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Authors

Raila, Hannah
Avanesyan, Tatevik
Valentine, Keara E
et al.

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Augmenting group hoarding disorder treatment with virtual reality discarding: A pilot study in older adults

Hannah Raila[a,b], Tatevik Avanesyan[a], Keara E. Valentine[a], Brenden Koo[a], Chloe Huang[a], Yuri Tsutsumi[a], Elisabeth Andreeff[a], Tori Qiu[a], Paula Andrea Muñoz Rodríguez[a,c], Andrea Varias[a], Maria Filippou-Frye[a], Peter van Roessel[a,d], Kim Bullock[a], Vyjeyanthi S. Periyakoil[e,f], Carolyn I. Rodríguez[a,g]

a. Department of Psychiatry and Behavioral Sciences, Stanford University, Stanford, CA, USA
b. Department of Psychology, University of California Santa Cruz, Santa Cruz, CA, USA
c. Department of Neurology and Neurological Sciences, Stanford University, Stanford, CA, USA
d. Sierra Pacific Mental Illness Research, Education, and Clinical Center (MIRECC), VA Palo Alto Health Care System, Palo Alto, CA, USA
e. Department of Medicine, Stanford University, Palo Alto, California, USA
f. Extended Care and Palliative Medicine Service, Veterans Affairs Palo Alto Health Care System, Palo Alto, California, USA
g. Veterans Affairs Palo Alto Health Care System, Palo Alto, CA, USA

Co-Corresponding Authors:

Hannah Raila (hraila@ucsc.edu) and Carolyn I. Rodriguez (cr2163@stanford.edu)
Department of Psychiatry and Behavioral Sciences
Stanford University
401 Quarry Road
Stanford, CA 94305
USA

Abstract

Hoarding disorder is common and debilitating, especially in older adults, and novel treatment approaches are needed. Many current treatments emphasize skills related to discarding and decisions-making about possessions, which can be practiced in the patient's home. However in many cases, in-home visits are unfeasible, or real-life discarding is too difficult. Virtual reality (VR) offers the ability to create a virtual "home" including 3D scans of the patient's actual possessions that can be moved or discarded. VR discarding is an alternative to in-home visits and an approach that provides a stepping stone to real-life discarding. VR has been successfully utilized to treat many disorders but tested minimally in hoarding disorder. In nine older adults with hoarding disorder, we tested an 8-week VR intervention administered to augment a 16-week Buried in Treasures group treatment. Individualized VR rooms were uniquely modeled after each patient's home. During clinician-administered VR sessions, patients practiced sorting and discarding their virtual possessions. The intervention was feasible to administer. Open-ended participant responses, examined by two independent evaluators, indicated that VR sessions were well-tolerated and that participants found them useful, with nearly all participants noting that VR helped them increase real-life discarding. Self-reported hoarding symptoms decreased from baseline to close, with seven of the nine participants showing reliable improvement in this timeframe and none showing deterioration. Results from this exploratory pilot study suggest that VR is a feasible way to simulate an at-home sorting and discarding experience in a manner that may augment skills acquisition. It remains an open question whether VR discarding practice yields greater improvement than existing treatments. VR for this population merits further clinical investigation.

*Keywords***:** Hoarding; Clutter; Virtual reality; Geropsychology

1. Introduction

Hoarding Disorder (HD) is characterized by difficulty discarding possessions, which results in an accumulation of clutter that can make living spaces unusable. It is a disabling public health problem present in 2.5% of the population (APA, 2014; Tolin et al., 2008; Postlethwaite et al., 2019). HD is linked with older age, as symptoms are three times more likely to occur in older adults than younger adults (Samuels et al., 2008). Those who seek treatment are typically age 55 or older, and they report increased hoarding severity with each successive decade of their lives (Ayers et al, 2010). Interventions such as cognitive behavioral therapy (CBT) and Buried in Treasures (BIT) workshops improve hoarding symptoms for many people (Steketee et al., 2010; Frost et al., 2011), but many patients refuse treatment (44%; Steketee et al., 2010), and most who complete treatment remain symptomatic (Tolin et al., 2015). To better treat HD, the field needs novel approaches that help these individuals learn to discard their possessions.

Existing treatments promote skills around discarding of and decision-making about possessions (Tolin et al., 2015), and it may be useful to practice these skills in the patient's home, for example via in-home visits (Linkovski et al., 2018). However, in many cases this is unfeasible. Patients' homes often pose health risks (e.g., pest infestation, fire hazards; Mataix-Cols, 2014) or are simply too far away for a clinician to regularly commute to. Older people, especially, may have trouble physically moving their clutter around in the home during the short duration of an in-home visit. Thus, clinicians need alternatives to spending time with patients in their real-life homes.

Virtual reality (VR) offers the ability to enter a virtual "home" that includes 3D versions of the patient's actual possessions that can be moved or discarded. Working with a patient in a VR home is an alternative to in-home visits and their drawbacks. Moreover, virtual discarding

provides a stepping stone to real-life discarding. Because VR does not involve real-life possessions, the experience of virtual discarding is distinctly different from discarding during either an in-home visit or with items the patient brings to the clinician's office. In this way, VR discarding is similar to imaginal exposure, which involves repeatedly evoking mental images of feared or avoided scenarios (e.g., discarding one's possessions) to practice tolerating distress (Abramowitz, 2018; Robichaud & Dugas, 2015). A case series found preliminary support for imaginal exposure for HD (Fracalanza et al., 2021). VR exposures are considered an extension of traditional imaginal exposures, and one of their benefits is that they do not require an effective imagination (Maples-Keller et al., 2017). Unlike real-life discarding, VR provides the opportunity to discard objects over and over to facilitate desensitization (e.g., a patient practices discarding a virtual mug, but the mug returns to the VR world to practice discarding it again). In short, repeatedly rehearsing discarding with virtual possessions in VR may make real-life discarding more tolerable, and VR discarding may serve as a stepping stone to real-life discarding.

VR has been successfully utilized in anxiety disorders and OCD (Maples-Keller et al., 2017), but it has only minimally been tested in HD. For people with HD, immersion in a VR rendering of one's home, but *without* clutter, was found to be acceptable and to enhance motivation for change (Chasson et al., 2020). Another study used a non-individualized VR apartment with the participant's individualized possessions in it, added this VR component to an inference-based therapy group (St-Pierre-Delorme & O'Connor, 2016), and found that this elicited greater reductions in clutter compared to a control VR environment with common household items. These early studies suggest that VR merits further investigation for this population. Importantly, no previous studies have tested a VR intervention as an augmentation to

an already well-validated intervention for hoarding, such as BIT groups (Frost et al., 2011). Additionally, none have tested VR for hoarding exclusively in *older* adults, and thus there are remaining questions about whether an older population (the most likely to report hoarding symptoms) would interface well with the VR technology or find it tolerable.

The present open-label pilot study investigated whether a VR intervention – with VR environments uniquely modeled after each participant's home – could be used to help older adults as an augmentative approach to BIT group treatment. We assessed the tolerability and feasibility of the VR approach, and we tested whether participants reported improvement in their HD symptoms at the end of treatment.

2. Materials and methods

2.1. Recruitment and Eligibility

Interested individuals were invited to participate if they were over age 55; were diagnosed with HD via the SCID-5-RV (First et al., 2015); reported clinically significant hoarding symptoms at screening (Saving Inventory-Revised [SIR; Frost et al., 2004] score ≥ 41; one participant's score dropped below this from screening to baseline); and had clinically significant clutter in at least one room in their house as rated by an independent evaluator (Clutter Image Rating [CIR; Frost et al., 2008] score ≥ 4). Psychotropic medication was allowed if the dose was stable for at least 4 weeks (8 weeks for fluoxetine) before study start. Participants were excluded if they were diagnosed via the SCID-5-RV with a current or past psychotic disorder, current severe alcohol use disorder, current severe depression, or current or past bipolar I disorder; at risk of suicide (Columbia Suicide Severity Rating Scale ≥ 4; Posner et al., 2011); at high risk for eviction (e.g., eviction-related legal proceedings that may require a higher level of care); had major medical or neurological conditions (e.g., seizure disorder) that increased the

risks of VR participation; received current services and/or help from professional organizers; had started CBT or a BIT group within 8 weeks before enrollment; or had a history of severe motion sickness. Participants were recruited via advertisements posted online, via invitation if they had participated in a prior study with the lab and indicated interest in additional studies, and via referrals from mental health professionals.

2.2. Participants

Fifteen people were screened between July 2020 and April 2021, and 13 met inclusion criteria. Three of those withdrew their consent (two of whom did so before completing full screening), and one was lost to follow-up. This provided a final sample of nine adults with HD. All participants provided IRB-approved written informed consent. Due to technical issues caused by the COVID-19 pandemic, study start date was postponed until August 2021.

Demographic information about the sample of nine can be found in Table 1. The sample was 55.6% female, with a mean age of 64.0 (*SD* = 4.8; range = 56-73). The mean baseline SIR score (*M* = 57.1, *SD* = 9.9) of participants in the current study was comparable to that of other clinical hoarding disorder samples (e.g., Kellman-McFarlane et al., 2019; Tolin et al., 2010). Five out of nine had a family history of hoarding disorder. The individual lost to follow-up was a White non-Hispanic female, age 59, who was not taking psychiatric medications (baseline SIR = 57; baseline CIR = 4.5).

2.3. Measures

Measures used are described below. For more details on measures, and Cronbach's alphas, see supplementary material. Internal validity of all measures was good.

Saving Inventory-Revised (SIR; Frost et al., 2004). The SIR is a self-report scale assessing hoarding severity over the past week; it was a primary outcome measure for this study.

The items assess three factors (Clutter Severity, Difficulty Discarding, and Excessive Acquisition). A single composite score ranges from 0 to 92, with higher scores indicating greater hoarding symptom severity.

Clutter Image Rating (CIR; Frost et al., 2008). The CIR is a pictographic rating scale of home clutter, assessed in the present study by study staff independent evaluators during home visits conducted remotely (i.e., via Zoom video visits). The CIR was a primary outcome measure for this study. On a scale of 1 to 9, the quantity of clutter in each room of the participant's home is matched by the independent evaluator to an image of a room. Total scores reflect the average clutter rating across all rated rooms in the home.

Saving Cognitions Inventory (SCI; Steketee et al., 2003). The SCI a self-report scale assessing cognitions (e.g., reliance on items for memory) related to hoarding. It was a secondary measure of hoarding-related symptoms for this study. A single composite score ranges from 24 to 168, with higher scores indicating stronger hoarding-related beliefs.

Depression Anxiety Stress Scale (DASS-21; Henry & Crawford, 2005). The DASS is a self-report scale assessing depression, anxiety, and stress over the past week, with higher scores indicating greater severity. A total score ranges from 0 to 63.

Simulator sickness questionnaire (SSQ; Kennedy et al., 1993). The SSQ is a self-report scale assessing participants' sickness (e.g., dizziness, headache) after every VR session, with higher scores indicating more severe sickness.

Credibility and expectancy questionnaire (CEQ; Devilly & Borkovec, 2000). The CEQ is a self-report scale assessing participants' thoughts and feelings about the intervention; it was reworded to apply specifically to the VR intervention. Three items assess the intervention's credibility and three assess its expectancy. A sum score was calculated for each of the two

factors, ranging from 3 to 27, with higher scores indicating stronger credibility and expectancy. For evaluating individual responses on each factor, an a priori cutoff was a score greater than 15 on each factor. Participants completed the CEQ at close out.

Open-Ended Questions (Fracalanza et al., 2021). The acceptability, impact, and usefulness of VR sessions were assessed using an open-ended, three-question form at closeout. Content themes were identified by two independent evaluators (KV and EA) to assess patterns of responses. Each independently developed a list of core themes by reviewing qualitative responses; then they met and modified these themes by discussing until consensus emerged (see Rodriguez et al., 2016). To assess clinician perspectives of the intervention, study clinicians responded to eight open-ended questions regarding their experiences administering the intervention and the perceived barriers and advantages of the technology used (e.g., "How difficult was it teaching the VR technology to your patients?").

2.4. Virtual Reality World Creation

Study staff recreated one room in each participant's home as a VR environment that allowed for navigation and interaction with virtual possessions. This process was developed with the assistance of VR company NeuroRehabVR. To do so, study staff did a virtual video visit in each participant's home, during which they instructed the participant on collecting 360^{o} photos and videos of the room that would be used to create the VR. The selected room was based on where participants felt the most distress about clutter. During this visit, participants were also instructed on taking pictures of 30 possessions that would be imported into the virtual world. They were asked to provide photos of objects of varying levels of difficulty discarding, from easier to discard (e.g., receipts) to more difficult (e.g., photo albums).

VR worlds were created using Unity Software (version 2020.1.6f1). Recreation of the home scene involved searching 3D modeling websites, such as SketchFab and the Unity Asset Store, to find representative 3D models of items similar to those in the room – such as couches and stoves. Assets were imported into the Unity project, placing each element into the virtual room. For certain items in the room (e.g., a poster, a colorful rug), the texture of the item captured in the participants' home photos was overlaid onto these assets to increase similarity between real home and virtual home. Virtual worlds were matched as closely as possible to the original reference. VR world creators estimated that each world took an average of 15 hours to create.

Each of the participants' 30 individual objects was cut out using Adobe Photoshop (version 22.5.0), converted into 2-dimensional billboards, and inserted in the home environment. To enable participants to manipulate the objects around the room, pick them up, and practice discarding them, the billboarded objects included scripts, RigidBody functions, and mesh colliders. A trash can, recycling bin, and donation box were placed in each VR world. VR world creation was first validated using two pilot participants.

For an example of a VR environment that is somewhat representative of a participant's, go to https://youtu.be/f_CdAa6bH9g. Note that this VR environment was not finalized to be used in the present study, but rather was part of the piloting and VR creation phase. Accordingly, it is relatively less cluttered than the finalized participants' environments, which aimed to be as cluttered as the participants' real homes. To see a member of our research team (HR) navigating a VR environment (also not a participant's from the present study) and moving objects into bins, go to https://www.youtube.com/shorts/Qu3-diadFzU. For confidentiality, finalized participant VR worlds are not shown.

2.5. VR Equipment

VR equipment included commercially available HTC VIVE headsets utilizing STEAM-VR. This allowed the participant to navigate naturally and use motion tracked handheld controllers to vividly manipulate objects with an avatar of their hands. The environments were generated on a Lenovo ThinkPad Laptop 2.60 GHz, with 16.0 GB of RAM and 128 MB of video memory.

2.6. Procedure Overview

Participants diagnosed with HD participated in study interventions for 16 weeks, including 16 weeks of remote BIT group sessions and 8 weeks of in-person individual VR-based sessions (the two session types overlapped during weeks 7-14 of BIT). VR environments were individualized to look like each participant's cluttered room. Primary outcome assessments were collected at Baseline (Week 0), immediately before starting VR sessions (Week 6), and at Close Out (Week 17). Participants completed the SSQ at the end of every session. See Figure 1 for a schematic of the intervention timeline.

2.7. Virtual Reality Treatment Protocol

Beginning seven weeks into the BIT group sessions, eight weekly 1-hour individual VR sessions were administered (one for orientation; seven using the VR). Session content was consistent with protocols for in-home decluttering visits (Linkovski et al., 2018). VR sessions were administered by doctoral trainee clinicians trained in the treatment protocol and VR equipment. Sessions were designed to augment sorting and discarding skills learned in the BIT group; they are described in more detail below.

In the first session, participants received psychoeducation on the VR approach, and in Session 2, they familiarized themselves with the virtual home. In Sessions 2 and 3, the focus was

on practicing cognitive skills with the virtual objects. This included identifying core beliefs about objects (“If you discarded this magazine, why would it be so upsetting?”) and thinking through decision-making skills (“How many mugs would be ‘enough’?”), while holding the virtual object in question (a magazine, a mug) and at times subsequently placing it into the virtual trash, recycling, or donation bins.

In Sessions 4 through 8, focus was on desensitizing to discarding in the virtual home. Participants created a hierarchy of how distressing it would feel to discard each virtual object, then started discarding items lower on the hierarchy and worked their way up. In virtual discarding, they placed objects into bins (trash, recycle, donate; there was no "keep" bin although this is sometimes used in real-life discarding practice). An animated trash truck came to pick up the items placed in the trash. Participants were encouraged to lean into the psychological immersion of the process and the worry thoughts associated with discarding. During virtual discarding, they regularly rated their subjective distress on a scale of 0 to 10. As homework, they were assigned to actually discard one of the items that they had virtually discarded in session (or a similar item). In the final (8^{th}) session, in addition to the VR activities, a relapse prevention plan was also made.

2.8. BIT Peer Support Group Treatment Protocol

The BIT group met online once per week for 16 weeks and followed the structured format detailed in the *Buried in Treasures* workbook (Tolin et al., 2013) and the BIT facilitator's guide (Shuer and Frost, 2014). Each two-hour group session was led by two study staff group facilitators (KV, TA), one of whom was a doctoral trainee clinician. The content began with psychoeducation about HD and non-acquiring skills, and then provided educational content

regarding skills for discarding possessions (e.g., behavioral experiments where one discards an item and then tracks how distressing it feels).

2.9. Statistical Analyses

The relatively small sample size limits inference-based statistics such as mixed effects models (MEMs); thus, primary analyses will be descriptive statistics. It is generally recommended that analysis of small samples, such as the present study, be descriptive (Grimes & Schulz, 2002; Lancaster et al., 2004). The goal is for preliminary data to support the potential effectiveness of this approach, which can then be examined in a larger study. For primary outcome measures, we calculated the reliable change index (RCI; Jacobson & Truax, 1991), a statistical approach for measuring individual change in self-report scores; RCIs greater than 1.96 indicate reliable change, likely attributable to treatment rather than measurement error. To be thorough, we also note clinically significant change on the SIR using a stringent standardized criterion for this questionnaire (Norberg et al., 2021).

3. Results

Participant clinical characteristics and effects of the BIT + VR intervention are shown in Table 1. All nine participants completed all assessment measures.

3.1. Tolerability and Feasibility

To evaluate credibility and expectancy of the VR intervention, we examined CEQ scores. Mean score on credibility was 18.33 (*SD* = 7.63), with seven of the nine participants indicating that it was higher than neutral credibility. Mean score on expectancy was 15.56 (*SD* = 7.57), with five of the nine participants indicating higher than neutral expectancy.

To assess engagement, we measured attendance of the VR sessions and completion of the intervention. Participants attended an average of 7.4 out of 8 VR sessions, with one participant

attending only five due to faraway travel. Zero of the nine participants withdrew from the VR intervention or BIT group.

To assess whether our participants (whose mean age = 64.0) could physically tolerate VR and did not experience illness-related side effects (e.g., feel dizzy or nauseous), we examined scores on the SSQ for all participants after the sessions during which VR was used (with a 65.1% rate of successfully completing the questionnaire). Participants' SSQ scores during sessions ranged from 0 to 18, with a mean across all participants and all sessions of 2.94 (*SD* = 4.54) and a modal score of 0. Scores at or below five are considered "negligible." Of the 41 sessions for which the SSQ was completed, participants scored at or below a five on 34 (82.9%) of them. However, one participant did report more consistent illness-related effects; her mean score was 14.7 (*SD* = 4.2).

3.2. Indicators of HD Symptom Reduction

To estimate reductions in HD symptoms and related processes that may be attributable to the BIT+VR intervention, we examined questionnaire scores across three Time Points: Baseline (Week 0), right before VR Start (Week 6), and Close (Week 17). Scores on the SIR and the CIR were the primary outcome measures, while the SCI and DASS were secondary outcome measures. We compared symptom change that occurred before VR sessions began (with BIT alone) to that which occurred after VR sessions began (with BIT + VR). Participants' individualized changes in symptoms are summarized in Table 1, while Figure 2 captures the group's mean changes across Time Points.

From Baseline to Close, all nine participants showed a decrease in SIR Total score. Baseline (*M* = 57.1, *SD* = 9.9) to Close (*M* = 42.9, *SD* = 10.5), SIR decreased by an average of 14.2 points (*SD* = 7.7), a 24.9% mean decrease. For specifics on change to each of the three

subscales, see supplementary material. RCI scores indicated reliable improvement in seven of the nine participants (RCIs from 2.01 to 7.05), while no participants deteriorated. An assessment of clinically significant change (Norberg et al., 2021) indicated that one participant was recovered (i.e., 20+ point decrease to 38 or below), one was improved but not recovered (i.e., 20+ point decrease to 39 or above), and seven showed a decrease that was not clinically significant (i.e., less than 20 point change). From Baseline to VR Start (M = 53.8, SD = 8.8), mean SIR decrease was 5.8%, while mean decrease from VR Start to Close was 20.3%. Across Time Points (from Baseline to Close), 76.6% of the total decrease in SIR score occurred *after* the VR sessions began (i.e., VR Start to Close) rather than before (i.e., Baseline to VR Start). SIR score changes that occurred after VR Start (i.e., VR Start to Close) were thus descriptively greater than those that occurred during BIT alone (i.e., Baseline to VR Start).

From Baseline to Close, eight of the nine participants showed a decrease in CIR Total scores, which were amalgamated across all rooms assessed in the home (that is, they were not isolated to the one room that was the focus of the VR environment). One participant showed no change. Baseline CIR Total (M = 5.23, SD = 1.53) to Close CIR Total (M = 4.46, SD = 1.29) decreased an average of 0.77 points (SD = 0.58), a 14.8% mean decrease. RCI scores indicated reliable improvement in three of the participants (RCIs from 2.14 to 2.81), while no participants deteriorated. Across all rooms (Kitchen, Bedroom, Living Room, Other), participants did not show an increase in any of their CIR scores in any room. Mean decrease from Baseline to VR Start (M = 4.78, SD = 1.49) was 8.6%, while mean decrease from VR Start to Close was 6.7%. Across Time Points, 41.5% of the decrease in CIR Total occurred *after* the VR sessions began.

To estimate changes in secondary measures, we report on the mean change of other self-report measures across Time Points. From Baseline to Close, all nine participants showed a

decreased in SCI Total score. Baseline SCI (*M* = 85.22, *SD* = 28.41) to Close SCI (*M* = 57.00, *SD* = 18.29) decreased by an average of 28.22 (*SD* = 17.34), a 33.1% mean decrease. Mean decrease from Baseline to VR Start (*M* = 75.67, *SD* = 24.19) was 11.2%, while mean decrease from VR Start to Close was 24.7%. Across Time Points, 66.1% of the decrease in SCI occurred *after* the VR sessions began. From Baseline to Close, seven of the nine participants showed a decrease in DASS Total score; two showed no change. Baseline DASS Total (*M* = 34.44, *SD* = 20.17) to Close DASS Total (*M* = 17.78, *SD* = 14.91) decreased an average of 16.67 (*SD* = 15.43), a 48.4% mean decrease. At VR Start (*M* = 30.00, *SD* = 20.30), mean decrease from Baseline to VR Start was 12.9%, while mean decrease from VR Start to Close was 40.7%. Across Time Points, 73.3% of the decrease in DASS Total occurred *after* the VR sessions began.

3.3. Qualitative Participant Responses

To assess participants' perception of the VR intervention, two independent evaluators coded open-ended participant responses (completed by all participants) answering questions related to the utility, acceptability, and impact of the intervention. Only responses that addressed the questions asked were included (as such, some themes have fewer than nine total responses). Eight of the nine participants who answered about the intervention's usefulness (89%) indicated that the intervention was useful; for example, "Yes, it helped me let go of some things that I didn't think I could let go of." Five of the six participants who answered about the intervention's acceptability (83%) reported the VR decluttering exercise was acceptable to them. Six of the seven who answered about the intervention's impact (86%) noted that the VR decluttering had an impact on their lives and lead to increased discarding (e.g., "VR decluttering helped me to be able to get rid of a lot of stuff in real life!"). There were no reported adverse events related to the intervention and no reported distress that participants found intolerable.

In addition to coding answers directly solicited from the questions, raters examined recurrent themes in the participants' spontaneous responses. Particularly, to look for ways to increase acceptability in future studies, responses were examined for intervention improvements. Only themes reliably identified by both raters are presented. Three participants stated that the VR decluttering increased their awareness and insight (e.g., "The VR exercise raised my awareness of the mental and emotional processes in decluttering"). Four reported that the VR exercises reinforced the skills they learned from the BIT group (e.g., "Doing more of Downward Arrow and Think It Through"). Four noted the role of the therapist's influence, separable from the VR itself (e.g., "It was talking with the VR therapist about exercises that helped me"). Three made remarks about how VR decluttering compares to real-life decluttering (e.g., "VR decluttering seemed fake"). Three commented on the limitations of the VR and made recommendations for future studies (e.g., "Technical difficulties. Some VR items not tagged for discarding").

3.4. Qualitative Clinician Perspectives on VR

To qualitatively assess clinician perspectives on the intervention, which is increasingly recognized as a valuable contribution to health services research (Chafe, 2017), an independent evaluator (YT) assessed the open-ended responses from clinicians. This has been done in previous studies testing interventions administered via new technology (Khatri et al., 2014). For description of clinician perspectives, see supplementary material.

4. Discussion

This is the first study testing a novel 8-week VR intervention – where participants entered virtual "homes" (individually modeled from their actual homes) to practice sorting and discarding – as an augmentation to a remote BIT group treatment. It focused on older adults with

HD, perhaps one of the most vulnerable populations within the mental health community. The present study is a recommended phase of developing novel VR interventions (Birckhead et al., 2019) that includes early testing to assess feasibility, acceptability, tolerability, and initial clinical efficacy.

The VR intervention was well-tolerated by participants. It generally did not make them feel sick (e.g., dizzy), and it was perceived as credible and associated with expected improvement. Open-ended responses from participants indicated that they found it acceptable and useful. Indeed, responses were positive and suggest that this older population, despite being relatively unfamiliar with VR technology, is amenable to VR treatment for hoarding.

Descriptive quantitative results suggest VR's utility, at least when used in combination with remote BIT. From baseline to close, participants exhibited reductions in self-reported HD symptoms (e.g., difficulty discarding; SIR) and severity of clutter in the home (CIR), which was independently rated by study staff. Participants also exhibited improvements in cognitions around saving items (SCI), a related construct, and a reduction in self-reported depression, anxiety, and stress (DASS-21). Notably, a substantial portion of these improvements occurred after the VR sessions began. However importantly, only two of the nine participants showed clinically significant improvement. Overall, these findings indicate that VR sorting and discarding merits further investigation, and they raise the possibility of using VR to augment existing hoarding disorder treatments.

We can compare these descriptive results to previous findings that tested the utility of in-person BIT alone. Our mean decreases in SIR, CIR, and SCI scores (24.9%, 14.8%, and 33.1%, respectively, in the present study) are comparable to those previously found with in-person BIT alone (21-31%%, 19-24%, and 18-30%, respectively; Frost et al., 2011; Frost et al., 2012)

though somewhat smaller than a recent study found with virtual (i.e., video teleconference) BIT alone (36%; Yap et al., 2022). And, our mean CIR decrease is smaller than that previously found with in-person BIT augmented with in-home decluttering visits (38%; Linkovski et al., 2018).

Interestingly, our decrease in DASS score (48.4% in the present study) is notably *greater* than that found with in-person BIT alone (≤16%; Frost et al., 2011). This may be due to the individual face-to-face component that the VR sessions added, which perhaps strengthened the therapeutic alliance, positive regard, or other common factors.

The trajectory of change in the present study, however, differs from previous BIT alone. In previous in-person BIT studies (both study 1 and study 2; Frost et al., 2011) and the previous video teleconference BIT study (Yap et al., 2021), SIR improvement was very similar from baseline to midpoint and from midpoint to end. In a study testing in-person BIT augmented with in-home decluttering visits (Linkovski et al., 2018), most SIR improvement occurred in weeks 1-12 (median decrease 16 points) when the intervention was primarily BIT alone, compared to that in weeks 12-18 (median decrease of 2 additional points) when the majority of the in-home decluttering visits occurred. By comparison, in the present study, SIR improvement significantly increased from midpoint to end after the introduction of VR, which could be indicative of a relative improvement in treatment impact once VR was introduced (though without a control group we naturally cannot know this).

Comparisons with previous studies should be interpreted cautiously, as it is reasonable to speculate that the COVID-19 pandemic – during which this study was conducted – changed typical improvement trajectories. For example, our BIT portion of the intervention may not have yielded its typical results during this time, in part because it was conducted remotely via video rather than in-person, and thus perhaps the VR discarding added more value than is conveyed by

some comparisons. However importantly, one video-administered BIT-only group showed as good if not better symptom reduction than the present study (Yap et al., 2022). Thus on the other hand, it is possible that VR sorting and discarding simply does not add value to BIT alone. As usual in an open-label pilot trial, we cannot rule out that symptom change reflects a placebo effect or was influenced by demand characteristics such as participants implicitly wanting to confirm the hypothesis. To evaluate these possibilities and to have inferential statistics on which to base conclusions, a larger controlled trial is needed.

To our knowledge, this is the first psychotherapeutic VR intervention to use individualized VR environments uniquely resembling each patient's home, and building these worlds took time and effort (approximately 15 hours each). With the state of technology at the time of this writing, it is impractical to expect clinical staff to build such a world for every patient. However, technology is rapidly evolving to allow for recreating one's *in vivo* surroundings in VR in more automated ways. For example, the recent addition of LiDAR scanning technology to some smartphones enables people to access user-friendly software to scan and create 3D representations of their surroundings (Stein, 2022). Or, future interventions may try using augmented reality (AR) to allow participants to navigate their home *in vivo* but with virtual objects overlaid (Riva et al., 2016).

The chance to practice discarding in a context similar to where it will occur in the home may be useful due to context-dependent learning (Godden & Baddeley, 1975), wherein information learned in a particular environment (e.g., in a kitchen, rather than a clinician's office) is recalled well in the same environment (e.g., the same kitchen). Yet, VR discarding is not the only way to do this. Other approaches for practicing discarding include in-home visits and virtual visits (e.g., Zoom visits). However, in addition to the obstacles of in-home visits noted above, the

drawbacks of in-home visits became more apparent during the COVID-19 pandemic, when VR became increasingly relevant as a way to allow patient and clinician to be jointly inside the patient's "home" with slightly reduced transmission risk from or to additional members of the home. Virtual (e.g., Zoom) visits also became more feasible during the COVID-19 pandemic, as older adults became more comfortable with this technology. However, this requires working immediately with *in vivo* possessions, whereas VR discarding serves as a stepping stone to real-life discarding that may benefit some patients.

Given the very small sample size, this pilot trial was underpowered for inferential analyses, and results should accordingly be interpreted with appropriate caution. Future studies should be conducted on a larger sample with randomized controlled assignment, which would enable conclusions about whether VR improves treatment outcomes more than BIT alone.

Overall, results from this exploratory pilot suggest that VR is an opportunity to simulate an at-home sorting and discarding experience in a manner that may augment skills acquisition. Results demonstrated feasibility and acceptability in an older population. Using VR overcomes several obstacles that an in-home discarding practice typically presents. It remains an intriguing question if VR significantly improves existing treatments. If VR discarding does prove an effective augmentation for HD treatment, the potential impact is large. In sum, the field should remain cautiously optimistic about VR discarding for this population, and it merits further clinical investigation.

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Table 1

Sample Characteristics.

Pt	Age/ Sex	Ethnicity/ Race	Comorbid Diagnoses	Family History of HD	Previous Professional Organizers	Current Psychiatric Medications	Pre/Post Total SIR Score with Change	Pre/Post Total DASS Score with Change
1	73/F	Non-Hispanic/ White	MDD, PDD, OCD	N	Y	Wellbutrin, Sertraline	66/42 -24	50/12 -38
2	63/F	Non-Hispanic/ Asian	OCD	Y	N	Prozac	58/43 -15	18/18 0
3	66/F	Non-Hispanic/ White	MDD, OCD	Y	N	Wellbutrin, Gabapentin	60/53 -7	34/8 -26
4	65/M	Non-Hispanic/ White	PDD	N	Y	None	47/42 -5	20/16 -4
5	56/F	Non-Hispanic/ White	None	Y	N	None	71/55 -16	54/50 -4
6	63/M	Non-Hispanic/ White	None	Y	N	None	56/28 -28	10/10 0
7	60/F	Non-Hispanic/ White	MDD, PDD, Soc. Anxiety Disorder	N	N	Duloxetine, Abilify	55/41 -14	72/34 -38
8	62/M	Non-Hispanic/ White	Other specified OCRD	Y	Y	Buspirone, Lexapro, Trazodone	63/55 -8	26/4 -22
9	68/M	Non-Hispanic/ White	ADHD	N	Y	Bupropion, Methylphenidate	38/27 -11	26/8 -18

Note. SIR=Saving Inventory Revised; DASS=Depression Anxiety Stress Scale

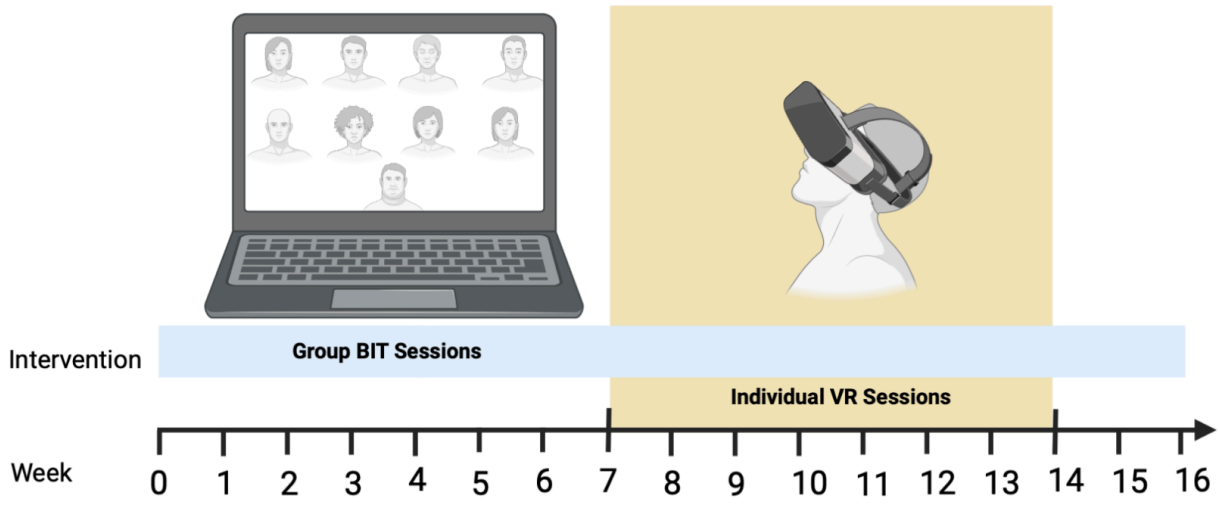

Figure 1. Timeline of interventions across 16 weeks.

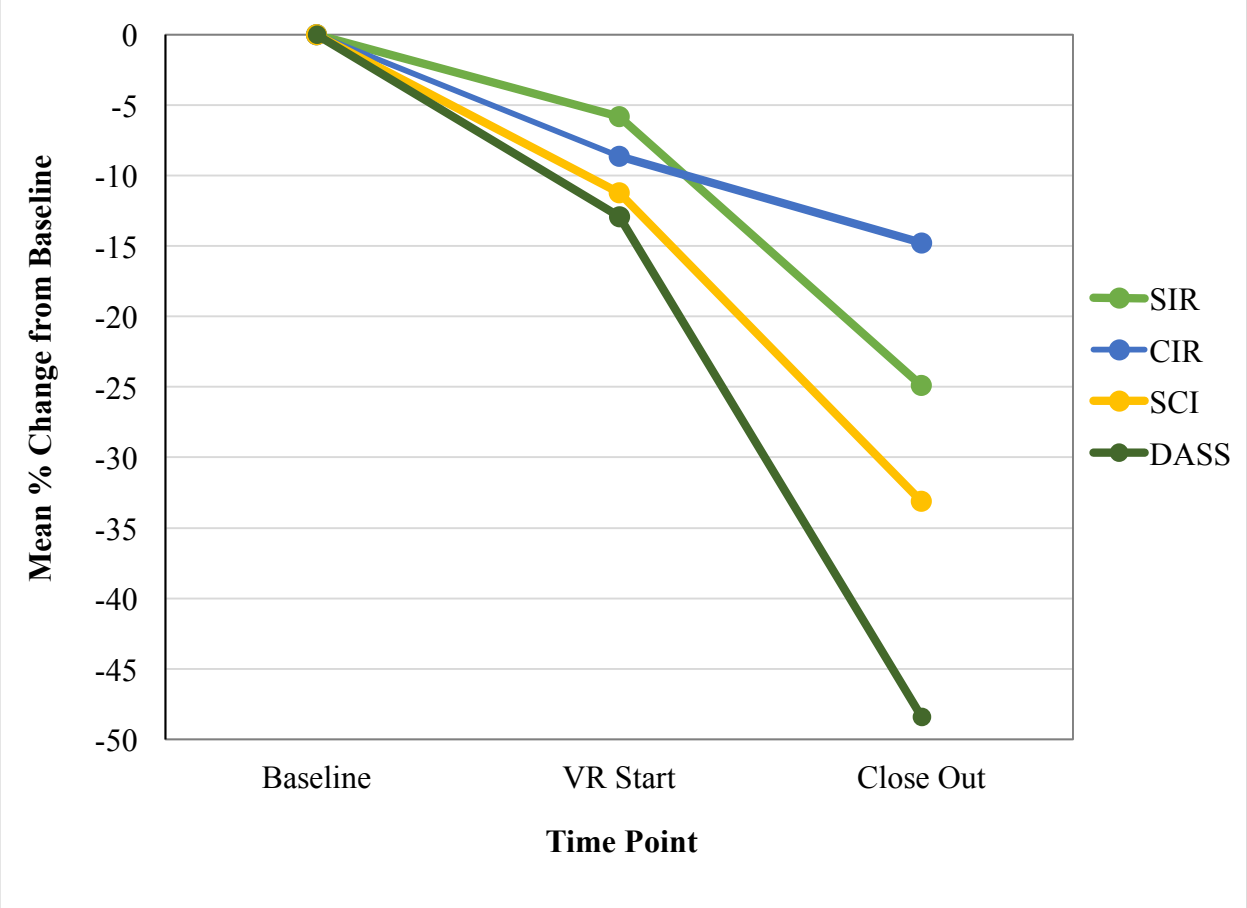

Figure 2. Mean symptom change across Time Points.

Note. SIR=Saving Inventory Revised; CIR=Clutter Image Rating Scale; SCI=Saving Cognitions Inventory; DASS=Depression Anxiety Stress Scale.