentation.

Interviewers reviewed each participant's diary submissions before their workshop to develop familiarity with that participant's environments and distraction patterns, enabling more contextually grounded follow-up questions. However, the overall workshop structure, co-design environments and prompts, and core interview questions remained standardized across all participants.

3.3 Phase 2: Co-design Workshop

We conducted individual speculative co-design workshops to explore how participants would design DR systems for their own

Table 1: Participant Demographics and ADHD Profiles

ID	Gender	Age	Ethnicity	XR Exp.	ASRS Severity	Presentation
P1	W	24	Middle Eastern	None	High	Combined
P2	W	21	E/SE Asian	Limited	High	Combined
P3	M	30	E/SE Asian	Limited	High	Combined
P4	W	24	E/SE Asian	Limited	Very High	Combined
P5	M	25	E/SE Asian	Extensive	High	Inattentive
P6	NB	24	White	Limited	Very High	Combined
P7	M	26	E/SE Asian	Limited	Very High	Combined
P8	W	25	E/SE Asian	None	Moderate	Inattentive
P9	M	24	E/SE Asian	None	High	Combined
P10	W	22	Middle Eastern	Limited	Very High	Combined
P11	W	24	E/SE Asian	None	Very High	Combined
P12	NB	22	E/SE Asian	Limited	High	Combined
P13	W	18	South Asian	Moderate	Very High	Combined
P14	M	27	South Asian	Limited	Very High	Combined
P15	NB	21	E/SE Asian	Limited	Very High	Inattentive

Gender: W = Woman, M = Man, NB = Non-binary. XR Exp. = prior experience with extended reality technologies. Presentation = ADHD presentation subtype.

attention support. Individual sessions avoided anchoring effects, where early design ideas constrain later participants' thinking, but allowed deeper exploration of each participant's attentional experiences and preferences. An intelligent, real-time DR system capable of context-aware filtering based on user intent and task relevance remains beyond current technical capabilities. Rather than constrain participants to what is presently implementable, we adopted a speculative design approach that invited participants to envision DR without technical limitations [22]. This allowed us to explore the conceptual boundaries of DR for attention support before those boundaries are fixed by engineering constraints.

Similarly, we chose low-fidelity, open-ended design methods over higher-fidelity prototyping to avoid constraining participant designs to common pre-defined DR techniques (e.g., blur, transparency, removal). Presenting participants with functional prototypes or predefined DR techniques risked anchoring their thinking to existing implementations and foreclosing alternative approaches. This concern is supported by recent speculative co-design work with disabled communities. Angelini et al. used fictional narrative scaffolds rather than concrete technological prompts in workshops with deaf participants, finding that avoiding anchoring to existing categories surfaced needs that standard technical framings would have missed [3]. We adopted an analogous strategy, providing only general-purpose digital drawing tools and framing the task as unconstrained environmental modification to surface how participants naturally reasoned about attention and distraction rather than how they responded to researcher-defined categories.

Each participant attended an individual workshop session lasting approximately 90 minutes with a 10-minute break. All sessions were audio-recorded and transcribed for analysis. Co-design images produced during the activity were collected as visual artifacts. Sessions were structured in three parts.

3.3.1 Contextual Review and Lived Experiences. We began with open-ended questions about participants' history with ADHD and its impact on their academic lives, their day-to-day challenges, and their current strategies for managing distraction and focus, probing specifically into where these strategies break down and why. We also discussed study habits and environmental preferences—where participants choose to study, why, and what factors influence these choices.

Participants then walked through each of their diary submissions, explaining the context, what was distracting them and why, and the environmental factors that were present. This grounded the conversation in concrete, participant-generated examples while allowing participants to elaborate beyond what they had written.

3.3.2 Speculative Design. Participants were then shown 10-second videos of three common student environments: a lecture hall, a library study area, and a private study room. For each environment, participants described what initially caught their eye, what held their attention and why, and what would be distracting if they were working in that space.

Using static images of the same three environments, we asked participants to draw their ideal transformed environment, assuming unlimited capabilities. Drawing on the tradition of using drama and props to scaffold speculative envisioning in participatory design [11] and the use of "magic" as a defamiliarization strategy to bypass technical vocabulary [2], we introduced the concept as a "magic wand" that could modify the world perceptually, deliberately avoiding DR-specific terminology such as blur, transparency, or inpainting during the instructions to prevent biasing participants toward existing technical DR operations.

Participants used an iPad with Procreate, with access to brush tools, selection tools, and filters. To enable participants to easily simulate object removal without requiring technical editing skills, we prepared each image with two layers: a base layer in which we had pre-edited the scene to remove objects and people, and a working layer displaying the original image. Thus, when participants used the eraser tool, the system revealed a clean background beneath, rather than blank space, allowing them to intuitively remove elements from the scene. The sessions followed a think-aloud protocol: as they worked, participants explained what they were doing and why, and we probed for clarification on their rationale and preferences.

Participants were explicitly encouraged to describe ideas beyond what the drawing tools could represent, using any combination of verbal description and gestural explanation. Many relied substantially on verbal description to convey their designs, drawing only to indicate spatial regions or rough visual appearance while articulating the intended effects through speech. During post-activity probing, we introduced specific terms, especially those typically associated with DR, to explore rationales and trade-offs. We acknowledge that the drawing tools may have biased participants toward certain visual operations, particularly erasure. However, participants frequently described effects that exceeded the tools' representational capacity, suggesting the approach successfully elicited ideas beyond what the medium alone would have afforded.

3.3.3 Refinement and Interaction. Following the co-design activity, we presented participants with hypothetical scenarios grounded in the same three environments to explore preferences regarding system agency and control. For example, participants considered whether the system should automatically apply their preferred modifications upon entering a familiar environment or wait for manual activation, and how it should respond if their attention shifted to something they had previously chosen to suppress. Topics spanned manual versus autonomous control, handling changes in decision-making, and whether the system should resist or follow the user's immediate attentional shifts.

We closed by asking where else participants could see the technology being useful and what concerns they had regarding safety, social stigma, and ethics.

3.4 Data Analysis

We analyzed diary submissions, interview transcripts, and co-design artifacts together as a unified corpus using reflexive thematic analysis [12, 13]. Given that participants relied heavily on verbal explanations to convey design intentions, visual artifacts were primarily used as reference material to contextualize participants' verbal descriptions rather than being coded independently. Two members of the research team first coded a subset of the data together to develop a shared analytic orientation, then coded the remaining data independently before reconvening to discuss, compare, and refine interpretations. Theme development was recursive. The team moved iteratively between data, codes, and candidate themes, with the codebook substantially restructured at several points as emerging interpretations rendered earlier framings inadequate. This iterative reworking is consistent with reflexive thematic analysis, in which themes are understood as interpretive patterns generated through sustained engagement with the data rather than stable entities uncovered through a fixed procedure. Analysis was conducted manually without dedicated qualitative software, and we did not calculate intercoder reliability, as themes in this framework reflect the researchers' interpretive work rather than objectively reproducible categorizations [13].

3.5 Researcher Positionality

The lead author identifies as having ADHD, which informed sensitivity to participants' experiences during data collection and shaped attentiveness to the nuances of attentional challenges during analysis. During analysis, the team held regular discussions to examine how their respective perspectives shaped interpretation of the data and to interrogate assumptions stemming from personal familiarity with or distance from the experiences described. These discussions were particularly important given the reflexive thematic analysis approach, which positions the researcher as an active participant in knowledge production.

4 Findings

Through diary studies, semi-structured interviews, and speculative co-design sessions, participants described their attention and distraction experiences in academic contexts and envisioned how Diminished Reality might address them. We organize findings into three areas: how participants characterized their attentional challenges and current strategies, their preferences for DR modifications, and their preferences for agency and control.

4.1 Characterizing Attentional Challenges

Participants described a persistent gap between what they intended to focus on and what actually captured their attention. They employed externalization strategies to manage this gap, but these strategies often encountered fundamental limitations in terms of what physical environments can afford.

4.1.1 Lack of Attentional Agency. Participants described experiencing attention as something beyond their control ("I feel like even if I try to ... my mind just automatically runs off to a different direction. It's really like out of my hands," P9; "It's hard having no control over what I can really focus on... I know there's been a lot of times where if I just focused, I know my GPA would have been a lot higher," P15). Participants identified that their challenge was not necessarily the inability to focus, but the gap between what they wanted to focus on and what involuntarily captured their attention ("I'll click [the notification] even though I know I shouldn't," P5). Participants understood what they needed to do and wanted to do it, yet found their attention repeatedly captured against their intentions ("I know it's the most important, my mind is usually wandering off somewhere else," P13).

> "All of these things that I'm telling you, I have no choice. It's not even that I want to... I have no choice." (P7)

4.1.2 The Nature of Distraction. While perceptually salient stimuli caused momentary capture, the distractions participants described as most costly were those that engaged meaning-making and narrative construction.

Semantic and narrative capture. Participants described how stimuli triggered not just a glance but sustained processing ("I see a plant, and it reminds me of how I need to buy plants for myself. And then I think, oh, I haven't cleaned my room... and the next thought and the next thought," P10). Seeing others' belongings triggered wondering about their owners and their stories (P2). Noticing how someone's hair was parted led to speculation about their sleep and styling habits (P4). A flyer on a desk prompted questions about its content and why it had not been discarded (P9). One participant explicitly named this as "narrative building" around strangers (P15).

Distraction chains and recovery costs. Individual distractions rarely remained isolated. A single attentional capture typically cascaded into extended sequences of task-irrelevant activities and thoughts. One participant described a "commercial break" pattern: once pulled from focus, attention cycled through checking the phone, opening new browser tabs, returning briefly to stare at work without engagement, then repeating (P6). Another described how one distraction can wipe out relevant thoughts, starting the cascade ("I have RAM in my head. There's only a certain amount of things that I can keep in my head... If someone's like, 'Yo give me a pencil,' boom it's all gone," P7). A momentary glance at a classmate's screen could initiate a chain that consumed the entire study session. One participant described how a single visual trigger led to checking their own phone, which led to scrolling, which led to guilt, which led to more avoidance ("that's three hours gone," P14). Participants attributed this pattern to the difficulty of returning to the task once the initial capture occurred: the primary cost of distraction was not the moment of capture itself but the cascade it initiated.

4.1.3 Externalization Strategies and Their Limitations.

In response to these challenges, participants employed externalization strategies. These strategies worked but encountered structural limits. Physical environments bundle properties together that participants need to be separated, offer limited choices, and cannot adapt to dynamic needs. This section describes four manifestations of these limits.

The device tension. Smartphones exemplified a bundling problem. Participants rated their phones as simultaneously highly distracting and highly necessary ("Distraction level is a five [out of five], but the need importance is also a five," P13). The distraction was not limited to active use. Consistent with research on the "brain drain" effect of smartphone presence [61], participants reported that the mere proximity of the device occupied cognitive resources. Essential functions, including time-tracking, calendar management, and emergency contact, were bundled with notifications, social media, and other distracting affordances within the same physical object.

Participants could not access the utilities they needed without also accepting access to distractions they could not resist. One reported being unwilling to enable do-not-disturb mode because family emergencies might occur ("I'm not even willing to turn on do not disturb. Like things could happen... My mom could call me and it's an emergency," P9). Another described the phone as like the mask from the film "The Mask," a supernatural object that compels whoever is near it to put it on despite knowing they will lose control (P6). To put it simply: "Sometimes I need those devices... but sometimes that also could distract me" (P3). The physical device offered no middle ground between complete presence with full affordances and complete absence with lost functionality.

The social tension. Body doubling, the practice of working in the presence of others for motivation and accountability, produced a parallel tension. Participants described needing others around to be productive, with presence providing external structure that internal motivation could not. Yet they simultaneously identified people as their primary source of distraction ("I need people around to work. But people are literally the most distracting thing," P12). Many participants noted that a major source of distractions from others in an academic setting was their screens ("I prefer having them around... it makes me feel better about studying. [But] I'm definitely reading what's on their screen," P1).

The tension was specific. The motivational benefit of knowing others were present came with the attentional cost of perceiving their details. Others provided accountability when perceived as productive, but their visible features afforded narrative elaboration: what they were doing, what was on their screens, their facial expressions, and movements.

The object and visual cue tension. Participants reported pronounced "out of sight, out of mind" effects, using visible objects as reminders: keeping planners open, task materials on desks, sticky notes in view, "doom piles" of items requiring action. Participants explained that putting things away would result in them forgetting about them or the tasks associated with them ("If a lot of these things aren't visibly there, then I won't know where they are, but the fact that it's just there is pretty distracting," P11). Another described using post-it notes for memory support, but the resulting clutter triggered task-switching thoughts (P4). P14 noted that they did not put their "doom piles" of laundry away, as that would result in them forgetting about the task, but those piles served as a constant, intrusive, and guilt-inducing reminder, distracting them from their studies. Visible objects could not be configured to provide their reminder function during relevant moments while remaining cognitively inert at other times.

The environmental tension. Multiple participants reported that sparse environments created their own challenges. Empty or sterile spaces triggered internal distraction through mind-wandering ("If I'm in a room with nothing in it, that's even worse because I'm kind of alone with my thoughts," P10). Another described wanting the visual equivalent of "brown noise" to regulate their attention (P14).

This finding aligns with Sergeant's cognitive-energetic model of ADHD, which positions dysregulation of arousal and activation as central to attentional difficulties [53]. Understimulating environments may fail to maintain adequate activation for sustained attention, just as overstimulating environments overwhelm regulatory capacity. This left participants navigating a narrow window of optimal stimulation ("I need the sweet spot. It's not binary," P7). What counted as optimal varied across individuals and tasks. Participants described needing a "calming kind of distraction" rather than an "overstimulating distraction" (P4), but the boundary between the two was highly personal. One participant studied at cafes with ambient stimuli to keep themselves engaged, while another specifically avoided cafes as they were overwhelming (P1, P3). Physical environments, designed around population-level assumptions about appropriate stimulation, could not provide the fine-grained personalization participants required.

(a) A virtual screen displaying task content blocks distracting individuals while preserving some awareness of their presence.

(b) Complete erasure eliminates both visual presence and cognitive awareness of others.

Figure 1: Contrasting approaches to managing social distractors. P3 preferred occlusion because it maintained a sense of presence, whereas P7 preferred removal for the same reason. Both suggest that removal diminishes the sense of presence, whereas occlusion does not.

4.2 Designing for Attention

When given the capacity to modify their perceived environment without constraint, participants consistently began with intended attentional effects and reasoned toward implementations that would achieve them. Rather than asking what a particular visual operation might accomplish, they articulated what properties of stimuli they needed to perceive versus what they needed filtered, then designed whatever would achieve that separation. In doing so, they revealed cases where visual diminishment did not reliably produce attentional diminishment: reducing visual information sometimes increased attentional capture, and visually similar outcomes, such as occluding versus removing a stimulus, produced different attentional effects.

Multiple participants described such cases explicitly. One explained that blur was insufficient for filtering people because even blurred movement might trigger speculation about what the person was doing (P2). Another recounted an experience with a semi-erased whiteboard where partial visibility of text triggered compulsive attempts to decipher it, making the board more distracting than if the text had been fully present or fully absent (P7). The same participant rejected occlusion, reasoning that awareness of someone behind a barrier would sustain their presence as an object of attention, whereas complete removal would eliminate even the thought of them (P7). This was in direct contrast to P3, who explicitly preferred occlusion because it preserved awareness of others' continued presence, maintaining the sense that people remained nearby but out of view, rather than absent entirely (Figure 1).

4.2.1 Preference for Removal. When a stimulus served no function in the participant's task, most participants preferred complete removal over partial modification. The reasoning was consistent: removal eliminates the stimulus entirely from consideration, while partial filtering preserves awareness that something exists ("If he's gone, I'm not even thinking about him. The thought cannot enter my mind," P7). A fourth rejected blur and desaturation because the stimulus would still be "technically there" (P15).

Removal was not always preferred. When specific properties of a stimulus served a function, participants accepted modification. Several wanted windows blurred to preserve light levels for time awareness while removing distracting view details (P2, P4). Others wanted people blurred to maintain social presence for body doubling while filtering identifying features (P4, P10, P14). The choice of technique followed from what each participant needed to perceive: removal when nothing warranted preservation, or modification when specific properties served a function that would be lost with removal.

4.2.2 Simplified or Abstract Representations. For stimuli that participants needed but found distracting, designs consistently sought to preserve useful properties while filtering others. Participants accomplished this through representations that carried only the information they needed, stripping away properties that triggered attentional capture.

Some designs simplified existing visual forms to filter semantic content. Multiple participants wanted people rendered as silhouettes or blurred figures. One explained wanting silhouettes because they would make "people less interesting" while maintaining awareness that others were there (P5). Another wanted blur to create the "illusion that they're there for motivation" while remaining "blurry so I'm focused on my own thing" (P10). A third wanted faces blurred while keeping bodies visible, enabling "knowing they're working around me but not seeing exactly what they're doing" (P4). The reasoning across these designs targeted the properties that visual detail communicated rather than the visual detail itself: identity, activity, and the features that afforded narrative elaboration about who people were and what they were doing.

Other designs created representations for properties that lack inherent visual form. Multiple participants wanted their phones to

Technique	Properties Preserved	Properties Filtered
Complete removal	None	All including presence
Silhouette	Presence, location, posture	Identity, expression, activity
Status indicator	Functional status	Interface, affordances
Directional cue	Approach direction, timing	Person's visual detail
Blur or dimming	Form, location, motion	Fine detail, identity
Replacement	Presence	Everything else

Table 2: Examples of selective attenuation designed by the participants.

be invisible but needed awareness of incoming notifications (P1, P3, P6). These designs gave visual form to a single property, notification, while filtering the physical presence of the phone itself that triggered impulsive engagement. Similarly, participants designed an indicator which would show when people who were removed were approaching, preserving only the information relevant for safety (P2, P10) and even replacing a clock with a countdown timer to preserve the information of time remaining for task, while filtering out what time of the day it is, which triggers time-related anxiety ("A timer is kind of helpful because it's like counting down how much time I have left, but it's not necessarily showing me the time of day, which I find to be like more nerve-wracking sometimes," P4). What constitutes a relevant property extends beyond what the term conventionally suggests. The distinction between time remaining and time of the day is not typically regarded as something that can be filtered or diminished, yet it proved meaningful for filtering anxiety-inducing rumination. We do not attempt to map this space exhaustively.

Across these designs, participants' reasoning operated at the level of properties: which to preserve, which to filter, and what representation would achieve that separation (Table 2). Just as blur attenuates visual detail or desaturation attenuates color, these designs attenuated properties like identity, affordance, and narrative potential. Such properties are communicated through visual appearance but are not reducible to visual features, suggesting that the target space for attention-supporting DR may extend beyond visual properties to encompass what stimuli mean and afford.

4.2.3 Task-Aligned and Arousal-Regulating Replacement. When removing distractions would leave the corresponding space empty, participants rejected emptiness. As reported in Section 4.1, understimulation triggered internal distraction through mind-wandering. Participants designed replacements that filled space with content chosen for its attentional properties, following two distinct chains of logic.

Some participants designed task-aligned replacement that simultaneously occluded distracting stimuli and channeled attention toward relevant material. Multiple participants wanted lecture slides or notes enlarged to fill their peripheral vision ("Have that [lecture slides] projected to like my entire like field of vision. That would like eliminate like being like even like having to like look at the people in front of me," P5). These designs mirrored a commonly described strategy in which participants chose to sit in the front of the lecture hall to avoid having other students and their views in their peripheral vision (Figure 2).

Other participants designed arousal-regulating replacements to maintain optimal stimulation rather than reinforce task content. Several wanted calming visual content: nature scenes described as a "calming kind of distraction" rather than an "overstimulating" one (P4), minimalist aesthetics (P6), or a "default state" with furniture but no clutter (P9). The reasoning was consistent: a room "with nothing in it" was intolerable (P10). One participant articulated wanting a visual equivalent of "brown noise" to occupy the part of attention that would otherwise wander (P14).

Across both chains of logic, the goal was not the absence of stimulation but regulated stimulation, with content chosen for its capacity to occupy attention without capturing it in ways that derailed the task.

4.3 Agency and Control

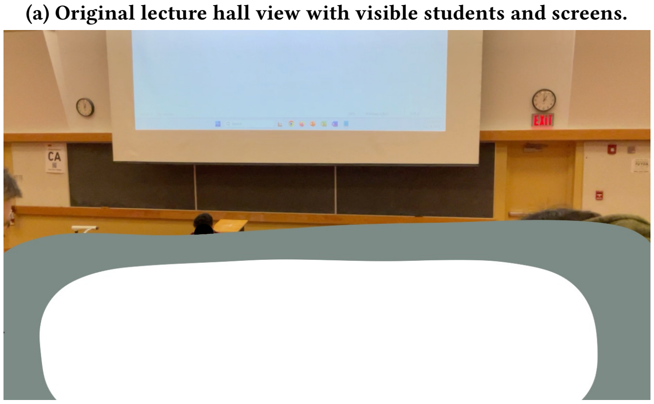
Because DR modifies perception itself, questions of agency and control carry weight beyond those raised by conventional productivity tools. Delegating control over what one sees raises concerns that participants recognized and reasoned about explicitly. During co-design sessions, we explored how control over DR should function through scenarios and direct questions about system behavior, probing for preferences between manual control and automation across different features and contexts. Rather than seeking to maximize moment-to-moment control, participants described wanting systems that would enforce their prior intentions against their anticipated future impulses. As one participant stated, they wanted systems "stricter than I am" (P15).

4.3.1 Frontloaded Control. Participants consistently preferred to concentrate control before the task rather than distribute it throughout. This preference connected directly to the context-switching costs described earlier: if a single distraction could cascade into extended derailment, then in-session prompts or decisions represented not just inconvenience but genuine risk. One participant explained that cognitive resources spent on system management were unavailable for the task itself, stating that too much of their "brain power" would go toward configuration rather than work (P1).

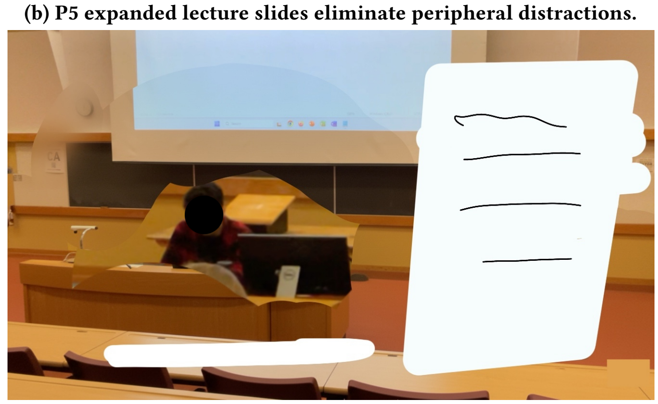
The preferred pattern concentrated decision-making before the task session began. Participants wanted to define rules, create presets, and configure parameters when they were not yet engaged in the task and their judgment was not yet compromised by distraction or fatigue. One participant specified that all configuration should occur before activating focus mode, after which the system should operate without requesting further input (P4). Several participants described wanting preset modes for different contexts that could

(a) Original lecture hall view with visible students and screens.

(b) P5 expanded lecture slides eliminate peripheral distractions.



(c) P3 positioned a virtual screen to occlude other students, "I just see my screen and then the professor's screen".



(d) P13 enlarged the instructor and notes display to occlude other students, making task content "unavoidable".

Figure 2: Task-aligned substitution: Rather than simply erasing distractions, participants replaced them with enlarged task-relevant content (slides, notes, or the instructor) to anchor attention while occluding other students' screens and movements.

be selected at the start of a session and then enforced automatically (P2, P6, P11).

4.3.2 Externalized Inhibition. Frontloaded control determined what rules governed a session. A separate question concerned how those rules would be enforced during task execution, particularly when participants' attention was captured by distractions they had chosen to filter. Participants anticipated that, despite their intentions, their gaze would wander toward filtered stimuli. They wanted the system to maintain their considered preferences when they could not maintain those preferences themselves.

When exploring how the system should respond if users try to pay attention to diminished distractions, participants consistently preferred that it remain diminished ("because I have no self-control. So in this case where I don't have self-control to kind of maintain that focus I would want the system to do it for me," P11; "If my goal was to study, even if [my] eyes are wandering, it should be actively blocking it to be like, 'yeah, get back to work,"' P3).

Participants framed this delegation as supporting rather than undermining their agency. The system would hold stable what they decided when clear-headed, against what they might impulsively pursue when distracted. Several connected this preference to self-imposed constraints they already employed. One participant used parental controls on her own internet access to enforce sleep (P5), while another described throwing his phone into another room before studying, explaining that he needed to eliminate the possibility of checking it from his awareness entirely (P7).

4.3.3 Design Friction. Participants wanted systems that would enforce their intentions, but they also anticipated attempting to override those systems when distracted. When asked how the system should distinguish between unwanted attentional capture and genuine intention to disengage from the task, participants designed friction mechanisms. They wanted systems that required deliberate effort to override, not systems that were generally difficult to use.

Proposed friction mechanisms included minimum session durations that prevented rapid cycling in and out of focus mode ("Can't turn off study mode for at least 15-20 minutes... can't just be on-off, on-off," P4) and overrides requiring navigation through settings menus rather than simple dismissal (P13). The difficulty of override was not a usability flaw to minimize, but a deliberately designed protective feature.

Other participants proposed graduated responses rather than absolute enforcement. One described a grace period of seven to eight seconds that would allow brief glances to satisfy curiosity before the system re-engaged filtering (P4). Another wanted the system to "let me look once, but then if I keep looking, ramp up the focus guardrails" (P5). A third wanted the ability to briefly check what caused a sudden noise before the system hid the source again (P7). These graduated approaches aimed to prevent momentary capture from becoming sustained attention rather than to prevent all looking.

4.3.4 Safety and Awareness. Safety emerged as a boundary condition on the filtering participants wanted. When discussing aggressive removal or blocking approaches, participants consistently acknowledged that emergencies required exceptions (P4, P5, P8). The system could be strict, but genuine threats demanded flexibility.

Approaching people presented a specific challenge. Participants wanted awareness that someone was entering their space, both for physical safety and to prepare for possible interaction, but they also recognized that most approaching figures would simply be passersby whose details would capture attention unnecessarily. Proposed solutions included abstract indicators of approach direction, proximity-based alerts, or brief unmasking followed by immediate re-filtering once the person passed (P2, P4, P6).

Two participants raised concerns specific to perception-altering technology. One noted that if others recognized the user could not see them, the user became vulnerable: "this is like a perfect victim" (P6). Another described anticipated discomfort at hearing sounds without seeing their sources, characterizing the sensory mismatch as "cognitive dissonance" (P14). These concerns suggest that even participants who wanted aggressive filtering recognized limits on how completely visual information could be removed while auditory information remained.

While participants recognized safety as a genuine concern, they were willing to accept significant tradeoffs in general awareness for effective attention support. One participant noted he would remove even people within arm's reach and preferred no indicators for approaching individuals, reasoning that the attentional benefits outweighed the risks (P7). Another, when discussing what they would accept from a system that could meaningfully support their daily functioning, expressed willingness to surrender considerable control and privacy (P14).

> "[If] it takes away like me having to do timesheets I don't give a shit, just do it... if the use case happens to be where they're good enough that they can actually meaningfully support my life, I will give that up in a heartbeat." (P14)

The scope of modification participants were willing to accept, rendering people invisible and trusting automated systems to manage their awareness, reflects the cumulative difficulty of navigating daily life with compromised attentional agency.

5 Discussion

We discuss two insights emerging from our findings: Attentional Diminishment, a sensitizing concept that reframes DR for attention support from visual outcomes to attentional effects, and participants' preferences for externalized control, which illuminate what attention-supporting DR may require.

5.1 Attentional Diminishment

Our findings revealed a consistent pattern: participants reasoned from intended attentional effects toward implementations, and in doing so articulated cases where visual modification failed to produce corresponding attentional effects. We propose Attentional Diminishment as a sensitizing concept that foregrounds this distinction, reframing DR for attention support from visual outcomes to attentional effects.

Current HCI work on distraction management focuses predominantly on perceptual salience as the primary mechanism of attentional capture. Visual decluttering, dark pattern research, and DR techniques such as blur, desaturation, and removal all target stimuli that are conspicuous, interruptive, or visually prominent [9, 17, 29, 50]. While perceptual registration is a precondition for distraction, the mechanisms that sustain unwanted engagement once a stimulus is registered (meaning-making, speculation, associative processing) remain largely underexplored as targets of intervention.

Every stimulus comprises multiple properties. Some are conventionally visual: colour, form, motion, and detail, while others are experiential or functional: presence, spatial awareness, notification status, and the distinction one participant drew between time-of-day and time-remaining. All these properties have attentional effects: they can capture attention, sustain engagement, and trigger elaboration. Under this view, the target space for attention-supporting DR extends beyond visual features to encompass any property with attentional consequences.

This reframes existing DR techniques as forms of property filtering, the selective attenuation of stimulus properties identified in Section 2. Desaturation filters color while preserving form, and removal filters all properties, including presence itself. Naturally, attentional diminishment suggests that we can filter properties that are not conventionally visual, such as identity, activity, and narrative affordance, by designing representations that give visual form only to properties we wish to preserve. For example, a silhouette preserves presence, location, and posture while filtering identity, expression, and activity. Or a status indicator preserves notification while filtering device affordances that trigger engagement.

This parallels how selective attention itself functions. In biased competition models, selective attention prioritizes task-relevant information while suppressing irrelevant information through inhibitory mechanisms. For users whose internal selective attention is unreliable, DR can externally provide this function, i.e., an external extension of cognitive filtering. The design question then becomes: which properties must be preserved for the task, and which drive unwanted capture? This cuts across existing technique taxonomies, which categorize by visual operation rather than attentional function.

Load theory may offer one account of why participants designed task-aligned replacements rather than simply removing distractions. Lavie distinguishes perceptual load, which exhausts early processing capacity, from cognitive load, which depletes working memory resources needed for top-down control [37]. Forster and Lavie demonstrated that high perceptual load can reduce ADHD-related distractibility by preventing distractor processing at early perceptual stages [24]. Participants' designs that fill peripheral vision with task content may function through this mechanism, occupying perceptual capacity that would otherwise process distracting stimuli.

Participants' rejection of understimulation connects to Sergeant's cognitive-energetic model, positioning arousal dysregulation as central to ADHD [53]. Understimulating environments fail to maintain activation for sustained attention. Replacement content, whether task-relevant or arousal-regulating, provides a way to modulate attention in a fine-grained manner, personalizing the perceptual environment to match the users' narrow windows of optimal stimulation.

The distinction between visual and attentional diminishment connects to Gaver et al.'s argument that ambiguity functions as a design resource by inviting interpretation and meaning-making [25]. Our findings confirm this mechanism. P7's compulsive attempts to decipher a semi-erased whiteboard and participants' rejection of blur because degraded detail triggered speculation are instances of information ambiguity that produce interpretive engagement, exactly as Gaver et al. describe. In our context, this interpretive engagement is precisely the attentional capture participants sought to eliminate. Gaver et al.'s framework thus explains why degradation-based DR approaches may fail to support attention. They create interpretive gaps that users with ADHD cannot voluntarily disengage from.

Participants' replacement designs avoid this failure by offering complete representations with no interpretive gap. A silhouette preserves presence and body doubling while filtering identity and narrative affordance. An avatar preserves spatial awareness while filtering activity and expression. These are not degraded versions of the original stimulus but purpose-built representations carrying only the properties participants wanted to preserve. Property filtering as a design strategy appears across HCI. Awareness systems balance social presence with privacy by filtering properties, using purpose-built abstract representations such as light silhouettes and physical proxies [41]. Kucera et al. demonstrated that a slow photo-stream achieved the connection benefits of always-on video while filtering temporal continuity that created social pressure and privacy costs [34]. Our participants applied the same principle to attention, filtering the properties that drove unwanted capture while preserving those needed for body doubling and spatial orientation. These property-filtered representations also function as a form of peripheral interaction [6], providing useful ambient awareness without the properties that force focal engagement.

We offer Attentional Diminishment not as a definition to replace existing framings but as a sensitizing concept, a way of directing attention toward questions that current framings may obscure. When designing DR for attention support, what properties of stimuli drive unwanted capture? When does visual reduction produce attentional reduction, and when does it fail? What representations might filter specific properties while preserving others? How do we address the mechanisms through which stimuli sustain unwanted engagement rather than merely initiate it? These questions cut across existing technique taxonomies and foreground attentional effects as the target of design rather than visual operations as the mechanism.

5.2 Agency and Externalized Control

Participants' preferences raise questions about the relationship between awareness and agency. Prior Digital Self-Control Tools constrain what users can *do*, blocking apps or imposing time limits, while preserving awareness of what exists [43]. Perceptual filtering goes further by constraining what users *perceive*, removing not just access but awareness. Conventional framings in HCI position awareness as a precondition for autonomous choice. This assumption is embedded in design critiques of dark patterns, which frame information-restricting interfaces as ethically problematic precisely because they prevent users from making informed, autonomous decisions [26]. Yet participants described awareness itself as triggering capture they could not resist, awareness that undermined rather than enabled their capacity to act on their intentions.

Their preference for systems configured in advance that restrict awareness without requiring in-session decisions suggests that, for some users in some contexts, limiting what one perceives may be a way to maintain agency over attention rather than a constraint upon it. This echoes a tension Lyngs et al. documented in self-control tools, where users want restrictions strict enough to override in-the-moment impulses yet resist those restrictions once enforced [42]. Our participants addressed this by designing constraints on their future selves, anticipating that they would attempt to circumvent their own prior decisions. Their preference for systems (configured by users in advance) that would restrict awareness suggests that, for some users in some contexts, limiting what one perceives may be how one maintains agency over attention rather than a constraint upon it. We do not claim this generalizes, but our findings suggest it warrants consideration in the design of attention-supporting technologies.

5.3 Limitations and Future Directions

Our sample of 15 students with ADHD at a single North American university limits generalizability. The sample skewed toward high symptom severity and combined presentation; individuals with predominantly hyperactive presentations or milder symptoms may reason differently about attention support. University students also face particular environmental constraints and task demands that may not transfer to the workplace or domestic contexts. Future research should extend to broader ADHD populations and other contexts where attentional challenges manifest differently.

Our speculative design method surfaces how participants reason about DR, but cannot validate whether proposed designs achieve intended attentional effects. The gap between imagined and actual effects of perceptual modification remains untested. Future work should develop functional prototypes implementing participant-generated designs and evaluate attentional outcomes through controlled studies combining behavioral measures, e.g., task performance or gaze tracking, with subjective experience reports.

Several participant designs assumed intelligent systems capable of real-time, near-perfect context-awareness and intent inference, capabilities beyond current technical reach. While research advances toward the contextual intelligence that participants envisioned, near-term implementations may need to rely on simpler approaches, such as user-defined rules or location-based presets.

We did not screen for co-occurring neurodevelopmental conditions such as autism, which has substantial overlap with ADHD in both prevalence and symptom presentation. Attentional and sensory profiles may differ meaningfully for individuals with co-occurring conditions, and the preferences expressed by our participants may not generalize to those with intersecting neurotypes. Future work should examine how co-occurring conditions shape preferences for DR-based attention support.

The co-design activity used Procreate on iPad, which may have biased participants toward visual operations the tool affords most readily, such as erasure. While participants were encouraged to describe ideas verbally and many did so extensively, participants with greater design fluency or different media might have generated different concepts. We did not collect information on participants' prior design experience, which limits our ability to assess how expertise shaped the speculative design outputs.

The concept of Attentional Diminishment emerged from studying ADHD; however, the boundaries remain unclear. Selective attention challenges also affect neurotypical individuals experiencing fatigue, anxiety, or high cognitive load. Extension to these populations would test whether the concept generalizes beyond ADHD-specific mechanisms. A longitudinal study is recommended to examine whether DR provides sustainable support or produces adaptation effects that diminish efficacy over time. Finally, participants' willingness to accept significant awareness restrictions raises ethical concerns about dependency, social implications, and appropriate boundaries of externalized control that warrant further investigation.

6 Conclusion

Through diary studies and co-design workshops with university students with ADHD, we explored how users with attention challenges reason about Diminished Reality and proposed Attentional Diminishment as a sensitizing concept. This foregrounds the distinction between visual and attentional outcomes. Existent technologies designed to support focus or reduce distraction intervene in the relationship between what users perceive and what captures their attention. Our findings suggest this relationship is less straightforward than visual modification alone can address. What is perceptible may matter as much as what is filtered. The conditions under which restricting perception supports rather than undermines autonomy remain an open question. These findings contribute to ongoing efforts to support human agency over attention.

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