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Research Article

Factor Structure of ASD Symptoms in Russian 3-4-Year-Olds

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Abstract

The study aims to reveal autism vectors that are inherent in 3-4-year-olds with ASD. Three hundred eighty-three children with ASD took part in the research. An online questionnaire developed earlier by our research group was used. In the first stage, with the repeated use of exploratory factor analysis, the task of identifying the simplest factor structure was solved. As a result, a 7-factor system was obtained, including from 9 to 14 items in each factor (78 items in total): 1) "Persistence on sameness" (Sam); 2) "Emotional dysregulation" (Em); 3) "Alienation" (Al); 4) "Speech understanding" (SU); 5) "Disinhibition/Hyperactivity" (Hyp); 6) "Echolalia" (Ech); 7) "Sensory disintegration" (Sen). Next, a "parcel approach" was applied: binary items included in each factor were randomly distributed into 3 packages, from 3 to 5 items in each box. Thus, instead of 78 binary things, 21 quantitative variables were analyzed. At the second stage, a multi-group confirmatory factor analysis was applied to verify the factor validity and structural and measurement equivalence of the obtained 7-factor model to the parts of the sample that differ by gender (m, f) and age (3 and 4 years). The factor validity of the 7-factor model was confirmed: the factors Em, Al, Su, and Ech correlated with each other (correlations from 0.33 to 0.65), forming a group of communication disorders, the second group consisted of factors Sam and Sen (r = 0.66), the factor Hyp did not

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correlate with other elements. The equivalence of this 7-factor model was confirmed with respect to samples differing in gender (m, f) and age (3 and 4 years). According to all 7 calculated factors-scales, the example of children with ASD statistically significantly differed from other children with the magnitude of the Coen's d effect from 0.688 to 2.088. However, it can be supposed that the factor dimension of autism symptoms can be even more significant, because the revealed structure is based on 436 initial hypothetical symptoms of autism.

Keywords
ASD; 3-4-year-olds; factor structure of autism

1. Introduction

Autism spectrum disorder (ASD) is a neurological developmental disorder characterized by abnormalities in social relationships and repetitive or restricted behaviors [1]. The problem of autism is as acute as ever due to the high prevalence of this complex neurodevelopmental disorder [2] and the severe consequences it causes for social adaptation and quality of life for those affected [3]. There is an excellent diversity of autistic symptoms and scenarios of its manifestation however, it is expected to distinguish a few core features such as impaired social communication, restricted and repetitive behavior, and sensory disintegration [4]. An etiology of autism is heterogeneous and includes both genetic risks [5] and atypical brain maturation reflected in altered development of the social brain with distinct abnormal features in the fronto-temporo-parietal cortex and cerebellum [6], which makes a differential diagnosis and an early intervention a challenging task [7]. At the same time, it is known that the earlier signs of ASD are detected, the faster rehabilitation is started and the better the expected results in correcting the core symptoms of autism and improving language and cognitive skills [8]. Even though numerous studies of ASD have been conducted, attributing the etiology of ASD to genetic, environmental, immunological, perinatal, neuro-anatomic, and biochemical factors [9], the structure of autism symptoms is still unclear, and even the DSM-5 doesn't provide us with a precise description, just stating that a child must have persistent deficits in each of three areas of social communication and interaction [1]. Besides, existing diagnostic screening tools have known limitations [10, 11]. Also, there is a gap in the literature regarding the factor structure of autism, an understanding of which is crucial for studying the mechanisms underlying ASD. Therefore, additional research is needed to identify the system of ASD in early childhood and to detect predictors of autism manifestation and development. In this regard, in 2020-2022, we surveyed 926 children (383 with ASD, 200 with developmental delay (DD), 343 typically developing (TD)) to elaborate a screening scale for rapid diagnosis of ASD in 3-4-year-olds. An extensive online questionnaire designed by us was used for the examination to identify 436 possible symptoms of autism. The main result of the study was the creation of an Autism Scale based on 40 autism symptoms (items) representing 4 vectors of its manifestation: "Emotional disorders", "Sensory disintegration", "Communication disorders" and "Hyperactivity/Disinhibition". The scale has a prediction accuracy of 88.91% (sensitivity 92.1%, specificity 87.2%) [12, 13]. The multi-group confirmatory factor analysis of

structural and measurement equivalence confirmed the 4-vector structure of ASD for a sample of children with ASD, its structural and measurement invariance was established with respect to children with ASD differing in gender and age for 3-4-year-olds boys and girls. However, with respect to children without ASD, the presence of such a structure was not confirmed, and thus, our initial assumption that selected factors were vectors common to all children, at one pole of which there was a conditional norm, at the other - ASD, was not proved. The obtained scales reflect the vectors of ASD in which children with ASD differ significantly from typically developing children and children with developmental delay (DD) [14]. Therefore, this study aimed to identify the autism vectors, which are typical in 3-4-year-olds children with ASD, based on the survey data of 383 children with ASD using an online questionnaire including 436 points - possible symptoms of ASD. We believe that identifying autism vectors will allow us to reach individual phenotypes within the framework of these neurodevelopmental disorders, which in turn could allow us to improve the quality of diagnostics and create targeted correction programs.

1.1 Previous Research of the Factor Structure of Autism

Attempts to explore factor structure of autism have been made before. Although studies are sparse and their results are not unambiguous, nevertheless, they are essential for interpreting patterns of ASD and identifying its heterogeneous phenotypes. In this regard, attempts to build a factor structure of autism have already been made by various research groups, including ours. Below, we present factor models of autism obtained as a part of the scientific exploration of this problem. First, we consider the models obtained fbased on diagnostic tools, and, accordingly, bearing significant limitations due to the predetermined structure of the tools themselves on which they were built. Then, we consider comparative models that explore vectors of differences between ASD and norm groups or between ASD and other developmental disorders.

Constantino and his research group studied the factor structure of autistic features using the data from 226 children with and without developmental disabilities, applying cluster analysis of the data from the revised Autism Diagnostic Interview (ADI-R) and factor analysis of the main components of the data from the Social Responsiveness Scale (SRS) [15]. Their results showed the existence of a single, permanently distributed main factor associated with disparate phenotypic manifestations in three classic areas of autistic disorder (communication deficit, language deficit, and repetitive/stereotypical behavior). Accordingly, their results did not confirm the existence of independent sub-domains of dysfunction in autistic spectrum conditions. However, the obvious limitation of the study is the reliance on existing screening. Similarly, an attempt was made to study the factor structure of ASD based on the ASD-DC [16]. The study was conducted on a sample consisting of 149 2-16-year-olds who met the criteria of ASD. A 4-factor solution was obtained: social relations, nonverbal communication/socialization, verbal communication, and limited interests/persistence in sameness. Further, the authors compared the results obtained on 125 typically developing peers according to the identified four-factor structure. It was found that children with ASD showed significantly more symptoms on all four factors of the scale. Several studies have been devoted to attempts to obtain the factor structure of autism, based on the questionnaire "The Autism Spectrum Quotient". Thus, Auyeung and co-authors [17] in a sample consisting of 540 4-11-year-olds children with ASD and 1225 normal-typical children received a 4-factor model of autism, which included the following factors: communication, attention to detail,

social skills and imagination. Another example is a study conducted by Hoekstra and co-authors [18]. They revealed the factor structure of the Dutch translation of the questionnaire "The Autism Spectrum Quotient", which makes it possible to quantify the severity of autistic traits. They also received a two-factor model consisting of the factors of "Social interaction" and the factor of "Attention to detail". A later study was also devoted to detecting the factor structure of autism through the same questionnaire on a sample of 522 participants [19]. Using confirmatory factor analysis, a partially validated 5-factor model was obtained, including such factors as: (1) social skills, (2) communication/mind reading, (3) limited/repetitive behavior, (4) imagination and (5) attention to details. Finally, a recent study conducted on the same questionnaire but on a Chinese sample allowed researchers to obtain a 5-factor model of autism, which included the following factors: imagination, attention bias, communicative competence, atypical attention to detail, and interest limited to unusual objects [20]. A similar study was conducted earlier by Snow and co-authors [21]. Again, an attempt was made to reach the factor structure of autism through the definition of the factor structure of the revised Diagnostic Autism Interview (ADI-R), one of the most widely used assessment tools. They studied the factor structure of the interview and its compliance with indicators of adaptive, linguistic, and intellectual functioning. The study sample consisted of 1861 4- to 18-year-old patients diagnosed with ASD. The ADI-R estimates were subjected to confirmatory and exploratory factor analysis. The analysis was carried out according to the verbal status of children (n = 1329 verbal, n = 532 nonverbal) and separately only for the elements of the algorithm and all elements. ADI-R scores correlated with scores on adaptive, linguistic and intellectual functioning indicators. The data obtained indicate that the symptoms of autism can be explained statistically using a two-factor model consisting of social and communication behavior and limited and repetitive behavior. However, the study has a significant limitation due to the ADI-R structure itself. In another study based on the accumulated collection of reports on quantitative signs of autism using the social responsiveness scale (N = 9635), a five-factor structure of ASD was obtained, in which three factors were associated with impaired social communication (emotion recognition, social avoidance, and interpersonal relationships). Two factors were associated with repetitive behavior (persistence in monotony and ritualism) [22]. Another five-factor structure of ASD obtained from the survey data of 275 participants with ASD aged 3 to 23 years (the Developmental, Dimensional and Diagnostic Interview) consisted of limited and repetitive behavior and interests, shaking hands and nodding (motor stereotypes), as well as three factors that represented a lack of social interaction and communication [23]. In another study, based on the analysis of data obtained using the ASD-DC questionnaire (the Autism Spectrum Disorders-Diagnostic for Children) on a sample of 149 2-16-year-old children, a four-factor structure was obtained consisting of social relations, nonverbal communication/socialization, verbal communication, and limited interests/persistence in sameness [16]. It is obvious that the obtained factor structures of ASD correspond to the two-factor structure in the updated DSM-5, but it also opens up some new aspects in the understanding of autism and its vectors.

Some factor models of autism deserve special attention, especially those trying to separate autistic traits and patterns from other developmental disorders by identifying vectors of differences and thereby delineating the factor structure of ASD. Thus, limited interests and repetitive behavior were studied in a large sample of children with ASD and ADHD (N = 1082) using exploratory factor analysis and factor invariance analysis by diagnostic status (ASD vs ADHD) [24].

The "Revised Repetitive Behavior Scale" (RBS-R) measured restricted interests and repetitive behavior. A 4-factor model was identified consisting of (1) Stereotyping, (2) Self-harm, (3) Obsessions and (4) Ritualism/Need for Sameness. Interestingly, the level of intellectual development was negatively associated with stereotypes, self-harm and obsessions in ASD, as well as negatively associated with obsessions and ritual/identical behavior in ADHD. A similar study of restricted and repetitive behavior subtypes was conducted on a sample of 827 preschoolers with and without ASD [25]. The authors identified 3 factors in the obtained factor model for the group with ASD, such as sensorimotor behavior, craving for sameness, and stereotyped speech.

Our research group also studied the vectors by which children with ASD differ from children with ASD and typically developing peers in a sample consisting of 863 children [26]. The most significant differences between children of the norm group and children with ASD were obtained in the "Logical thinking" and "Motor skills" scales. However, the study showed that initially a wide range of tasks used was insufficient to diagnose children with ASD. A preliminary data analysis showed that readings suitable for children with developmental delays gave an uncertain result for children with ASD. In our recent publications devoted to the elaboration of a scale for early and accurate differentiation of 3-4-year-olds children at risk for ASD, a 4-factor model of autism was obtained in a sample consisting of 828 children (294-with ASD, 334-TD, 200-with DD), which included the following four vectors: sensory disorders, emotional disorders, communication disorders, hyperactivity/disinhibition [12]. These vectors, consisting of 40 items (points on the autism scale), were the directions that most accurately (88%) separated children with ASD from other children. However, a subsequent check of this model's structural and measurement equivalence in relation to different parts of the sample showed that the equality is maintained for only samples of children with ASD (boys and girls, 3 and 4 years old). Still, for other children (not ASD) the model is not equivalent [14]. Thus, our initial assumption was not confirmed that the selected vectors are common to all children, at one pole of which there is a conditional norm, at the other - ASD.

2. Materials and Methods

2.1 The Sample

The initial data were 436 binary variables - the results of using an Autism Markers Questionnaire implemented as an online survey. Our research group developed an autism questionnaire at the previous stage of our research project [12]. The tasks' content (situations, areas of activity, behavioral pattern, and possible signs of ASD) was obtained by interviewing experienced practitioners engaged in psychological, behavioral, and pedagogical support of children in ordinary and extraordinary preschool institutions. The surveyed specialists selected the signs of ASD that are key for assessment by observing the child's behavior and interviewing their parents. As a result, an array of distinctive signs was collected, including well-known ones used in CARS and ADOS and features specific for the Russian sample. In total 926 children were examined during the period 2020-2022 (383-with ASD, 200-with DD, 343-TD). At the stage of identifying the factor structure of ASD symptoms, the data from a survey of 383 children with ASD was used. Data was collected bya group of experienced practitioners engaged in psychological and pedagogical support of children in specialized and ordinary preschool institutions of St. Petersburg. These specialists accumulated experience in collaboration with the main executors of this project in the

past as part of research or training groups. The project executors invited specialists to take part in the online survey by email, providing a link to the survey website and indicating which groups of children should be examined. The assignment of children to the groups of ASD, DD, or TD was based on a previously obtained opinion from other official assessments (e.g., presented upon admission to a preschool educational institution, established by a special commission consisting of psychiatrists, neurologists, speech therapists, psychologists). Thus, the data was collected for children who special commissions had already classified as belonging to either ASD, DD, or TD before the study began.

2.2 Identification of the Factor Structure

Using exploratory factor analysis (EFA), the simplest factor structure of ASD symptoms was identified by the following requirements: a) factor loads of items included in each factor should be more than |0.35|; b) each factor should include at least 9 items with maximum factor loads for this factor c) each factor should have a clear, meaningful interpretation of the items included in it; d) a set of items included in each factor should ensure acceptable reliability of the corresponding scale (Cronbach's alpha is not lower than 0.7). The listed below methods were used: Extraction Method: Principal Axis Factoring, Rotation Method: Equamax with Kaiser Normalization. Statistical analysis was performed using IBM SPSS Statistics 28 version (Armonk, NY: IBM Corp.). 7 factors were identified, including a total of 78 binary items.

2.3 The Parcels Formation

The number of samples homogeneous by gender and age is insufficient for the confirmatory factor analysis (CFA) application to 78 initial binary items of the scale because 78 articles and 7 factors in the CFA will require an assessment of at least 156 parameters (78 error variances, 71 regression coefficients, 7 factor variances). However, even a 5-fold excess of the sample size over the number of estimated parameters (N/T) is insufficient [27]. In addition, the ratio of the number of indicators to the number of factors (P/F) affects the value of the model's compliance indices with the initial data: the value of the consent indices tends to worsen as the number of indicators per factor in the CFA increases [28, 29]. The optimal number of items per factor remains debatable [30]; however, using at least three items for each factor is often recommended [28, 30].

The solution to these problems is a "parcel" approach, which implies combining (parcelling) items included in one factor into several parcels of items [31]. Usually, a random distribution of items by parcels is used, or their forced distribution by a priori assumptions about the content of constructs [22]. In addition to solving the problems of sample size (N/T) and the number of variables per factor (P/F), the parcel approach allows "strengthening" the scale of measuring from binary to quantitative.

2.4 Exploratory Factor Analysis of Parcels

At this step, the EFA was carried out 7 times with the number of factors from 1 to 7 to identify structures subject to factor validation with the help of CFA at the next step. The following methods were used: Extraction Method-Principal Axis Factoring, Rotation Method-Promax with Kaiser Normalization.

2.5 Confirmatory Factor Analysis of Parcels

A confirmatory factor analysis was used to verify the factor validity of the structures obtained in the previous step (CFA). Statistical analysis was performed using IBM AMOS 28 version (Amos Development Corporation 3000 Village Run Road Unit 103, #315 Wexford, PA 15090 USA). Confirmatory factor models were evaluated using the following indices: Chi-square ratio to the number of degrees of freedom (χ^2/df), Comparative Fit Index (CFI), Tucker-Lewis index (TLI), Root mean square error of approximation (RMSEA) and its accuracy (Pclose). CFI and TLI values from 0.90 to 0.92 were considered adequate, from 0.92 to 0.95 good and >0.95 excellent. RMSEA values <0.070 were deemed adequate, and ≤0.05 were evaluated as excellent compliance, Pclose values greater than 0.1 were evaluated as acceptable compliance, and about 0.4 and higher were assessed as excellent compliance [27, 32]. The comparison of the original and nested models (with fewer degrees of freedom) was carried out with the determination of the statistical significance (p) of the "improvement" by the Chi-squared difference ($\Delta\chi^2$) of the nested model, compared with the original one, by the corresponding difference in the number of degrees of freedom (Δdf). The nested model (with a smaller df) was recognized as better corresponding to the data if $p \leq 0.05$ [27, 32].

2.6 Checking the Structural and Measurement Invariance of the Model

The structural and measurement invariance of the multifactorial structure obtained in the previous step was checked against two pairs of samples: a) 3-4-year-olds b) boys and girls. The multi-group CFA was applied using IBM AMOS 28 version. Comparison of models for the measurement invariance analysis was based on empirical studies showing that a decrease in CFI or TLI > 0.01, or an increase in RMSEA > 0.01 implies nonequivalence of measurements [32, 33]. For the present study, if any of these indices went beyond this limitation, it was considered that the more limited model has an unacceptable fitness.

2.7 Comparison of ASD, TD and DD Samples by Selected Factors

Robust Walch Tests of Equality of Means were used to compare the samples with multiple comparisons (Post Hoc Tests Gams-Howell).

Ethical review and approval were waived for this study due to no disclosure of any personal information. Written consent from the parents was obtained for all subjects involved in the study.

3. Results

3.1 Preliminary Selection of Items and Scales Formation

First, those items for which the answers to one of the two alternatives were less than 10% were excluded, 273 items remained. According to Scree Plot, 12 factors were initially set. But 3 factors after rotation included less than 9 items with more than |0.35|. At the next iteration, the number of factors was consistently reduced so that each factor included at least 9 items with loads greater than |0.35|, and 9 such factors remained. However, three elements did not have a distinct interpretation after rotation. The first included a mixture of items related to asthenia and sensory disintegration, the second of active speech items and speech comprehension, and the third of

items related to self-care and communication. Items pertaining to functional speech, asthenia, and self-care have been removed. The number of factors was reduced to 7, after which items with factor loads less than |0.35| were removed. As a result, a 7-factor structure was obtained, including from 9 to 14 items in each factor (78 items in total). Each factor was clearly interpreted according to the items included in it: 1) "Persistence on sameness" (Sam); 2) "Emotional dysregulation" (Em); 3) "Alienation" (Al); 4) "Speech understanding" (SU); 5) "Disinhibition/Hyperactivity" (Hyp); 6) "Echolalia" (Ech); 7) "Sensory disintegration" (Sen) (Table 1). Some of the items were inverted so that all the items included in each factor had the same signs of factor loads. The items in each element formed fairly reliable scales for the internal consistency of Cronbach's Alpha (from 0.730 to 0.871).

Table 1 Factor loadings for seven-factor solution (EFA) and reliability check on Cronbach's alpha scales.

Rotated Factor loadings of 78 Items (n = 383), 36.31% of Variance	**FL[1]**
Factor 1 (Sam[3]): "Insistence on sameness" (11 items; 6.22%, α = 0.871)	
F2304 It is difficult to make a child put on some new clothes, he/she gets used to old clothes	0.687
B6503 When it is necessary to change clothes, problems arise - a child refuses to wear unfamiliar clothes (for example, when the weather or the season changes).	0.678
B6402 It is difficult for a child to change his/her mind (for example, if he/she decides that he will wear red socks, or take his own, and not someone else's car, it is difficult to convince him/her otherwise).	0.638
B6401 Insists on completing tasks in the same way every time.	0.590
N6704 He/she protests against wearing clothes that strongly fit the body, intolerable to hard seams, certain fabrics are unpleasant for him, refuses wearing mittens or hats.	0.571
F2303 He/she is capricious, and demands to change into the clothes that he/she likes.	0.561
B2801 Experiencing stress due to changes (in the daily routine, walking routes).	0.539
N4602 The child is sensitive to touching the mouth or an area around the mouth (does not like brushing teeth, speech therapy massage, dentist's examination).	0.520
B2802 Experiences difficulties with switching (for example, from one type of activity to another).	0.469
N6702 The child does not like being touched (avoids hygienic procedures, especially haircuts, combing, and cutting nails), tends to break out of the embrace.	0.467
N4201 The child is sensitive to light, squints in the sun, covers his/her eyes with his/her hands, prefers subdued light.	0.434
Factor 2 (Em[3]): "Emotional dysregulation" (11 items; 6.08%, α = 0.849)	
L7704 When the child hears his/her name, he/she immediately turns and looks at the speaker. [2]	0.643
E0301 He/she smiles as soon as she sees an adult's friendly attitude.[2]	0.627
L1103 The child draws the attention of another person to some object or event in search of emotional responses (empathy). [2]	0.600
C8003 The child reacts to a sudden somewhat tangible touch (for example, a foot under the table) by looking under the table, checking what exactly is interfering with his/her leg. [2]	0.589
E7402 The child reacts to the positive emotions of others "gets infected" with them, demonstrating a positive mood shift, laughs. [2]	0.577
L0903 Immediately looks at the person who is addressing him/her.	0.532

L1003 Showing something to another person positions the object so that it can be viewed, checking whether the person sees what he/she is showing. [2]	0.528
E7401 It is difficult for a child to recognize emotions in other people and react accordingly to them.	-0.501
L8204 Communicates with friends and family often (almost every day, for 1-2 hours). [2]	0.491
E0304 Does not smile in response to the smile of another person (adult or child); the social smile is limited.	-0.466
E7403 When watching a cartoon, the child understands what is happening on the screen and emotionally reacts adequately in the same way in familiar situations.[2]	0.375
Factor 3 (Al^3): "Alienation" (14 items; 5.87%, α = 0.862)	
L7701 When called by name or asked a question, the child does not react in any way, it seems that he/she does not hear.	0, 593
L1001 Does not use pointing gestures in communication with another person.	0.576
L7703 When he/she hears their name, the child casts a cursory glance at the speaker. Further actions depend on the presence of interest in the speaker (or what he has in his hands) - either turns around or continues to go about his business. [2]	-0.555
L1501 He/she does not imitate other people's actions: the child is busy with his/her own business and does not pay attention to people.	0.539
L8201 Practically does not communicate with family and friends	0.526
L1002 When showing something to another person, the child does not care whether the person has seen this object (including pointing with a finger, glance, naming or otherwise). [2]	-0.502
C8001 He/she does not react to a sudden, quite tangible touch in any way, continues to do his/her business.	0.492
N6802 Facial expressions are impoverished, facial muscles are too relaxed.	0.467
G2102 Usually prefers to play by him/herself, but can play NEXT to another child (children), watching them, but not interacting. [2]	-0.457
G2101 As a rule, he/she plays him/herself, aloof and does not allow other people into his/her game - neither adults nor children.	0.457
L1302 Ignores the presence of others does not respond to the attempts of others to establish contact.	0.449
L1102 The child tries to share emotions but does it clumsily, incomprehensibly for another person; for example, turns a cursory glance in their direction or inaccurately points to an object (event). [2]	-0.439
C7802 At a sudden loud enough sound, the child briefly turns around, does not find anything interesting for themself and returns to his/her occupation.	-0.431
C3201 It seems that the child ignores the surrounding reality - they wander around the room, studies the space, takes objects, does not focus on them and immediately throws them, sometimes behind his/her back.	0.413

Factor 4 (Su^3): ” Speech understanding” (11 items; 5.56%, α = 0.868)	
S0502 Distinguishes between the words "big" and "small", "short" and "long", "wide" and "narrow". Put a large and small ball (a cube, a doll, a toy car) in front of the child. Can the child show where the BIG ONE is (ball, cube...)? The statement is true if the child demonstrates a steady (repeated) distinction in at least one pair of words.	0.625
S4703 He/she can fulfill a double request: "Bring dad the keys and then close the door!" or "Pick up the ring from the floor and give it to mom."	0.564
S0506 The child correctly points at the geometric figures when the adult calls them: square, rectangle and triangle.	0.563
S0503 The child can show where his arm, leg, eye, ear is (two answers are enough).	0.553
S4708 Indicates an object of the same color that the adult calls.	0.537
S0508 Distinguishes between sounds made by different animals. Put figures or images of animals in front of the child. Pronounce the sound of an animal hiding behind a screen. Ask the child to show which animal "sounded". Check if the child can distinguish (show).	0.521
S0507 Distinguishes between sounds made by different objects. Introduce the child to different sounds (bell ringing, pencil tapping on the table, clapping). Hide the object behind the screen and repeat the sound. The statement is true if the child can distinguish (show) at least two different objects.	0.521
S4701 Understands the request "Give me another one".	0.514
S4707 Shows where the right/left hand is, (eye, leg, ear) (even if wrongly).	0.502
S4705 Finds objects or their images when an adult calls a generalizing word (for example, "Show a piece of furniture", "Show a fruit").	0.477
S0505 Fulfills the request: "Give me one/many ...".	0.476
Factor 5 (Hyp^3): “Hyperactivity/Disinhibition” (13 items; 4.68%, α = 0.813)	
P3905 The child cannot sit still, he/she leaves his/her place in class or elsewhere, jumps up and wanders around.	0.610
N6901 There are "too many unnecessary movements" in the activity, the child is fussy, seems "hyperactive".	0.572
B2502 Can't play quietly, the child is inadequately noisy.	0.545
B2503 The child is difficult to control. External stimuli control his/her behavior.	0.541
B6202 The child strives to achieve his/her goal, easily loses his/her temper.	0.541
B2605 Does not obey and refuses to follow the rules set by adults.	0.527
B2603 He/she is often angry and irritable.	0.522
B2901 Aggressive, pugnacious, prone to physical violence against animals and others.	0.485

N4106 Usually the child talks loudly, makes strange sounds like humming, buzzing.	0.485
B6201 Loses self-control, the child is prone to emotional "explosions".	0.471
B2404 The pace of the child's activity is high if he/she likes the activity, and low if it is something he/she does not like (for example, the child does everything slowly in class, "falls asleep", and as soon as the activity stops, he/she runs briskly).	0.428
N7103 Often and for a long time jumps on the bed or any other elastic surface.	0.412
B2403 A uniform pace in different types of activities - walking, classes, entertainment.[2]	-0.408
Factor 6 (Ech[3]): "Echolalia" (9 items; 4.25%, α = 0.778)	
S5304 If the child hears a question, instead of answering, he/she repeats it.	0.670
S5404 The child's speech is "repetitive", there is echolalia: he/she repeats the words of other people, just for repeating but not for communication purposes.	0.649
S5405 The child "talks" using words and phrases from cartoons or words and phrases previously heard from adult conversations.	0.520
M7203 The child can say what he/she wants in one word.	0.484
M1802 Verbally addresses a close adult only in situations of nervous tension or a certain need. The child does not use speech in other cases.	0.461
S5403 The child can say words (even very complex ones, for example, "excavator") in a certain situation, but then he/she never repeats them at the request of an adult.	0.445
S5305 Uses memorized phrases, without meaning, out of context, it seems that there is no speech of his/her own.	0.443
S0602 Imitates individual words spoken by an adult or another child.	0.430
M1604 When you name the objects that you think the child wants, he/she responds by repeating the word you have just said (immediate echolalia).	0.417
Factor 7 (Sen[3]): "Sensory disintegration" (9 items; 3.66%, α = 0.730)	
N4205 Likes to watch the lights switch on and off, doors opening and closing, wheels turning, fan, blinds opening and closing, shiny objects, pacing pages when flipping through, etc.	0.522
C3304 Visual and mechanical skills are well developed (for example, making puzzles and constructors, working with electronic devices, and understanding the essence of the work of various mechanisms).	0.490
N4303 Shows an extraordinary need to touch certain textures of surfaces, toys; studies objects groping them.	0.440
C3205 The child's attention is selective: it can be focused on a favorite activity (lining up objects in a row, spinning wheels, playing with constructors and puzzles), at the same time, he/she is absent-minded and inattentive when it comes to "unwanted" activities.	0.431

N4406 Leans or presses vibrating or sounding objects to the face and other parts of his/her body.	0.428
G2003 The child is interested in the parts, and details of the object, but not the whole object (obsession with the wheels of cars, details of human clothing).	0.419
B2805 The child is very picky about food, he/she has a limited range of favorite dishes, constant demands to consume the same meal, and special requirements for food (color, consistency, execution).	0.407
S0806 Visual-motor skills are ahead of speech skills (for example, he/she puts puzzles together deals with gadgets, while there is no speech and communication with other people).	0.372
L1405 The child can safely stay alone in the room for 10-15 minutes.	0.364

[1]-Factor loadings; [2]-inverted items; [3]-the scales' designation used below in the text.

3.2 Parcels Formation

In our case, we used an a priori strategy of distributing packages by factors, in accordance with the 7-factor result of the EFA (Table 1), 3 packages per factor, and a random distribution of items by packages within each factor. In each of the 7 factors, the items were randomly distributed in 3 packages, at least 3 items in each package. Thus, 78 items were distributed in 21 packages, 3 for each factor and 3-5 for each package. The value of the package for each case was calculated as the average value of the items included in it. As a result, 21 new variables corresponding to the packages were presented in a 4-6-point quantitative scale (depending on the number of items in the package), and each value represented the proportion of affirmative answers to the items included in this package. Then, these 21 new variables were analyzed, three variables for each of the 7 hypothetical factors.

3.3 Exploratory Factor Analysis of Packages

The analysis was carried out 7 times, specifying the number of factors from 1 to 7. The following methods were used: Extraction Method: Principal Axis Factoring, Rotation Method: Promax with Kaiser Normalization. The structure was considered quite simple if the factor load of each package was more than |0.4| for only one factor, and for the rest, it was no more than |0.3|. Structures with 3, 6 and 7 factors turned out to be simple. In the 3-factor structure, the first factor included packages of factors Em, Al, Su, Ech (factors related to problems in communication), the second factor - packages Sen and Sam (sensory disintegration and insistence on sameness), the third - all 3 packages of Hyp. In the 6-factor structure, Sen and Sam packages were combined into one factor whilst the remaining packages were distributed according to the corresponding factors. In the 7-factor structure, each factor was formed by three related packages. Thus, according to the results of the EFA, there are no formal grounds to determine which of the 3 models is more consistent, with 3, 6 or 7 factors.

3.4 Confirmatory Factor Analysis: Comparison of Models with a Different Number of Factors

For comparison, 3 models with 3, 6 and 7 factors were formed, following the results of the EFA at the previous stage. Covariances between factors whose statistical significance was within the range of $p < 0.01$ were added to each model. The results are shown in Table 2.

Table 2 Factor loadings for seven-factor solution (EFA) and reliability check on Cronbach's alpha scales.

	χ^2	df	CFI	TLI	RMSEA	Pclose	$\Delta\chi^2(\Delta df)$	p
3-factor	1315.055	187	0.714	0.679	0.126	<0.001	-	-
6-factor	461.251	184	0.930	0.920	0.063	0.002	852.804(3)	<0.001
7-factor	361.736	183	0.955	0.948	0.051	0.441	99.515(1)	<0.001

The 6-factor model matches the initial data statistically better than the 3-factor model. However the 7-factor model should be recognized as the best in terms of consent indices, all the estimated parameters of which are statistically reliable ($p < 0.001$) (Figure 1). The identified factors

form 3 groups of symptoms: problems in communication (Em, Su, Ech, Al), persistence on sameness and sensory disintegration (Sam, Sen) and hyperactivity/disinhibition (Hyp). It is noteworthy that Echolalia is positively associated with Speech understanding and negatively with Alienation.

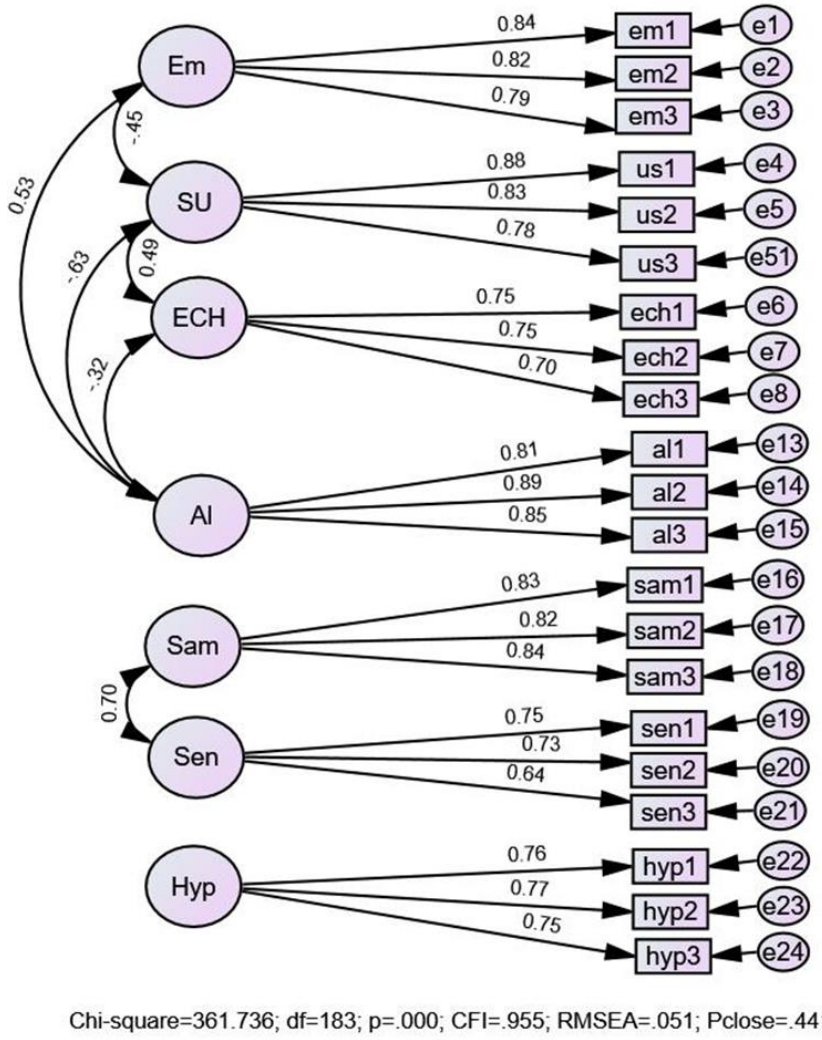

Figure 1 The 7-factor model of ASD symptoms for 3-4-year-olds children.

Pearson correlations between age and factors were also calculated (Table 3). With age, the values of the factors "Persistence on sameness", "Sensory disintegration", "Speech understanding" and "Echolalia" increase statistically significantly.

Table 3 Pearson correlations of age (in days) and factors for ASD sample (N = 383).

		Sam	Em	Al	Su	Hyp	Echo	Sen
Age (Days)	r	0.233	0.014	-0.013	0.259	0.022	0.237	0.220
	p	<0.001	0.780	0.804	<0.001	0.661	<0.001	<0.001

3.5 Testing the Structural and Measurement Invariance of the Model

3.5.1 Testing the Invariance of Models for 3-4-Year-Olds Samples

The results of this stage are presented in Table 4.

Table 4 Model agreement indices for 3-4-year-olds.

Model	χ^2	df	CFI	TLI	RMSEA
Unconstrained	593.627	366	0.940	0.931	0.041
Measurement weights	604.457	380	0.940	0.934	0.040
Structural covariances	640.786	393	0.934	0.930	0.041
Measurement residuals	668.582	414	0.933	0.932	0.041

The model without restrictions (Unconstrained) corresponds fairly well to the initial data for all the following indicators: $\chi^2/df < 2$; CFI > 0.95 and TLI > 0.90; RMSEA < 0.05. However, the differences are crucial for deciding on equivalence at one or another level of CFI, TLI, and RMSEA parameters fixation for the preceding and subsequent unconstrained models. If this difference exceeds 0.01, the equivalence at the appropriate level is not confirmed. Based on these considerations, the equivalence of models for 3-4-year-olds samples is certainly and established for all levels of restriction: a) measurement level of explicit variables (Measurement weights); b) the level of covariance between factors (Structural covariances); c) strict invariance: equality of the residuals of explicit variables (Measurement residuals). Thus, the measurement model's high configuration, metric, scalar and strict invariance for 3-4-year-olds samples is confirmed.

3.5.2 Testing the Invariance of Models for Samples of Boys and Girls

The results of this step are presented in Table 5.

Table 5 Model consent indexes for boys and girls.

Model	χ^2	df	CFI	TLI	RMSEA
Unconstrained	610.443	366	0.938	0.929	0.042
Measurement weights	620.109	380	0.939	0.933	0.041
Structural covariances	639.613	393	0.938	0.933	0.041
Measurement residuals	666.124	414	0.936	0.935	0.040

All models, starting from the configuration (Unconstrained) and ending with strictly limited (Measurement residuals) correspond well to the initial data for all the following indicators: $\chi^2/df < 2$; CFI > 0.95; TLI > 0.97; RMSEA < 0.05. The CFI, TLI and RMSEA difference for each preceding and subsequent of the limited models does not exceed 0.01. Thus, the equivalence of measurement models for samples of boys and girls is confirmed at all levels: from configuration to strict measurement equivalence.

3.5.3 Comparison of Samples of ASD, TD, and DD by Identified Factors

The values of the factors were calculated for all the samples (ASD, DD, and TD) as the average values of the items included in these factors. Descriptive statistics are given in Table 6.

Table 6 Descriptives of the values of the selected factors for the ASD, TD, and DD samples.

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
						Lower Bound	Upper Bound
Sam	ASD	383	0.3889	0.31936	0.01632	0.3568	0.4210
	TD	330	0.0631	0.12051	0.00663	0.0500	0.0761
	DD	201	0.1931	0.17247	0.01217	0.1691	0.2171
	Total	914	0.2282	0.27456	0.00908	0.2104	0.2460
Em	ASD	383	0.8002	0.24998	0.01277	0.7751	0.8253
	TD	330	0.1888	0.18392	0.01012	0.1689	0.2087
	DD	201	0.4203	0.28009	0.01976	0.3813	0.4592
	Total	914	0.4959	0.36016	0.01191	0.4725	0.5193
Al	ASD	383	0.4777	0.29166	0.01490	0.4484	0.5070
	TD	330	0.2758	0.07468	0.00411	0.2677	0.2838
	DD	201	0.2588	0.14136	0.00997	0.2392	0.2785
	Total	914	0.3567	0.22933	0.00759	0.3418	0.3715
Su	ASD	383	0.3385	0.30103	0.01538	0.3082	0.3687
	TD	330	0.8339	0.25787	0.01420	0.8060	0.8618
	DD	201	0.4690	0.26024	0.01836	0.4328	0.5052
	Total	914	0.5461	0.35502	0.01174	0.5230	0.5691
Hyp	ASD	383	0.3252	0.24989	0.01277	0.3001	0.3503
	TD	330	0.1110	0.11295	0.00622	0.0987	0.1232
	DD	201	0.2605	0.20971	0.01479	0.2314	0.2897
	Total	914	0.2336	0.22242	0.00736	0.2192	0.2481
Echo	ASD	383	0.2385	0.25397	0.01298	0.2130	0.2640
	TD	330	0.0545	0.09810	0.00540	0.0439	0.0652
	DD	201	0.1786	0.17881	0.01261	0.1537	0.2034
	Total	914	0.1589	0.21009	0.00695	0.1452	0.1725
Sen	ASD	383	0.4029	0.27077	0.01384	0.3757	0.4301
	TD	330	0.1303	0.10701	0.00589	0.1187	0.1419
	DD	201	0.1774	0.16894	0.01192	0.1539	0.2009
	Total	914	0.2549	0.23912	0.00791	0.2394	0.2704

The results of Robust Walch Tests of Equality of Means application are presented in Table 7, and the comparison of samples with multiple comparisons (Post Hoc Gams-Howell's Tests) is in Table 8.

Table 7 Robust Walch's Tests of Equality of Means.

Factors	Statistic[a]	df1	df2	Sig.	Eta-squared
Sam	189.716	2	481.571	<0.001	0.278
Em	702.644	2	480.524	<0.001	0.572
Al	89.385	2	433.228	<0.001	0.202
Su	300.776	2	529.609	<0.001	0.391
Hyp	137.064	2	451.818	<0.001	0.184
Echo	110.945	2	448.798	<0.001	0.151
Sen	164.186	2	467.989	<0.001	0.282

[a]Asymptotically F distributed.

Table 8 Pairwise comparisons (Gams-Howell's Post Hoc Tests).

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	Cohen's d
Sam	ASD	TD	0.32582	0.01762	<0.001	1.161
		DD	0.19578	0.02035	<0.001	
Em	ASD	TD	0.61142	0.01630	<0.001	2.088
		DD	0.37992	0.02353	<0.001	
Al	ASD	TD	0.20192	0.01546	<0.001	1.016
		DD	0.21883	0.01793	<0.001	
Su	ASD	TD	-0.49541	0.02093	<0.001	1.159
		DD	-0.13054	0.02395	<0.001	
Hyp	ASD	TD	0.21419	0.01420	<0.001	0.756
		DD	0.06464	0.01954	0.003	
Echo	ASD	TD	0.18392	0.01406	<0.001	0.688
		DD	0.05992	0.01810	0.003	
Sen	ASD	TD	0.27262	0.01504	<0.001	1.252
		DD	0.22548	0.01826	<0.001	

The ASD sample differs statistically significantly from the other two samples in each factor. An illustration of the differences is shown in Figure 2. For all the factors, except Speech understanding, the average values for the ASD sample are statistically significantly higher than for the TD and DD samples. The average values for ASD are statistically significantly lower than for the TD and DD samples in the factor of Speech understanding.

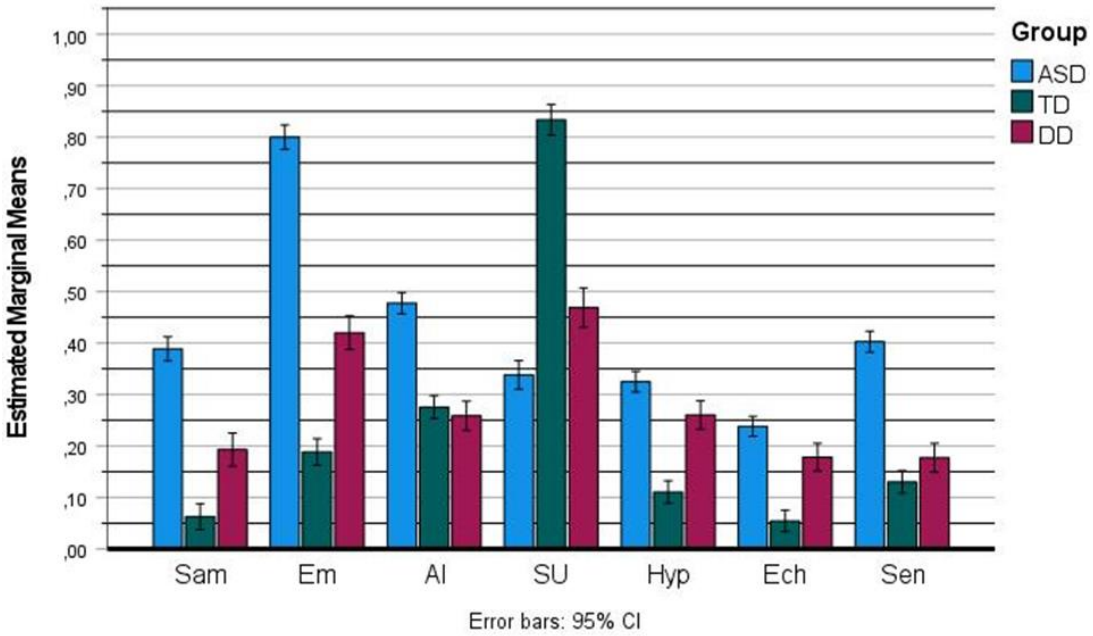

Figure 2 Average values of ASD symptoms factors for 3-4-year-olds.

4. Discussion

As the result of this study 7-factor structure of autism for 3-4-year-olds was obtained. Our first factor was Insistence on sameness (Sam) because all the points with the largest factor loads included in this factor are related with persistence on the same routines, clothes, routes, performing tasks in the same way and experiencing stress as a response to changes. Our second factor was named Emotional dysregulation (Em) because all the points with the most significant factor loads included in this factor are connected with emotional responses in social interaction and include typical and atypical emotional reactions or the lack of adequate emotional responses. Our third factor is Alienation (AL) because all the points with the largest factor loads included in this factor are linked with the reactions of social withdrawal, the lack of social motivation for communication, and reactions of social avoidance. The fourth factor was called Speech understanding (Su) because all the points with the largest factor loads included in this factor are connected with speech understanding tasks, performing tasks as a response to verbal instructions. The fifth factor was named Hyperactivity/Disinhibition (Hyp) because all the points with the largest factor loads included in this factor are related to jumping, swaying, wandering around, performing lots of unnecessary movements, and restlessness. Our sixth factor is Echolalia (Ech) because all the points with the largest factor loads included in this factor are linked with repeating words and phrases heard from other people or from cartoons. The seventh factor was named Sensory disintegration (Sen) because all the points with the most significant factor loads included in this factor are related to increased or decreased sensitivity in various sensory modalities, manifested in the child's need for sensory self-stimulation or avoidance of specific sensory impressions.

Discussing the results obtained, it should be emphasized that we used the exploratory approach in identifying factor structure of ASD by processing initially very wide range of symptoms, whilst the most common approach is the confirmatory one, based on exploring factor structure of autism by using existing screenings or questionnaires with a priory predetermined structure. Our

main result is the identification of 7-factor structure of autism in 3-4-year-olds and the finding of statistically significant differences of ASD sample compared with the samples of TD and DD in each factor. Confirmatory factor analysis confirmed the configuration and measurement invariance of the revealed 7-factor model of ASD to different parts of the sample: boys and girls, children 3 and 4 years old. This is convincing evidence in favor of the validity of the results obtained. The identified factors form 3 groups of symptoms which can be summed up under common denominators, such as problems in communication (Em, Su, Ech, Al), persistence on sameness and sensory disintegration (Sam, Sen), and hyperactivity/disinhibition (Hyp). We will discuss and interpret them based on the received groups of symptoms.

The first group of symptoms can be named problems in communication and includes 4 factors (Em, Su, Ech, Al). Unsurprisingly, one of the obtained factors is Emotional dysregulation (Em). It is known that emotional regulation is impaired in ASD because children with ASD experience difficulties with emotion recognition in self and others, reading emotional clues, and inhibiting emotional responses [34]. Many researches directly link emotional dysregulation in ASD with its core symptoms such as social difficulties and repetitive behaviors [35, 36]. According to the results of the observational studies, children with ASD show stronger and longer adverse emotional reactions when facing the necessity to perform structured tasks. They tend to use negative behavioral strategies, including avoidance, yelling, and aggressive reactions as compared to typically developing children [37]. It is also known that children with ASD are more prone to self-harm reactions [38]. It is also believed that emotional dysregulation in ASD is connected with higher probabilities of co-occurring psychiatric disorders and mental health problems [39]. Some research groups claim that the heavier the symptoms of emotional disinhibition in ASD, the more serious the psychiatric burden, and the less favorable the forecast for those children's further development and adaptation [40, 41].

Concerning verbal development and speech understanding in autism (our second factor in this group) it is well known that communication impairment is a core feature of ASD closely associated with difficulties in the integration of verbal and nonverbal communication in affected children [42]. There is an enormous diversity of language impairment in the population of children with ASD regardless of cognitive abilities, but early language abilities and their development can predict social adaptation, academic achievements, and psychiatric outcomes in late childhood and adulthood [43]. Speech impairment is also one of the core autism symptoms because even highly functioning children with ASD are likely to experience impairments in language pragmatics when the components of structural language are unimpaired [44]. It is not surprising that children with ASD experience difficulties in speech understanding because it was shown that they demonstrate low sensory responses to single speech sounds [45], atypical neural responses on lexical stimuli connected with increasing motivation and task complexity compared with typically developing peers [46], restricted spontaneous attentional orienting to spoken words [47], specific difficulties with categorical speech sound discrimination which remains for lifespan [48], and reduced processing of semantic content [49].

The third factor in this group of symptoms was Echolalia, which is a salient speech disturbance commonly found in children with ASD [50] and which can be considered as a defining characteristic of ASD [51]. It is believed that approximately 75% of children with ASD manifest echolalia at a certain stage of speech development [52]. Though the exact etiology and pathogenesis of echolalia are not entirely clear, it is known that in typically developing children,

sound imitation and verbal echo reactions disappear by the age of three years [53], whilst in children with ASD echolalia persists much longer and can last for long years [54]. Some of the offered neurophysiological explanations of this phenomenon are impairment in the mirror neuron system [55] and dysfunction of the frontal lobe leading to the lack of inhibitory control [56]. It is common to distinguish several types of echolalia in ASD, such as immediate and delayed echolalia [57]; also, there is ambient echolalia, which is typical for children with ASD and refers to the repetition of words or sentences they learn from the environment [58]; in addition there are verbal and vocal stereotypies [59]. Interestingly, according to our results, Echolalia is positively associated with the factor of Speech understanding and negatively with the factor Alienation. Our results correspond to the previous findings. Thus it was discussed that Echolalia in ASD should be considered as a specific type of communicative behavior [60] and can be communicatively purposeful [61]. So, indeed, Echolalia may facilitate speech understanding and contribute to communicative behavior, whilst totally non-verbal children with ASD more often show severe impairments in communication [62], which stands for the fourth factor Alienation included in the first group of symptoms according to our results.

Alienation or social withdrawal is another core autistic symptom [63] in its extreme manifestation known as hikikomori, a form of pathological social withdrawal [64]. It is not surprising that one of the factors included in the 7 factor structure of autism was alienation. According to the results of the previous studies, this phenomenon is closely related to loneliness and emotional problems such as anxiety and depression [65]. It is well known that even adult highly functional individuals with ASD tend to be involved in fewer social relationships [66]. Following the social motivation theory of autism, it is claimed that people with autism have both less desire for social interaction and gain less pleasure from it [67]. It is also understood that for the most highly functional people with ASD with Asperger's Syndrome, children and adults, it is tough to maintain high-quality friendships, which results in less enjoyment and leads to the best extent rather than social proximity than emotional connectedness [68, 69]. It is discussed that those specific communicative patterns are correlated with different brain activations in people with autism [70]. Thus, obtaining the factor Alienation as a part of the factor structure of autism was expected.

The second group of symptoms obtained in our research was formed by such factors as persistence on sameness and sensory disintegration, which correspond to universally acknowledged core features of autism. According to DSM-5 [1], repetitive behaviors and restricted interests may be reflected in the following main domains: stereotyped and repetitive movements, insistence on sameness, fixed and restricted interests, and sensory disintegration (hyper-/hyporeactivity). Sensory disintegration is, to date, the most frequently detected impairment in children with ASD [71]. It is proved that repetitive behaviors and sensory processing problems negatively affect the daily functioning of children with ASD by altering their social, cognitive, and motor development [72]. It is assumed that children with ASD can manifest repetitive behaviors as a response to sensory overloads. Such behaviors can be considered a coping mechanism aimed at reducing the excessive hyper-sensory stimulation and lowering the child's arousal level [73]. It is also discussed that in case of hyporesponsiveness, repetitive behaviors and stereotypical movements could serve as a form of self-stimulation, providing a desirable level of sensory comfort [74]. It is noteworthy that in our findings, the factors of persistence on sameness and sensory disintegration were linked together, which also goes in accordance with DSM-5 [1].

However, some researchers proposed that repetitive behaviors and insistence on sameness are two different aspects of the same phenomenon [75]. Nevertheless, the connection between sensory profiles and repetitive behaviors in ASD has long been known. Indeed, in accordance with previous studies, sensory disintegration often leads to repetitive behavioral patterns [76]. Furthermore, it was revealed that hyperresponsiveness in children with ASD predicted high levels of repetitive behaviors, whilst sensory-seeking behavior was connected with rituals and persistence on sameness [77].

And eventually, the third group of symptoms was included only one-factor hyperactivity or disinhibition (Hyp). Hyperactivity or disinhibition is a rather specific symptom known to deteriorate inhibitory control deficits and is linked with more severe repetitive behaviors [78]. In our model, this factor did not correlate with other factors, which corresponds to the results of the previous studies. Even though hyperactivity is not considered as a core autistic trait and is not included in DSM-5 [1] it is believed that approximately 30-80% of children with ASD have concurrent symptoms of inattention and hyperactivity [79]. It is discussed that hyperactivity in autistic children can be explained by violations in frontal cortex maturation, resulting in executive function deficits [80]. It is often accompanied by a lack of inhibitory control and impairments in working memory [81]. However, the alternative explanation of hyperactivity in autism can be a neurochemical imbalance caused by the prevalence of excitatory neurotransmitters [82]. Notably, the dysfunction of the nigrostriatal circuit manifesting in an imbalance of dopamine in the subcortical nuclei also led to disinhibition and stereotyped behaviors [83]. It is believed that hyperactivity in children with autism is an unfavorable symptom that aggravates the severity of ASD core symptoms [84].

Thus, as the result of our study, the 7-factor structure of autism for 3-4-year-olds was obtained. Correlations between 7 factors allow us to talk about 3 groups of ASD symptoms (Figure 1): 1) communication disorders (factors Em, Su, Ech & Al), 2) sensory disintegration and persistence on sameness (Sam & Sen), and 3) hyperactivity/disinhibition (Hyp). It is important to note that there is no correlation between these three groups of symptoms - they manifest independently of each other. Perhaps this can be explained if we assume the presence of various phenotypes of autism with the dominance of specific symptoms to each subtype. The most numerous group of symptoms refers to communication disorders. It is pretty clear that Emotional dysregulation (Em) is positively associated with Alienation (Al), and both are negatively associated with Speech understanding (Su). It is also interesting that Echolalia (Ech) is positively associated with Speech understanding (Su), and negatively with Alienation (Al). This may be explained by Echolalia's communicative function, which was discussed earlier. It seems that Echolalia can be a specific stage on developing language skills and speech understanding, whilst Alienation, on the contrary, should be less pronounced for mastering verbal abilities because it implies the accumulation of communicative experience. The apparent contradiction of the negative connections of Echolalia with other communicative symptoms is eliminated when comparing the group of ASD and two other groups (TD and DD) by the severity of 7 factors of autism symptoms (Tables 6-8). In children with ASD, the seriousness of all 7 groups of autism symptoms, including Echolalia (Ech), is significantly higher ($p < 0.01$) than in each of the other two groups. According to our results, the models of the actual ASD have larger dimensions. It can also be assumed that this structure changes with age - both in extent and in the content of symptoms, which is the subject of further investigation.

5. Conclusions

The main problem of this study was to identify the factor structure of ASD in 3-4-year-olds using the exploratory approach and initially wide range of autistic symptoms, which is part of a multidimensional mathematical model of autism. The 7-factor structure of autism was obtained, forming 3 groups of the core symptoms, such as problems in communication (Em, Su, Ech, Al), persistence on sameness and sensory disintegration (Sam, Sen), and hyperactivity/disinhibition. On the one hand, these vectors may determine the directions that most clearly distinguish ASD from the TD or DD groups. On the other hand, as a practical implication of the results obtained, those vectors could set the directions for the most optimal correction of ASD depending on its subtype and prevalence of one or the other autistic-like symptoms. We plan to develop the same models for different age groups of preschoolers to assess the likelihood of ASD and, ultimately, predict the trajectories of ASD manifestations, which in turn allow for determining the subtypes of ASD. For future research, the methodological recommendations for the correctional programs creation will be developed for each identified subtype of ASD, including a detailed description of the optimal interventions during rehabilitation.

6. Limitations

The revealed 7-factor structure of ASD for 3-4-year-olds is based on 436 initial hypothetical symptoms of autism, i.e. on a relatively significant number of them. Nevertheless, it can be assumed that the factor dimension of autism symptoms is even greater. Initially, we set a condition - at least 9 items per factor, so some potential factors might not be included in our model due to the limited amount of items.

Author Contributions

Conceptualization and methodology, A.N.; software, S.M.; validation and formal analysis, A.N. and S.F.; investigation and resources, S.M.; data curation, A.N.; writing-original draft preparation, A.N. and L.T.; writing-review and editing, L.T.; visualization, A.N. and S.F.; supervision, A.N.; project administration, A.N.; funding acquisition, A.N. All authors have read and agreed to the published version of the manuscript.

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Competing Interests

The authors have declared that no competing interests exist.

References

1. American Psychiatric Association. Diagnostic and statistical manual of mental disorders: DSM-5™. 5th ed. Washington, DC, US: American Psychiatric Publishing; 2013.

2. Maenner MJ, Shaw KA, Baio J, Washington A, Patrick M, DiRienzo M, et al. Prevalence of autism spectrum disorder among children aged 8 years-autism and developmental disabilities monitoring network, 11 sites, United States, 2016. MMWR Surveill Summ. 2020; 69: 1-12.
3. Mason D, Capp SJ, Stewart GR, Kempton MJ, Glaser K, Howlin P, et al. A meta-analysis of outcome studies of autistic adults: Quantifying effect size, quality, and meta-regression. J Autism Dev Disord. 2021; 51: 3165-3179.
4. Happé F, Frith U. Annual research review: Looking back to look forward-changes in the concept of autism and implications for future research. J Child Psychol Psychiatry. 2020; 61: 218-232.
5. Lord C, Elsabbagh M, Baird G, Veenstra Vanderweele J. Autism spectrum disorder. Lancet. 2018; 392: 508-520.
6. Hadders-Algra M. Emerging signs of autism spectrum disorder in infancy: Putative neural substrate. Dev Med Child Neurol. 2022; 64: 1344-1350.
7. van 't Hof M, Tisseur C, van Berckelear Onnes I, van Nieuwenhuyzen A, Daniels AM, Deen M, et al. Age at autism spectrum disorder diagnosis: A systematic review and meta-analysis from 2012 to 2019. Autism. 2021; 25: 862-873.
8. Clark ML, Vinen Z, Barbaro J, Dissanayake C. School age outcomes of children diagnosed early and later with autism spectrum disorder. J Autism Dev Disord. 2018; 48: 92-102.
9. Pennington ML, Cullinan D, Southern LB. Defining autism: Variability in state education agency definitions of and evaluations for autism spectrum disorders. Autism Res Treat. 2014; 2014: 327271.
10. Hus V, Lord C. Effects of child characteristics on the Autism Diagnostic Interview-revised: Implications for use of scores as a measure of ASD severity. J Autism Dev Disord. 2013; 43: 371-381.
11. Kim SH, Joseph RM, Frazier JA, O'Shea TM, Chawarska K, Allred EN, et al. Predictive validity of the modified checklist for autism in toddlers (M-CHAT) born very preterm. J Pediatr. 2016; 178: 101-107.e2.
12. Nasledov A, Miroshnikov S, Tkacheva L, Miroshnik K, Semeta MU. Application of psychometric approach for ASD evaluation in Russian 3-4-year-olds. Mathematics. 2021; 9: 1608.
13. Nasledov AD, Miroshnikov SA, Zashchirinskaya OV, Tkacheva LO, Kompanets NN. Autism Scale application for identifying the risk of mental development disorders among children ages 3 and 4. SIBIRSKIY PSIKHOL ZH. 2022; 83: 166-185.
14. Nasledov A, Tkacheva L, Miroshnikov S. Factor structure and measurement equivalence of the autism scale for children 3-4 years old: Analysis of binary data. Psychol J High Sch Econ. 2023; 20: 191-210.
15. Constantino JN, Gruber CP, Davis S, Hayes S, Passanante N, Przybeck T. The factor structure of autistic traits. J Child Psychol Psychiatry. 2004; 45: 719-726.
16. Matson JL, Boisjoli JA, Dempsey T. Factor structure of the autism spectrumdisorders-diagnostic for children (ASD-DC). J Dev Phys Disabil. 2009; 21: 195-211.
17. Auyeung B, Baron Cohen S, Wheelwright S, Allison C. The autism spectrum quotient: Children's version (AQ-Child). J Autism Dev Disord. 2008; 38: 1230-1240.
18. Hoekstra RA, Bartels M, Cath DC, Boomsma DI. Factor structure, reliability and criterion validity of the Autism-Spectrum Quotient (AQ): A study in Dutch population and patient groups. J Autism Dev Disord. 2008; 38: 1555-1566.

19. Kloosterman PH, Keefer KV, Kelley EA, Summerfeldt LJ, Parker JD. Evaluation of the factor structure of the Autism-Spectrum Quotient. Pers Individ Differ. 2011; 50: 310-314.
20. Sun F, Dai M, Lin L, Sun X, Murray AL, Auyeung B, et al. Psychometric properties of the chinese version of autism spectrum quotient-children's version: A sex-specific analysis. Autism Res. 2019; 12: 303-315.
21. Snow AV, Lecavalier L, Houts C. The structure of the Autism Diagnostic Interview-Revised: Diagnostic and phenotypic implications. J Child Psychol Psychiatry. 2009; 50: 734-742.
22. Frazier TW, Ratliff KR, Gruber C, Zhang Y, Law PA, Constantino JN. Confirmatory factor analytic structure and measurement invariance of quantitative autistic traits measured by the social responsiveness scale-2. Autism. 2014; 18: 31-44.
23. De la Marche W, Noens I, Boets B, Kuppens S, Steyaert J. The underlying symptom structure of autism spectrum disorders: A factor analytic approach using the developmental, dimensional and diagnostic interview. Res Autism Spectr Disord. 2015; 12: 40-51.
24. Brierley NJ, McDonnell CG, Parks KMA, Schulz SE, Dalal TC, Kelley E, et al. Factor structure of repetitive behaviors across autism spectrum disorder and attention-deficit/hyperactivity disorder. J Autism Dev Disord. 2021; 51: 3391-3400.
25. Hiruma L, Pretzel RE, Tapia AL, Bodfish JW, Bradley C, Wiggins L, et al. A distinct three-factor structure of restricted and repetitive behaviors in an epidemiologically sound sample of preschool-age children with autism spectrum disorder. J Autism Dev Disord. 2021; 51: 3456-3468.
26. Nasledov A, Miroshnikov S, Tkacheva L, Goncharov V. Elaboration of screening scales for mental development problems detection in Russian preschool children: Psychometric approach. Diagnostics. 2020; 10: 646.
27. Kline RB. Principles and practice of structural equation modeling. 3rd ed. New York, NY: Guilford Press; 2011.
28. Ding L, Velicer WF, Harlow L. Effects of estimation methods, number of indicators per factor, and improper solutions on structural equation modeling fit indices. Struct Equ Modeling. 1995; 2: 119-143.
29. Marsh HW, Hau KT, Balla JR, Grayson D. Is more ever too much? The number of indicators per factor in confirmatory factor analysis. Multivariate Behav Res. 1998; 33: 181-220.
30. Hall RJ, Snell AF, Foust MS. Item parceling strategies in SEM: Investigating the subtle effects of unmodeled secondary constructs. Organ Res Methods. 1999; 2: 233-256.
31. Little TD, Cunningham WA, Shahar G, Widaman KF. To parcel or not to parcel: Exploring the question, weighing the merits. Struct Equ Modeling. 2002; 9: 151-173.
32. Byrne BM. Structural equation modeling with AMOS: Basic concepts, applications and programming. 2nd ed. New York, NY: Taylor and Francis Group; 2010.
33. Chen FF. Sensitivity of goodness of fit indexes to lack of measurement invariance. Struct Equ Modeling. 2007; 14: 464-504.
34. Mazefsky CA, Herrington J, Siegel M, Scarpa A, Maddox BB, Scahill L, et al. The role of emotion regulation in autism spectrum disorder. J Am Acad Child Adolesc Psychiatry. 2013; 52: 679-688.
35. Berkovits L, Eisenhower A, Blacher J. Emotion regulation in young children with autism spectrum disorders. J Autism Dev Disord. 2017; 47: 68-79.

36. Samson AC, Hardan AY, Lee IA, Phillips JM, Gross JJ. Maladaptive behavior in autism spectrum disorder: The role of emotion experience and emotion regulation. J Autism Dev Disord. 2015; 45: 3424-3432.
37. Jahromi LB, Meek SE, Ober Reynolds S. Emotion regulation in the context of frustration in children with high functioning autism and their typical peers. J Child Psychol Psychiatry. 2012; 53: 1250-1258.
38. Blanchard A, Chihuri S, DiGuiseppi CG, Li G. Risk of self-harm in children and adults with autism spectrum disorder: A systematic review and meta-analysis. JAMA Netw Open. 2021; 4: e2130272.
39. Charlton AS, Smith IC, Mazefsky CA, White SW. The role of emotion regulation on co-occurring psychopathology in emerging adults with ASD. J Autism Dev Disord. 2020; 50: 2585-2592.
40. Plesa Skwerer D, Joseph RM, Eggleston B, Meyer SR, Tager Flusberg H. Prevalence and correlates of psychiatric symptoms in minimally verbal children and adolescents with ASD. Front Psychiatry. 2019; 10: 43.
41. Conner CM, Golt J, Shaffer R, Righi G, Siegel M, Mazefsky CA. Emotion dysregulation is substantially elevated in autism compared to the general population: Impact on psychiatric services. Autism Res. 2021; 14: 169-181.
42. Vogindroukas I, Stankova M, Chelas EN, Proedrou A. Language and speech characteristics in autism. Neuropsychiatr Dis Treat. 2022; 18: 2367-2377.
43. Miranda A, Berenguer C, Baixauli I, Roselló B. Childhood language skills as predictors of social, adaptive and behavior outcomes of adolescents with autism spectrum disorder. Res Autism Spectr Disord. 2023; 103: 102143.
44. McKernan EP, Kim SH. School-entry language skills as predictors of concurrent and future academic, social, and adaptive skills in kindergarteners with ASD. Clin Neuropsychol. 2022; 36: 899-920.
45. Key AP, D'Ambrose Slaboch K. Speech processing in autism spectrum disorder: An integrative review of auditory neurophysiology findings. J Speech Lang Hear Res. 2021; 64: 4192-4212.
46. McWeeny S, Norton ES. Understanding event-related potentials (ERPs) in clinical and basic language and communication disorders research: A tutorial. Int J Lang Commun Disord. 2020; 55: 445-457.
47. Tenenbaum EJ, Amso D, Abar B, Sheinkopf SJ. Attention and word learning in autistic, language delayed and typically developing children. Front Psychol. 2014; 5: 490.
48. Stewart ME, Petrou AM, Ota M. Categorical speech perception in adults with autism spectrum conditions. J Autism Dev Disord. 2018; 48: 72-82.
49. Ahtam B, Braeutigam S, Bailey A. Semantic processing in autism spectrum disorders is associated with the timing of language acquisition: A magnetoencephalographic study. Front Hum Neurosci. 2020; 14: 267.
50. Xie F, Pascual E, Oakley T. Functional echolalia in autism speech: Verbal formulae and repeated prior utterances as communicative and cognitive strategies. Front Psychol. 2023; 14: 1010615.
51. Gernsbacher MA, Morson EM, Grace EJ. Language and speech in autism. Annu Rev Linguist. 2016; 2: 413-425.
52. Van Santen JP, Sproat RW, Hill AP. Quantifying repetitive speech in autism spectrum disorders and language impairment. Autism Res. 2013; 6: 372-383.

53. Stiegler LN. Examining the echolalia literature: Where do speech-language pathologists stand? Am J Speech Lang Pathol. 2015; 24: 750-762.
54. Ip A, Zwaigenbaum L, Brian JA. Post-diagnostic management and follow-up care for autism spectrum disorder. Paediatr Child Health. 2019; 24: 461-468.
55. Perkins T, Stokes M, McGillivray J, Bittar R. Mirror neuron dysfunction in autism spectrum disorders. J Clin Neurosci. 2010; 17: 1239-1243.
56. Margari L, De Giacomo A, Craig F, Palumbi R, Peschechera A, Margari M, et al. Frontal lobe metabolic alterations in autism spectrum disorder: A 1H-magnetic resonance spectroscopy study. Neuropsychiatr Dis Treat. 2018; 14: 1871-1876.
57. Patra KP, De Jesus O. Echolalia. StatPearls [Internet]. St. Petersburg, FL, US: StatPearls Publishing; 2023. Available from: https://www.ncbi.nlm.nih.gov/books/NBK565908/.
58. McFayden TC, Kennison SM, Bowers JM. Echolalia from a transdiagnostic perspective. Autism Dev Lang Impair. 2022; 7. Doi: 10.1177/23969415221140464.
59. Gladfelter A, VanZuiden C. The influence of language context on repetitive speech use in children with autism spectrum disorder. Am J Speech Lang Pathol. 2020; 29: 327-334.
60. Luyster RJ, Zane E, Wisman Weil L. Conventions for unconventional language: Revisiting a framework for spoken language features in autism. Autism Dev Lang Impair. 2022; 7: 23969415221105472.
61. Cohn EG, McVilly KR, Harrison MJ, Stiegler LN. Repeating purposefully: Empowering educators with functional communication models of echolalia in Autism. Autism Dev Lang Impair. 2022; 7. Doi: 10.1177/23969415221091928.
62. Forgeot d'Arc B, Devaine M, Daunizeau J. Social behavioural adaptation in autism. PLoS Comput Biol. 2020; 16: e1007700.
63. Kwan C, Gitimoghaddam M, Collet JP. Effects of social isolation and loneliness in children with neurodevelopmental disabilities: A scoping review. Brain Sci. 2020; 10: 786.
64. Yamada M, Kato TA, Katsuki RI, Yokoi H, Igarashi M, Komine Y, et al. Pathological social withdrawal in autism spectrum disorder: A case control study of hikikomori in Japan. Front Psychiatry. 2023; 14: 1114224.
65. Hymas R, Badcock JC, Mille E. Loneliness in autism and its association with anxiety and depression: A systematic review with meta-analyses. Rev J Autism Dev Disord. 2022. Doi: 10.1007/s40489-022-00330-w.
66. Milton D, Sims T. How is a sense of well-being and belonging constructed in the accounts of autistic adults? Disabil Soc. 2016; 31: 520-534.
67. Chevallier C, Kohls G, Troiani V, Brodkin ES, Schultz RT. The social motivation theory of autism. Trends Cogn Sci. 2012; 16: 231-239.
68. Whitehouse AJ, Durkin K, Jaquette, Ziatas K. Friendship, loneliness and depression in adolescents with Asperger's Syndrome. J Adolesc. 2009; 32: 309-322.
69. Uljarević M, Frazier TW, Jo B, Phillips JM, Billingham W, Cooper MN, et al. Relationship between social motivation in children with autism spectrum disorder and their parents. Front Neurosci. 2021; 15: 660330.
70. Yaseen ZS, Zhang X, Muran JC, Winston A, Galynker II. Comparison of brain activity correlating with self-report versus narrative attachment measures during conscious appraisal of an attachment figure. Front Hum Neurosci. 2016; 10: 90.

71. Baum SH, Stevenson RA, Wallace MT. Behavioral, perceptual, and neural alterations in sensory and multi sensory function in autism spectrum disorder. Prog Neurobiol. 2015; 134:140-160.
72. Melo C, Ruano L, Jorge J, Pinto Ribeiro T, Oliveira G, Azevedo L, et al. Prevalence and determinants of motor stereotypies in autism spectrum disorder: A systematic review and meta-analysis. Autism. 2020; 24: 569-590.
73. Schulz SE, Stevenson RA. Sensory hypersensitivity predicts repetitive behaviours in autistic and typically-developing children. Autism. 2019; 23: 1028-1041.
74. Péter Z, Oliphant ME, Fernandez TV. Motor stereotypies: A pathophysiological review. Front Neurosci. 2017; 11: 171.
75. Ausderau K, Sideris J, Furlong M, Little LM, Bulluck J, Baranek GT. National survey of sensory features in children with ASD: Factor structure of the sensory experience questionnaire (3.0). J Autism Dev Disord. 2014; 44: 915-925.
76. Fetta A, Carati E, Moneti L, Pignataro V, Angotti M, Bardasi MC, et al. Relationship between sensory alterations and repetitive behaviours in children with autism spectrum disorders: A parents' questionnaire based study. Brain Sci. 2021; 11: 484.
77. Boyd BA, Baranek GT, Sideris J, Poe MD, Watson LR, Patten E, et al. Sensory features and repetitive behaviors in children with autism and developmental delays. Autism Res. 2010; 3: 78-87.
78. Schmitt LM, White SP, Cook EH, Sweeney JA, Mosconi MW. Cognitive mechanisms of inhibitory control deficits in autism spectrum disorder. J Child Psychol Psychiatry. 2018; 59: 586-595.
79. Cremone Caira A, Trier K, Sanchez V, Kohn B, Gilbert R, Faja S. Inhibition in developmental disorders: A comparison of inhibition profiles between children with autism spectrum disorder, attention-deficit/hyperactivity disorder, and comorbid symptom presentation. Autism. 2021; 25: 227-243.
80. Craig F, Margari F, Legrottaglie AR, Palumbi R, De Giambattista C, Margari L. A review of executive function deficits in autism spectrum disorder and attention-deficit/hyperactivity disorder. Neuropsychiatr Dis Treat. 2016; 12: 1191-1202.
81. Colombi C, Ghaziuddin M. Neuropsychological characteristics of children with mixed autism and ADHD. Autism Res Treat. 2017; 2017: 5781781.
82. Marotta R, Risoleo MC, Messina G, Parisi L, Carotenuto M, Vetri L, et al. The neurochemistry of autism. Brain Sci. 2020; 10: 163.
83. Pavăl D. A dopamine hypothesis of autism spectrum disorder. Dev Neurosci. 2017; 39: 355-360.
84. Sprenger L, Bühler E, Poustka L, Bach C, Heinzel Gutenbrunner M, Kamp Becker I, et al. Impact of ADHD symptoms on autism spectrum disorder symptom severity. Res Dev Disabil. 2013; 34: 3545-3552.