Original Paper

Cocreated Immersive Virtual Reality for Nutrition Education in Autistic Children and Adolescents: Development and Usability Study

José Ferrer Costa[1,2,3], MD, MSc; Anna Maria Vallmitjana Soler[4], BSc; Pol Florences Serra[4], BSc, MSc; Verónica Villarejo Romero[1], BSc; Tania González Penadés[1], BSc; Xavier Bayona-Huguet[1], MD

[1]Research and Innovation Department, Badalona Serveis Assistencials, Badalona, Catalonia, Spain

[2]Grup de Recerca Multidisciplinar en Salut i Societat (GREMSAS), Institut Universitari d'Investigació en Atenció Primària Jordi Gol, Barcelona, Catalonia, Spain

[3]Behavioural Design Lab (BDLab), UOC eHealth Centre, Faculty of Psychology and Education Sciences, Universitat Oberta de Catalunya, Barcelona, Catalonia, Spain

[4]Mental Health Service, Badalona Serveis Assistencials, Badalona, Catalonia, Spain

Corresponding Author:
José Ferrer Costa, MD, MSc
Research and Innovation Department
Badalona Serveis Assistencials
Pl Pau Casals, 1
Badalona, Catalonia, 08911
Spain
Phone: 34 937407482
Email: jferrercosta@uoc.edu

Abstract

Background: Feeding difficulties and restrictive eating patterns are common among autistic children and adolescents, but evidence on immersive virtual reality (VR) for nutrition education in this population remains limited. NutriVRTEA was cocreated as an immersive VR nutrition education intervention within routine clinical care, with attention to sensory tolerability, interaction design, and professional supervision.

Objective: This study evaluated participant-perceived usability and acceptability of NutriVRTEA among autistic children and adolescents. Professional-perceived usability, intervention completion, and tolerability were assessed as feasibility outcomes, while changes in attitudes toward healthy eating, Mediterranean diet adherence, and feeding behaviors were examined exploratorily.

Methods: We conducted a prospective, single-center, uncontrolled, single-arm pilot study at a child and adolescent mental health center in Badalona, Spain. Participants completed 4 individually supervised VR sessions of approximately 30 minutes, delivered about 2 weeks apart. The intervention used hand tracking, guided audiovisual instructions, and 4 progressively structured nutrition activities, with professional supervision through a companion tablet. Participant-perceived usability, acceptability, and tolerability were assessed after the intervention using study-specific questionnaires normalized to 0-100 scales. Professional-perceived usability, intervention completion, and adverse events were recorded. Exploratory eating-related outcomes were assessed before the intervention, after session 4, and at least 6 months after completion of the intervention. Longitudinal changes were analyzed using Friedman tests with Kendall W, followed by Wilcoxon signed rank comparisons with Holm correction.

Results: A total of 20 participants were included, with a mean age of 11.20 (SD 2.76) years; 15 (75%) were male. Among the 19 (95%) participants who completed all 4 sessions, mean participant-perceived usability was 69.74 (SD 20.08), tolerability was 82.73 (SD 19.53), and acceptability was 89.47 (SD 15.36). Mean professional-perceived usability was 92.71 (SD 10.05) among the 3 professionals who completed the assessment. No investigator-recorded adverse events required session termination or specific clinical management. No statistically significant overall changes were identified in attitudes toward healthy eating, Mediterranean diet adherence, or feeding-related behaviors across assessment points (all $P \geq .06$). None of the pairwise comparisons remained statistically significant after Holm correction (all adjusted $P \geq .17$).

Conclusions: In this small single-center pilot, NutriVRTEA appeared feasible for professionally supervised use in routine outpatient care, supported by high completion and favorable descriptive ratings of acceptability and tolerability on study-specific

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scales. The supervised delivery was not associated with any investigator-recorded event requiring session termination or specific clinical management. Participant-perceived usability scores covered a wide range, indicating that interaction design may still require refinement. The exploratory eating-related findings should not be interpreted as evidence of effectiveness. Future controlled studies should include prespecified measures of educational learning and real-world dietary behavior and examine whether virtual food familiarization is associated with changes in eating behavior beyond the immersive environment.

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KEYWORDS

autism; feasibility; immersive technology; nutrition education; usability; virtual reality

Introduction

Background

Feeding difficulties are common among autistic children and adolescents and include food selectivity, restricted dietary repertoires, food refusal, sensory-related aversions, and difficulties during mealtimes [1,2]. A recent systematic review of 88 empirical studies identified food selectivity, sensory sensitivities, and restrictive eating patterns as recurrent concerns, with potential consequences for nutritional intake and family life [1]. In a separate systematic review of school-aged children and adolescents, food selectivity was reported in 21% to 76% of autistic participants, while sensitivity to food texture and taste was consistently more frequent than in comparison groups [2]. More severe restrictive eating may meet criteria for avoidant/restrictive food intake disorder (ARFID). A recent meta-analysis estimated a pooled ARFID prevalence of 11.4% among autistic populations, although with substantial heterogeneity across studies [3].

These difficulties are heterogeneous, and no single intervention is likely to address all of them. Behavioral, sensory, and caregiver-mediated approaches have been used to reduce food refusal, selectivity, and mealtime problems, with variable results across populations, intervention components, and outcome measures [4,5]. More recent digital nutrition programs have taken a somewhat different approach, focusing on dietary behaviors and psychosocial determinants of healthy eating rather than treating a specific feeding disorder [6,7].

Evidence in this area remains limited. The BALANCE pilot program delivered 8 virtual nutrition education sessions to autistic adolescents and young adults and reported improvements in behavioral strategies, self-efficacy, and outcome expectations related to healthy eating, together with reduced added sugar intake, but no significant changes in fruit or vegetable intake [6]. In a randomized mobile health intervention involving autistic children who were picky eaters, no significant group-by-time effects were found for the primary dietary outcomes, although fruit and vegetable intake increased over time in both groups [7]. These findings suggest that eating-related cognitions and dietary behavior may change differently, which is relevant when selecting outcomes for early nutrition interventions.

Virtual reality (VR) provides another way to deliver nutrition education by embedding food-related information and decisions within interactive simulated environments. A 2025 systematic review identified 25 pediatric studies using VR to promote healthy eating or physical activity, including 6 focused specifically on healthy eating. Most used nonimmersive or semi-immersive systems, while only 3 used fully immersive VR. Short intervention periods and small samples were identified as important limitations of the available evidence [8]. In a pilot randomized trial involving 27 child-caregiver dyads, a fully immersive VR experience designed to promote healthy lifestyle behaviors showed high acceptability and greater improvement in attitudes toward healthy eating than an active control condition. However, the intervention consisted of a brief exposure and was not developed specifically for autistic children [9].

The use of immersive VR with autistic children introduces additional design considerations. Sensory reactivity in autism is highly heterogeneous and may involve hyperreactivity, hyporeactivity, or sensory-seeking responses across different modalities and individuals [10,11]. A recent systematic review of VR interventions in autistic children and adolescents reported generally positive findings but also identified adverse effects such as dizziness, eye fatigue, and sensory overload in some studies [12]. More directly, a multisite study involving 21 autistic learners aged 6 to 17 years found high usability and no major safety concerns with immersive VR, while identifying sensory load, task complexity, and professional supervision as relevant aspects of design and delivery [13]. These findings support assessing tolerability and safety alongside usability rather than assuming that an immersive experience will be acceptable because it is engaging.

The development process is also relevant. An evidence framework codeveloped with autistic people, family members, practitioners, and researchers identified reliability, engagement, and effectiveness as distinct domains for evaluating digital supports for autism [14]. Subsequent work on autism-specific user-centered design has emphasized direct end user input alongside contributions from families and professionals, including iterative involvement throughout technology development [15]. A systematic review of technology co-design with autistic children similarly found that participation methods need to accommodate differences in communication, sensory characteristics, and support needs [16]. These considerations are particularly relevant for immersive applications intended for repeated use by children in clinical settings.

Study Rationale and Objectives

Evidence directly combining these areas remains limited. Digital nutrition education has been studied in autistic populations [6,7], VR has been used to promote healthy eating in broader pediatric

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populations [8,9], and immersive VR has been evaluated with autistic children and adolescents for other purposes [12,13]. Much less is known about immersive nutrition education developed specifically around the sensory and interaction needs of autistic children and evaluated across repeated sessions.

NutriVRTEA was created to address this gap as a cocreated immersive VR nutrition education intervention rather than as a treatment for ARFID, food selectivity, or other specific feeding disorders. Its development involved health care professionals, VR developers, a family representative, and an autistic child. The primary objective of this prospective pilot study was to evaluate its usability and acceptability among autistic children and adolescents. Intervention completion and tolerability were assessed as additional feasibility outcomes. Changes in attitudes toward healthy eating, adherence to the Mediterranean diet, and feeding behaviors immediately after the intervention and at follow-up at least 6 months after completion of the intervention were examined as exploratory outcomes.

Methods

Study Design and Setting

We conducted a prospective, single-center, uncontrolled, single-arm pilot study to evaluate NutriVRTEA, a cocreated immersive VR nutrition education intervention for autistic children and adolescents. The primary outcomes were participant-perceived usability and acceptability. Professional-perceived usability, intervention completion, and tolerability were assessed as additional feasibility outcomes, and adverse events were monitored. Changes in eating-related measures were examined exploratorily and were not considered measures of intervention efficacy.

The uncontrolled single-arm design was selected because the primary purpose of this early-stage study was to evaluate usability, acceptability, and feasibility in routine clinical delivery rather than comparative efficacy.

The study was conducted at the Child and Adolescent Mental Health Center (CSMIJ) in Badalona, Spain, as part of routine outpatient care. Recruitment took place between October and November 2024, and the intervention was delivered between January and August 2025. Follow-up assessments began 6 months after completion of the intervention.

Given the pilot nature of the study, convenience sampling was used, and no formal sample size calculation was performed.

Recruitment

Participants were recruited among autistic children and adolescents receiving care at the CSMIJ and followed by the nurses who delivered the intervention. Potential participants were identified during routine nursing visits. Eligible participants were aged 7 to 17 years at inclusion, had a documented autism diagnosis according to the *DSM-5* (*Diagnostic and Statistical Manual of Mental Disorders* [Fifth Edition]) or the *International Statistical Classification of Diseases, Tenth Revision* criteria with *DSM-5* severity level 1 or 2, and were considered able to understand and follow simple instructions within a VR environment. This ability was assessed clinically by the recruiting nurses based on their knowledge of the participant's usual communication, functioning, and engagement during routine care, with input from the treating team when needed.

Exclusion criteria were medical contraindications to VR exposure or other conditions that could compromise safe headset use, participation in another intervention study that could interfere with study outcomes, and severe uncontrolled psychiatric disorders. Recruitment was pragmatic rather than consecutive, and no formal screening log was maintained.

Baseline information obtained from the clinical record included age, sex, recorded comorbidities, and the presence and type of feeding-related condition.

Intervention

Development and Cocreation of NutriVRTEA

NutriVRTEA was developed through an iterative cocreation process to adapt nutrition education to the characteristics and needs of autistic children and adolescents. The development group included child and adolescent mental health nurses, a community nurse, a primary care nutritionist, VR developers, professionals from the innovation and research team, and family and end user representatives.

Five working sessions were conducted with the professional group, and 2 additional sessions included direct family or end user participation. Feedback from these sessions and prototype testing was documented in project meeting notes and development specifications. The main cocreation inputs and resulting design decisions are summarized in Table 1.

Key stages of cocreation, iterative testing, and subsequent clinical implementation are shown in Figure 1. This participatory approach is consistent with autism-specific work emphasizing direct involvement of autistic users alongside family and professional perspectives in the development of digital supports [14-16].

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Table 1. Main cocreation inputs and resulting NutriVRTEA design decisions during development in Badalona, Spain, 2024[a].

Development stage and stakeholders	Issue or need identified	Cocreation input	Resulting design decision
Initial clinical, nutritional, and technical definition	Need for a progressive educational structure suitable for repeated use	Clinical and nutrition professionals prioritized food classification, understanding of food groups, food choice, portion concepts, and balanced meal composition	Content was structured into 4 sequential activities progressing from guided food classification to classification with quantity targets, contextual food choice, and complete meal composition
Professional and family/end user prototype testing	Potential sensory and attentional overload	A neutral environment with limited distracting stimuli was considered appropriate	The final application used a visually simplified domestic environment with few unnecessary distractors
Technical development with clinical input	Need for simple and intuitive interaction	Direct manipulation of food items was preferred, with restrained audiovisual feedback	Hand tracking was used for grasping and placing food items, together with simple visual and auditory feedback
Professional prototype review	Difficulty understanding food categories and the educational meaning of the tasks	Feedback should identify the food group and reinforce its nutritional relevance, rather than only indicate whether a response was correct	Guided audiovisual instructions and feedback explicitly reinforced food classification and the educational objective of each activity
Nutrition and clinical review of food-choice feedback	Risk of presenting individual foods as intrinsically “good,” “bad,” or prohibited	Stronger negative reactions to less healthy foods were discussed, but the clinical team favored a nonprohibitive approach	Less appropriate choices received subtle audiovisual feedback and wording such as “not for every day” rather than being presented as prohibited
Clinical and nutrition review of portions and food representation	Need for recognizable food models and meaningful representation of quantities	Specific food models, portion sizes, and numbers of food items were reviewed during prototype testing	Food presentation was refined, and quantity targets were incorporated into the classification and meal-composition activities
Preclinical family/end user and professional testing	Physical comfort, headset stability, and heterogeneous sensory sensitivity	Alternative Quest headset strap configurations were compared, and exposure duration was reviewed according to sensory tolerance	Headset configuration and exposure duration were refined before clinical implementation
Multidisciplinary implementation planning	Need to integrate the application safely into routine nursing care	Professionals identified the need to guide the experience and contextualize the educational content	NutriVRTEA was delivered as a professionally supervised intervention within the nursing consultation rather than as a standalone application

[a]The table summarizes documented cocreation inputs that informed features incorporated into the final NutriVRTEA application. Suggestions discussed during development but not incorporated into the final version are not shown. Family and end user participation occurred during preclinical development and was separate from the subsequent pilot study sample.

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Figure 1. Cocreation, iterative testing, and clinical implementation of NutriVRTEA (Badalona, Spain, 2024-2025). (A) Pediatric professional testing an early version during the cocreation process. (B) Child and adolescent mental health nurse testing the immersive application during development. (C) Autistic child involved in preclinical testing of headset fit and alternative strap systems to assess stability and comfort. (D) Mental health nurse using the companion tablet while supervising a participant wearing the headset during the clinical study. (E) Participant interacting with the NutriVRTEA application during a study session.



NutriVRTEA Immersive VR Application and Technical Setup

NutriVRTEA is an immersive VR application developed in Unity 2022.3.9f1 to support professionally guided nutrition education rather than as an autonomous treatment for a specific feeding disorder. NutriVRTEA version 3 was used throughout the study.

The application was deployed on Meta Quest 3 stand-alone headsets and used hand tracking for all participant interactions within a room-scale environment. The main interaction area consisted of a virtual table spatially aligned with the consultation environment, typically corresponding to the position of the examination bed. The environment could be recentered according to the participant's position and adjusted between 2 predefined height settings.

Each session began with a brief guided onboarding sequence. The participant initiated the activity by grasping a virtual cube, after which a bear avatar welcomed them and explained the task through visual and audio instructions. Interactive objects remained unavailable until the explanation was complete, preventing participants from starting the activity before receiving the instructions. An in-world menu positioned to the participant's left provided access to the 4 activities. Although individual activities could be selected through the interface, they were delivered in a predefined sequence, with 1 activity assigned to each of the 4 sessions.

The first activity introduced food classification through a guided 3D matching task. Food items were presented alongside 3 plates representing carbohydrates, fruits and vegetables, and proteins. Visual silhouettes indicated where each food item belonged. Participants grasped and moved the foods using hand tracking and matched each item to the appropriate plate.

The second activity retained the same food categories but removed the visual silhouettes and introduced quantity targets. A larger selection of food items was available, while visual indicators showed the number of items required for each plate. Participants selected foods, assigned them to the corresponding category, and continued until the predefined quantity was reached.

The third activity introduced food choice within a social context. A child avatar was seated at the table with a plate in front of them, and participants selected individual food items and placed them on the avatar's plate. Choices aligned with the nutritional objectives triggered an encouraging animation with positive

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text and audio feedback. Other choices triggered a subtle rejection animation and audiovisual feedback indicating that the selected food was "not for every day." This wording was selected with input from the nutritionist to avoid presenting individual foods as intrinsically "good" or "bad" or as prohibited.

The fourth activity integrated the concepts introduced in the previous sessions into the composition of a complete meal. Separate areas represented a beverage, first course, second course, and dessert, with visual indicators showing the required number of items for each component. Once the meal was complete, the bear avatar congratulated the participant and the food items became available for a simulated eating interaction. Participants could grasp individual foods or drinks and bring them toward their mouth, triggering corresponding eating or drinking sounds. This final interaction provided virtual familiarization with foods from different categories without requiring actual food consumption.

A companion tablet application supported professional supervision and control of the experience. It displayed the participant's first-person view in real time, allowing the supervising nurse to follow the interaction outside the headset. From the tablet, the nurse could launch the activity assigned to each session, recenter the virtual environment, and select between the 2 predefined height settings. Selecting an activity restarted it from the beginning.

Wi-Fi connectivity was required for communication between the headset and companion tablet. Neither application required participant identification, and no personal, clinical, or usage data were collected or stored by the VR or tablet applications.

Intervention Delivery

The intervention consisted of 4 individual sessions of approximately 30 minutes, delivered at intervals of approximately 2 weeks and integrated into routine outpatient nursing care.

The 4 educational activities were delivered in a predefined order, with 1 activity assigned to each session. The same sequence was used for all participants.

Each session was conducted individually under the supervision of a nurse. Before study implementation, nurses involved in intervention delivery received practical training from the Badalona Serveis Assistencials (BSA) innovation team on the use of NutriVRTEA, including the headset and companion tablet. During VR exposure, the nurse followed the participant's first-person view through the companion tablet and could recenter the virtual environment or adjust its height when required. Verbal clarification and practical assistance were provided according to participant needs without changing the predefined educational content or sequence.

This setup allowed the nurse to follow task progression, respond to interaction difficulties, and observe participant reactions during the immersive experience. NutriVRTEA was therefore delivered as part of a professionally guided educational encounter rather than as a stand-alone digital intervention.

Reporting Guidelines

Reporting of intervention development was informed by the GUIDED (Guidance for Reporting Intervention Development Studies in Health Research) [17]. The description of the immersive intervention and its early clinical evaluation was informed by the RATE-XR (Reporting Guidelines for the Early-Phase Clinical Evaluation of Applications Using Extended Reality) [18]. The TIDieR (Template for Intervention Description and Replication) checklist was also used to support a sufficiently detailed description of the intervention [19]. These guidelines were applied retrospectively for reporting purposes and did not prospectively govern the original development process.

Measures

Assessment Schedule

Eating-related outcomes were assessed at 3 time points: before the first NutriVRTEA session (T1), after completion of the fourth session (T2), and at least 6 months after completion of the intervention (T3).

Participant-perceived usability, acceptability, and tolerability were assessed after completion of the 4-session intervention. Professionals involved in delivering NutriVRTEA completed a separate usability questionnaire.

Feasibility Outcomes

Feasibility was assessed through intervention completion, participant-perceived usability, acceptability and tolerability, and professional-perceived usability. Adverse events and other reactions associated with VR exposure were also recorded.

Participant- and professional-perceived usability were assessed using separate study-specific questionnaires. The participant questionnaire addressed comprehension of the activities, ease of learning and navigation, clarity of interaction, and difficulties encountered while using the virtual environment. The professional questionnaire comprised 8 items addressing interface clarity, perceived integration into routine clinical practice, relevance for nutrition education, anticipated patient learnability, perceived usefulness, and professional familiarization with the system. Although the original study documentation referred to these instruments using the term "SUS," neither was a validated version of the standardized 10-item System Usability Scale. Their scores were therefore treated as descriptive, study-specific indices of perceived usability.

Participant tolerability was assessed separately through items addressing headset comfort and the occurrence of discomfort or symptoms during use. Acceptability included satisfaction with the experience, willingness to recommend it, and willingness to continue using it.

Responses to the study-specific questionnaires were scored from 0 to 4, with negatively worded items reverse-scored before summation. Total scores were normalized to a 0 to 100 scale according to the maximum possible score for each instrument, with higher values indicating more favorable evaluations. No item-level responses were missing from the feasibility

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questionnaires included in the analysis, and no imputation or prorating was required. As these instruments were study-specific measures without established psychometric properties or normative thresholds, scores were interpreted descriptively. The original Catalan questionnaires, English translations, scoring directions, and instrument-specific scoring procedures are provided in Multimedia Appendix 1.

Safety and Tolerability Monitoring

Safety and tolerability were monitored throughout the intervention. During each VR exposure, the supervising nurse observed the participant for physical discomfort, sensory intolerance, interaction difficulties, or behavioral responses occurring during or immediately after the session. Assistance could be provided at any time, and the exposure could be interrupted if necessary.

This approach is consistent with previous recommendations supporting active observation and prompt response to discomfort when head-mounted VR is used with autistic individuals [20].

Headset comfort and any symptoms or discomfort associated with VR exposure were also assessed after the intervention. Physical, sensory, or behavioral reactions occurring in temporal relation to the sessions were recorded as part of the safety assessment. The study protocol specifically included monitoring for possible VR-related symptoms such as dizziness, nausea, and disorientation.

Exploratory Eating-Related Outcomes

Feeding behaviors were assessed using the Behavioral Pediatrics Feeding Assessment Scale (BPFAS), a 35-item parent-reported measure of mealtime and feeding behavior [21]. Its psychometric properties have also been examined in young autistic children [22]. The Spanish-language version used in this study was based on the translation of the original BPFAS reported by López López [23]. The total frequency score (TFS) and total problem score (TPS) were analyzed. Higher TFS values indicate a greater frequency of problematic feeding-related behaviors, whereas higher TPS values indicate a greater number of behaviors perceived as problematic by the caregiver. The child and parent components of the TFS were also examined exploratorily.

Adherence to the Mediterranean diet was assessed using the 16-item Mediterranean Diet Quality Index for Children and Adolescents (KIDMED) [24], with higher scores indicating greater adherence to a Mediterranean dietary pattern.

Attitude toward healthy eating was assessed using a Catalan-language translation of the 10-item attitude toward eating scale developed and validated in Spanish by Lima-Serrano et al [25]. The original 10-item concepts were retained and translated into Catalan using equivalent 5-point agreement response categories, yielding scores from 0 to 40. The Catalan-language version was not formally psychometrically validated before use in this study, and the resulting scores were therefore treated as exploratory, with higher scores indicating a more favorable attitude toward healthy eating.

All eating-related measures were treated as exploratory outcomes and were not used to determine intervention efficacy.

Statistical Analysis

Continuous variables were summarized using means and SDs or medians and IQRs, as appropriate. Categorical variables were described using frequencies and percentages. Feasibility outcomes were analyzed descriptively.

Given the small sample, rank-based nonparametric methods were selected to avoid relying on distributional assumptions for the exploratory outcome scores. Changes in exploratory eating-related outcomes across T1, T2, and T3 were assessed using the Friedman test restricted to participants with complete observations at all 3 assessment points for each outcome, with correction for tied ranks and Kendall W reported as an effect-size measure. In contrast, pairwise Wilcoxon signed rank tests included all participants with available paired observations for the 2 time points being compared, irrespective of data availability at the remaining assessment point. *P* values were adjusted using the Holm procedure separately within each outcome. Hodges-Lehmann estimates with 95% CIs, Holm-adjusted *P* values, and effect size *r* were reported.

Missing data were not imputed. All tests were 2-sided, with α=.05. Associations between age and participant-perceived usability, tolerability, and acceptability were examined exploratorily using Spearman rank correlation coefficients because the sample covered a broad age range.

Statistical analyses were performed using IBM SPSS Statistics (version 21) and numiqo (online statistical analysis software; numiqo eU).

Ethical Considerations

The study was approved by the Research Ethics Committee of Germans Trias i Pujol University Hospital (Comitè d'Ètica de la Investigació de l'Hospital Universitari Germans Trias i Pujol; reference PI-24-149), which issued a favorable opinion on May 24, 2024.

Legal representatives provided written informed consent for study participation and publication of project-related images, and assent was obtained from participating children and adolescents when appropriate. Participation was voluntary, and participants could withdraw at any time without affecting their clinical care.

Research data were pseudonymized using a unique participant code and stored within secure BSA systems, with access restricted to the research team. Data handling complied with Regulation (EU) 2016/679 and Spanish Organic Law 3/2018 on Personal Data Protection and Guarantee of Digital Rights.

The NutriVRTEA VR and tablet applications did not collect or store personal, clinical, or usage data. Participants incurred no additional costs and received no financial compensation for participation. The app was developed in-house by the BSA innovation team specifically for this research project and was not commercially available or publicly distributed at the time of the study.

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Results

Recruitment

A total of 20 participants were included in the study. Of those, 11 (55%) had *DSM-5* level 1 autism and 9 (45%) had level 2 autism. The mean age was 11.20 (SD 2.76; range 8-17) years, and 15 (75%) participants were male. Additionally, 17 (85%) had at least 1 recorded comorbidity, and 16 (80%) presented a feeding-related condition in the clinical record. Baseline participant characteristics and recorded feeding profiles are presented in Table 2.

Table 2. Baseline characteristics of participants[a].

Characteristic	Value (N=20)
Age (years), mean (SD)	11.20 (2.76)
Age (years), median (IQR; range)	10 (9-13; 8-17)
Sex, n (%)	
Male	15 (75)
Female	5 (25)
At least 1 recorded comorbidity, n (%)	17 (85)
No recorded comorbidity, n (%)	3 (15)
DSM-5[b] autism severity level, n (%)	
Level 1	11 (55)
Level 2	9 (45)
Recorded feeding-related frequency, n (%)	
Yes	16 (80)
No	4 (20)
Recorded feeding-related condition, n (%)	
ARFID	5 (25)
Restrictive eating	6 (30)
Restriction associated with obesity	3 (15)
Restriction associated with overweight	1 (5)
Obesity without documented restriction	1 (5)
No documented feeding-related condition	4 (20)

[a]Participants were autistic children and adolescents recruited at the Child and Adolescent Mental Health Center in Badalona, Spain, between October and November 2024. Recorded feeding-related conditions reflect classifications documented in the clinical record and were not diagnoses assigned as part of the study.

[b]DSM-5: Diagnostic and Statistical Manual of Mental Disorders (5th Edition).

[c]ARFID: avoidant/restrictive food intake disorder.

Development and Cocreation Outcomes

The final cocreated NutriVRTEA application incorporated a visually simplified immersive environment, guided onboarding, hand-based interaction, audiovisual instructions and feedback, progressively structured educational tasks, and professional supervision through a companion tablet. The tablet displayed the participant's first-person view and allowed the supervising professional to launch activities, recenter the virtual environment, and adjust the interaction height according to the participant.

The educational content was organized into 4 activities delivered sequentially across the 4 intervention sessions. The sequence progressed from visually guided food-category matching to classification with quantity targets, contextual food selection with immediate audiovisual feedback, and composition of a complete meal followed by simulated food consumption. Figure 2 shows the main participant-facing interfaces and educational sequence of the final application.

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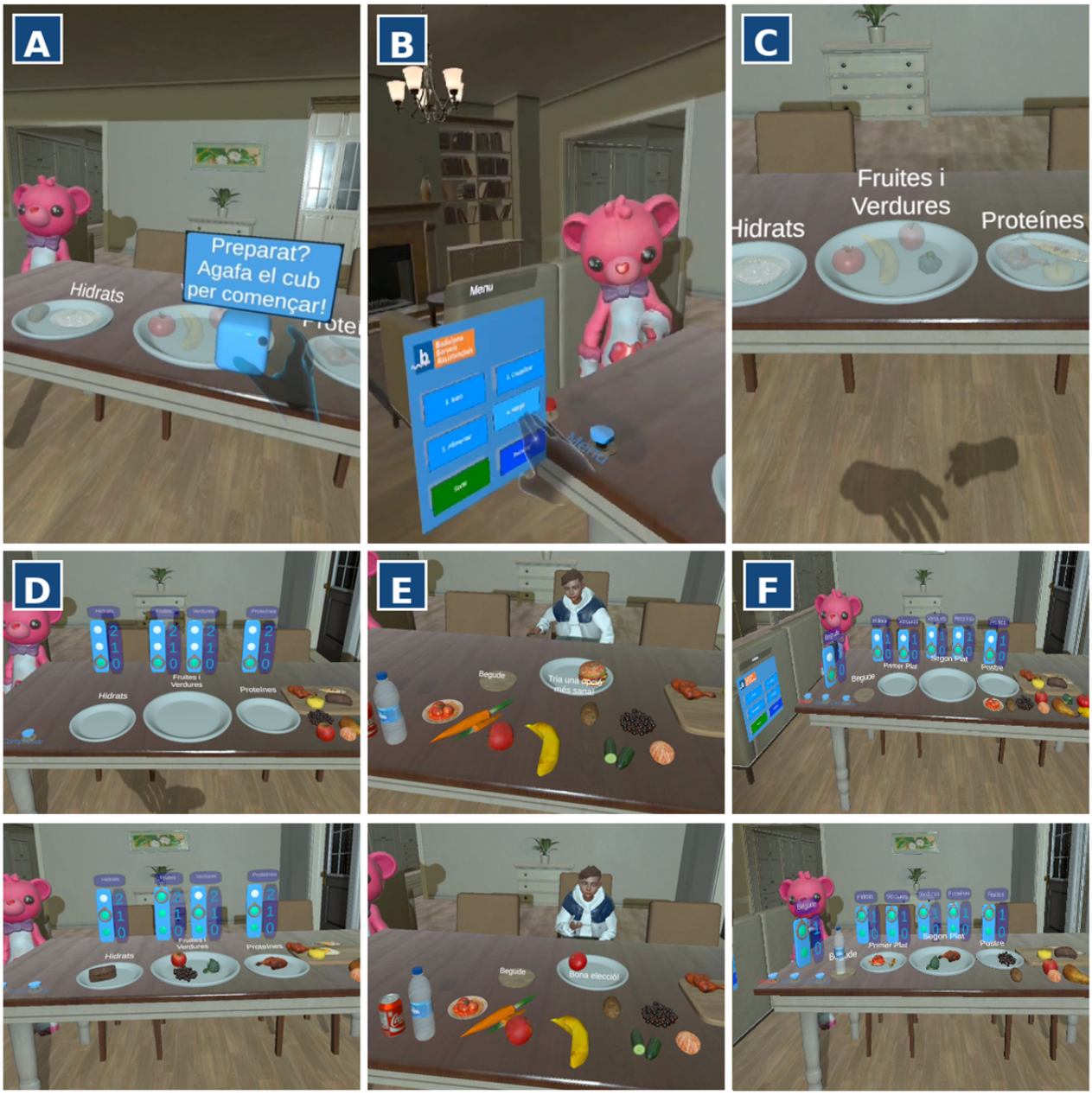
Figure 2. NutriVRTEA immersive virtual reality application (version 3) and nutrition education sequence. Screenshots illustrate the application used in a 4-session, nurse-supervised intervention for autistic children and adolescents in Badalona, Spain (2025). (A) Guided onboarding, in which the participant initiates the experience by grasping a virtual cube and receives audiovisual instructions from the bear avatar. (B) In-world activity menu and guiding bear avatar, providing access to the 4 educational activities. (C) Activity 1, visually guided food-category matching using food silhouettes displayed on the corresponding plates. (D) Activity 2, food classification with quantity targets, showing the initial setup and task progression as food items are added and visual counters updated (bottom). (E) Activity 3, contextual food selection for a virtual child avatar, illustrating feedback encouraging an alternative food choice and positive feedback for an appropriate selection. (F) Activity 4, complete meal composition, shown before food selection and after completion (bottom) of the beverage, first course, second course, and dessert according to predefined quantity targets.



Feasibility Outcomes

A total of 19 (95%) of the 20 participants completed all 4 NutriVRTEA sessions. One adolescent discontinued participation after the first session because they did not wish to continue participating in nutrition-focused activities.

Only the 19 participants who completed the intervention provided usability, acceptability, and tolerability assessments. Mean participant-perceived usability was 69.74 (SD 20.08), mean tolerability was 82.73 (SD 19.53), and mean acceptability was 89.47 (SD 15.36) on the corresponding 0-100 study-specific scales (Table 3). Individual participant ratings and their distribution across the 3 feasibility domains are shown in Figure 3.

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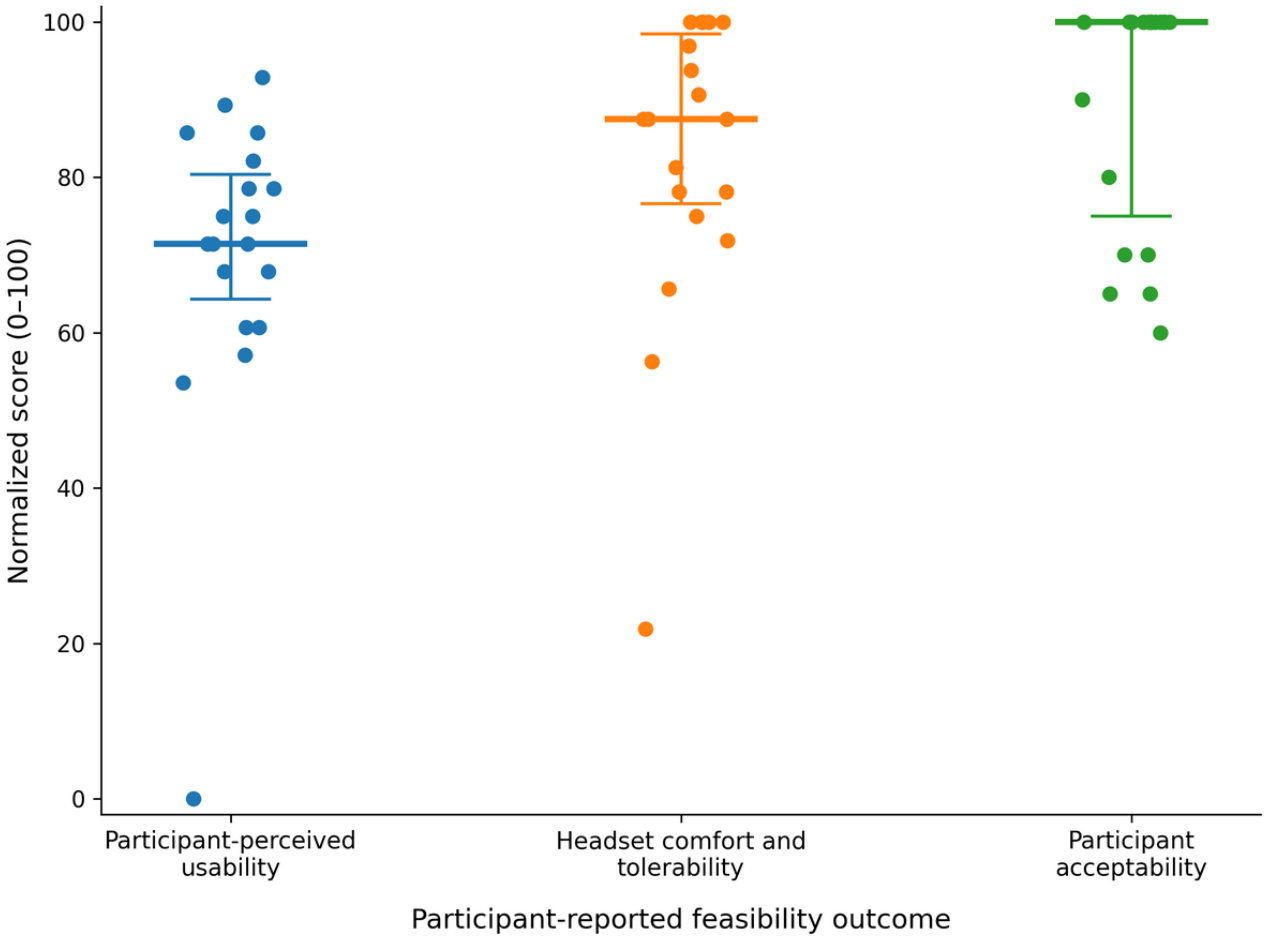
Table 3. Feasibility, usability, acceptability, and tolerability outcomes[a].

Outcome	Available data (N=20), n (%)	Mean (SD)	Median (IQR)	Range
Completed all 4 sessions	19 (95)	—[b]	—	—
Discontinued after session 1	1 (5)	—	—	—
Participant-perceived usability	19 (95)	69.74 (20.08)	71.43 (64.29-80.36)	0.00-92.86
Headset comfort and tolerability	19 (95)	82.73 (19.53)	87.50 (76.56-98.44)	21.88-100
Participant acceptability	19 (95)	89.47 (15.36)	100 (75.00-100)	60.00-100
Professional-perceived usability	n=3	92.71 (10.05)	96.88 (89.06-98.44)	81.25-100

[a]The intervention was delivered to autistic children and adolescents in outpatient nursing care at the Child and Adolescent Mental Health Center in Badalona, Spain, between January and August 2025. For continuous outcomes, n indicates the number of participants or professionals with available data. Continuous scores were normalized to a 0-100 scale, with negatively worded items reverse-scored so that higher scores indicated more favorable evaluations. Participant and professional usability were assessed using separate study-specific questionnaires.

[b]Not available.

Figure 3. Individual participant ratings of perceived usability, headset comfort and tolerability, and acceptability after the NutriVRTEA intervention. Ratings are shown on normalized 0-100 scales, with higher scores indicating more favorable evaluation. Dots represent individual participant scores, central horizontal lines indicate the medians, and vertical intervals with horizontal caps represent the IQRs. Data are shown for the 19 participants who completed all 4 NutriVRTEA sessions at the Child and Adolescent Mental Health Center in Badalona, Spain.



Professional-perceived usability data were available from the 3 professionals involved in the intervention. Mean professional-perceived usability was 92.71 (SD 10.05), with a median of 96.88 (range 81.25-100; Table 3).

Exploratory Spearman rank correlations showed no statistically significant associations between age and participant-perceived usability (ρ=–0.453; *P*=.051), headset comfort and tolerability (ρ=0.398; *P*=.09), or participant acceptability (ρ=–0.250; *P*=.30).

Safety and Tolerability Monitoring

No investigator-recorded adverse events required termination of a session or specific clinical management. One participant

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showed a transient increase in motor activity after 1 session, which resolved spontaneously during the same consultation. Questionnaire-reported discomfort included arm or finger tiredness in 21.1% (4/19) participants, difficulty using the headset and interaction controls in 15.8% (3/19), headset discomfort or heaviness in 10.5% (2/19), visual discomfort in 10.5% (2/19), dizziness in 10.5% (2/19), and headache in 5.3% (1/19) participants. One (5.3%) participant strongly agreed with the item stating that the VR intervention had been interrupted because of discomfort. This reflected the participant's retrospective perception and was not associated with a recorded session termination. Full item-level tolerability responses are provided in Multimedia Appendix 1.

Exploratory Eating-Related Outcomes

Of the 20 participants enrolled, 19 completed the intervention, and 17 attended the T3 follow-up. Among these 17 participants, follow-up occurred a median of 9.2 (IQR 7.9-11.1; range 6.0-15.2) months after intervention completion. The number of available observations varied across outcomes and assessment points because some questionnaires were incomplete. Depending on the measure, data were available for 17 to 20 participants at T1, 14 to 19 at T2, and 15 to 17 at T3. One participant discontinued the study after the first session and did not complete subsequent assessments. Two additional participants could not be reached for the T3 follow-up, one after transitioning to adult services and one following a change of residence. Missing BPFAS data were mainly due to incomplete caregiver responses to this relatively lengthy questionnaire. The 2 participants unavailable for T3 were both male, had *DSM-5* level 1 autism and restrictive eating documented, but differed in age and baseline eating-related scores. Given the small number of participants without T3 follow-up, no formal comparison with those completing T3 was performed. Descriptive results and overall longitudinal comparisons for attitudes toward healthy eating, KIDMED, and BPFAS measures are presented in Table 4.

Table 4. Exploratory eating-related outcomes across assessment points[a].

Outcome	T1, median (IQR; n)	T2, median (IQR; n)	T3, median (IQR; n)	Available data, n[b]	Chi-square (*df*)	*P* value	Kendall W
Attitude toward healthy eating	24 (10.25; 20)	27 (9.00; 19)	25 (6.00; 17)	17	2.9 (2)	.24	0.085
KIDMED[c]	5 (3.00; 20)	5 (3.50; 18)	4 (4.00; 17)	16	2.3 (2)	.32	0.071
BPFAS[d] TFS[e], total	72 (28.00; 17)	72 (31.00; 16)	64 (23.00; 17)	12	4.7 (2)	.09	0.197
BPFAS TPS[f]	10.5 (10.50; 18)	11.5 (9.50; 14)	7 (11.50; 15)	10	1.5 (2)	.47	0.076
BPFAS TFS, child component	54 (14.00; 17)	49 (22.00; 17)	48 (15.00; 17)	12	4.9 (2)	.09	0.206
BPFAS TFS, parent component	18 (10.00; 17)	20 (8.50; 16)	18 (8.00; 17)	12	5.7 (2)	.06	0.239

[a]T1: baseline; T2: after completion of the fourth NutriVRTEA session; T3: follow-up conducted at least 6 months after completion of the intervention. Outcomes were assessed in autistic children and adolescents enrolled in the prospective, single-center pilot study in Badalona, Spain.

[b]Number of participants with available data at all 3 assessment points for the corresponding Friedman test.

[c]KIDMED: 16-item Mediterranean Diet Quality Index for Children and Adolescents.

[d]BPFAS: Behavioral Pediatrics Feeding Assessment Scale.

[e]TFS: total frequency score.

[f]TPS: total problem score.

Pairwise Wilcoxon signed rank comparisons were conducted using all available paired observations for each comparison. None remained statistically significant after Holm correction (all adjusted $P \geq .17$). Hodges-Lehmann estimates, 95% CIs, unadjusted and Holm-adjusted *P* values, and effect sizes for all pairwise comparisons are reported in Table S2 in Multimedia Appendix 2.

Discussion

Principal Findings

This prospective pilot study evaluated the feasibility of NutriVRTEA, a cocreated immersive VR nutrition education intervention delivered to autistic children and adolescents during routine outpatient nursing care. A total of 19 of 20 participants completed all 4 sessions. Acceptability and tolerability scores were generally toward the upper end of their respective study-specific scales, whereas participant-perceived usability was more variable. No investigator-recorded adverse events required session termination or specific clinical management. Professional-perceived usability was also rated favorably, although data were available from only 3 professionals and should therefore be interpreted descriptively.

No statistically significant changes were identified in attitudes toward healthy eating, adherence to the Mediterranean diet, or feeding-related behaviors across the assessment points. Pairwise estimates were imprecise, and none remained statistically significant after correction for multiple testing. These findings should not be interpreted as evidence that NutriVRTEA changes eating behavior.

Because participant-perceived usability, acceptability, and tolerability were assessed using separate study-specific questionnaires, direct psychometric comparison is not appropriate. The variability in usability scores nevertheless suggests that interaction design remains an area for refinement.

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The exploratory associations with age were not statistically significant, although the small sample limits their interpretation. The documented cocreation process also showed how clinical, nutritional, and end user input was translated into specific design decisions, including simplified visual presentation, progressive task structure, nonprohibitive nutritional feedback, and refinement of headset comfort and exposure duration.

Comparison With Prior Work

The feasibility findings are broadly consistent with previous research suggesting that immersive technologies can be used with autistic children when sensory characteristics, task demands, and professional support are considered during design and delivery. Herrera et al [13] reported high usability and no major safety concerns in a multisite immersive VR study involving autistic learners, while also identifying sensory load, task complexity, and supervision as relevant design considerations. Recommendations for head-mounted VR in autistic populations similarly emphasize active observation, adaptation, and prompt response to discomfort [20]. The high completion rate in this study and the absence of adverse events requiring intervention are consistent with the feasibility of this supervised approach, although the small sample does not allow broader conclusions about safety. In NutriVRTEA, these considerations were incorporated prospectively during development rather than introduced only during clinical delivery. Cocreation led to specific modifications in visual complexity, interaction, nutritional feedback, food representation, headset configuration, and exposure duration.

NutriVRTEA also differs from much of the existing digital nutrition literature in autism. BALANCE used a multicomponent virtual nutrition education program and reported improvements in self-efficacy, behavioral strategies, and outcome expectations, together with reduced added sugar intake, but no significant changes in fruit or vegetable intake [6]. In the mobile health study by Kral et al, no significant group-by-time effects were observed for the main dietary outcomes, although greater improvements were reported among participants with lower baseline fruit and vegetable intake and higher engagement with the intervention [7]. Together with these findings, these studies suggest that engagement with a digital nutrition intervention does not necessarily translate into measurable changes in broader dietary behavior.

Evidence specifically combining immersive VR, autism, and nutrition remains limited. Banire et al [26] reviewed virtual, augmented, and mixed reality as potential tools for food-related interventions in autistic children, with particular attention to interactive environments and ecological validity. Their work, however, provided a conceptual rationale rather than evidence that interaction with virtual foods changes subsequent real-world eating behavior. NutriVRTEA builds on this approach through a repeated immersive intervention that moves from food classification to meal composition and simulated consumption. This study was not designed to determine whether these virtual experiences translate into changes in actual food acceptance or consumption.

This distinction is particularly relevant to the simulated eating component of the fourth activity. Exposure-based and desensitization approaches have been used to increase food acceptance in people with developmental disorders. In a systematic review, Chawner et al [27] identified several intervention approaches, with successful interventions frequently incorporating learning-based components such as operant conditioning or systematic desensitization, often within multicomponent approaches that also addressed environmental or family practices. NutriVRTEA did not implement a formal exposure protocol. Its simulated eating component was designed as a low-demand form of virtual familiarization with foods from different categories. Whether repeated virtual interaction or simulated consumption can influence willingness to approach, taste, or consume corresponding foods outside VR remains unknown.

The absence of statistically significant changes in BPFAS scores should also be considered in relation to the target of the intervention and the characteristics of the sample. NutriVRTEA was developed as a nutrition education intervention, not as a treatment for ARFID, food selectivity, or another specific feeding disorder. Four participants had no feeding-related condition documented in their clinical record, while the remainder had heterogeneous conditions that included ARFID, restrictive eating, and restriction associated with overweight or obesity. The BPFAS assesses feeding and mealtime problems and may therefore be relatively distal from some of the educational objectives addressed by NutriVRTEA. Similarly, KIDMED reflects a broader dietary pattern influenced by factors beyond the child's interaction with the application, including food availability, family routines, and meal preparation.

Implications for Future Development and Research

Future evaluations should distinguish more clearly between proximal educational outcomes and changes in eating behavior. Measures that directly capture what participants learn within the intervention, such as food classification and portion concepts, would provide a closer assessment of its educational objectives. These could then be complemented by measures of everyday dietary behavior, including dietary variety and acceptance of new foods.

The simulated consumption component also warrants further study. Future research could examine whether repeated virtual familiarization with initially avoided foods is associated with greater willingness to approach, taste, or consume those foods outside the immersive environment. This should be evaluated separately from established behavioral or sensory feeding interventions, without assuming that changes observed within VR will translate to real-world eating.

Larger controlled studies could also examine whether response differs according to baseline feeding profile, sensory characteristics, or degree of food selectivity, while accounting for age. If changing everyday dietary behavior becomes an explicit intervention target, a structured caregiver component could also be considered, given the role of food availability, meal preparation, and responses to food refusal within the home environment. Caregiver-mediated approaches already form an important part of the intervention literature for food selectivity in autism [4,5], and the mobile health intervention by Kral et al [7] involved parents directly in supporting dietary change.

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Further refinement of interaction design should continue to involve autistic users, families, and clinical professionals, consistent with the emphasis on participatory and user-centered development in autism-specific digital health research [14-16].

Strengths and Limitations

A strength of this study is the multidisciplinary and participatory development of NutriVRTEA, with documented translation of clinical, nutritional, technical, and end user input into specific design decisions. The intervention was subsequently evaluated across repeated sessions in routine outpatient care rather than through a single laboratory exposure. The evaluation also considered participant-perceived usability, acceptability, and tolerability, as well as professional-perceived usability and safety, alongside exploratory eating-related outcomes, providing a broad formative assessment of both the technology and its clinical delivery.

Several limitations should be considered. The study involved a small convenience sample from a single center and did not include a control group, preventing causal attribution of changes over time to NutriVRTEA. Missing data varied across measures and assessment points, reducing the complete-case samples available for longitudinal analyses. For the BPFAS, missingness was partly related to the length and complexity of the questionnaire, which resulted in incomplete caregiver responses in some cases. Follow-up assessments were conducted at least 6 months after intervention completion rather than at a uniform fixed interval, and this variability in follow-up timing may have influenced the exploratory longitudinal comparisons.

The cocreation process combined iterative multidisciplinary professional review with direct participation from an autistic child and a family representative, incorporating end user perspectives into intervention development. However, this limited end user representation cannot capture the diversity of sensory, communication, and interaction preferences across autistic children and adolescents. Future iterations should involve a broader range of autistic users and families throughout development.

Recruitment also relied on clinical judgment that participants could engage with the VR activities, which may limit generalizability to autistic children and adolescents with greater communication, cognitive, sensory, or support needs. The sample was heterogeneous, particularly in age and feeding profile, and included participants with several different comorbidities. This was consistent with the broad feasibility objective of the pilot but limits the interpretation of feeding-specific outcomes. Eating-related outcomes were assessed using questionnaires and did not include direct measures of dietary intake, food variety, or acceptance of new foods. The study also did not include a specific measure of nutritional knowledge or learning, despite education being the primary function of the application. In addition, the available psychometric evidence for the BPFAS and the healthy-eating attitude scale does not cover the full age range represented in this sample, and the Catalan-language version of the attitude scale was not independently validated, which should be considered when interpreting these exploratory outcomes.

Participant and professional feasibility outcomes were assessed using study-specific instruments without established normative thresholds or established psychometric properties, and professional-perceived usability was evaluated by only 3 professionals. The study therefore cannot support comparison with standardized usability benchmarks or provide precise estimates of professional-perceived usability. The observed completion and feasibility findings also reflect professionally supervised outpatient delivery and should not be extrapolated to independent or home-based use, which was not evaluated. The cocreation process was documented descriptively rather than evaluated through formal qualitative analysis, so the relative contribution of individual stakeholders or specific design modifications cannot be determined. Finally, the eating-related analyses were exploratory and involved small and varying sample sizes and multiple comparisons. Effect-size estimates and pairwise comparisons should therefore be interpreted cautiously, and none remained statistically significant after Holm correction.

Conclusions

The findings suggest that NutriVRTEA was feasible to deliver as a professionally supervised, 4-session intervention in this outpatient setting, with high completion and favorable descriptive ratings of acceptability and tolerability. No investigator-recorded adverse events required session termination or specific clinical management. Participant-perceived usability scores spanned a wide range, suggesting that interaction design remains an area for refinement.

No statistically significant changes were observed in attitudes toward healthy eating, Mediterranean diet adherence, or feeding-related behaviors. These exploratory findings do not provide evidence that NutriVRTEA changes eating behavior. Further controlled studies should include prespecified measures of educational learning together with measures of real-world dietary behavior, better characterize participants' feeding profiles, and examine whether virtual food familiarization is associated with changes outside the immersive environment.

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Data Availability

The datasets generated and analyzed during this study are not publicly available because they contain data from a small clinical sample of children and adolescents and are subject to institutional, ethical, and data protection requirements. Deidentified data may be made available from the corresponding author upon reasonable request, subject to approval by Badalona Serveis Assistencials, and compliance with applicable ethical and data protection requirements. NutriVRTEA version 3 was developed in-house by Badalona Serveis Assistencials for educational and research use and is not commercially distributed or publicly available. Access for research or educational purposes may be requested from the corresponding author, subject to approval by Badalona Serveis Assistencials.

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Generative AI Use

ChatGPT (OpenAI) was used during manuscript preparation to support language editing and wording refinement. All AI-assisted text was reviewed and revised by the authors, who take full responsibility for the final manuscript.

Authors' Contributions

Conceptualization: JFC, AMVS, VVR, TGP
Methodology: JFC, AMVS, VVR, TGP, XB-H
Software: JFC
Project administration: JFC
Formal analysis: JFC
Visualization: JFC
Investigation: AMVS, PFS, VVR, TGP
Supervision: XB-H
Validation: XB-H
Writing – original draft: JFC
Writing – review & editing: AMVS, PFS, VVR, TGP, XB-H

Conflicts of Interest

The authors were involved in the development and/or clinical implementation of NutriVRTEA as part of their professional roles at Badalona Serveis Assistencials. No other financial or nonfinancial conflicts of interest were declared.

Multimedia Appendix 1

Study-specific feasibility questionnaires used in the NutriVRTEA pilot, including the original Catalan versions and English translations.
[PDF File (Adobe PDF File), 208 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Pairwise comparisons of exploratory eating-related outcomes across assessment points, including Hodges-Lehmann estimates, 95% CIs, unadjusted and Holm-adjusted *P* values, and effect sizes.
[PDF File (Adobe PDF File), 85 KB-Multimedia Appendix 2]

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Abbreviations

ARFID: avoidant/restrictive food intake disorder
BPFAS: Behavioral Pediatrics Feeding Assessment Scale
BSA: Badalona Serveis Assistencials
CSMIJ: Child and Adolescent Mental Health Center
DSM-5: Diagnostic and Statistical Manual of Mental Disorders (Fifth Edition)
GUIDED: Guidance for Reporting Intervention Development Studies in Health Research
KIDMED: Mediterranean Diet Quality Index for Children and Adolescents
RATE-XR: Reporting Guidelines for the Early-Phase Clinical Evaluation of Applications Using Extended Reality
TFS: total frequency score
TIDieR: Template for Intervention Description and Replication
TPS: total problem score
VR: virtual reality

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