Navigating Uncertainty in a Virtual Supermarket: Designing a VR Tool to Promote Autonomy in Autistic Youth

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Figure 1: Screen capture of the virtual supermarket

Abstract

This work describes the iterative design and development of a Virtual Reality (VR) tool intended to explore how immersive technologies can support autistic adolescents when facing everyday situations characterised by uncertainty. We report the results of a co-design workshop with four psychologists specialised in neurodevelopmental intervention, which led to the creation of storyboards about uncertainty in a supermarket context. Results include sensory and social considerations in the simulation of uncertainty, as well as coping strategies and design implications for virtual environments with potential clinical relevance. These storyboards were used to develop a mid-fidelity prototype of a VR system. We then invited six autistic adolescents (aged 10-18) to interact with the prototype and act as expert advisors. Feedback data were gathered through semi-structured interviews and field observations. Our findings reveal that designing for autonomy in VR experiences is shaped by tensions related to individual, social, and interactive aspects. This work contributes to research on designing VR tools for autistic people by providing critical reflections on autonomy, competence, and relatedness.

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CCS Concepts

• **Human-centered computing → Empirical studies in HCI**; • **Social and professional topics → People with disabilities**.

Keywords

Virtual Reality, Autism, Neurodiversity, Self-Determination Theory, Game, Accessibility

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1 Introduction

The United Nations Convention on the Rights of Persons with Disabilities (CRPD) emphasises "inherent dignity, individual autonomy including the freedom to make one's own choices, and independence of persons" as fundamental principles [36]. Nevertheless, few studies have focused on designing technology that centres on the needs and preferences of disabled and neurodivergent people to achieve greater well-being and autonomy [31, 32]. Even though many of these technologies are intended for autistic audiences, there is limited research that has considered their interests, needs, and desires [31]. Indeed, the requirements for such technologies are often externally driven by therapeutic or educational goals rather than by the potential users.

Since its conception as a clinical category in the 1940s, descriptions of autism have varied, reflecting a complex system of disciplines and discourses [3, 13, 21]. According to disability studies, these conceptions can be interpreted through the perspectives of the medical, social, and neurodiversity approaches [13, 22, 31]. The medical model views autism primarily in terms of individual-level impairments [3, 13]. In contrast, the social model emphasises the role of society in creating barriers for autistic people, focusing less on individuals and more on the systemic challenges they face [3, 13, 31]. The neurodiversity approach has been proposed as a way to bridge these perspectives by considering the interaction between personal and environmental characteristics [13]. Research aligned with this approach understands autism as a form of human diversity, focusing on addressing systemic barriers [38], and supporting adaptive strategies [13].

This paper applies a neurodiversity approach into the design and exploration of a Virtual Reality (VR) prototype aimed at supporting the autonomy of autistic people by simulating unpredictable or ambiguous situations in everyday life tasks, which are commonly associated with increased anxiety [4, 26]. This framing attempts to balance the agencies of different stakeholders while assigning greater weight to neurodivergent voices in the design process. Accordingly, all participants were approached as experts, and their lived experiences were considered central to assessing the system through interpretations and reflections. This viewpoint is also reflected in the decision of adopting an identity-first language around neurodiversity (i.e., by referring to "autistic person") in this paper [3, 12, 29, 30].

In clinical research, heightened anxiety in situations characterised by unpredictability or ambiguity can be conceptualised as Intolerance of Uncertainty (IU) [9]. For this study, IU is used to explore the design of simulated scenarios of uncertainty in daily life. VR solutions offer controlled and immersive means to simulate uncertain situations, enabling the exploration and support of coping strategies in ecologically valid contexts [17]. In this sense, VR environments provide an opportunity to move beyond an exclusively individual-focused perspective by examining contextual and systemic aspects that the simulations represent. In this study, we investigate how therapists (N = 4) conceptualise and represent uncertainty in everyday contexts, and how these conceptualisations can be translated into a VR environment. Further, we explore how autistic youth (N = 6) perceive, interpret, and engage with the VR simulation, aiming to tailor it to their needs and preferences.

2 Related Work

Psychological research has identified IU as a major aspect influencing anxiety in neurotypical people [9]. For autistic individuals, IU can be particularly distressful, negatively influencing everyday experiences [4, 18, 39]. Unexpected changes, such as variations in routine, may increase stress and lead to strategies that prioritise predictability. According to the *intense world* hypothesis, heightened reactivity in brain networks may contribute to sensory sensitivity [23]. This discomfort leads to a preference for structure as a means to increase the predictability of the world and manage emotional regulation [23, 26, 33]. Yet, uncertainty is challenging to identify, reproduce, and control due to its highly contextual and individual nature. In this regard, VR technologies may be well-suited for this purpose [17], as they can be personalised by adjusting parameters such as complexity or unpredictability, both before and during a session, to match individual and contextual needs.

2.1 HCI and Autism

Understanding how technology can support the autonomy of neurodivergent people is an area of ongoing exploration in HCI [31, 32]. Some work have used Self-Determination Theory (SDT), a macro-theory of human motivation [27], as a theoretical foundation and interpretative approach [28, 35]. Consistent with the neurodiversity model, SDT focuses on both the individual and the context to explain intrinsic and extrinsic motivation [27]. One of its mini-theories describes the basic psychological needs as autonomy, competence, and relatedness [27, 37]. When these needs are satisfied, they contribute to well-being and, when hampered, they present a detriment to personal health [27, 37]. In HCI, these needs have been used as lenses for creating meaningful experiences that become intrinsically motivating [10, 28, 35], while also exploring how technology can support well-being.

Despite a growing research corpus advocating for user engagement, many technologies for autism have historically excluded direct input from autistic individuals in the design process [31]. This led to an over-representation of technologies seeking to regulate perceived deficits rather than improve individual experiences and well-being [16, 31, 40]. The disparity between the concerns of autistic people and the research focus has been highlighted as a significant limitation [25]. As explained in a meta-analysis of 185 HCI papers on technologies for autistic children, more than 80% of them aimed to improve social skills and only 4% described experiences tailored to the needs and preferences of autistic children as the main purpose of a given technology [31]. This paper contributes to a small but steadily growing corpus of research that rethinks ways in which technology can be designed following the preferences of autistic participants through situated design practices [2, 15].

2.2 VR and Autism

VR technologies often face challenges regarding their accessibility to diverse audiences, with limited guidelines and a lack of standardisation resulting in fewer options to accommodate diverse individual and situational needs [2]. VR research for autistic individuals has developed systems in areas such as social competencies and emotional skills [20]. VR studies have explored the preferences of autistic users, including locomotion techniques [5], perceptions of difficulty, frustration, presence, and motion sickness [6]. In their systematic review on VR accessibility, Dudley et al. [11] highlight the importance of conducting research that values sensory-inclusive techniques, offering neurodivergent users control over sensory stimuli.

Some studies have explored VR simulations of everyday scenarios for autistic people utilising a supermarket environment, similar to the one presented in this study. These studies investigate how daily living skills can be trained through VR interventions, providing valuable insights into technical features [34], intervention strategies [19], and performance outcomes [1, 14, 24]. The design implications of the VR systems are predominantly derived from caregivers, teachers, or therapists, without addressing the perspective of autistic users themselves. Unlike previous works centred on task performance and intervention effectiveness, this paper examines how reflections from autistic youth and therapists can be integrated to inform the design of VR applications.

3 Co-design Workshop with Therapists

The project was conceived as a clinically-driven VR supportive solution for IU. Within this frame, a team of nine researchers, including clinicians, computer scientists, and HCI researchers, identified the supermarket as the initial context of study. Based on therapists' and autistic people's experiences reported during therapy sessions, it offered a necessary and challenging environment open to uncertainty. Still, it did not pose precise and individual constraints of realism, which may have affected other venues, such as schools. To check the potentialities and the challenges of the supermarket context, we designed and conducted a co-design workshop with four clinical psychologists specialised in the functional diagnosis and intervention of neurodevelopmental conditions. The goal of the workshop was to create and reflect on storyboards depicting situations of uncertainty, and discuss how a VR system that simulates these situations could be relevant for clinically informed research and supportive practices. The participants worked as colleagues at the ODFLab (Rovereto, Italy), and were already familiar with each other, which facilitated smooth cooperation during the workshop.

3.1 Procedure

The workshop began with an introduction to the research project and to the use of storyboards to support thinking and reflecting about uncertainty in a supermarket. Three researchers facilitated the study, one acting as moderator and two taking field notes. Participants were given a blank template composed of nine sequential panels to create the storyboards. To drive their tasks, we added cues *(i.e. "the user enters the supermarket", "trigger", "reaction")* at the beginning, middle, and end of the storyboard template. These cues guided therapists in creating the storyboard and elicited essential elements such as triggering situations or reactions of uncertainty. A researcher introduced participants to the other available materials (Figure 2), including a map of a supermarket illustrating different aisles, as well as sets of printed images of supermarkets. The provided materials also contained a set of eighteen images displaying common events or stimuli that can elicit uncertainty in a supermarket. These included overcrowded aisles or halls, a crying baby, missing products, or disorganised shelves. Finally, we provided standard stationery items to support writing and drawing.

After familiarising themselves with the materials, participants were presented with a guiding question: *"What types of events could create uncertainty in autistic youth?"* At this point, the therapists, working in pairs, began developing the storyboards using the provided materials as they wished. The storyboards served a double purpose: on one hand, they provided a representation of a situation that could be easily translated into a VR prototype, and on the other hand, they served as probes to engage them in a discussion about the nuances of simulating such situations in VR.

Following the storyboard creation activity, the workshop moved into a discussion focused on collectively evaluating one storyboard from each group. The goal of the discussion was to reflect on how well the storyboards resonated with their clinical experience and how they might help support their practice. We provided the therapists with a worksheet consisting of a table divided into three columns: environmental stimuli, individual reactions, and therapeutic support tools. Participants were invited to identify the relevant elements they perceived during the storyboard presentation, using the worksheet as a guide. To conclude, participants were invited to individually reflect on the risks and benefits of using a VR tool to support IU management for autistic people and write them on post-it notes. These outputs were discussed in a concluding plenary session.

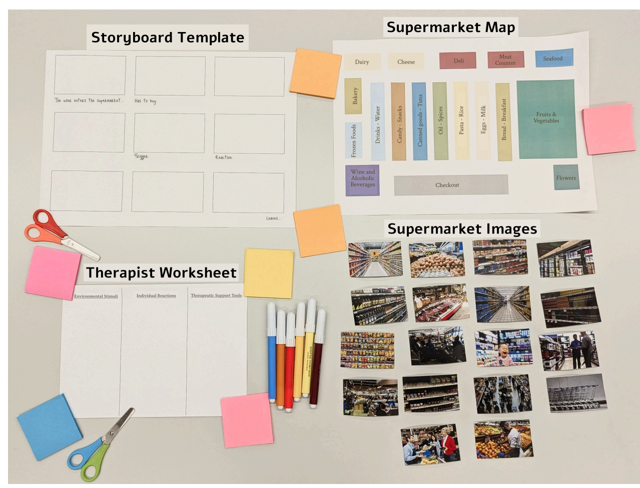

Figure 2: Workshop materials

3.2 Findings

Overall, participants were deeply engaged in the workshop to the point that both groups proactively decided to create an additional storyboard. Interactions between the two groups were characterised by a light, convivial tone. The discussions within groups about the storyboards were grounded in their clinical experience, with psychologists often supporting their suggestions with examples drawn from therapeutic practices. One participant was often more active in physically composing the storyboard, drawing, or writing, while the other supported the process with comments, revisions, or ideas. The set of images was used to represent environmental stimuli or gain inspiration for the storyboard, while drawing and writing were employed when existing images did not capture the aspects of the storyboard that the group wanted to display. The final ideas were broadly perceived as the result of a collective effort. Storyboards and field notes were analysed using inductive thematic analysis [7, 8], leading to the following themes.

3.2.1 Triggering Uncertainty. Therapists created four storyboards in total. They elicited a range of social and sensory triggers that could contribute to uncertainty in a supermarket, with some storyboard panels ramifying into different possible events. For instance, the third panel of Figure 3 illustrates how therapists enlisted a range of different reactions to the same situation. The participants identified social triggers in Non-Player Characters (NPCs), meaning characters whose actions were defined and that could not be interactively controlled by the user. NPCs could act as social triggers by blocking access to products, creating long queues at checkout, overcrowding spaces, and acting as if they were meeting a friend. They also paid attention to sensory details, reflecting on different types of stimulation that could create discomfort. These elements included strong smells in specific aisles, tactile discomfort when handling certain products, and sensory overload resulting from multiple stimuli. Therapists expressed concerns about the technological limitations in simulating multisensorial VR experiences. Additionally, they noted that the unique characteristics of each autistic person should be taken into account when choosing stimuli, emphasising the importance of knowing more about their profile before exposing participants to undesired scenarios.

3.2.2 Coping with Uncertainty. These uncertain situations were accompanied by various reactions and coping strategies by the characters depicted in the storyboard. These reactions included asking politely for assistance from a staff member or following a learned script on what to do in such a situation. Sometimes characters froze or broke social norms. In these cases, the storyboards envisaged different forms of external support, which were typically enacted through NPCs. For example, a client or staff member could empathise with the player and help them find a way to overcome obstacles. Overall, the ideas proposed in the storyboards about coping mechanisms involved a careful balancing of the evident tension between the agency of autistic youth to respond to unexpected situations and the provision of aids or support when individual reactions were not successful at resolving the situation. Therapists discussed how these circumstances require a careful balance between respecting autonomous problem-solving and providing support to overcome the challenge.

3.2.3 The Therapist Role. The discussion around the storyboards surfaced a range of considerations related to therapists' expectations and requirements for a VR tool capable of simulating such situations for therapeutic use. A strong preference for personalisation was noted; therapists expressed that the tool should have the ability to adapt to individual situations based on the goals of each therapy session. This entailed that therapists were able to intervene in the virtual world in real-time by implementing adjustable layers of difficulty, ranging from simple and controlled environments to situations of greater uncertainty and complexity. In the middle of the discussion, a debate arose concerning the role of the therapist in the virtual environment. They discussed how the therapist could control NPCs inside the game, for instance, role-playing as part of the supermarket staff. One perspective envisioned the therapist as an integral part of the VR experience. They were envisioned as specific characters within the simulation that provided guidance or support. In contrast, another participant suggested that this proposal might reflect a limiting bias rooted in the way they perform real-life training by occasionally accompanying autistic people in grocery shopping. The argument was based on the reasoning that although the idea of the therapist as a virtual character was intuitive, the therapist might have a more effective role outside the virtual world. This view saw the therapist as a "game master", controlling the simulation from the outside, adjusting parameters to introduce or remove stressors, and dynamically modulating the level of difficulty of the experience.

3.2.4 Relevance for Professional Practice. Therapists reflected on the broader professional relevance of such a tool. They highlighted how its potential usefulness could support autonomy while training participants to cope with anxiety and stress, and working on executive functions and behavioural inhibition. These reflections were accompanied by considerations related to the individual characteristics of autistic people, such as age and support needs. Therapists noted that the storyboards created might not be sufficiently challenging for those who were already autonomous in grocery shopping. Two therapists argued that such a tool could be of greater value for younger autistic people who are beginning to develop autonomy in similar tasks, or for those whose particular sensory, cognitive, or emotional characteristics make such environments challenging. The discussion enabled the storyboards to be explored in greater depth, prompting reflections on the feasibility and usefulness of simulating such situations in virtual therapy. Participants debated how different aspects of the storyboards could be translated into relevant contributions to their therapeutic practice and what constraints or opportunities might emerge in a virtual setting. Risks included concerns such as lack of generalisability, discomfort while using a head-mounted display, task complexity, and sensorial overstimulation. At the same time, benefits highlighted greater engagement, personalisation, increased problem-solving, and the possibility of creating gradual levels of difficulty.

4 Experiential Evaluation with Autistic Youth

Based on the workshop results, the research team engaged in a series of iterative design cycles, and early prototypes were discussed in regular meetings with therapists. Feedback from these sessions informed revisions, leading to progressive refinements of the environment layout, interaction mechanics, and interface features. The platform was incrementally designed as a tool to support observation, exploration, and reflection on how autistic adolescents interact with uncertain situations in a controlled virtual setting.

4.1 Mid-fidelity Prototype

The prototype was developed as an immersive VR setup, intended for use in a supervised laboratory context. The prototype was developed using the Unity game engine (version 6). The virtual environment in the prototype consisted of a simplified supermarket with

Figure 3: Segment of a storyboard created during the workshop translated to English

multiple aisles of shelves displaying everyday grocery items, along with a checkout area (as seen in Figure 1). Visual design choices favoured neutral colours and consistent lighting. Audio design included ambient supermarket sounds, such as distant chatter and background noise. Regarding locomotion, users could choose between teleportation and continuous movement, with the option to enable or disable tunnelling. Users could access their shopping list, grab items from shelves to add to their basket (Figure 4), and complete a payment at checkout. NPCs represented other customers and checkout staff, primarily serving as environmental context rather than active social agents. NPCs followed simple routines, such as standing in a queue or moving inside the supermarket.

A subset of the clinical requirements was implemented, prioritising usability and system stability. In the implementation, uncertainty was primarily set to low-intensity mechanics that the therapist could control via a dedicated desktop interface outside the virtual world. Uncertainty-related elements were conceived as adjustable components that the therapist could introduce, intensify, or remove during the session. They included the possibility of modulating the ambient sounds and introducing unexpected auditory stimuli. Another source of uncertainty was choosing between different payment methods (cash or card), which therapists could enable or disable at checkout.

Figure 4: VR shopping list and basket

4.2 Participants

Six autistic adolescents and pre-adolescents agreed to participate in the study as expert advisors to interact with the VR prototype and provide feedback to inform the design of a grocery shopping simulation in a supermarket. All participants were informed about the aims and procedures of the pilot study, and their parents provided written informed consent before participation. Participants ranged in age from 10 to 18 years and included five boys and one girl. All participants attended therapy sessions at the same clinical facility where the therapists involved in the earlier co-design workshop worked. All participants reported having previous experience playing video games, although one noted that they did not enjoy them very much. Four participants had prior experience using VR systems, while the others were using a Head Mounted Display (HMD) for the first time. Four participants had previously shopped for groceries autonomously, while the others had no such experience.

4.3 Procedure

Each session lasted approximately 30 minutes. It began with a brief introduction to the project, followed by a phase of familiarisation with the VR equipment and the interaction with the prototype. The prototype was running on a laptop equipped with an AMD Ryzen 9 processor, 16 GB RAM, and a NVidia RTX 3070 graphics card, connected via cable to an HTC Vive Focus Vision. The sessions concluded with a semi-structured interview focused on participants' experiences. The VR experience involved completing a short grocery shopping task. It began with a tutorial introducing fundamental interactions with VR, including using the shopping basket, shopping list, and wallet. Participants then started navigating the virtual supermarket to locate items, place them in the basket, and proceed to checkout, where they queued and paid for their groceries. Two researchers were present during each session. One observed participants' interactions and documented field notes, while the other facilitated the session by providing guidance and support during the VR experience and conducted interviews at the end of each session. Interview questions focused on the experiences participants had while interacting with the VR prototype. SDT [27, 28] informed the interview script, with the aim of understanding how the experience supported or constrained autonomy, competence, and relatedness.

5 Findings

Field notes and interview transcripts were analysed using reflexive thematic analysis, following the phases and principles outlined by Braun and Clarke [7, 8]. The analysis was conducted primarily by the first author, who was present during the sessions and adopts an interpretivist-constructionist epistemological position with a neurodiversity-affirming stance. The first step involved data familiarisation, with three researchers reading and discussing the initial transcripts. After this phase, codes were developed inductively, collating data relevant to each code across the entire data set. Afterwards, codes were collected into potential themes, and iteratively reviewed by three researchers, through a combination of data-driven and theory-driven analysis [8]. The theory-driven analysis sought to identify themes related to the theories used in this study, such as Self-Determination Theory, and to understand the extent to which they overlapped. The themes were then defined and named, producing a report that was later discussed between all co-authors and is reported below (Figure 5).

5.1 Freedom vs. Boundaries

Participants navigated a tension between the perception of freedom and the presence or absence of constraints in the virtual supermarket. While some appreciated the freedom to do whatever they preferred in the supermarket, others would have preferred to experience more boundaries or limits to what was possible to do.

5.1.1 Autonomy. While completing shopping tasks, several participants described feeling free to move and act according to their preferences. This freedom was only partial according to one participant, who noted that the requirement to buy items from the shopping list constrained their choices. This participant picked up items outside the list just for fun, saying that they wanted to buy everything in the supermarket. On the other hand, another participant appreciated being able to pick up items outside the shopping list, noting that a possible improvement would be having multiple brands of the same product type.

5.1.2 Responsibility. Two participants critiqued the absence of consequences for boundary-breaking behaviour. One participant noted that there were no consequences for bypassing checkout without paying or for taking items from NPC carts and proposed adding alarms or reactions from NPCs when rules were broken. This suggests an expectation to encounter similar social or systemic boundaries to those found in the real world.

5.1.3 Disinhibition. The two youngest participants engaged more explicitly with the lack of boundaries, exhibiting transgressive or violent behaviour (e.g., "I just want to cause trouble" or "I will find out how to burn the supermarket") and insulting or being aggressive towards NPCs. One suggestion was to add "horror" or "insane" modes, allowing players to kill NPCs or purchase weapons, and a "killer bunny" that chases players. During the sessions, when participants exhibited this behaviour, the facilitator redirected their attention towards the task. These two participants wanted to try another session in which they were free to play however they preferred, and they did so outside of the study with their therapist. In contrast, this style of play was not observed among older participants, who tended to follow supermarket conventions (e.g., queuing, avoiding harm to NPCs). These patterns suggest a variation in how participants interpreted and explored the affordances and limits of the virtual scenario.

5.2 Realism and Virtuality

Participants reflected on their perception of the realism of the virtual supermarket through a range of interconnected dimensions, including social behaviour, physical interaction, representational fidelity, and the alignment between expectations and events within the simulation. Realism was articulated through comparisons with everyday experiences, such as grocery shopping and previous gaming experiences.

5.2.1 Non-Player Characters. NPCs played a significant role in the perceptions of realism. Some participants described NPCs as resembling real shoppers encountered in supermarkets. For instance, there were comments about waiting in line during checkout while NPCs were completing their transactions. This aspect led participants to express frustration at how slowly NPCs progressed through checkout, while others reported that waiting in the queue was a realistic feature, noting that queuing is a common aspect of grocery shopping.

Participants also expressed interest in richer forms of social interaction with NPCs. Suggestions included the presence of staff members, such as an NPC at the fish counter who could take orders and hand over items. While some participants evaluated NPCs primarily in terms of their behaviour, others commented on their appearance, describing them as resembling characters from mobile games they play. One participant proposed that one way to make NPCs more engaging could be to change their appearance to anthropomorphic cats, suggesting that fantasy may have greater value for some participants compared to realism.

5.2.2 Fidelity. The fidelity of the VR simulations was elaborated with respect to the visual representations, but also to physical and social interactions. Visual, physical, and social representations shaped the way participants perceived realism. Three participants compared the visual style of the supermarket to mobile games such as Roblox, often noting limited graphical fidelity. Participants also considered the extent to which the VR simulation resembled the physical interactions in the real world. For instance, one participant noted how objects were not "throwable" and dropped to the ground when trying to throw them. Another participant remarked on the absence of perceived weight when many items were added to the shopping basket. Comments on the fidelity of social interactions included observations about not receiving change when paying with cash and inconsistencies between the written language on product packaging and the language spoken by NPCs.

5.2.3 Unexpected Events. Participants encountered several elements they described as unexpected. For instance, most participants did not anticipate the presence of a queue at checkout and reported that waiting required patience, similar to real-world shopping. Others noted surprise related to the size of the supermarket or the presence of unexpected items such as books or teddy bears. These moments were often discussed in relation to realism, suggesting that these unanticipated elements could reinforce the sense of being in a real supermarket.

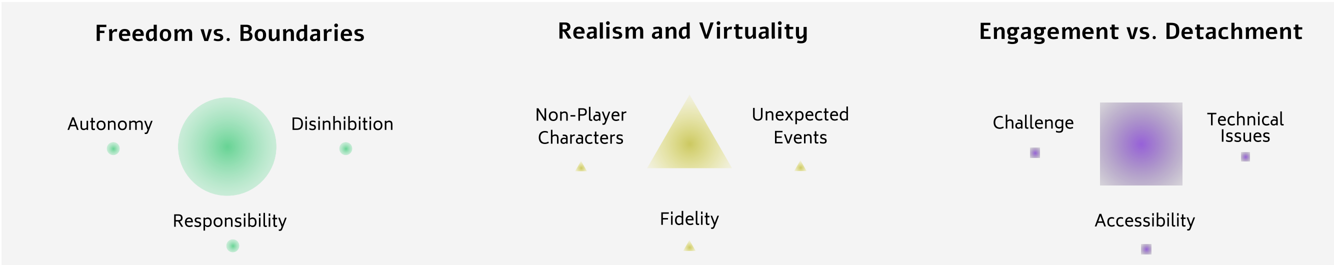

Figure 5: Themes resulting from the thematic analysis

Across participants, perceptions of realism were accounted for as the sum of their experiences with social cues, physical interactions, visual elements, and expectations. Although some participants identified mismatches between the virtual and real worlds, many reported a sense of immersion, describing the experience as comparable to being physically present in a supermarket.

5.3 Engagement vs. Detachment

Participants' reflections were influenced by their past experiences with VR, video games, and grocery shopping, and they reported varying degrees of engagement, difficulty, and accessibility in the VR experience. One participant noted that VR enables people to "see differently", and the majority of participants described the experience as entertaining and engaging. Even those who had previously used VR described the experience as novel. Completing the task successfully, gathering items from shelves, and exploring the supermarket were all linked to feelings of satisfaction.

5.3.1 Challenge. Prior experience using VR or playing video games accounted for how easily they navigated in the 3D world and used the controllers. Similarly, prior experiences of autonomous grocery shopping made the simulation feel overly simplistic, with little to no challenge. Indeed, one participant, who frequently does groceries, questioned the level of challenge of the activity, deeming it too simple for them. Another participant with no prior VR experience and limited interest in video games described the experience as less pleasant. This participant had difficulties coordinating controller movements and interacting with objects in the 3D space, with repeated unsuccessful attempts to pick up items. Across participants, challenge emerged as relative and specific to each individual, shaped by prior experience both inside and outside VR.

Participants also noted the fast learning curve within the experience, with one of them mentioning that it becomes easier over time. For two of them, grabbing the first products was challenging, but after completing the tutorial, they were able to do it more easily. This indicates that repeated interaction supports growing confidence and competence.

5.3.2 Accessibility. Accessibility issues were noted, with font size being the most frequently cited concern. Many participants mentioned that reading signs and shopping list elements was difficult, which highlights a tension between visual realism and readability. One participant found the lighting and colours comfortable, but reported discomfort caused by the background music. Regarding locomotion, continuous movement was the most frequent option, with only one participant preferring teleportation.

5.3.3 Technical Issues. Technical issues related to the VR setup were also noted during the sessions, with some participants reporting blurred peripheral vision and having issues with inter-pupillary distance (IPD) calibration. Additionally, one participant noted that the HMD was too warm. One session was interrupted due to a connectivity issue while the participant was completing the checkout process. None of the participants reported motion sickness during the sessions, although one participant described brief dizziness after removing the headset.

6 Discussion

One of the aims of this study was to explore how reflections from therapists and autistic youth could be integrated for designing VR simulations of daily activities, emphasising the preferences of the autistic participants. We integrate the results from the experiential evaluation and the therapist workshop by using SDT and the neurodiversity paradigm as reflective theoretical lenses. We highlight how autonomy in VR experiences of everyday uncertainty is shaped by tensions between freedom and structure, realism and personal preference, and by the diverse strategies participants adopt to cope with uncertainty. Insights reveal how both individual responses and contextual design choices contribute to participants' experiences within the VR environment.

6.1 Considerations for Design

We propose design considerations for VR experiences centred on the well-being of autistic youth, grounded in the basic needs of SDT. The themes and empirical results from the experiential evaluation and the workshop with therapists are contrasted with the constructs of autonomy, competence, and relatedness, as well as with previous literature, to discuss areas that require thoughtful attention from designers of such technologies and warrant deeper exploration for future research.

6.1.1 Autonomy. Some participants appreciated the freedom they experienced in the virtual supermarket, while others perceived the lack of boundaries as a limitation. Previous research explores how SDT can support autonomy within gaming experiences, and how game mechanics should be tailored to allow users to explore the world according to their preferences [28]. The boundaries mentioned by participants appeared to stem from a desire for social structures that align with real-world expectations and could be implemented as environmental constraints or interaction rules. Therapists emphasised the importance of generalisability and supporting user autonomy beyond the VR experience. This opens up the discussion to how the VR experience translates to real-world contexts and whether these behaviours could become self-determined and intrinsically motivated [1, 28]. Further research is needed to examine whether and how such virtual scenarios may support well-being and autonomy over time. From the perspective of the therapists, autonomy was reflected in the level of personalisation supported by the prototype, allowing them to adapt the experience to their therapeutic style and to the individual needs of autistic people.

Supporting autonomy involves providing options for customisation, including sensorial parameters [11], which was an expressed concern of some autistic participants and therapists. This suggests the need for configurable boundaries and consequences that balance user freedom and predictable structure. From a neurodiversity perspective, the role of the therapist as a "game master", as suggested by one of them during the workshop, requires deeper exploration, since it could reinforce power dynamics that attribute less agency over the experience to autistic youth [31].

6.1.2 Competence. Perceived competence is central to intrinsic motivation. For neurodivergent individuals who may feel less confident performing certain daily activities autonomously, VR simulations like the one presented here, or similar systems [1, 24, 34], may offer opportunities to increase their perceived competence and self-efficacy. In the VR experience, it is important to distinguish between perceived competence related to the contextual task, such as grocery shopping in a supermarket, and perceived competence related to operating the VR system itself. As reported in the Section 5.3, VR experiences must be made accessible, and participants, especially those new to VR, should be given time to learn and adapt. Developers must consider accessibility guidelines [2, 6] to minimise friction when using the system so that users can focus on the contextual task.

Factors such as reported difficulties with readability, peripheral blur, interpupillary distance, and headset comfort may directly influence perceived competence or sense of control and represent an added layer of unintentional uncertainty linked to the experience. These accessibility considerations are even more crucial for multiply disabled users. The same accessibility and usability considerations are also important for therapists, who rely on these systems to support their clients.

6.1.3 Relatedness. For autistic youth, it is important that the experience relates to familiar elements or things they care about. From an IU perspective, mismatches between user expectations and system behaviour may represent an additional source of perceived uncertainty. Within the VR environment, the behaviour of NPCs should align with users' expectations, whether these stem from video games they enjoy or from real-life social behaviour. NPC behaviour served as a social reference point, shaping participants' behaviour within the simulation and their judgements of realism. This raises the question of how to account for fidelity contextuality in VR and handle it when simulating uncertain scenarios. For instance, therapists preferred greater fidelity, but one participant wanted NPCs to look like anthropomorphic cats and another participant wanted a "killer bunny" chasing players. From one perspective, striving for prototypes with greater fidelity [6] that closely resemble real-world situations is important. However, it is worth noting that this may not be valid for all users, for whom real-world fidelity may be less significant, and elements that align with what they care about could make the experience more enjoyable and engaging.

6.2 Limitations and Future Work

A key limitation of this study is the lack of autistic youth involvement in the framing of the project, the technological choice, and design decisions. We sought to address this by emphasising the tensions produced when interacting with the prototype, and by incorporating the preferences and insights of the autistic participants to refine the prototype for future iterations. Despite its limitations from a critical disability studies perspective, this compromise can help navigate common situations in which technology needs to be defined upfront due to funding schemes or stakeholders. Another limitation is the small and heterogeneous sample. As a study that primarily reports qualitative findings, the results cannot be generalised to a broader population. Nevertheless, they provide valuable methodological and empirical insights for designing technologies in similar contexts.

Regarding future research, several aspects should be considered. One area that deserves deeper exploration is autistic youth's preferences regarding how freedom and constraints are manifested in VR experiences. Further work is also needed to understand the factors contributing to disinhibited or transgressive play in VR, as observed in two participants. This phenomenon could be a disinhibition effect of the VR medium, or an exploration of agency in a perceived safe space. VR requires continuous attention to accessibility, particularly for multiply disabled people. Additionally, further work extending SDT could offer deeper explanations of the afore-mentioned aspects and provide deeper explanations through its mini-theories.

7 Conclusion

This study explored how reflections from therapists and autistic youth can be integrated to inform the design of VR experiences that support autonomy in daily life situations involving uncertainty. Key considerations for designing these types of experiences are presented, drawing on insights from a co-design workshop with therapists and the experiential evaluation of a VR supermarket prototype. The study provides a perspective on how to balance the requirements of therapists and autistic youth. Additionally, it underscores the value of SDT as an analytical lens for VR, and offers directions for future work that support the autonomy and well-being of neurodivergent people.

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References

[1] Ali Adjorlu, Emil Rosenlund Høeg, Luca Mangano, and Stefania Serafin. 2017. Daily Living Skills Training in Virtual Reality to Help Children with Autism Spectrum Disorder in a Real Shopping Scenario. In *2017 IEEE International Symposium on Mixed and Augmented Reality (ISMAR-Adjunct)*. 294–302. doi:10.1109/ISMAR-Adjunct.2017.93

[2] Craig Anderton, Chris Creed, Sayan Sarcar, and Arthur Theil. 2025. Asleep at the Virtual Wheel: The Increasing Inaccessibility of Virtual Reality Applications. In *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems (CHI '25)*. Association for Computing Machinery, New York, NY, USA, 1–20. doi:10.1145/3706598.3713558

[3] Kristen Bottema-Beutel, Steven K. Kapp, Jessica Nina Lester, Noah J. Sasson, and Brittany N. Hand. 2021. Avoiding Ableist Language: Suggestions for Autism Researchers. *Autism in Adulthood* 3, 1 (2021), 18–29. doi:10.1089/aut.2020.0014

[4] Christina Boulter, Mark Freeston, Mikle South, and Jacqui Rodgers. 2014. Intolerance of Uncertainty as a Framework for Understanding Anxiety in Children and Adolescents with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders* 44, 6 (June 2014), 1391–1402. doi:10.1007/s10803-013-2001-x

[5] Evren Bozgeyikli, Andrew Raij, Srinivas Katkoori, and Rajiv Dubey. 2016. Locomotion in Virtual Reality for Individuals with Autism Spectrum Disorder. In *Proceedings of the 2016 Symposium on Spatial User Interaction*. ACM, Tokyo Japan, 33–42. doi:10.1145/2983310.2985763

[6] Lal "Lila" Bozgeyikli, Evren Bozgeyikli, Srinivas Katkoori, Andrew Raij, and Redwan Alqasemi. 2018. Effects of Virtual Reality Properties on User Experience of Individuals with Autism. *ACM Trans. Access. Comput.* 11, 4 (Nov. 2018), 22:1–22:27. doi:10.1145/3267340

[7] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (Jan. 2006), 77–101. doi:10.1191/1478088706qp063oa

[8] Virginia Braun and Victoria Clarke. 2022. Conceptual and design thinking for thematic analysis. *Qualitative Psychology* 9, 1 (Feb. 2022), 3–26. doi:10.1037/qup0000196

[9] R Nicholas Carleton. 2012. The intolerance of uncertainty construct in the context of anxiety disorders: theoretical and practical perspectives. *Expert Review of Neurotherapeutics* 12, 8 (Aug. 2012), 937–947. doi:10.1586/ern.12.82

[10] Sebastian Deterding. 2015. The Lens of Intrinsic Skill Atoms: A Method for Gameful Design. *Human–Computer Interaction* 30, 3-4 (May 2015), 294–335. doi:10.1080/07370024.2014.993471

[11] John Dudley, Lulu Yin, Vanja Garaj, and Per Ola Kristensson. 2023. Inclusive Immersion: a review of efforts to improve accessibility in virtual reality, augmented reality and the metaverse. *Virtual Reality* 27, 4 (Dec. 2023), 2989–3020. doi:10.1007/s10055-023-00850-8

[12] Dana S. Dunn and Erin E. Andrews. 2015. Person-first and identity-first language: Developing psychologists' cultural competence using disability language. *American Psychologist* 70, 3 (2015), 255–264. doi:10.1037/a0038636

[13] Paul Dwyer. 2022. The Neurodiversity Approach(es): What Are They and What Do They Mean for Researchers? *Human Development* 66, 2 (2022), 73–92. doi:10.1159/000523723

[14] Merna El-Gohary, Mohamed Aborizka, Mona El-Sheikh, and Zeinab El-Nagar. 2022. Shopping Training to Autistic Children and Adolescents for Enhancing Daily Life Shopping Skills using Virtual Reality and Leap Motion. In *2022 1st IEEE International Conference on Cognitive Aspects of Virtual Reality (CVR)*. 000055–000060. doi:10.1109/CVR55417.2022.9967646

[15] Christopher Frauenberger. 2015. Disability and Technology: A Critical Realist Perspective. In *Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility (ASSETS '15)*. Association for Computing Machinery, New York, NY, USA, 89–96. doi:10.1145/2700648.2809851

[16] Christopher Frauenberger, Julia Makhaeva, and Katta Spiel. 2016. Designing Smart Objects with Autistic Children: Four Design Exposès. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. Association for Computing Machinery, New York, NY, USA, 130–139. doi:10.1145/2858036.2858050

[17] Jorge Fernández Herrero and Gonzalo Lorenzo. 2020. An immersive virtual reality educational intervention on people with autism spectrum disorders (ASD) for the development of communication skills and problem solving. *Education and Information Technologies* 25, 3 (May 2020), 1689–1722. doi:10.1007/s10639-019-10050-0

[18] Richard Jenkinson, Elizabeth Milne, and Andrew Thompson. 2020. The relationship between intolerance of uncertainty and anxiety in autism: A systematic literature review and meta-analysis. *Autism* 24, 8 (2020), 1933–1944. doi:10.1177/1362361320932437

[19] Phichete Julrode, Perasuk Worragin, Pakinee Ariya, Kitti Puritat, and Kannikar Intawong. 2025. Designing Gamified Virtual Reality Intervention Based on Experiential Learning to Enhance Social Reciprocity in Children with Autism Spectrum Disorder. *Education Sciences* 15, 9 (Sept. 2025), 1104. doi:10.3390/educsci15091104

[20] Kwanguk Kim, M. Zachary Rosenthal, Mary Gwaltney, William Jarrold, Naomi Hatt, Nancy McIntyre, Lindsay Swain, Marjorie Solomon, and Peter Mundy. 2015. A Virtual Joy-Stick Study of Emotional Responses and Social Motivation in Children with Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders* 45, 12 (2015), 3891–3899. doi:10.1007/s10803-014-2036-7

[21] Catherine Lord, Traolach S Brugha, Tony Charman, James Cusack, Guillaume Dumas, Thomas Frazier, Emily JH Jones, Rebecca M Jones, Andrew Pickles, Matthew W State, et al. 2020. Autism spectrum disorder. *Nature reviews Disease primers* 6, 1 (2020), 5.

[22] Jennifer Mankoff, Gillian R. Hayes, and Devva Kasnitz. 2010. Disability studies as a source of critical inquiry for the field of assistive technology. In *Proceedings of the 12th international ACM SIGACCESS conference on Computers and accessibility (ASSETS '10)*. Association for Computing Machinery, New York, NY, USA, 3–10. doi:10.1145/1878803.1878807

[23] Kamila Markram and Henry Markram. 2010. The Intense World Theory – A Unifying Theory of the Neurobiology of Autism. *Frontiers in Human Neuroscience* 4 (Dec. 2010). doi:10.3389/fnhum.2010.00224

[24] Safinaz Mustapha, Yong Bang Yang, and Muhammad Ashraq Salahuddin. 2021. Virtual Reality Based Application for Autistic Adolescents in Malaysia. *2021 IEEE 11th IEEE Symposium on Computer Applications & Industrial Electronics (ISCAIE)* (2021). doi:10.1109/ISCAIE51753.2021.9431838

[25] Elizabeth Pellicano, Adam Dinsmore, and Tony Charman. 2014. What should autism research focus upon? Community views and priorities from the United Kingdom. *Autism: The International Journal of Research and Practice* 18, 7 (Oct. 2014), 756–770. doi:10.1177/1362361314529627

[26] Caroline E Robertson and Simon Baron-Cohen. 2017. Sensory perception in autism. *Nature Reviews Neuroscience* 18, 11 (2017), 671–684. doi:10.1038/nrn.2017.112

[27] Richard M. Ryan and Edward L. Deci. 2000. Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. *American Psychologist* 55, 1 (2000), 68–78. doi:10.1037/0003-066X.55.1.68

[28] Richard M. Ryan, C. Scott Rigby, and Andrew Przybylski. 2006. The Motivational Pull of Video Games: A Self-Determination Theory Approach. *Motivation and Emotion* 30, 4 (Dec. 2006), 344–360. doi:10.1007/s11031-006-9051-8

[29] Ather Sharif, Aedan Lidan McCall, and Kianna Roces Bolante. 2022. Should i Say "disabled People" or "people with Disabilities" Language Preferences of Disabled People between Identity- and Person-First Language. doi:10.1145/3517428.3544813

[30] Jim Sinclair. 2013. Why I dislike "Person First" language. *Autonomy, the Critical Journal of Interdisciplinary Autism Studies* 1, 2 (2013).

[31] Katta Spiel, Christopher Frauenberger, Os Keyes, and Geraldine Fitzpatrick. 2019. Agency of Autistic Children in Technology Research—A Critical Literature Review. *ACM Trans. Comput.-Hum. Interact.* 26, 6 (Nov. 2019), 38:1–38:40. doi:10.1145/3344919

[32] Katta Spiel and Kathrin Gerling. 2021. The Purpose of Play: How HCI Games Research Fails Neurodivergent Populations. *ACM Transactions on Computer-Human Interaction* 28, 2 (2021). doi:10.1145/3432245

[33] Katherine Kuhl-Meltzoff Stavropoulos. 2017. Using neuroscience as an outcome measure for behavioral interventions in Autism spectrum disorders (ASD): A review. *Research in Autism Spectrum Disorders* 35 (March 2017), 62–73. doi:10.1016/j.rasd.2017.01.001

[34] Lui Albak Thomsen and Ali Adjorlu. 2021. A Collaborative Virtual Reality Supermarket Training Application to Teach Shopping Skills to Young Individuals with Autism Spectrum Disorder. *2021 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW)* (2021). doi:10.1109/VRW52623.2021.00015

[35] April Tyack and Elisa D. Mekler. 2024. Self-Determination Theory and HCI Games Research: Unfulfilled Promises and Unquestioned Paradigms. *ACM Trans. Comput.-Hum. Interact.* 31, 3 (Aug. 2024), 40:1–40:74. doi:10.1145/3673230

[36] United Nations. 2006. Convention on the Rights of Persons with Disabilities. *Treaty Series* 2515 (Dec. 2006), 3.

[37] Maarten Vansteenkiste, Bart Soenens, and Richard M. Ryan. 2023. Basic Psychological Needs Theory: A Conceptual and Empirical Review of Key Criteria. In *The Oxford Handbook of Self-Determination Theory*, Richard M. Ryan (Ed.). Oxford University Press, 0. doi:10.1093/oxfordhb/9780197600047.013.5

[38] Nick Walker. 2021. Neurodiversity: Some Basic Terms & Definitions. In *Neuroqueer heresies: notes on the neurodiversity paradigm, autistic empowerment, and postnormal possibilities*. Autonomous Press.

[39] Sarah Wigham, Jacqui Rodgers, Mikle South, Helen McConachie, and Mark Freeston. 2015. The Interplay Between Sensory Processing Abnormalities, Intolerance of Uncertainty, Anxiety and Restricted and Repetitive Behaviours in Autism Spectrum Disorder. *Journal of Autism and Developmental Disorders* 45, 4 (April 2015), 943–952. doi:10.1007/s10803-014-2248-x

[40] Rua M. Williams and Juan E. Gilbert. 2020. Perseverations of the academy: A survey of wearable technologies applied to autism intervention. *International Journal of Human-Computer Studies* 143 (Nov. 2020), 102485. doi:10.1016/j.ijhcs.2020.102485