Open Access

OBM Neurobiology

LIDSEN Publishing Inc.

Technical Note

A New Computer-Aided Method for Assessing Children's Cognition in Bioengineering Systems for Diagnosing Developmental Delay

Igor Val Danilov [1, *], Araksia Svajyan [2], Sandra Mihailova [3]

1. Academic Center for Coherent Intelligence, Italy; E-Mail: igor_val.danilov@acci.center
2. The Ministry of Education, Science, Culture and Sports of the Republic of Armenia; E-Mail: svajyanaraqsya41@aspu.am
3. Riga Stradins University, Riga, Latvia; E-Mail: sandra.mihailova@rsu.lv

* **Correspondence:** Igor Val Danilov; E-Mail: igor_val.danilov@acci.center

Academic Editor: Bart Ellenbroek

Special Issue: New Concepts and Advances in Neurotechnology

OBM Neurobiology
2023, volume 7, issue 4
doi:10.21926/obm.neurobiol.2304189

Received: April 05, 2023
Accepted: October 11, 2023
Published: October 18, 2023

Abstract

This pilot study (n = 19) examines fidelity rates of the new computer-aided method of diagnosing cognitive development delay in 3-to-6-year-old children. The small-scale research repeats the methodological components of the previous two studies, only changing the data collection process by introducing the baseline value (BV). Experimental data show a significant increase of 9.4 times in the shared intentionality magnitude in neurodivergent children. The results support the hypothesis that the bioengineering system (computer-mother-child) can encourage shared intentionality in the dyad by emulating the mother-newborn communication model. The outcome shows the association between the shared intentionality magnitude and children's diagnosis. However, the bioengineering diagnostic paradigm and the new BV method still need more evidence since the pilot study observes the effect in a small sample size. The pilot study evaluates the fidelity rates of this new BV method through nine markers. It shows the feasibility (with the limitations) of testing this new BV method in further research with a large sample size.

Keywords
Shared intentionality; brain-computer interaction; computer-aided assessment; developmental delay

1. Introduction

The current pilot study is a repetition of two recent research studies (conducted by Val Danilov, Mihailova, and Svajyan in 2022 [1] and later research conducted by Val Danilov in 2022 [2]) on developing a new paradigm of diagnosing cognitive development delay in 3-to-6-year-old children. The diagnostic paradigm relies on assessing a shared intentionality magnitude. The central idea of this bioengineering paradigm is an association between the shared intentionality magnitude and cognitive delay in children [1, 2]. The novelty of the current study is that it experimentally tests and evaluates the fidelity rates of the new computer-aided method of assessing cognitive development delay in children that implements a new algorithm and math model based on comparing the children's results with a baseline value (BV). It is a small-scale test of the new BV assessment method to be tested in further research with a large sample size. It only assesses the feasibility/acceptability of a new approach but does not test the hypothesis itself.

1.1 Challenges in the Cognitive Development Assessment of Children

The progress in human-computer systems in medicine can solve various diagnostic objectives, contributing to the growth of a healthy population ratio due to the maintenance of the ecological context during child cognitive development. About 15 percent of the world's population-some, 785 million people-has a significant physical or mental disability, according to a new report prepared jointly by the World Health Organization and the World Bank. For example, the economic impact of mental illness amounts to 600 billion euros in the European Union, or more than 4% of GDP [3]. In the USA, Social Security Disability Insurance (SSDI) pays to approved recipients with mental health disorders: the national average monthly amount of $ 1,258 [4]. Early intervention can help many children to become healthy and reduce many costs.

According to Val Danilov et al. [1], early prediction of developmental disabilities in preschool children is urgent as it provides efficient intervention in their growing years. However, the classical psychometric approach, based on assessing behavior markers, is limited [1, 2]. This verbal-perceptual paradigm of diagnosing cognitive development delay in children requires both the high professionalism of the specialist as well as a parent's perception and awareness of the disease in reporting to a specialist [1]. Subsequently, parents should be aware of the early stages and understand the need for medical intervention. Another limitation appears from the incongruence between the dynamics of personal development and universal ranges of markers' application, which yields an extent of uncertainty in developmental diagnosis [1, 5]. Finally, in a multicultural environment (bilingual families, migrants, etc.), parents may not always fully explain behavior markers because of social, cultural, and linguistic differences [1]. Similar behavior patterns may have different meanings in different cultures and countries. Given all arguments, the classical psychometric approach can provide a medical diagnosis of a child's developmental delay by verbal-perceptual expertise of their skills only at school [1, 6-8]. There is serious concern regarding the computer-assisted future (automation of data collection and processing with computer tools) of methods based on this classical psychometric paradigm [9]. In addition to the limitations mentioned above, the impact of ecological context limits the application of this approach to computerized assessment at a distance. The classical psychometric methods are relative to the situation in which the child is being [9]. Testing a child without a specialist in an unpredictable environment limits an interpretation of the results. Several studies have been undertaken to develop new psychometric methods for diagnosing learning disabilities by observing early signs in the initial growth phase. For instance, early signs of mathematical learning difficulties can be detected by assessing problems in numeracy [10, 11]. However, even seeing early signs of developmental disabilities in children requires both the high professionalism of the specialist as well as a parent's perception and awareness of the disease in reporting to a specialist. In sum, the psychometric diagnosis of developmental disorders in children extracts data about behavior markers through observation, interviews, family history, and school reports [1]. Psychometric methods bear the limitations noted above, which stem from the nature of this paradigm – verbal-perceptual expertise of children's behavior markers. Assessment methods under the classical psychometric paradigm do not offer excellent prospects for developing a possible computer-aided tool for assessing cognitive development in young children. Even employing a computer, these methods under the psychometric paradigm are still based on the expertise of behavior markers by accomplishing the questionnaire.

1.2 Shared Intentionality for the Cognitive Development Assessment

Initially, shared intentionality was defined as collaborative interactions in which participants share psychological states [12-14]. Tomasello and colleagues developed the definition: cognition forms at the onset of life due to gradually increasing social bonds between children and caregivers beginning from the primary motive force of shared intentionality [15-17]. According to the received view, organisms assimilate the first cues in interaction with mature relatives during shared intentionality. A recent theoretical article argued that shared intentionality allows individuals in psychophysiological coherence to simultaneously choose the relevant stimulus from the chaos of irrelevant ones [18]. In the case of the fetus or newborn (organisms at the reflexes substage of the sensorimotor stage of development), it enables her to attribute this relevant stimulus to a proper reaction in the specific ecological context indicated by the contributor organism (mother) [18]. It is argued that shared intentionality allows organisms to perceive the cues and assimilate the meanings simultaneously with or before grasping perception [18]. Children' 's lack of interaction ability indicates a developmental delay [19-25]. Although the etiology of developmental disabilities is multifaceted (genetic, neurobiological, perceptual, and cognitive factors, etc.), the social interaction deficit is a critical factor in most developmental disabilities [1, 26].

According to Val Danilov et al. [1], an assessment of the shared intentionality magnitude can show cognitive development trajectory. This hypothesis uncovered a new research field for developing a new bioengineering paradigm for diagnosing cognitive development delays in children based on assessing shared intentionality in the mother-child dyads. In contrast to the classical psychometric paradigm, the new bioengineering paradigm induces human-computer interaction to implement psychophysiological coherence in the dyads by stimulating their ongoing interpersonal dynamics [1, 2, 9]. Under the new assessment paradigm, the bioengineering system shapes the "mother-newborn" model in the dyads for detecting comprehended (meaningful) interactions within these pairs via shared intentionality since this communication model eliminates other interactions via sensory cues within couples [1, 2, 9]. According to Val Danilov et al. [1], the mother-newborn communication model is a biological system in which the caregiver-child interactions can succeed without sensory cues between the contributor (mother) and the recipient (child). The bioengineering system can encourage shared intentionality in this model by prompting subjects with two-component stimuli: (i) unfamiliar tasks and (ii) a single harmonic oscillator [1, 2]. In specific, the methodological components of the previous research [1, 2] were:

Assessing objective: Shared intentionality was evidenced by increased performance above the random choice value.

The contributors (mothers) and the recipients (children) were an object of influence. The bioengineering system stimulated interpersonal dynamics in pairs using human-computer interaction to shape the mother-newborn communication model.

Stimuli enabled neurophysiological coherence in dyads by (i) unfamiliar tasks (unintelligible test items) and (ii) a single harmonic oscillator to enhance interpersonal dynamics in pairs. The smartphone generated low-frequency pulsed oscillations of 1.3 Hz (LF-PEMF with the frequency of impulses of 1.3 Hz) of waves length 400 nm violet and 700 nm red colors alternately [1, 2, 9]. The smartphone produced the stimuli and collected data [1, 2, 9].

The data collection process was based on the difference between the number of correct responses of subjects on unintelligible items and the random choice value. The original probability-based (PB) assessment method explained the outcome in probabilistic terms.

These research studies [1, 2] observed the differences in the shared intentionality magnitude in mother-child dyads with neurodivergent (ND) and neurotypical (NT) children. Research reported that ND and NT children solved unintelligible tasks more accurately than probability predicted [1, 2]. The improved performance (above chance) of all children could mean that the computer-dyad bioengineering system successfully emulated the mother-newborn communication model for stimulating shared intentionality in human pairs. Research presented evidence of interaction in human teams through shared intentionality [1, 2]. The outcomes of both studies [1, 2] showed the contrasting abilities of ND and NT children to interact via shared intentionality.

However, research [1, 2, 9] also highlighted the limitations of the original PB method developed under the bioengineering paradigm. Firstly, subjects' attention and motivation affect results [1, 2, 9]. Secondly, because this PB method assessed the psychological construct of a single individual based on probabilistic tools, its outcome could bear an extent of uncertainty due to a small volume of data [1, 2, 9]. Thirdly, the PB method did not consider the environmental and content impact on cognitive performance [1, 2, 9]. Finally, because many endogenous and exogenous factors affect the shared intentionality magnitude, it appears in human pairs only in some interpersonal dynamics and not always to the same extent. Therefore, accounting for each endogenous and exogenous factor loading is a problem for the former PB method [1, 2, 9].

1.3 The Research Scope

A recent theoretical study proposed a new computer-aided method under the bioengineering paradigm of assessment cognitive development [9]. The latest computer-aided approach encompasses the significant components of the PB computer-assisted one [9]. As the PB method, this new assessment method also emulates the mother-newborn communication model by employing human-computer interaction to detect shared intentionality in mother-child dyads [9]. The novelty of this new method lies in introducing the baseline value (BV) into computations [9]. It applies the new mathematical model and algorithm [9]. The BV assessment method is based on the data collection from the difference between the number of correct recipients' responses to the unintelligible items in the "primed" condition of contributors and those in the "unprimed" need of contributors. The theoretical study [9] argued that this enhancement could reduce the assessment method's shortcomings (content and context dependency as well as outcome uncertainty) within the bioengineering paradigm by decreasing the probabilistic tools' impact on the computation.

The current study examines the new BV method's measurement-specific fidelity rates. A high degree of fidelity to the intervention is critical to the reliability, validity, replicability, and scale-up of the results [27] of the further research study with a large sample size. The current research question is, can the measurement be delivered per this new BV method by obtaining children's results from the dyads-computer bioengineering system and comparing them with a baseline obtained without human-computer interaction? The article is outlined as follows. Section Materials and Methods describes the methodological components of the new BV computer-aided method. The results of the pilot study with 19 mother-child dyads are presented in Section 3. Section Discussion examines (i) the purpose and scope of the fidelity assessment, (ii) the essential components of the fidelity monitoring system, and (iii) the fidelity tool used for monitoring fidelity during the study. This section infers the fidelity rating of the proposed method. Finally, Section Conclusions summarizes all findings.

2. Materials and Methods

The pilot study experimentally tests the feasibility and analytically evaluates the fidelity rates of the new BV method. The fidelity rates assessment attempts to answer whether the results obtained by this new BV method are relevant to an evaluation of shared intentionality or casual. The method of the current study provides the experiment data analysis at the individual and organizational levels. The present pilot study's BV method pursues the goal of two previous research [1, 2] aimed to assess a shared intentionality magnitude in 3-to-6-year-old children. It applies the main methodological components of the original probability-based (PB) method within the bioengineering paradigm of diagnosing cognitive development delay. The assessing objective, the object of influence, and the stimuli of the new BV method are equal to the components of the former PB method. It also involves similar instrumental parts using the exact configuration of the bioengineering system. Only the data collection process differs from the old method since the new BV method introduces the baseline value (BV): the primary indicator of the new way. BV is computed from recipients' answers in the condition of unprimed contributors in two sessions, $b1$ and $b2$ (Equation 1). Therefore, the data collection extracts information from the result difference between the number of correct recipients' responses to the unintelligible items in the "primed" condition of contributors ($O1$ and $O2$) and those in the "unprimed" need of contributors (Equation 2).

$$bv = b1 + b2 \tag{1}$$

$$\Delta bv = (O1 + O2) – (b1 + b2) \tag{2}$$

3. Results

This BV is computed from the two successive baseline measures $b1 + b2$. The outcome of each child is derived from the differences between 5 BV items and 5 primed items of the first session and 5 BV items and 5 primed items of the second one (Equation 2). The values $\Delta ch(pr)$ and Δch are calculated to check whether the results are casual or associated with the implicit variable of shared intentionality (above zero means the "shared intentionality" effect).

$$\Delta ch(pr) = (O1 + O2) - P(10) \tag{3}$$

$$\Delta ch = (O1 + O2 + b1 + b2) - P(20) \tag{4}$$

The P(10) and P(20) values mean that the event occurs precisely k times out of n independent trials. They are derived from the Bernoulli equation (5). It shows the probability of some events (correct answers) made in independent trials, where: C – number of combinations n by k; p – the possibility in each task; n – independent trials (tasks), the probability of each is p (0 < p < 1); k-events, how many studies the child answers correctly; q = 1 - p.

$$P(k) = C^k p^k q^{n-k} \tag{5}$$

The *R* coefficient means a child's result deviation from the BV value; the higher its positive value, the stronger the mother-child shared intentionality (Equation 6). The expected value *X*(*e*) is equal to the BV value $b1 + b2$ (Equation 1), and *X*(*o*) is equal to the observed results in two sessions $O1 + O2$. The results are in Table 1.

$$R = \frac{1}{n}\sum_{n=0}^{n}\frac{\left(X(o) - X(e)\right)}{X(e)} \tag{6}$$

Table 1 The results.

ID	Child	First session *O1/b1*	First session *O2/b2*	Δ*bv*	*Rbv*	Δ*ch(pr)*	Δ*ch*
1	Boy 5y.6m. ND	3/0	2/1	4	4	3	1
2	Girl 6y. ND	1/0	2/2	1	0.5	1	0
3	Boy 6y. ND	1/1	3/1	2	1	2	1
4	Boy 4y. ND	2/0	Refused	2	-	1	0
5	Boy 3y.6m. NT	2/1	0/2	-1	0	0	0
6	Boy 3y.6m. NT	0/1	2/1	0	0	0	-1
7	Girl 4y.	0/0	1/1	0	0	-1	-3

	NT						
8	Girl 4y.6m. NT	2/1	2/3	0	0	2	3
9	Girl 5y. NT	1/1	2/3	-1	-0.25	1	2
10	Girl 4y. NT	2/3	1/1	-1	-0.25	1	2
11	Boy 4y.6m. NT	0/2	2/2	-2	-0.5	0	1
12	Girl 4y.6m. NT	1/1	3/2	1	0.33	2	2
13	Boy 4y. NT	3/3	2/1	1	0.33	3	3
14	Boy 6y. NT	1/3	1/1	-2	-0.5	0	1
15	Boy 3y.6m. NT	2/2	0/2	-2	-0.5	0	1
16	Boy 5y.6m. NT	2/2	2/2	0	0	2	3
17	Boy 5y. ND	2/1	0/1	0	0	0	-1
18	Boy 4y.6m. NT	0/2	1/0	-1	-0.5	-1	-2
19	Boy 5y.6m. NT	2/2	1/1	0	0	1	1
	Mean ND			1.8	1.1	1.4	0.25
	Mean NT			-0.57	-0.13	0.71	0.92

4. Discussion

Fidelity is defined as the degree to which the research study implements variables as intended by the research design [27]. Measuring and maintaining fidelity is critically important in research studies to confirm that the intervention is being delivered as it was designed and intended [27]. The fidelity rates are essential in the method's progress, revealing the relationships between the intervention and the intervention outcomes [27]. This knowledge allows future research to improve the process relevant to the aim and scope of the study. This section provides a fidelity assessment of the crucial components of the current pilot study. Finally, it infers the fidelity rating of the proposed method and discusses the limitations of the recent research study.

4.1 The Fidelity Assessment

4.1.1 The Purpose and Scope of the Fidelity Assessment

The fidelity assessment rates the current intervention research study that deals with the implicit psychological construct of shared intentionality. Therefore, it should ensure that the results can be accurately attributed to assessing this psychological construct. The central question is: whether the results obtained by this new BV method are relevant to an assessment of shared intentionality or casual. Due to the purpose of the fidelity assessment, we operate with data of two levels. First, we analyze data at the individual level to rate specialists' competence in providing the procedure as intended and subjects' responsiveness. At the organizational level, we are concerned with the data obtained from the research outcome and organizational variables showing the procedure's adherence to the research purpose. From the perspectives of these two levels, we observe the essential components of the current fidelity monitoring system: the process, the content and subjects responsiveness. Our rating system is based on binary scores "Positive"/"Negative" because we currently do not know and cannot assess all factors that impact the shared intentionality magnitude. The correct and rigorous assessment of the fidelity markers of the assessing cognitive development method is an issue of further research. However, three markers we evaluated were "positive with limitations" (PwL). We explain why we estimate the second, eighth, and ninth markers.

4.1.2 Components of the Fidelity Monitoring System

Process. The bioengineering system can only assess the implicit psychological construct of shared intentionality in the mother-newborn communication model. Therefore, the first marker of the fidelity rating is procedure adherence to this communication model. During testing, we controlled whether the research procedure fitted the features of this model. Only in the case of the procedure's adherence to the mother-newborn communication model, the obtained results could show scores of the shared intentionality magnitude. We rate each trial by binary scores for this marker: “Positive”/“Negative”. Because all current research tests adhere to this requirement, this marker shows that this bioengineering system assessed shared intentionality (Table 2).

Table 2 The fidelity assessment rates of the BV Method for Assessing Children's Cognition in Bioengineered Systems (PwL means positive with limitations).

Fidelity Markers	Assessing Component	Description	Rate
1	Process	Procedure adherence to the mother-newborn communication model	Positive
2	Process	Consistency of the procedure to the research problem from the perspectives of obtained results	PwL
3	Process	Result's relevance to shared intentionality using probabilistic values derived from the Bernoulli equation	Positive
4	Process	Consistency of the procedure to the research	Positive

		problem comparing with other relevant research	
5	Process	Intervention specialists' competence: level of training, education, and experience	Positive
6	Content	Subjects'''' adherence to the content	Positive
7	Subjects Respons-iveness	Children's engagement at the beginning of the testing	Positive
8	Subjects Respons-iveness	Children's engagement during testing	PwL
9	Subjects Respons-iveness	Children's motivation during testing	PwL

The second marker shows the consistency of the procedure to the research problem from the perspectives of obtained results. The current pilot study experimented with an extended pilot group (n = 19). Five children were diagnosed with a cognitive development delay. The outcome of one ND child (ID17) shows zero effect of shared intentionality. While another ND subject (ID04) refused to pass the second trial, her results and the results of all other NT children fit the hypothesis: ND children show an increased ability to communicate via shared intentionality than NT children. The average results of these ND (with a deviation of 20%) and NT groups are consistent with the expected outcome. However, the data collection process provides a small volume of data that needs to be improved to analyze data obtained from the nonlocal interaction of nonlinear dynamical systems (see subsection 4.3.3). While the BV method of collecting data adheres to the purpose of the fidelity assessment, the scope of the collection data process does not ensure the data power and high precision in estimates. One-time data collection in the BV method does not prompt obtaining an acceptable measure of information. Therefore, we rate this procedure as 'positive with limitations' (PwL) because of constraints in assessing this psychological construct (Table 2).

We estimated the consistency of the procedure to the research problem in probabilistic terms. Specifically, the third marker accounts for the result's relevance to the shared intentionality magnitude by calculating the values $\Delta ch(pr)$ and Δch (Equations 3 and 4, also see Table 1) using probabilistic values derived from the Bernoulli equation (Equation 5). To our mind, these values can show whether or not the results are relevant to the implicit variable of shared intentionality from the perspective of probability. The outcome above zero means the "shared intentionality" effect, and about (or below) zero means random or no effect. The mean scores of both values show a significant increase of these values above zero, indicating the non-random outcome of the research (Table 2).

While the fourth marker also estimated the consistency of the procedure to the research problem accounting for probabilistic terms, it gathers relevant information from similar research for providing a comparative analysis of obtained results. The previous research studies [1, 2] showed the average values of *R*-effect for ND 3-to-6-year-olds children 0.62 and 0.69 and the average values of *R*-effect for NT children of 0.09 and 0.25, which means an increase of 6.8 and 2.8 times in the value of shared intentionality in children with ND. The current study shows an increase of 9.4 times in the shared intentionality magnitude in ND children. The comparison with previous similar research [1, 2] shows the consistency of their outcomes. Therefore, the fourth marker is positive.

At the individual level, the fifth marker shows whether the intervention specialists provided the procedure as intended, indicating their competence: level of training, education, and experience. We estimate specialists as competent, responding "Positive" in binary scores: "Positive"/"Negative".

These five markers can mean the consistency of the process with the research purpose of assessing the implicit psychological construct of shared intentionality during the MBV method experiments.

Content. In the individual level of interactions between subjects and testing items, one of the central questions of the fidelity measurement is the content, i.e., what we ask subjects for subjects-the informational part of the intervention. The content of the intervention is an active ingredient that the research seeks to deliver to its recipients [27, 28]. Adherence to the scope is often considered the primary objective in measuring fidelity [27-29]. The current pilot study engaged children in the game during testing. Before testing, the specialist told the child a short fairy tale, asking her to help Wizard Letterin with coloring letters. During testing, the computer soft presented the dyad ten tasks connected to this story. This game allowed for engaging children in the content of test items with a high degree of involvement. The subjects' adherence to the range is the sixth marker of the fidelity rating that we rate as "Positive" (Table 2).

Subjects Responsiveness. Subjects' responsiveness shows participants' engagement in the intervention [30]. The BV research design installed in the procedure two fidelity tools used for monitoring fidelity during the study. These two parameters yield information for deriving two fidelity markers of subjects' responsiveness. During the experiments, the research design observed the extent of subjects' involvement in the procedure and comprehension of the content. This first fidelity tool was installed at the beginning of the testing. It encouraged children to count objects on the smartphone screen up to 10 before testing. This seventh marker of the fidelity rating shows the children's engagement at the beginning of the testing (Table 2). All children accurately counted objects. Therefore, we estimate this binary marker as "positive" for all trials. Second, another monitoring tool observed children's engagement during testing. The research design verified the children's concentration by observing their attention during testing. It estimated children's attention by (a) visual monitoring, (b) the number of responses above seven from 10 of each session, and (c) a continuous sequence of responses to items. More than two missed responses in a row mean a decreasing subject's attention while testing. Therefore, we could estimate this eighth fidelity marker as "Negative", only if all these three elements of this marker (a, b, and c) are unfavorable. We do not meet such a trinity in any trial. We evaluate this marker as "positive with limitations" (PwL), which means that while we accept all results, this issue should be studied in further research.

The ninth marker reflects a child's motivation to each task, i.e., whether or not the new BV research design encourages enough children's motivation. The BV method design used short movies with fireworks between jobs to engage cause in subjects during testing (a total 9 spots in each session). We used these spots as entertainment for the kids that, to our mind, could motivate them to keep their attention to the tasks during the entire test. The experimental data of the current pilot study show that the fireworks spots are not a universal motivation. The analysis of visual monitoring of subjects during the testing shows that some of them lost engagement even while continuing to answer test items until the end. Even though we highlight this problem, we do not find a correlation between kids' attention to the spots and their performances. Therefore, we rate the ninth marker as "positive with limitations" (PwL), for the same reason as marker eight (Table 2).

Finally, we decided to reject any subject's outcome if all three Subjects Responsiveness markers (markers 7, 8, and 9) were negative since such an outcome might mean the loss of subjects' responsiveness. Although the analysis shows that some issues had borderline rates (only one positive marker out of three), we did not find a correlation between these deviations and the test results. However, this circumstance can impact the results of a further quantitative research study discussed in subsection limitations.

4.2 The Main Inferences

This small-scale study evaluated the fidelity rates of a new BV method of assessing shared intentionality for diagnosing cognitive development delay in young children. The analysis of fidelity rates by nine markers shows the feasibility (with the limitation) of testing this new BV method in further research with a large sample size. The second marker indicates that the scope of the collection data process needs to be extended for the data power and high precision in estimates. A dynamic data collection process with several data extractions in different environments can address this issue. Fidelity data provides an understanding of the relationship between the delivery quality and the intervention's effectiveness at the data analysis stage [27]. For developing realistic and measurable criteria for the method's progress and implementation, further research can establish qualitative indicators by applying these nine markers. Another block of the quantitative indicators can ensure method validity by monitoring the dynamic data collection process while observing a large volume of data. The definition of these indicators is the scope of further research.

While the research design examines the measurement-specific fidelity rates of applying the new BV method, it supports the hypothesis that the bioengineering system (computer-dyad) can encourage shared intentionality in human pairs by emulating the mother-newborn communication model. It also indicates the pre-perceptual nature of shared intentionality communication since it appears in this communication model. Even though the method for assessing shared intentionality needs to be tested in further research with a large sample size, the shared intentionality effect has already been observed in this small-scale study, especially considering the consistency of the outcome with the evidence of previous research [1]. The work of the current study demonstrates the contrasting abilities of ND and NT children to interact via shared intentionality. The BV method shows a significant increase of 9.4 times (940%) in the value of shared intentionality in ND children above NT children (n = 19). The previous research [1] on the PB method showed an increase of 6.8 times in ND vs NT children (n = 15). The comparison indicates the relevance of the current study outcome. That is, comparing the BV research with relevant PB research shows the consistency of the product with previously obtained data. These research studies show a significant increase in shared intentionality value in ND children above NT children. Because of many factors that impact shared intentionality magnitude in children [1, 2, 9] and the small volume of data, an in-depth analysis of these data does not provide more information than those we already obtained about significantly increased shared intentionality magnitude in ND children in research under the bioengineering paradigm.

The state-of-the-art methods (psychometric) of diagnosing cognitive development delay in children are biased tools limited by at least three following issues [9]. (a) These verbal-perceptual methods require both the high professionalism of the specialist as well as a parent's perception and awareness of the disease in reporting to a specialist [1, 2, 9]. (b) Behavior markers are not a universal tool [1, 2, 9]. (c) The multicultural environment limits communication between parents and specialists, which is essential for diagnosing [1, 2, 9]. Therefore, assessment methods under the classical psychometric paradigm offer poor prospects for developing a possible computer-assisted diagnostic tool. In contrast, the computer-aided BV method of assessing cognitive development under the bioengineering paradigm successfully addresses the challenges noted above since it provides an unbiased procedure and reduces ecological factors [1, 2, 9].

The methods of the cognitive development assessment under both the psychometric paradigm (e.g., Behavioral Observation of Students in Schools-Early Childhood (BOSS-EE) [31]; Behavior Assessment System for Children Student Observation System (BASC-3 SOS)[32]; Direct Behavior Rating (DBR)[33]; Revised School Observation Coding System (REDSOCS)[34]; Systematic direct observation (SDO)[35]; Sutter-Eyberg Student Behavior Inventory (SESBI-R)[36]; the Preschool Observation Code (POC)[37]) and the bioengineering paradigm (PB and BV methods) evaluate the same psychological construct applying the different data collection processes and computation. The methodological difference and common aim enable an opportunity to join both approaches in one diagnostic protocol to improve assessing validity.

4.3 Limitations

4.3.1 Limitation of the BV Method

The current BV method assesses shared intentionality, which relates to the caregiver's intentionality in the case of mothers and their 3-6-year-old children. The assessing test consists of a set of unintelligible tasks of the same type. Two reasons challenge the BV research design efficiency, doubting the ability of 3-6-year-old children to be attentional while responding to the whole test procedure out of 10 unintelligible items in each session.

First, unintelligible tasks decrease performance. Recent research revealed task difficulties [38-40] and limited feedback reduce performance [41, 42]. This may mean that only the initial items from the row of similar unintelligible tasks can engage the child's intentionality due to their novelty. If items are the same type, the child's intentionality towards these unintelligible tasks can disappear after several attempts without feedback. So, while the research design requires unintelligible tasks for emulating the mother-newborn communication model in subjects, repeating these tasks decreases performance.

Second, monotonous tasks can tire young children, causing tests to be challenging to complete. For them, 10 items of the same type of task (moreover unintelligible) are not too attractive to keep their attention during the entire test. There is a broad consensus about concentration as a state in which cognitive resources are focused on certain aspects of the environment rather than others [43]. In contrast to unaware intentionality, such a concentration of awareness on tasks would engage a child's intention during testing despite the problem of unintelligible tasks. However, while the attention span in children grows, the scope of a child's attention at this developmental stage is limited by about 20 different objects in 10 minutes. Research on 2,5 and 3,5-year-old children's voluntary attention spans showed a significant difference in frequency (12 and 20 episodes, respectively) and duration (78 s and 154 s, respectively) of attention episodes during 10 minutes of free play [44]. This difference in 3,5 and 4,5-year-old children is insignificant: 20 and 22 episodes, respectively, and duration of 154 s and 180 s, respectively [44]. Due to these findings, we designed our two-stage assessment test consisting of two quizzes with 10 tasks of 5 minutes each. However, in contrast to Ruff and Lawson's [44] attention span study with different items, all of our research design items were of the same type of task. During testing, we could only ask subjects for the same kind of tasks during the entire test. We could not change the task type because of the research problem of assessing shared intentionality by observing the result difference between two conditions of contributors. The items must be the same type of task throughout the test. Since the task type did not differ from one thing to another, the children's attention to the items throughout the quiz could have decreased. As intended, the research design stimulated children's motivation through the fairy tale context of the tasks, motivationally relevant stimuli, and video entertainment (9 spots in each session). Cause is linked with performance [1, 2, 9]. However, the research design did not account for the extent of basis during testing. Therefore, we cannot be sure that children were attentional while responding during the procedure. Therefore, further research can only provide a sophisticated performance analysis if the research design ensures the assessment of subjects' attention and motivation.

4.3.2 Limitation of the BV Method 2

Biomedical signals are small; they reach the sensors attenuated and with noise. There is a need for amplifiers that are used to amplify the signals [45]. However, the amplifier's increasing adequate capacity can reduce the bandwidth of the amplifier, restricting its range of operation and decreasing data. Data are the facts or details (obtained from measurements) from which information is derived. The losing information problem emerges due to amplifier and noise issues and a knowledge gap about the context, e.g., factors of the observation object, observer, and measuring processes. Noise reduction using various filtering techniques is a solution that benefits biomedical systems by collecting and processing a large amount of data. However, this solution leads to dealing with the extended data set. Therefore, when obtaining an enormous measure of data, biomedical systems tend to work with fewer qualities that describe the applicable properties of the signal [46-48]. Feature extraction can be characterized by an activity that changes one or a few signals into a feature vector [48]. Biomedical systems use sophisticated algorithms to decompose signals into wavelets for their translations and scaling [48]. The big data processing and the multi-level factors of estimates pose another issue of data classification that different machine learning algorithms manage (e.g., support vector machine [48]). Because biomedical systems deal with an enormous volume of data obtained from biomedical signals, they use software frameworks (e.g., Hadoop [47]) to store these data.

The current pilot study on the fidelity rates of the BV method manages a small volume of data. The BV method demands subjects to solve 10 unfamiliar items (n = 19). It extracts information from the result difference between the number of correct recipients' responses to the unintelligible items in the "primed" condition of contributors (mothers) and those in the "unprimed" need of contributors. However, the attention of young students for more than 10 items in 5 minutes is challenged, as we noted above in the limitation of the BV method 1 (unintelligible and monotonous tasks decrease performance). Therefore, we limit the experiment to only 10 items. The sample size of the pilot study is also small; we observed only five ND children. This small data is insufficient for in-depth analysis. Despite the advantages of small data, such as easier visualization, inspection, and understanding of the results, small datasets cause lower precision in estimates and power than extensive data. This limitation of assessing shared intentionality does not allow for an in-depth comparative analysis between the former PB and BV methods. In the second mark of the fidelity rates, we note that future research needs to introduce the dynamical data collection process for the data power and high precision in estimates and relevant sophisticated algorithms.

4.3.3 Limitations of the Bioengineering Diagnostic Paradigm

According to the received view, the human brain is a complex nonlinear system for review e.g., [49-52]. Due to the continuous development, this complex nonlinear system is also dynamic. The assessment methods of cognitive functions manage data of the complex nonlinear dynamical system. While the PB and BV methods within the bioengineering paradigm do not assess children's intelligence, they evaluate one of the cognitive functions - shared intentionality [1, 2, 9, 18] - dealing with data obtained from the complex nonlinear dynamical system.

As it is conventionally accepted, cognition forms at the onset of life due to gradually increasing social bonds between children and caregivers beginning from the primary motive force of shared intentionality [15-17]. Shared intentionality is implicit interaction within the mother-newborn communication model; this pre-perceptual communication appears without sensory cues [1, 2, 9, 18, 53, 54]. Again, it is an interaction between the mother and her child at the simple reflexes substage of the sensorimotor stage of cognitive development when communication via sensory cues is impossible. Indeed, organisms with only simple reflexes can assimilate the first cues in interaction with mature relatives, which succeeds due to shared intentionality [1, 2, 9, 15-18, 53, 54]. The bioengineering system emulates the mother-newborn communication model in older children (3- to 6-year-olds) to observe shared intentionality. The shared intentionality assessment is not provided by biomedical signals collected from a body (at the organ, cell, or molecular levels). This bioengineering system individuals' aware responses to unfamiliar tasks that children (3- to 6-year-olds) perform due to shared intentionality. It is assumed that this interaction appears in coordinated neuronal activity due to a single electromagnetic oscillator [1, 2, 9, 18, 53]. The nonlocal coupling of neurons provides shared intentionality between the contributor and recipient (the mother and newborn, respectively) [18]. This hypothesis of nonlocal coupling of neurons can rely on two different assumptions (that can also be concomitant) [9]. First, low-frequency electromagnetic oscillations can simultaneously alter membrane ion channel function [55] in both organisms. According to Premi et al. [55], low-frequency electromagnetic oscillations act primarily at the synapse level, altering membrane ion channel function. It is proposed that Ca^{2+} and Na^{+} channel activity can be perturbed by magnetic fields, considering the diamagnetic anisotropic characteristics of membrane phospholipids [55]. Second, low-frequency oscillations can mediate an increase in A(2A) adenosine receptors simultaneously in the contributor (mother) and the recipient (child). Low-frequency oscillations mediate a transient and significant increase in A(2A) adenosine receptors' neuronal communication [56]. Adenosine modifies cell functioning by operating G-protein-coupled receptors (GPCR; A(1), A(2A), A(2B), A(3)) that can enhance neuronal communication [56] since A(2A) has a vital role in the brain, regulating the release of other neurotransmitters such as dopamine and glutamate. Interactions between adenosine receptors and other G-protein-coupled receptors, ionotropic receptors, and receptors for neurotrophins also occur, contributing to a fine-tuning of neuronal function [56]. This nonlocal coupling of neurons may provide a template for training immature nervous systems for multisensory integration [18] (for review, see [18]).

Therefore, the bioengineering paradigm of diagnosing cognitive development delay in children deals with the implicit variable of shared intentionality, which emerges in interaction through nonlocal coupling between two nonlinear dynamic systems. It employs human-computer interaction to stimulate psychophysiological coherence in subjects but not to collect data at the organ, cell, or molecular levels for processing. While this bioengineering paradigm deals with nonlinear and nonlocal dynamical systems, other biomedical measuring systems obtain data adhering to principles of locality and linearity. Even though some biomedical systems use nonlinear system analytic tools, they still receive linear signals applying the nonlinear analysis apparatus to avoid the losing information problem mentioned in limitation 2. This particularity of the bioengineering paradigm of assessing cognition means that while it should manage similar problems that general biomedical systems address, such as the losing information problem, it also deals with the additional issue of dynamic data obtained from the nonlocal coupling between two nonlinear dynamical systems. Therefore, a sophisticated math model for computing the dynamic data should be implemented to improve data robustness and method validity, which is the scope for further research. Table 3 highlights the main characteristics of the assessment paradigms, demonstrating the difference between psychometric methods (BOSS-EE [31]; BASC-3 SOS [32]; DBR [33]; REDSOCS [34]; SDO [35]; SESBI-R [36]; POC [37]) and PB and BV methods of assessing cognitive development delay in children.

Table 3 The difference between the two paradigms of diagnosing cognitive development delay in children.

	The psychometric paradigm	The bioengineering paradigm	
Methods	Questionnaires: BOSS-EE, BASC-3 SOS, DBR, REDSOCS, SDO, SESBI-R, POC	The computer-aided PB method of assessing shared intentionality	The computer-aided BV method of assessing shared intentionality
Data collection processes	The estimation of the children's behavior markers by filling out a questionnaire by a specialist together with parents	Computing a shared intentionality magnitude from the difference between the number of correct responses and the random choice value	Computing a shared intentionality magnitude from the difference between the number of correct responses and baseline
Limitations	1. It requires the high professionalism of the specialist and a parent's competence in reporting	1.Effect of subjects' attention and motivation on results.	1.Effect of subjects' attention and motivation on results.

	2. Behavior markers are not a universal tool. 3. The multicultural environment affects results	2.Small volume of data. 3.Effect of environment and content on results. 4.Endogenous and exogenous factors of shared intentionality	2.Small volume of data.

5. Conclusions

The pilot study conducted the experiment within a new bioengineering paradigm of diagnosing cognitive development delay in children based on evaluating shared intentionality in the mother-child dyads. The state-of-the-art methods (psychometric) of analyzing cognitive development delay in children are the biased tool (a questionnaire) limited to at least three following issues. (a) These verbal-perceptual methods require both the high professionalism of the specialist as well as a parent's perception and awareness of the disease in reporting to a specialist. (b) Behavior markers are not a universal tool. (c) The multicultural environment limits communication between parents and specialists, which is essential for diagnosing. Therefore, methods under the classical psychometric paradigm offer poor prospects for developing a possible computer-assisted diagnostic tool. In contrast, the computer-aided BV method of assessing cognitive development under the bioengineering paradigm successfully addresses the challenges noted above since it provides an unbiased data collection procedure and reduces ecological factors. Under the new assessment paradigm, the bioengineering system shapes the "mother-newborn" model in the dyads for detecting comprehended (meaningful) interactions within these pairs via shared intentionality since this communication model eliminates other interactions via sensory cues within teams.

The current small-scale study (n = 19) was designed to assess the fidelity of the new computer-aided method of assessing cognitive development in young children. It evaluated a shared intentionality magnitude in 3- to 6-year-old children as in two previous research [1, 2]. The current pilot study applied the main methodological components of the former probability-based research studies based on the same bioengineering paradigm. The novelty of this study was introducing the baseline value (BV) into computations. The BV assessment method was based on the data collection from the result difference between the number of correct recipients' responses to the unintelligible items in the "primed" condition of contributors and those in the "unprimed" need of contributors. The fidelity rates showed the feasibility of testing this new method in further research with a large sample size. These fidelity rates highlighted several limitations that future research should address for progress in the method development.

This research study observed the differences in the shared intentionality magnitude in mother-child dyads with neurodivergent (ND) and neurotypical (NT) children. Research presented evidence of interaction in human pairs through shared intentionality. The outcome of the study showed the contrasting abilities of ND and NT children to interact via shared intentionality. It showed an increase of 9.4 times (940%) in the value of shared intentionality in ND children. The comparison with relevant research [1] under the same research paradigm showed the consistency of this outcome with previously obtained data.

The psychometric and BV methods (within the bioengineering paradigm) evaluate the same psychological construct by observing the indicators and applying different data collection processes and computations. The methodological difference and common aim enable an opportunity to join both approaches in one diagnostic protocol to improve assessing validity.

Acknowledgments

Many thanks to RPPC specialists Haykanush Dilanyan and Yana Karapetyan that have technically supported this work.

Author Contributions

Igor Val Danilov conceived and designed the research design. Sandra Mihailova and Araksia Svajyan reviewed the research design and gave valuable remarks. Igor Val Danilov and Araksia Svajyan coducted the experiments. Igor Val Danilov formulated the hypothesis and wrote the first draft of the manuscript. Igor Val Danilov, Sandra Mihailova and Araksia Svajyan improved the text over several iterations.

Competing Interests

The authors have declared that no competing interests exist.

References

1. Val Danilov I, Mihailova S, Svajyan A. Computerized assessment of cognitive development in neurotypical and neurodivergent children. OBM Neurobiol. 2022; 6: 18.
2. Val Danilov I. A bioengineering system for assessing children's cognitive development by computerized evaluation of shared intentionality. Proceedings of International Conference on Computational Science and Computational Intelligence (CSCI); 2022; Las Vegas, NV, USA.
3. EDJNet. The European data journalism network [Internet]. 2018 [cited date 2023 March 15]. Available from: https://www.europeandatajournalism.eu/News/Data-news/Mental-illness-costs-Europe-600-billion-euro.
4. SSDIG. Social Security Disability Insurance (SSDI) guide [Internet]. 2022 [cited date 2023 March 15]. Available from: https://eligibility.com/social-security-disability.
5. Volkmar FR, Langford Booth L, McPartland JC, Wiesner LA. Clinical evaluation in multidisciplinary settings. In: Handbook of autism and pervasive developmental disorders: Assessment, interventions, and policy. New York: John Wiley & Sons, Inc.; 2014. pp. 661-672.
6. American Psychiatric Association. Diagnostic and statistical manual of mental disorders, fifth edition (DSM-5). Washington: American Psychiatric Association Publishing; 2013.
7. Young AR, Beitchman JH. Specific learning disorder. In: Gabbard's treatments of psychiatric disorders. 5th ed. Washington: American Psychiatric Publishing; 2014. pp. 77-92.
8. Kulkarni M, Kalantre S, Upadhye S, Karande S, Ahuja S. Approach to learning disability. Indian J Pediatr. 2001; 68: 539-546.
9. Val Danilov I. Advances in computer-aided diagnosis of developmental delay in children using bioengineering systems: A new math model and algorithm. In: Intelligent Communication Technologies and Virtual Mobile Networks. Singapore: Springer; 2023.

10. Jordan NC, Glutting J, Ramineni C. The importance of number sense to mathematics achievement in first and third grades. Learn Individ Differ. 2010; 20: 82-88.
11. Karagiannakis G, Baccaglini-Frank A, Papadatos Y. Mathematical learning difficulties subtypes classification. Front Hum Neurosci. 2014; 8: 57.
12. Gilbert M. On social facts. London: Routledge; 1989.
13. Searle JR. The rediscovery of the mind. London: MIT Press; 1992.
14. Tuomela R. The importance of us: A philosophical study of basic social notions. Stanford, CA: Stanford University Press; 1995.
15. Tomasello M, Rakoczy H. What makes human cognition unique? From individual to shared to collective intentionality. Mind Lang. 2003; 18: 121-147.
16. Tomasello M, Carpenter M, Call J, Behne T, Moll H. Understanding and sharing intentions: The origins of cultural cognition. Behav Brain Sci. 2005; 28: 675-691.
17. Tomasello M. Becoming human: A theory of ontogeny. Cambridge: Harvard University Press; 2019.
18. Val Danilov I. Theoretical grounds of shared intentionality for neuroscience in developing bioengineering systems. OBM Neurobiol. 2023; 7: 156.
19. Erikson EH. Childhood and society. New York: WW Norton & Company; 1993.
20. Winnicott DW. The child, the family, and the outside world [Internet]. Penguin UK; 1964 [cited date 2023 July 18]. Available from: https://www.goodreads.com/book/show/202755.The_Child_the_Family_and_the_Outside_World.
21. Gresham FM, MacMillan DL. Social competence and affective characteristics of students with mild disabilities. Rev Educ Res. 1997; 67: 377-415.
22. Cullinan D. Students with emotional and behavioral disorders: An introduction for teachers and other helping professionals. Upper Saddle River: Merrill/Prentice Hall; 2002.
23. Prior M, Ozonoff S. Autism and pervasive developmental disorders. Cambridge: Cambridge University Press; 2007. pp. 69-128.
24. Pierce K, Gazestani VH, Bacon E, Carter Barnes C, Cha D, Nalabolu S, et al. Evaluation of the diagnostic stability of the early autism spectrum disorder phenotype in the general population starting at 12 months. JAMA Pediatr. 2019; 173: 578-587.
25. Rojas-Torres LP, Alonso-Esteban Y, Alcantud-Marín F. Early intervention with parents of children with autism spectrum disorders: A review of programs. Children. 2020; 7: 294.
26. Grigorenko EL, Compton DL, Fuchs LS, Wagner RK, Willcutt EG, Fletcher JM. Understanding, educating, and supporting children with specific learning disabilities: 50 years of science and practice. Am Psychol. 2020; 75: 37.
27. Feely M, Seay KD, Lanier P, Auslander W, Kohl PL. Measuring fidelity in research studies: A field guide to developing a comprehensive fidelity measurement system. Child Adolesc Soc Work J. 2018; 35: 139-152.
28. Carroll C, Patterson M, Wood S, Booth A, Rick J, Balain S. A conceptual framework for implementation fidelity. Implement Sci. 2007; 2: 1-9.
29. Cross W, West J. Examining implementer fidelity: Conceptualising and measuring adherence and competence. J Child Serv. 2011; 6: 18-33.
30. Dane AV, Schneider BH. Program integrity in primary and early secondary prevention: Are implementation effects out of control? Clin Psychol Rev. 1998; 18: 23-45.

31. Hojnoski RL, Missall KN, Wood BK. Measuring engagement in early education: Preliminary evidence for the behavioral observation of students in schools-early education. Assess Eff Interv. 2020; 45: 243-254.
32. Reynolds CR, Kamphaus RW, Vannest KJ. BASC3: Behavior assessment system for children [Internet]. Bloomington: PscyhCorp; 2015. Available from: https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/10328287.
33. Christ TJ, Riley-Tillman TC, Chafouleas SM. Foundation for the development and use of Direct Behavior Rating (DBR) to assess and evaluate student behavior. Assess Eff Interv. 2009; 34: 201-213.
34. Fowler AM. Implementation of teacher child interaction training of at risk children in an urban school. Virginia Beach: Regent University; 2020.
35. Hintze JM, Volpe RJ, Shapiro ES. Best practices in the systematic direct observation of student behavior. Best Pract Sch Psychol. 2002; 4: 993-1006.
36. Kirkhaug B, Drugli MB, Mørch WT, Handegård BH. Teacher report of children's problem behavior on the Sutter–Eyberg Student Behavior Inventory—Revised (SESBI-R) in a Norwegian sample of preschool and school children. Scand J Educ Res. 2012; 56: 139-153.
37. Bramlett RK, Barnett DW. The development of a direct observation code for use in preschool settings. Sch Psychol Rev. 1993; 22: 49-62.
38. Huber VL. Effects of task difficulty, goal setting, and strategy on performance of a heuristic task. J Appl Psychol. 1985; 70: 492-504.
39. Wood RE, Mento AJ, Locke EA. Task complexity as a moderator of goal effects: A meta-analysis. J Appl Psychol. 1987; 72: 416-425.
40. Gellatly IR, Meyer JP. The effects of goal difficulty on physiological arousal, cognition, and task performance. J Appl Psychol. 1992; 77: 694.
41. Salmoni AW, Schmidt RA, Walter CB. Knowledge of results and motor learning: A review and critical reappraisal. Psychol Bull. 1984; 95: 355-386.
42. Cope P, Simmons M. Some effects of limited feedback on performance and problem-solving strategy in a Logo microworld. J Educ Psychol. 1994; 86: 368.
43. American Psychological Association. Attention [Internet]. Washington, DC: American Psychological Association; 2023 [cited date 2023 March 28]. Available from: https://dictionary.apa.org/attention.
44. Ruff HA, Lawson KR. Development of sustained, focused attention in young children during free play. Dev Psychol. 1990; 26: 85-93.
45. AlHinai N. Introduction to biomedical signal processing and artificial intelligence. In: Biomedical signal processing and artificial intelligence in healthcare. Cambridge: Academic Press; 2020. pp. 1-28.
46. Manoharan H, Selvarajan S, Yafoz A, Alterazi HA, Uddin M, Chen CL, et al. Deep conviction systems for biomedical applications using intuiting procedures with cross point approach. Front Public Health. 2022; 10: 909628.
47. Selvarajan S, Manoharan H, Hasanin T, Alsini R, Uddin M, Shorfuzzaman M, et al. Biomedical signals for healthcare using Hadoop infrastructure with artificial intelligence and fuzzy logic interpretation. Appl Sci. 2022; 12: 5097.
48. Manoharan H, Haleem SL, Shitharth S, Kshirsagar PR, Tirth V, Thangamani M, et al. A machine learning algorithm for classification of mental tasks. Comput Electr Eng. 2022; 99: 107785.

49. Blumenfeld H. Brain mechanisms of conscious awareness: Detect, pulse, switch, and wave. Neuroscientist. 2023; 29: 9-18.
50. Long LN, Kelley TD. Review of consciousness and the possibility of conscious robots. J Aerosp Comput Inf Commun. 2010; 7: 68-84.
51. Kurzweil R. The singularity is near. In: Ethics and emerging technologies. London: Palgrave Macmillan UK; 2005. pp. 393-406.
52. Walling PT, Hicks KN. Dimensions of consciousness. Proc (Bayl Univ Med Cent). 2003; 16: 162-166.
53. Val Danilov I. Smartphone in detecting developmental disability in infancy: A theoretical approach to shared intentionality for assessment tool of cognitive decline and e-learning. In: Science and Information Conference. Switzerland: Springer Nature; 2022. pp. 305-315.
54. Val Danilov I, Mihailova S. A new perspective on assessing cognition in children through estimating shared intentionality. J Intell. 2022; 10: 21.
55. Premi E, Benussi A, La Gatta A, Visconti S, Costa A, Gilberti N, et al. Modulation of long-term potentiation-like cortical plasticity in the healthy brain with low frequency-pulsed electromagnetic fields. BMC Neurosci. 2018; 19: 34.
56. Ribeiro JA, Sebastião AM, de Mendonça A. Adenosine receptors in the nervous system: Pathophysiological implications. Prog Neurobiol. 2002; 68: 377-392.