Narrative Review Article

Virtual Reality Technology as an Intervention for Autism Spectrum Disorder: A Narrative Review

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ABSTRACT

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that is often associated with ongoing attention deficits, lack of inhibitory control, dysfunction in executive functioning, and poor classroom behavior. These are all necessary for adaptive functioning in everyday life, but it is quite challenging to improve them through traditional methods. Virtual reality (VR) is a newer option as it can produce realistic, repeatable tasks in an engaging, interactive format that may be a neurodivergent individual's preferred way of working. This narrative review aims to determine whether immersive or semi-immersive VR interventions can lead to substantial improvements in core cognitive and behavioral symptoms of children and adolescents with ASD. For this narrative review, evidence was synthesized from 12 peer-reviewed studies examining VR interventions in ASD populations. The findings indicate that VR-based interventions are consistently effective in improving attention and inhibitory control, with small to moderate short-term gains being reported in several studies. On the other hand, the findings on executive functioning and working memory are mixed, and the results for classroom behavior and daily functioning are promising within VR environments. Still, there is limited evidence of reliable transfer to real-world settings. The common limitations across the research are small sample sizes, short intervention durations, and inconsistent outcome reporting. Nevertheless, VR seems to be a safe and engaging complementary tool that can facilitate cognitive development in ASD when it is supervised and individualized.

Keywords: Autism Spectrum Disorder; virtual reality; attention; inhibitory control; executive function; classroom behavior

INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition that impairs social communication, behavior, and cognitive processing. The symptom manifestations typically become apparent in early childhood and are retained throughout life. The term "spectrum" denotes the variety of presentations and degrees of the disorder. Individuals might be nonverbal and have severe cognitive challenges, whereas others might have high intellectual function but face difficulties in social interaction and behavioral flexibility. Most typical symptoms are restricted interests, repetitive behaviors, sensory sensitivities, and challenges in understanding social cues (1, 2).

ASD remains without a cure after decades of research, and interventions are mostly designed to help the development and alleviate the symptoms through behavioral therapy, educational accommodations, and medication, if necessary. A significant challenge in the

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treatment of ASD is the difference between the highly structured evaluations in the clinic and the disorderly, multisensory nature of the real world. Standard assessments, e.g., caregiver rating scales or therapist observations, frequently have ecological validity issues; they cannot fully capture the behavior of individuals in such naturalistic settings as schools or social events(1).

Virtual Reality (VR) has the potential to serve as an effective intermediary between controlled experiments and real-life situations. With VR, researchers can design various scenarios in a classroom, a playground, or a home setting that are not only consistent and interactive but also enable them to have complete control over factors like distractions, timing, and stimuli. Furthermore, VR is very engaging, particularly for children with ASD who may positively react to game-like elements and virtual environments (3). Because of its immersive nature, VR can capture subtle behavioral responses like gaze, movement, and reaction time while maintaining a sense of presence—the psychological state of "being there" in the environment.

It is still unclear if VR training results in long-term improvements in fundamental ASD symptoms like attention, memory, and social skills. In particular, we are lacking evidence on the transfer of the improvements made in virtual reality to real-world behaviors, the durability of the effects over time, and the feasibility, safety, and accessibility of the technology for autistic people (3-7). This narrative review aims to evaluate the evidence base regarding the efficacy, safety, and feasibility of VR interventions for cognitive and behavioral outcomes in children and adolescents with ASD.

ATTENTION AND INHIBITORY CONTROL

Attention refers to the capacity of focusing on the relevant aspects of a situation and ignoring that which distracts. This is, however, a skill that children with autism spectrum disorder are often less capable of. Inhibitory control is the ability to suppress an impulsive or inappropriate response and, instead, carry out the goal-directed action. These cognitive functions constitute the foundation of academic functioning, behavioral regulation, and social participation. Deficits in attention and inhibition can result in so-called symptoms of distractibility, impulsivity, and difficulties in following rules.

A meta-analysis by Yang *et al.,* 2025 of 12 VR-based interventions for improving attention and impulse control in ASD individuals distinguished between immersive and non-immersive systems (5). Immersive VR platforms were found to generally produce greater improvements in continuous performance tasks (CPT) performance. A CPT is a test designed to assess sustained attention to a target stimulus amidst distractions and inhibit responses to non-target stimuli. Interventions with adaptive task difficulty and personalized feedback were the ones in which gains were particularly notable. The review provides evidence that ecologically valid and engaging VR scenarios can facilitate attentional control. These findings imply that immersive VR may be more effective in supporting the development of attention than traditional methods.

Lahiri *et al*., 2018 implemented eye tracking in a VR social setting to observe gaze behavior in children with ASD (8). The participants had to react to social cues in a virtual setting, and their eye movements were recorded. The study found that after repeated VR exposure, there was a noticeable increase in fixation on socially relevant areas such as faces and eyes. The results suggest that VR has the potential to improve social attention, which is a factor that is highly correlated with cognitive inhibition. The gist of this study is that VR-based social environments might be able to not only directly train social skills but also have an indirect effect on strengthening the executive control processes that support social functioning by providing more socio-cognitive integration.

These studies demonstrate the feasibility and utility of VR in assessing and improving attention and inhibitory control in people with ASD. The adherence rates were mostly high, notably when the settings involved structured goals and feedback. There were just a few instances of cybersickness. The data indicate that immersive VR, particularly when used with adaptive features and through repeated sessions, has the potential to bring about quantifiable changes in the attention and inhibition capacity of children with ASD.

The cognitive improvements observed across these studies likely reflect engagement of the frontoparietal network, which includes the dorsolateral prefrontal cortex, posterior parietal cortex, and anterior cingulate cortex, and governs top-down attentional control and response inhibition. In ASD, this network is often underactivated, and the structured, goal-oriented demands of immersive VR may serve as a scaffold that repeatedly engages these circuits (7). Reward-based feedback mechanisms offer a complementary explanation: immediate, contingent feedback activates the mesolimbic dopaminergic system, reinforcing correct inhibitory responses and sustaining

motivational engagement. The transient nature of gains observed at follow-up suggests that without continued activation, these circuit-level changes do not consolidate into durable neuroplastic reorganization.

WORKING MEMORY AND EXECUTIVE FUNCTION

Working memory is the ability to hold and manipulate information for brief periods. Executive function, on the other hand, is a wider range of cognitive abilities such as planning, flexibility, inhibition, and task switching. These skills are fundamental to goal-directed behavior and self-control. People with ASD who have these functions impaired are likely to experience problems with academic tasks, making decisions, and adaptive functioning.

Bioulac *et al*., 2020 conducted a controlled trial to examine the impact of VR-based cognitive tasks on working memory and executive function (9). Although the research primarily dealt with attention-deficit/hyperactivity disorder, a subgroup of participants with ASD was also included who engaged in attention and cognitive flexibility exercises in a virtual classroom. The intervention lasted four weeks, with multiple sessions each week. The outcomes illustrated slight but quantifiable gains in verbal and visual working memory as well as in performance on two tests of executive function, the Stroop and Trail Making tests. Nevertheless, the ASD subgroup was too small to determine statistical significance. The conclusion from this research is that VR may have the potential to enhance executive functioning in ASD, but a greater number of specifically targeted trials with larger sample sizes are required.

Didehbani *et al*., 2016 developed a Virtual Reality Social Cognition Training (VR-SCT) platform for children with high-functioning ASD aged 7–16 (10). Thirty participants completed 10 one-hour sessions across five weeks, engaging in social scenarios that targeted emotion recognition, social attribution, and conversational skills. Tasks required participants to interpret social cues, retain dialogue rules, and respond to emotionally relevant stimuli. Results revealed improvements in emotion recognition and executive function related to analogical reasoning, though gains varied across participants. The study concluded that VR-based social tasks have the potential to support executive function development; however, the outcomes are not consistent for all users. This implies that VR needs to be adapted to the cognitive profile and engagement level of each child.

Combining these studies offers preliminary support for VR as a potential instrument for enhancing working memory and executive function in ASD. Nevertheless, the impact is limited in magnitude and frequently brief, and there is a significant variation in the results of different individuals. Hence, it is imperative to perform well-controlled, long-term investigations to confirm whether these gains generalize to everyday contexts.

Working memory improvements are plausibly mediated by VR's repeated engagement of the prefrontal-parietal network, particularly the dorsolateral prefrontal cortex and inferior parietal lobule, which support active maintenance and manipulation of information. In ASD, atypical prefrontal connectivity and weaker inhibitory signaling between neurons contribute to working memory inefficiencies (11). VR's structured, predictable environment may allow these circuits to be exercised without triggering the anxiety or sensory overload that typically suppresses performance. Reward-based feedback further supports this through dopaminergic reinforcement of memory encoding processes. The high individual variability observed across studies likely reflects heterogeneity in baseline prefrontal connectivity across the ASD population, reinforcing the need for individualized VR protocols to produce consistent gains.

CLASSROOM AND DAILY FUNCTIONING

Therapy primarily aims to observe the transfer of cognitive gains to actual behavior in the real world. Children with ASD can be considered successful at school and in their daily environments if they are able to concentrate for a long time, follow their routines, and interact with other children in a socially appropriate manner. Assessing whether the improvements through VR are generalized to contexts beyond the training is essential, as ecological validity, meaning the degree to which an intervention mirrors real-world conditions, determines whether cognitive gains translate into functional, everyday behavior.

Strickland *et al*., 2007 conducted one of the earliest VR interventions for school readiness in children with ASD (12). Participants navigated virtual classroom simulations and participated in routines such as lining up and following instructions from officials, such as teachers. The study found that children who completed VR training showed fewer behavioral disruptions in actual classrooms. This implies that recreated school scenarios in VR can assist generalization of learned

behaviors, demonstrating ecological validity by replicating the contextual cues children encounter in real classrooms, which appears to support skill transfer.

Zhang *et al*., 2025 performed a scoping review of VR interventions for school-age children with ASD (3). They found consistent evidence that immersive VR led to increased task engagement, decreased off-task behavior, and improved social imitation in classroom-like environments. These effects were particularly strong when avatars demonstrated correct behaviors, and when the tasks were set in familiar school contexts. The underlying idea is that realistic modeling and environmental familiarity are key mechanisms of ecological validity, lowering the cognitive distance between the training context and the real-world setting, thereby facilitating more reliable generalization of learned skills.

Yang *et al*., 2025 compared immersive and non-immersive VR systems for role-playing tasks in ASD (5). Participants in immersive VR demonstrated more significant improvements in conversational turn-taking and role comprehension. These were quantified through ratings by blinded observers in post-intervention role-play assessments. This research provides evidence that immersive VR could be a vehicle for real-world conversational skills, particularly when the virtual scenarios closely mirror the social structures and demand that children face actual school and community settings.

These studies provide evidence for the effectiveness of VR-based interventions in increasing behavioral readiness and task adherence in educational contexts. Nevertheless, the continuation of the intervention effects and the influence on classrooms over time are still scarce in documentation. It is suggested that upcoming research incorporates teacher ratings and direct school observations to confirm the transfer of VR training to actual performance more thoroughly. Without such ecologically grounded measures, it remains difficult to determine whether cognitive gains observed in VR translate into meaningful behavioral generalization across authentic school and daily living contexts.

ACCEPTABILITY, SAFETY AND ADHERENCE

A crucial factor to consider when assessing the effectiveness of VR as a therapy for ASD is how well children can adhere to VR-based protocols. Acceptability is the participant's willingness to engage with the VR experience. Safety involves the risk of side effects such as motion sickness, sensory overload, etc. Adherence indicates whether participants can complete the intervention as required and scheduled, including the number of sessions and their duration. These factors are especially relevant in autism research, where typical comorbidities such as sensory hypersensitivities, anxiety, and reduced cognitive flexibility are present (1, 2).

Didehbani *et al*., 2016 implemented a multi-session VR intervention in which participants engaged in socially immersive tasks with embedded executive function components (10). The study involved 30 children with ASD who completed 10 one-hour sessions over five weeks. The majority of participants were able to complete the full protocol without significant issues. Sessions were conducted with a trained clinician acting as a live coach within the virtual environment, guiding participants through social scenarios and providing real-time feedback. The presence of this supportive professional guidance appeared to enhance both safety and adherence in this population.

In sum, research evidence supports that VR is a relatively safe and well-tolerated treatment in children with ASD, especially if the above-mentioned four conditions (short tasks, adjustable difficulty, less stimulating environment, and presence of adult facilitators) are fulfilled. Kids under 5 years of age or those with a severe sensory profile may need some modifications; however, few studies report dropout rates. Hence, although VR cannot be regarded as a suitable intervention for all children without any accommodations, publications serve as a vehicle to implement it as a viable solution when taking into account user requirements.

WHAT THE FIELD CURRENTLY SUPPORTS

Current research in this area is generally supportive of VR as a tool to enhance core cognitive and behavioral domains in children with ASD. However, it is still limited and warrants further studies. A synthesis of various studies shows that there are some areas where the effects of VR on children with ASD are promising, while in other areas, there are inconsistencies. This, therefore, stresses the need for more research and standardization. See Figure 1 for an overview of how virtual reality can be used in ASD populations.

In the domain of attention and inhibitory control, structured VR interventions appear to produce short-term improvements. Studies such as Bioulac *et al*., 2020 found improvements in reaction time stability and resistance to distractions, while Didehbani *et al*., 2016 reported gains in emotion recognition and executive function related

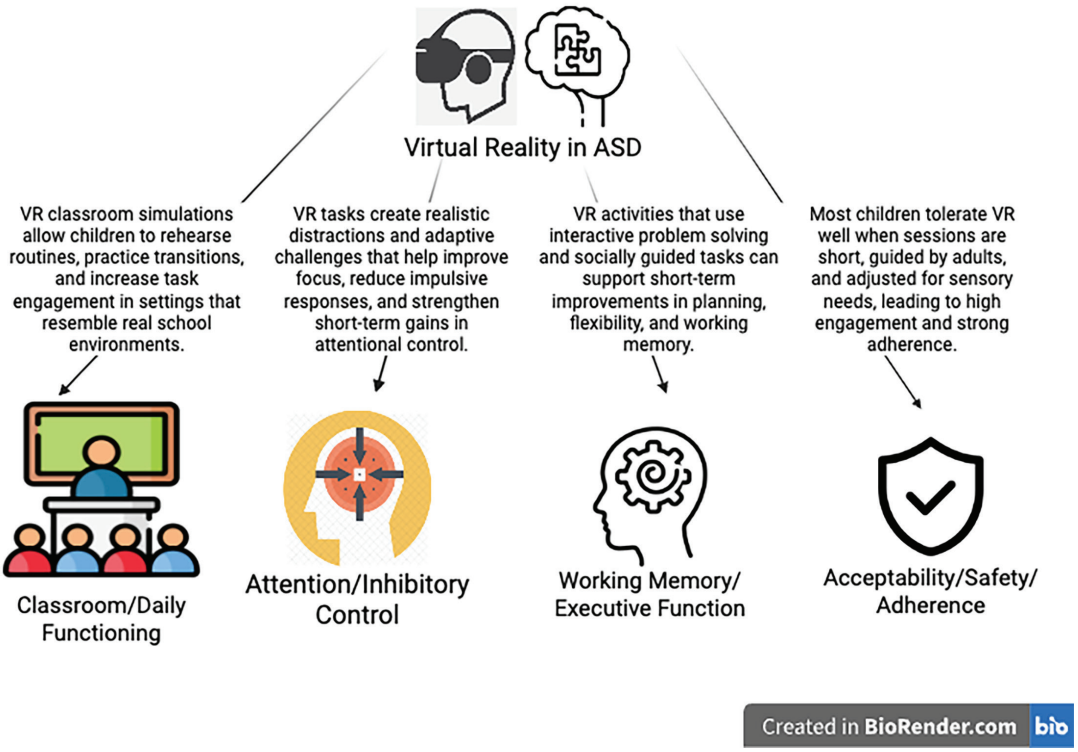

Figure 1. ***Summary of the impacts of virtual reality on Autism Spectrum Disorder.*** *Summarizes how virtual reality impacts classroom and daily functioning, attention and inhibitory control, working memory and executive function, as well as the acceptability, safety, and adherence of virtual reality in ASD populations. ASD = Autism Spectrum Disorder; VR = Virtual Reality.*

to analogical reasoning (9, 10). These results indicate that VR-based tasks have the potential to simulate real-world distractions and measure attentional performance in a controlled way. By using immersive environments that offer well-organized feedback and suitable difficulty levels, children with ASD may be able to enhance their attention regulation.

However, in the area of working memory and broader executive function, the effects are less consistent. Bioulac *et al*., 2020 found improvements in goal-directed behavior tasks such as task-switching and short-term memory tasks (9). However, these were primarily small, and the studies are missing some form of long-term follow-ups, limiting interpretations of long-term benefits. Didehbani *et al*., 2016 noted that while some participants showed improvement in emotion recognition and executive function during social VR tasks, others did not respond as well (10). This variability suggests that executive function may be harder to target through VR alone or may require more individualized and prolonged interventions.

Classroom and daily functioning outcomes are promising, particularly in VR simulations designed to replicate school settings. Strickland *et al*., 2007 and Zhang *et al*., 2025 proved gains in on-task behavior, smoother transitions, and reduced behavioral incidents following VR treatment (3, 12). Yang *et al*., 2025 found that immersive social VR led to improved conversational success and peer role-playing, which are vital factors of school functioning (5). Nevertheless, the majority of studies had not evaluated the transfer of these improvements from the VR setting to the real-world classrooms.

Studies have consistently shown that, in terms of safety and adherence, VR systems are well tolerated when they are semi-immersive, the tasks are of short duration, and adults supervise the activities. Most of the side effects reported are minor and can be easily managed. The use of feedback systems and gamified elements has led to higher engagement and lower dropout rates.

Overall, virtual reality seems to be a powerful

tool for improving attention and inhibitory control in children with ASD, with consistent short-term gains during structured sessions. The question of its impact on executive function and real-world behavior is still open; however, it looks like a positive direction. Some of the factors that contribute to positive outcomes are: adjusting the difficulty level, providing structured repetition, including feedback, and having an adult facilitator. While long-term effectiveness and transfer to daily life still need to be verified, the current body of research provides ample rationale for further development and clinical use of VR in autism intervention.

LIMITATIONS OF EVIDENCE

Although the research on VR use for ASD appears promising, the body of evidence supporting it is constrained in multiple significant aspects. The majority of studies considered in this review had limited sample sizes, generally less than 30 participants, thus limiting the statistical power and the ability to generalize the results (9, 10). Furthermore, interventions varied in terms of content, duration, and delivery format. Some programs emphasized cognitive tasks like the CPT, while others included social interaction or physical activity components. This diversity of experiences hinders efforts to compare different studies' outcomes and decide what factors drive effectiveness.

Outcome measures also differed significantly. Some researchers relied on behavioral task metrics, while others took the caregivers' ratings or used standardized executive function tests. Due to the absence of consistent assessment tools or a core outcome set, it is challenging to decipher the size and the direction of the effects (1, 2). Furthermore, follow-up durations were often short, around a few weeks, with minimal tracking of whether gains were retained after training ended (9).

Another major limitation is the lack of rigorous comparison groups. Many studies did not include control conditions beyond baseline assessment, and only a few directly compared VR to standard of care interventions or non-immersive digital tasks. Adverse event reporting was inconsistent across studies, and only a subset explicitly mentioned whether participants experienced side effects such as motion sickness or sensory overload (10).

THERAPEUTIC IMPLICATIONS

Virtual reality may be a valuable therapeutic tool for children with ASD, even though it has some limitations. This is especially true for structured settings where the main goals are to improve attention and inhibitory control. According to the studies reviewed, VR might be used as a supplement to current treatments to provide concentrated attention exercises, social cue training, or behavioral rehearsal in a way that is easily repeatable, controlled, and attractive to the child (9, 10). For instance, VR classrooms might enable kids to rehearse the skill of ignoring distractions or, in a more specific case, to learn the appropriate way of reacting to a peer interaction scenario before actually encountering a similar challenge at school.

Though a positive outcome largely hinges on thorough checking of those who are sensitive to motion and their sensory aspects, which are quite common in ASD. Immersive systems are not something that all children like equally, and hence, VR might have to be adjusted according to the individual profile of each child. Additionally, sessions require adult supervision to ensure that participants remain engaged in the treatment and can troubleshoot potential technological issues (1, 2).

From a clinical perspective, VR should not be considered as a separate treatment. However, it has the potential to improve traditional cognitive, behavioral strategies if combined with coaching, reinforcement, and structured feedback. The main advantages of VR are in offering a transition from the less tangible skill, building, to the actual real-world environments.

FUTURE DIRECTIONS

Several methodological gaps of future research have to be filled to make the evidence base stronger and to guide clinical application. The first necessary step is to carry out head-to-head comparisons between VR-based interventions and standard care, e.g., behavioral therapy and classroom accommodations. This will make it possible to find out whether VR brings an added benefit or just imitates existing approaches in a new way without making any real difference (1, 2). Sessions should also include comparisons between immersive and non-immersive tools to isolate the effects of simulation and reality.

Outcome reporting cannot be done without standardization. The studies must at least report a set of behavioral, neuropsychological, and functional measures and also ensure consistent tracking of adverse events. Besides that, the protocols should outline minimum session lengths, supervision requirements, and details on how to adjust the sensory input. It is difficult for the field

to keep being fragmented and having limited replicability because it lacks these common standards (9, 10).

Long-term follow-ups are another major requirement. Researchers must evaluate whether the benefits observed after short-term VR interventions persist over months or years and whether these gains translate into meaningful changes in academic, social, or behavioral functioning. Sustained improvements, rather than novelty-driven responses, should be the gold standard for evaluating effectiveness.

THE EFFECTIVENESS OF VIRTUAL REALITY AS A TREATMENT FOR AUTISM SPECTRUM DISORDER

This review examined how virtual reality might enhance core cognitive and behavioral symptoms in children with Autism Spectrum Disorder. The data warrant a nuanced conclusion that varies according to symptom domain. The most consistent findings are those related to attention and inhibitory control, with a number of studies indicating small to moderate gains that are transient in nature. VR tasks that recreate classroom distractions seem to be especially effective in both assessing and training concentration.

Results have been somewhat inconsistent in working memory and general executive function. A few studies have found that the ability to switch between tasks and short-term memory can improve, particularly if the virtual reality tasks are emotionally engaging and adaptive. Nevertheless, these improvements are usually slight, and the effects are seldom tracked over a long period.

The potential of VR is evident for classroom and daily functioning, in well-designed simulations that reflect real school environments. Improvements in on-task behavior and rule-following within VR show that this approach may help prepare children for real-world environments, but more research is needed to confirm generalization outside the headset.

Virtual reality, in general, holds significant potential for some components of ASD treatment. When used in well organized settings, VR could be an effective instrument for the practice of skills, catching attention, and modifying behavior. Nevertheless, the broad application of this technology in clinical or educational environments will need further standardization, evaluation against currently available treatments, and more robust evidence of lasting effects in the natural environment.

CONCLUSION

This review outlines the expanding potential of virtual reality as a method to enhance certain cognitive and behavioral functions in children with Autism Spectrum Disorder. The most convincing evidence shows that VR tasks with adaptive difficulty, delivered in structured and distraction-rich environments, lead to short-term gains in attention and inhibitory control. Additionally, some improvements in working memory and executive function have been noted, especially when the tasks are socially engaging and repeated over sessions. VR-based assessments and interventions also have the potential to improve classroom-like behavior in VR environments. Nevertheless, there is still a considerable amount of doubt as to whether these improvements can be transferred to regular functioning outside the VR setting.

These results are of great significance to clinicians, educators, and families. VR-based tools might become a source of additional support for existing interventions, providing engaging, repeatable, and customizable experiences that users can virtually face real-world demands. Besides, these tools' immersive character makes it possible to achieve high ecological validity and, at the same time, obtain exact behavioral data. However, the problems of small sample sizes, lack of long-term follow-up, and limited adverse event reporting, which have been raised simultaneously with this promising technology, have to be resolved before the VR tools can be widely used.

A next step, specifically, would be a large-scale, controlled trial in the field that compares VR interventions directly with standard care treatments, which include traditional cognitive training and non-immersive digital tools. It will also be very important that clear reporting guidelines are set and diverse participants are included, as this will contribute to the effectiveness and equity of these tools.

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CONFLICT OF INTEREST

The author(s) declare that there are no conflicts of interest regarding the publication of this article.

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