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Cognitive Mechanism Hypothesis of Decreasing Repetitive and Stereotypical Behaviors in ASD Over Time

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Abstract: Repetitive and stereotyped behaviors are the core symptoms of ASD and the indicators of the severity of ASD, which seriously affect the daily life, learning, and social interaction of children with ASD. The reasons for the formation of repetitive behaviors in children with ASD have not been clear. Through long-term clinical observation of children with ASD, the study found that part of the stereotyped behavior, which is the interests and activities of children with ASD, can be changed. By finding the regularity of the stereotyped behavior, the stereotyped behavior will be reduced or stopped. The study proposed a cognitive mechanism hypothesis for the reduction of stereotyped behaviors: some stereotyped behaviors have potential functions, such as finding regularity. ASD finds the regularity and improves the accuracy of the knowledge of the regularity by repeating the operation. After finding regularity, ASD accomplishes its purpose, forming functional behaviors and reducing stereotyped behaviors. With the accumulation of time, the known regularities are gradually integrated, which shows the tendency of more complete cognition, more functional behavior, and less rigid behavior. This hypothesis provides a new perspective to understand the stereotyping of ASD. The study views stereotypy as non-disease, potentially functional and mutable, which can expand the understanding of ASD and help parents better understand and develop its advantages, with important potential social implications.

Keywords: Cognitive mechanisms; Stereotyped behavior; Autism; Interest activities

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1. Introduction

The prevalence of autism spectrum disorder (ASD) has been increasing [1–2]. According to a report released by the Centers for Disease Control and Prevention in the United States, the prevalence of 8-year-olds in 2018 is 1 in 44, and that of 8-year-olds in 2020 was 1 in 36 [2–3]. In China, the prevalence of children aged 6–12 in 2020 will be 0.7%, and the prevalence of children aged 0–6 in 2023 will be 1.8%, among which the prevalence of children aged 4–6 will be 2.5% [4–5]. ASD is mainly diagnosed at ages 3 to 4. Overall, the prevalence of ASD in China and the United

States is basically the same.

At present, the etiology of ASD is still unclear. Due to the lack of objective biological indicators for diagnosis, ASD is diagnosed through behavioral manifestations [6–8]. According to The Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5), a core symptom of ASD is difficulty in social interaction; The second is limited, repetitive behavior or interest. As one of the core symptoms, repetitive behavior is the indicator to measure the severity of ASD, and it also seriously affects the daily life, learning, and social interaction of children with ASD [8]. The reasons for the formation of repetitive behaviors in children with ASD have not been clear.

Mainstream theories, such as the theory of mind and the executive function hypothesis, can partially explain the core symptoms of social dysfunction and stereotyped behavior. According to the theory of mind, people with ASD lack awareness or the ability to infer the emotions, intentions, or thoughts of others and themselves, and lack the ability to predict and explain the consequences of corresponding behaviors. The executive function hypothesis suggests that stereotyped behaviors in ASD are related to executive dysfunction. Executive function is a process responsible for controlling high-level cognitive activities, including planning, inhibition, control, switching, working memory, etc. It is a psychological process in which individuals consciously control thoughts and actions [9–10]. Executive dysfunction can explain the inhibition deficit in working memory and the difficulty in switching dominant response in ASD, and can explain their stereotyped behavior.

2. Discussion

Through long-term clinical observation of children with ASD, researchers found that the purpose of part of the stereotypical behaviors of children with ASD in their interest activities is to find regularity. In other words, they try to find the essence of things, such as certainty, invariance, expansibility, and richness, and after the completion of their goal, stereotypical operation is reduced or stopped. For example, (1) ASD children play with the Bluetooth headset box, repeatedly opening and closing the box. This behavior seems meaningless. But researchers found that repetitive behavior changed over time. At first, children open and close the box, check whether the light on the box's shell is on or off (with eyes open); After repeated for a period of time, the child opened and closed the box with his eyes closed, then opened his eyes to check the box shell light on and off (with eyes closed); After the child finally confirmed that the light on or off was only affected by the opening or closing of the box, he show it to the researchers with words and behaviors. Then he stopped this repetitive behavior. Through observation, the researchers realized that children with ASD look for regularity through repetitive and stereotypical behaviors, that is, to find and verify the causal relationship between the light on/off and the box turning on/off. (2) Another child with ASD repeatedly played a subway-themed game for several days, that is, manipulating the doors of the subway and verbally describing the doors opening and closing. The researchers noticed the change of this repetitive behavior over time, such as children building subway doors of different shapes with different materials at different times, expanding language in this process, such as the door opening, going to the park; "The door opened", "there were many people", "door is open", and "get out of the car." The researchers realized that after a certain amount of repetition, this child expanded his play style and developed language and social interaction skills. (3) A child with ASD said, "I want to eat rocket candy" when he wanted a chocolate chip cookie. This sentence demonstrates the two cognitive concepts of triangle and sweetness. A cookie is a triangle, like a rocket head; chocolate is sweet. Through the child's language, the researchers found that he not only understood the concepts of triangle and sweet, but also used these two concepts to form his own language. Language is based on cognition (conceptual structure),

and the seemingly meaningless language can also represent its cognitive structure (concept) (**Table 1** shows more examples) [11–12].

Table 1. Examples of the change from stereotyped behaviors to functional behaviors

Situation	Stereotyped behavior	Change of stereotyped behavior	Understanding of regularity
Drawing	Repeatedly dripping milk onto a plate without ink and attempting to drink it	In different locations, placing milk in a plate and drinking it, disappeared after this behavior	Milk can be placed in different containers (boxes, plates, etc.)
Seeing fruits on a tree	Repeatedly saying "Eat hawthorn without spitting out the hawthorn pits"	Subsequent sentences appeared like "Eat oranges without spitting out the orange peel"; later, shifted to other sentence structures	"Eat something without spitting out its peel" is a grammatical sentence pattern
On the street	Repeatedly looking at air conditioner vents and outdoor unit fans	Air conditioners have fans, hens have fans (wings, wind), clouds have fans (speculated to have fans)	Discovered the relationship between fans and wind

These stereotypical behaviors cannot be explained by theories of mind and executive dysfunction alone. The hypersystemizing theory and predictive coding theory can partly explain these problems. Based on the imbalance of the male-to-female ratio in ASD, Cohen proposed the hypersystemizing theory (empathy-systematization theory) [13]. He believes that ASD is a masculine brain, largely influenced by hormones. The masculine brain is characterized by reduced empathy, with systematic mechanisms tuned to above-average levels. Stereotyped behavior is thought of as ASD operating the input-operate-output work of a system and finding regularities. Another study found that neuroanatomical variation in amygdala volume and gyrification of LOC could be potential biomarkers for the empathizing–systemizing difference in children with ASD but not in TD children [14]. The hypersystemizing theory explains that the stereotyped behavior of autism is to seek regularities, and in this process, they adjust the known regularities by repeating the operation and paying attention to the changing part of the result [13]. The predictive coding theory posits that individuals with ASD assign high weight to perceptual accuracy [15]. This means that they repeatedly notice details that do not match expectations and then make adjustments in the direction of accuracy [16]. However, hypersystemizing theory and predictive coding theory do not explain changes in stereotypical behavior in autism. Changes in stereotypical behaviors may lead to changes in the core symptoms of ASD.

Notably, a recent study found that 37.1% of children diagnosed with ASD between the ages of 1 and 3 no longer met the criteria for ASD by the age of 6 [17]. Combined with our observation that ASD often uses repetitive ways to manipulate objects or interact with the environment during spontaneous interest activities, the authors hypothesize that the high number of hat removals at age 6 is due to the beneficial effects of stereotypical behavior in spontaneous activities. Therefore, the authors believe that the study of why stereotyped behaviors change in children with ASD, as well as the internal mechanism of repeated stereotyped behaviors changes, is of great significance to further correctly understand ASD and find better intervention methods.

There are two kinds of cognitive processing: bottom-up processing is the process of transmitting information directly from sensory organs to the brain, which is influenced by the physical properties of stimuli, the properties of receptors and some coding characteristics of the nervous system; Top-down processing is a process in which human brain uses known information to influence cognitive activities. It is represented by people making use

of existing cognitive structures to choose, reason, explain, and expect external stimuli. The authors believe that children with ASD show more bottom-up processing. Through clinical observation, the authors found that it was possible to explain the cognitive mechanism behind the stereotypical behavior through children's attention and interest.

The attention preference and interest of children with ASD may be caused by different brain connections (too many or too few connections), which lead to strong responses to external stimuli such as light, sound, and movement [18]. Compared to the TD children, some areas of the brain may develop too quickly in children with ASD early in life, resulting in overconnectivity in specific areas, usually the frontal and occipital regions, and insufficient connectivity overall.

Selective attention, attention control, and transfer are also different in children with ASD. Differences in selective attention are common in ASD [19]. In addition, changes in attention control and learning development may also be specific features of ASD during their development [20]. In different movement types, the ASD group has been found to have a visual preference for repetitive movement [21]. The attention transfer of ASD is also different, and the attention transfer time of ASD to auditory targets is the largest [22].

Individuals with ASD often have difficulty with face-to-face social interactions [23]. They typically show reduced visual attention to social stimuli compared to their typically developing peers [24]. In one study, immersive virtual reality paradigms were used to investigate how gaze is used in interaction with communication gestures, a task that requires attention to social stimuli. The results showed that the ASD group was similar to the control group in terms of responding to shared attention requests for hand cues. This suggests that individuals with ASD can effectively pay attention to social stimuli [23].

3. Conclusion

Based on the above discussion, the authors propose the cognitive mechanism hypothesis that individual with ASD stereotyped behaviors decreases over time: ASD is known to have perceptual sensitivity and abnormal attention; they strongly pay attention to restrictive interests, and exhibit stereotyped behaviors, that is, manipulate objects of interest in a repetitive manner. The authors hypothesize that some of the stereotypical behaviors have potential functions, such as finding regularities. Before a regularity is found/the knowledge of the regularity is not perfect, ASD finds the regularity and improves the accuracy of the knowledge of the regularity by repeating the operation. After determining the regularity, ASD accomplishes his purpose, forming functional behaviors and reducing stereotyped behaviors. With the accumulation of time, the known regularities are gradually integrated, which shows the tendency of more complete cognition, more functional behavior, and less stereotyped behavior.

The above hypothesis needs to be verified by a variety of research methods, such as semi-structured interviews, natural observation, parent education and intervention, eye movement analysis, and longitudinal study. In any case, the hypothesis in this study provides a new perspective to understand stereotyped behavior of ASD. The authors view stereotyped behavior as non-disease, potentially functional, and mutable, expanding the understanding of ASD and helping both children and their parents to better recognize and develop their advantages. The hypothesis of this study can further explain the inherent cognitive mechanism of the stereotyped behavior of children with ASD and provide a theoretical basis for the intervention of ASD. Therefore, it has important potential social significance.

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Disclosure statement

The authors declare no conflict of interest.

Author contributions

Dan Duan and Shouhui Wang conceived the idea of the study and wrote the paper.

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