



# Short- and Long-Term Effects of Passive and Active Screen Time on Young Children's Phonological Memory

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The purpose of this study was to fill this gap by examining the relationship between phonological memory in preschool children and their passive (watching TV) and active screen time with using of Smart Screen Technologies such as tablets and phones with a touch screen interface. Study was conducted in two stages: in Time 1, the association between children's phonological memory, passive and active screen time and family factors was examined; in Time 2 (1 year later) the impact of passive and active screen time on a child's individual progress in phonological memory development was evaluated. The study enrolled 122 preschool children aged 5–6 years ( $M = 5.72$ ,  $SD = 0.33$ ); boys (54.9%). Information on each child's average daily passive and active screen time was obtained from a survey with the mother. The survey provided information on how much time each child spent on a typical day with passive ("traditional") and active (interactive) use of digital devices. For family factors, we included maternal highest educational qualification, family's financial situation. For children's characteristics, age, gender and non-verbal fluid intelligence were included. The results indicate that time spent passively with digital devices (watching TV) is negatively related to a child's ability to process verbal information. In contrast, the interactive time the child spent with Smart Screen Technologies is not significant and does not pose a threat to the development of phonological memory in preschool age. The study also showed that passive and active use of digital devices has no long-term impact on children's phonological memory development progress over a year. The implications are that use of Smart Screen Technologies, which implies a higher degree of interactivity, is not associated with either short- or long-term negative effects on phonological memory development in preschool age, contrary to passive screen time exposure. The results can be applied in the elaboration of principles and programs on the use of digital devices for the entertainment and education of preschool children.

**Keywords:** screen time, television exposure, preschool age development, phonological memory, smart electronic devices

## INTRODUCTION

The development of speech and literacy occurs primarily through communication and interaction with adults and peers (Vygotsky, 1978). Preschool age is also the age of active play, which has traditionally been a field for the development of a child's social skills, in particular, the development of speech and literacy (Smirnova, 2016). The fascination of modern children with television or smart electronic devices leads to a reduction in the time of communication and play of a child, which inevitably reflects in the developmental outcomes. Children's consumption of media and technology begins at an early age, while watching television is still the favorite way of consuming technology among children (Gutnick et al., 2010). However, there are smart electronic devices (tablets and smartphones) that are also actively used by children (Papadakis et al., 2019). It is quite obvious that these forms of screen time do not involve children in the same way and their impact on development is different, therefore we consider watching television as passive screen time, and the interaction with smart electronic devices as an active screen time (Sweetser et al., 2012). In addition, this interaction often replaces real communication, therefore, identifying the developmental outcomes of preschool children exposure to television and smart screen technologies should be considered in speech and literacy context of development.

The development of speech in preschool age is characterized by active and intense process: a child is faced with the task of expanding the active vocabulary which grows considerably in the preschool period, as well as improving the quality side of the speech system (Luria and Yudovich, 1971). In particular, the semantic content of words is learned, and more complex language grammatical structures are assimilated. The origin and development of speech directly depend on the social environment where a child is brought up (Piaget, 1954; Vygotsky, 1978). Speech begins to develop at an early age in conditions of active interaction with adults, which means both direct communication and imitation to master the correct forms of language. Parents act as a traditional agent and driving force for the development of speech, and it is the features of child-parent relations that are directly related to characteristics of both the development of the child in general and the development of speech, in particular.

Parent-child relations transform in accordance with cultural and social changes, where special attention is paid to the interaction of children with electronic devices (Chonchaiya and Pruksananonda, 2008), starting from a very early age. At the present time, the active (via smart screen technologies) and passive (via watching television) consumption of technologies by children largely depends on parental attitudes toward smart electronic devices. This issue is a particular problem in today's science, since there are cases when a child's interaction with smart electronic devices supplants to one degree or another real communication with parents and peers, which, in turn, may affect the formation of the child's personality and individual mental functions (Clarke and Kurtz-Costes, 1997). The children use of electronic devices may be conditioned by different parental beliefs, among which we can highlight the fact that some parents are afraid of children's lag behind their peers

(Martens et al., 2018), as well as the importance of the modern technology employment in preschool age to improve and enrich the learning process (Eisen and Lillard, 2017), along with this there are tough opponents of the use of smart electronic devices by children. Parents' own enthusiasm and confidence in using smart devices is associated with the idea that there are more benefits than disadvantages in children use of smart electronic devices (Mascheroni et al., 2016). Most often, children prefer tablets than other electronic devices due to their widespread use, ergonomic design, as well as the attractive and various sensory stimulation, which results attractive for children of preschool age. Furthermore, in general, children are engaged in watching videos or playing with various applications. At the present time there are thousands of free and paid mobile applications that are announced to be educational applications for kids, but parents tend to prefer those that teach kids math and literacy skills. For instance, many parents in Greece perceive technological development as beneficial and use it to support, enhance and enrich the developmental environment, however, they want to study more themselves about these specific applications in order to select those that are truly useful, thus demonstrating a general positive attitude toward the use of electronic devices (Papadakis et al., 2019). There are cultural differences regarding parental attitudes concerning their children's use of smart electronic devices. For example, a study of South Korean families revealed negative parental attitudes based on fears of potential psychological problems and physical effects due to parent's belief that children are overly attached to smart electronic devices (Seo and Lee, 2017).

The moment of acquaintance of children with electronic devices is shifting every year to an ever earlier moment of development: on the one hand, they can act as a means of children's development, and on the other hand, as a source of entertainment and distraction, so while the child spends time with the smart electronic device, parents free up time for themselves. In some cases, such pastime with a television, tablet or mobile phone can take up a significant part of the child's time, which reduces the amount of time that could be devoted to interacting with parents or peers and affects communication skills (Duch et al., 2013). Replacing the child's social contacts with individual pastime with electronic devices can lead to speech development disorders, and cause problems with adaptability of behavior in general (for review, see Kostyrka-Allchorne et al., 2017). The described cases of social deprivation of children and the irreversibility of the consequences emphasize the importance of this problem. So far, language development is poorer at an early age if the child watches more television (Zimmerman et al., 2007), which is confirmed by longitudinal studies (Barr et al., 2010). The motivation for active exploration of the environment in early childhood and preschool age pushes the child's development and, in particular, his/her speech development, since the child has a need to express his/her needs and to be understood, and this, in turn, requires the development of speech and literacy.

A significant amount of research was conducted on the impact of children's interactions with electronic devices on cognitive and emotional development. In a study by Radesky et al. (2015), which monitored the interaction of mothers and their children,

it was found that mothers who used mobile devices during this observed experiment interacted significantly less with their children during the process, which refers to verbal and non-verbal manifestations as well as encouragements to the children. A large number of studies showed that there is an influence of passive consumption of media content through watching television on the emotional development of children, and more specifically, there is such a negative outcome as aggression (for review, see Anderson et al., 2003). Viewing scenes of violence and cruelty by preschool children causes an increase in aggression manifestation of all kinds in boys and verbal aggression in girls. However, if the parents controlled the television consumption of their children, the repeated measure showed that such children showed significantly less physical aggression (Ostrov et al., 2006). Longitudinal studies confirm that viewing content with scenes of aggression in childhood is associated with higher levels of aggression in adulthood (Huesmann et al., 2003). The perception of such scenes is enhanced if the scenes are intense and the character has expertise and significance for the child, as well as if the target actions are repeated in the context of television content consumption (Prikhozhan, 2010).

Since all mental functions develop in a systemic and interconnected manner (Vygotsky, 1978), passive and active screen time also affects the cognitive sphere of the child. A study of cognitive performance (regulation, control, verbal, and visual-spatial functions) in the Russian sample of children and adolescents showed significant differences depending on their online activity (Soldatova and Vishneva, 2019). In preschoolers' group significant differences were observed in various neuropsychological trials and at the level of trends in the indices of processing of auditory information, so the group with low online activity outperformed the rest. Moreover, preschoolers with low digital activity demonstrated better results in storytelling task. In elementary school students and younger adolescents there were more differences according to digital activity, compared to preschool children, but unlikely, participants with average online activity (1–3 h a day) were the most productive when performing neuropsychological trials. Attention functions are also influenced by children's screen time: early television viewing is a significant predictor of attention problems in early school years (Christakis et al., 2004).

A particular research line is devoted to the analysis of the influence of screen time on executive functions among preschoolers. Preschool age is also characterized by the rapid development of executive functions, which are extremely important for academic success while entering school (Jacobson et al., 2011; Schwarz and Gawrilow, 2019). The development of speech and literacy in a child is inextricably connected with the development of executive functions, and there are at least two explanations for this connection (Veraksa et al., 2019). The first is due to the fact that executive functions expand the foundation for the intellectual development of a child and, in particular, an increase in working memory helps to facilitate the acquisition of speech. On the other hand, the development of regulatory functions is facilitated by the child's internal speech, which performs the planning function (Vygotsky, 1978). The passive consumption of technologies influence on the executive functions

finds contradictory data, so the question about the content of the programs arises again. Fantastical television content (Rhodes et al., 2020), such as cartoons, is rigorously studied because it distracts children and develop unrealistic expectations (Lillard and Peterson, 2011). As a consequence, children cannot consistently integrate new information into existing beliefs and representations. Watching fantastical television content had a generalized negative effect on executive functions, and impairments in working memory and planning were found in preschoolers (Rhodes et al., 2020). Longitudinal studies examined attention problems in the light of children's television exposure and found that childhood and adolescent television viewing is linked, and early childhood television exposure predicts attention problems in early school years (Christakis et al., 2004) and adolescence (Landhuis et al., 2007).

The relative stability of the pathways for the development of speech and literacy is laid in early childhood (Linebarger et al., 2004), where the socio-economic status of the family and the child's involvement in preschool activities play an important role. Since role-play activity is actively developing in preschool age, it is presented as an additional base for the development of a child's speech: elaboration of various role-play scenarios and participating in them, composing and memorizing game rules – all this and much more allows a child to develop and enhance communication and speech skills. It is the environment that supports this development and results critical, since the results of this stage will manifest themselves at the stage of entering school. Creating a stimulating and nourishing environment for the child will appear as improved reading and literacy skills in general (Bracken and Fischel, 2008), although this can be challenging for some families, for example in the case of high employment or low socio-economic status. Accordingly, parental education level is a significant predictor of time of children television exposure (Guryan et al., 2008).

Watching television is a passive consumption of technology and traditionally it was considered that such media show negative effects on child development. However, in the case of the development of various aspects of speech and literacy in children, the effect of watching television no longer looks so clear. Emerging literacy (Clay, 1979) is a set of skills necessary for successfully learning to read expresses in terms of alphabet knowledge, knowledge of print concepts, phonemic awareness, and oral language. Later, literacy was described as two groups of skills: code related (letter knowledge, letter – sound correspondence, phonemic and phonological awareness, etc.) and oral language (narrative comprehension, vocabulary and conceptual knowledge, etc.) skills (Whitehurst and Lonigan, 1998).

A study by Linebarger et al. (2004) clarified the role of home media environments, and in particular educational television programs, in improvement of various literacy skills in 79 kindergarten and 85 first grade students. Specifically, they assessed concepts of print (where a child was shown stimulus and asked specific words, words that rhyme or mean the same, etc.), phonemic awareness and letter – sound correspondence. During the intervention the children were assigned to viewing group (television program *Between the lions*) or control group.

All children who viewed the program during the intervention had better performance in the word recognition task while phonemic awareness increased more in kindergarten children (those with higher reading risk status and viewers of the educational series during the intervention). Furthermore, the home media environment for the children with higher reading risk status was described as less time reading, less enjoyment reading, fewer books available, they also knew fewer sounds and watched more television. Choosing the program content is important, however different areas of development and skills may be affected. Adult-oriented content exposure to children also showed negative outcome: media consumption at 6 months predicts lower auditory comprehension and communication at 14 months (Tomopoulos et al., 2010).

Phonological awareness as the ability to comprehend words' sound structure, consists of various components required for language and literacy acquisition: phonemic awareness, word and sentence awareness, rhyming and syllabication (Kenner et al., 2017), though phonological awareness is considered as the strongest predictor of reading success (Goodman et al., 2010). Phonemic awareness is a component of language and literacy development and it is one of the features that first emerge in the ontogeny (Kenner et al., 2017). Phonemic awareness, as the ability to identify individual sounds and phonemes in words (Clay, 1979; Walsh, 2009), is a critical foundation for reading mastery and academic success in the long term (Mann, 1993, it was described at the age of 2.5 years at the level of distinguishing individual phonemes (Kenner et al., 2017), which means it is an extremely important part of pre-reading skills. Moreover, training phonemic awareness in preschoolers predicts 30–40% of the reading ability (Roberts et al., 1984; Mann, 1993). However, phonological processing expressed in terms of different levels which are interconnected, i.e., phonological skills, also explain the variance of individual differences in reading (Del Campo et al., 2015). Phonological processing involves both perception and encoding, and consequently is based on phonological working memory and auditory processing, while phonological memory refers to simultaneous storage and manipulation and represents a component of working memory, the same as attentional-controlling system and visuospatial segment (Baddeley, 1992). As far as phonological processing and memory are based on stimuli storage and processing, more complex stimuli with more syllables are associated with worse performance of phonological working memory (Perrachione et al., 2017). Phonological awareness and phonological memory are two distinct phonological skills, although these domains are highly correlated (Del Campo et al., 2015).

Since the use of electronic devices in children affects all aspects of development (Shiue, 2015), this longitudinal study aims to contribute to this growing area of research by exploring the connection between phonological memory in preschool children and their passive (watching television) and active screen time with (using of smart screen technologies) such as tablets and phones with a touch screen interface. As long as preschool age is characterized by a particularly active development of mental functions, and mainly by a leap in speech and literacy development, the ability to track the characteristics of children's

progress in the level of phonological and phonemic awareness, and consequently, phonological memory will help expand the opportunities for preparing children for such an important period as entering school. Phonemic awareness is the basis for receiving and processing verbal information and represents the ability to identify and use phonemes (Clay, 1979), being a component of phonological awareness, it refers to the minor meaningful unit, which is required for further literacy development, in particular, for sound-grapheme correspondence and understanding (Kenner et al., 2017). The development of speech is a complex designation of various mental processes that are associated with the child's mastery in oral and written speech. Speech development is a precise and concise indicator for assessing the neurological status and mental development of a child.

Phonological memory is reflected in both phonological and phonemic awareness acquisition process, therefore it could be related with speech and literacy development, therefore, we chose it as the central construct of our research. Hence, phonological working memory is considered as efficient dynamic basis for reading skills acquisition, because it implies representation and coding of stimuli (Wagner and Torgesen, 1987). It forms part of phonological processing along with phonological awareness and rapid automatized naming which are predictors of reading success (Torgesen et al., 1994). Various cognitive processes as speech perception, phonological decoding and working memory (Dandache et al., 2014) are involved in phonological processing assessment, therefore the relationship between phonological and phonemic awareness with phonological memory is even more complex. Kroese et al. (2000) stated that phonemic awareness and phonological memory interconnection with reading decoding and spelling is complemented by regression model where phonemic awareness and phonological memory explain significant part of the variance. Various explanations are suggested for understanding this interrelation (Nithart et al., 2011): verbal memory is implied in phonemic and phonological awareness tasks, or, on the contrary, phonological processing is performed in verbal memory tests. Consequently, it can be considered that both contribute to phonological processing substrate, or alternatively, phonological memory and phonological awareness rely on different phenomena (phonological structure and phonological representations). Since the impact of media consumption has been widely discussed in the context of impact on child development, it should be highlighted that the input provided by passive (watching television) and active (use of smart electronic devices) screen time is different, consequently, we suppose that their impact is unequal. Phonological awareness acquisition process affected by the input child receives has to be considered based on the screen time spent both passively and actively to evaluate the development outcomes. Thus, we have identified the following research questions: (1) Is there a difference between developmental outcome for active and passive screen time in preschool children? (2) Is watching television (passive screen time) a negative predictor for the development of phonological memory in children? (3) Is the interaction of children with smart electronic devices an auxiliary factor for the development of

phonological memory in children? (4) Is there an influence of family factors on the development of phonological memory in preschoolers?

## MATERIALS AND METHODS

### Participants

The study involved 122 preschool children from kindergartens in Moscow, Russia and their mothers. The age of children was 5–6 years ( $M = 5.72$ ,  $SD = 0.33$ ), girls – 45.08%, boys – 54.92%. All children were Russian native speakers without developmental delays or disabilities. An overwhelming majority of mothers have a higher education 79.51%, the rest have an academic degree (2.46%), incomplete higher education (4.92%), specialized secondary (11.48%) or secondary general education (1.63%). Family income data was also provided, which was rated by mothers as insufficient (4.96%), low (13.22%), average (78.51%) or high (3.31%). Such a high percentage of higher education of mothers of the study participants is associated, in our opinion, with the peculiarities of the educational system in Russia, where free education is provided at all levels. The study participants were tested at the end of the senior group of kindergarten (5–6 years old), repeated assessment of their development occurred at the end of the preparatory group (6–7 years old). At the Time 2 we tested  $N$  (Time 1) – 7 participants, i.e.,  $N = 115$  for Time 2. Thereby, our longitudinal design included 2 measurements: Time 1 in the April of 2018 and Time 2 in the April of 2019.

The participants of our study were recruited in public kindergartens in Moscow, Russia. Since the study reported is a part of a research funded by a public foundation, corresponding agreements were signed between our research institution and the kindergartens involved. All the parents who made a decision on participation of their children in the study signed the informed consent.

### Methods

The Understanding of Similar Sounding Words (USSW; Akhutina et al., 2016). This technique assesses the level of development of the child's phonemic awareness and verbal memory. The test is extremely sensitive with respect to the processing of auditory information, since during its conduct, sound recognition of the words retained in memory is necessary. For this test, 10 pictures with images of objects whose names are close in sound or pronunciation are needed {[tochka (point in Russian) – dochka (daughter in Russian)], [pochka (tree bud in Russian) – bochka (barrel in Russian)], [trava (grass in Russian) – drova (woods in Russian)], [kosa (braid hair in Russian) – koza (goat in Russian)], [tochka (point in Russian) – pochka (tree bud in Russian)], [dochka (daughter in Russian) – bochka (barrel in Russian)], [miska (plate in Russian) – mishka (teddybear in Russian)]}. The child is presented with 2 sheets with 10 pictures with images of objects whose names are similar in sound. First, the child is asked to name all the pictures. Psychologist names the picture reflecting an object that could be called in different ways [e.g., (miska) can also be called as (tazik), but for experimental task only the words similar in sound

or pronunciation are used]. Nominative function of speech in evaluated in this part. This test is followed by the main task where the child is named several objects, and he or she must remember them and show them in the same sequence in which they were named. The number of named objects gradually increases from 2 to 6. Children are presented with more complex tests until they make mistakes in three tasks in a row. During the test the child is asked to look at the psychologist in order not to relate a picture with a word while the sequence is being read. If the child begins to pronounce the sequence, he/she is asked to perform the test in silence. In each task, the child was awarded 1 point for each correctly displayed picture (productivity), and the following indicators were also taken into account: duplications (if the child names the correct word and sounds close to him, he/she gets 1 point), word order change/replaces (1 point), misses (1 point), extra words (1 point). The Productivity assessment includes: the number of named pictures; understanding words (with alternating trials according to the rule of completion of testing after three errors – the number of correctly displayed pictures/the number of words presented; or with a constant set of samples – the number of correctly displayed images). A correct display is considered to be the first attempt at the right order. The productivity of the task is a complex indicator that depends on both the actual auditory-speech memory and other functions, for example, programming and control, therefore, an error analysis is additionally required to establish the qualitative specifics of the violation. Errors of understanding and retention: sound substitutions and duplications, that is, showing the target picture with a name similar in sound; distant replacements; skips; interlaces (extra words, not related to duplication); changing the order of words in a series (the number of series is estimated with out-of-order). The weakness of the processing of auditory information is evidenced, first of all, by sound substitutions and duplications. Distant substitutions, omissions, violations of the order can be associated with both the same factor and with the weakness of programming and control. Interlaces are usually associated with insufficient selectivity, elements of field behavior (when pictures are shown between target stimuli).

Albeit this experimental task was originally conceptualized and designed as phonemic awareness test, we suppose that it would be rather considered as phonological memory trial (here and below referred as phonological memory test), because although phoneme discrimination is involved, there is no explicit manipulation or judgment of phonemic sequence. Therefore, in our study we examined verbal memory with some auditory processing components that could be referred as phonological memory which is a part of the phonological processing.

Information about the child's passive and active screen time was obtained from the written questionnaire for parents, which was filled in by the mothers of the children. To obtain information about watching television, they answered the question "How much time while at home does your child spend watching television every day?", Where the answer options were: (0) the child does not watch television; (1) up to 30 min; (2) 0.5 to 1 h; (3) from 1 to 1.5 h; (4) from 1.5 to 2 h; and (5) more than 2 h. To assess the child's interaction with smart electronic devices, the question was asked: "How much time, being at home,

does your child spend every day” interacting “with a computer, game console, tablet?” The answer options for each of them were identical: (0) the child does not use smart electronic devices; (1) up to 30 min; (2) 0.5 to 1 h; (3) from 1 to 1.5 h; (4) from 1.5 to 2 h; and (5) more than 2 h.

Age, gender and non-verbal fluid intelligence were included as children characteristics. Child’s non-verbal fluid intelligence was assessed with Raven’s Colored Progressive Matrices (CMP; Raven, 1936). Children did tasks up to 4 mistakes in a row, the number of correctly completed tasks was counted and that time was not taken into account. For families’ characteristics, maternal education level and families’ income level were assessed. Maternal education was coded in following categories: (1) secondary general education; (2) specialized secondary education; (3) incomplete higher education; (4) higher education; and (5) academic degree. The information on family’s income level was described as insufficient, low, average, or high.

All the tasks were performed during individual meeting with each child (each lasting 20–25 min), in a quiet room of a child’s kindergarten. The study was approved by the Ethics Committee of the Faculty of Psychology at Lomonosov Moscow State University (the approval No: 2019/50).

The IBM SPSS Statistics 23 and RStudio software was used to process the results of this study. Statistical procedures included analysis of differences between samples, correlation and regression analyses. Analysis of differences between the samples (Student’s *t*-test) was used to test hypotheses about the presence of differences in the level of development of phonemic awareness, as well as passive and active screen time, depending on additional variables. Correlation analysis (Spearman’s rho rank correlation) included consideration of relationships between all variables of the study. Regression analysis was used to test the hypotheses of the study about the effect of screen time on the development of phonemic awareness in preschoolers.

## RESULTS

### Preliminary Analyses

To determine if there are any differences in the level of phonological memory development, as well as in the level of passive and active screen time in children, depending on their gender, the Student’s *t*-test was used. Only one significant difference was found at Time 1 in the level of passive screen time (watching television) by gender  $t = 2.07, p < 0.04$ . So, boys had significantly more television exposure than girls. There were no significant differences by gender at Time 2 and in progress in the level of the child’s phonological memory development for the year  $\Delta$ , which was calculated as the difference between Time 1 and Time 2 ( $\Delta = \text{Time 2} - \text{Time 1}$ ).

The results of the correlation analyses of the variables of this study are presented in **Table 1** (for Time 1) and **Table 2** (for Time 2). Since target variables (i.e., phonological memory experimental task variables) did not satisfied normal distribution tests, we ran Spearman nonparametric correlations. A weak significant negative relationship was found between passive screen time and the level of general productivity in the phonological memory

test ( $r = -0.24, p < 0.01$ ). The negative correlation between passive screen time and the level of development of phonological memory demonstrates that more time of television exposure is associated with a worse level of phonological memory in preschool age [i.e., at Time 1, children aged 5–6 years ( $M = 5.72, SD = 0.33$ )]. However, if analyzed separately by gender, the strength of this relationship between passive screen time and the level of development of phonological memory does not hold up similarly for boys and for girls: for boys it increases ( $r = -0.29, p < 0.02$ ), while for girls, on the contrary, decreases and becomes non-significant.

The level of general productivity in the phonological memory test, in addition to passive screen time (watching television), also found significant correlations with the mother’s education level ( $r = 0.27, p < 0.002$ ) and the family income ( $r = 0.22, p < 0.02$ ), however gender or age associations were not found. Thus, a higher level of education of the mother and a higher level of family income are associated with a better level of development of phonological memory.

Active screen time (interaction with smart electronic devices) did not reveal significant correlations with the rest of the variables at the Time 1. No significant correlations were found for Time 2. The indicators of progress in the level of development of the child’s phonological memory for the year  $\Delta$  did not find significant correlations with other indicators, therefore, they are not presented in **Tables 1, 2**.

More specific interrelations in phonological memory experimental task were found at Time 1. Phonological memory test scale “Misses” was correlated with age ( $r = -0.21, p < 0.05$ ), while phonological memory test scale “Replaces” was correlated with Raven CPM score ( $r = 0.18, p < 0.05$ ). As far as sound replaces refer to weakness of auditory information processing, higher level of non-verbal intelligence is associated with worse level of auditory information processing, according to our data. Furthermore, omissions are considered as weakness of programming and control, which means that our data suppose worse programming and control level in younger children.

Since all the correlation indices reported in our study were generally quite low (below 0.3, often below 0.2), we ran corrections for multiple testing, because a correlation of less than 0.3 is usually considered as negligible. However, after performing corrections for multiple testing all the correlations described before became insignificant.

### Influence of Passive and Active Screen Time on the Development of Phonemic Awareness

Therefore, we tested models where the child’s passive (watching television) and active (interacting with smart electronic devices) screen time were predictors of progress in the level of phonological memory development in preschoolers. However, no significant constants were found.

Then, at the first stage, using Time 1 data which demonstrated various correlations between target variables and television and smart electronic devices exposure variables, we tested 2 models,

**TABLE 1** | Descriptive statistics and correlations for study variables (Time 1).

	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9	10	11
1. Age (years)	5.72	0.33	–										
2. Gender	NA	NA	– 0.0e4	–									
3. Raven CPM	14.00	7.28	0.06	0.03	–								
4. TV exposure	2.64	1.25	0.01	– 0.18*	– 0.09	–							
5. Smart electronic devices exposure	1.86	2.04	– 0.05	– 0.07	– 0.07	0.25**	–						
6. Phonological memory (productivity scale)	17.89	7.33	0.11	0.11	0.17	– 0.24**	– 0.14	–					
7. Phonological memory (replaces)	2.25	1.48	– 0.09	0.02	0.18*	0.03	– 0.06	– 0.12	–				
8. Phonological memory (misses)	1.27	1.47	– 0.21*	– 0.09	0.096	– 0.004	0.16	0.13	– 0.26**	–			
9. Phonological memory (extrawords)	0.45	0.74	0.09	– 0.14	0.01	0.02	0.13	0.14	– 0.07	– 0.02	–		
10. Phonological memory (duplicates)	0.13	0.36	– 0.04	– 0.09	0.002	– 0.08	0.02	0.12	0.04	– 0.03	0.18	–	
11. Maternal education	3.70	0.77	– 0.002	– 0.05	0.10	0.09	– 0.09	0.27**	– 0.02	– 0.09	0.07	0.08	–
12. Family SES	2.80	0.57	0.11	0.11	– 0.02	– 0.04	– 0.01	0.22*	0.05	– 0.06	0.17	0.095	0.31**

\*\*Correlation is significant at the 0.01 level (two-tailed).

\*Correlation is significant at the 0.05 level (two-tailed).

**TABLE 2** | Descriptive statistics and correlations for study variables (Time 2).

	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9	10	11
1. Age (years)	5.72	0.33	–										
2. Gender	NA	NA	– 0.04	–									
3. Raven CPM	14.00	7.28	0.06	0.03	–								
4. TV exposure	2.64	1.25	0.01	– 0.18*	– 0.09	–							
5. Smart electronic devices exposure	1.86	2.04	– 0.05	– 0.07	– 0.07	0.25**	–						
6. Phonological memory (productivity scale)	19.23	8.47	0.04	0.02	0.05	– 0.14	– 0.18	–					
7. Phonological memory (replaces)	2.42	2.18	– 0.08	– 0.08	0.07	– 0.01	– 0.01	– 0.05	–				
8. Phonological memory (misses)	1.61	2.31	– 0.05	– 0.19*	0.03	0.12	– 0.06	0.15	– 0.04	–			
9. Phonological memory (extrawords)	0.22	1.00	0.15	– 0.13	0.06	0.05	0.07	0.07	0.12	– 0.14	–		
10. Phonological memory (duplicates)	0.62	1.09	0.05	0.03	0.02	0.001	– 0.15	0.16	0.06	0.02	0.04	–	
11. Maternal education	3.70	0.77	– 0.002	– 0.05	0.10	0.09	– 0.09	0.05	– 0.004	– 0.12	0.08	0.01	–
12. Family SES	2.80	0.57	0.11	0.11	– 0.02	– 0.04	– 0.01	0.098	0.05	– 0.095	0.101	0.16	0.31**

\*\*Correlation is significant at the 0.01 level (two-tailed).

\*Correlation is significant at the 0.05 level (two-tailed).

where in the first one television watching (passive screen time) acted as a predictor, and in the second – the child's interaction with smart electronic devices (active screen time) acted as a predictor of child's phonological memory level. Only passive screen time (watching television) ( $\beta = -0.22$ ,  $p < 0.02$ ) turned out to be a significant predictor of the level of development of phonological memory. The model, where television viewing acts as a predictor of the level of development of phonological memory, explained 5% ( $R^2 = 0.05$ ) of the variance of the dependent variable ( $F = 5.87$ ,  $p < 0.02$ ).

Since at the stage of preliminary analysis correlations of the level of development of phonological memory with the level of education of the mother and the level of family income were found, we performed additional hierarchical regression analysis for a statistically significant model, where passive screen time (watching television) is a predictor of the level of development of phonological memory in preschoolers, but now controlling for these family factors. After controlling for the mother's education and family income, the model that predicted the level of phonological memory development through watching television

explained 13% ( $R^2 = 0.13$ ) of the variance of the dependent variable ( $F = 8.87, p < 0.00$ ). The variable of the socio-economic status of the family turned out to be an insignificant constant, but both the level of passive screen time (watching television) ( $\beta = -0.23, p < 0.01$ ) and the level of education of the mother ( $\beta = 0.298, p < 0.001$ ) turned out to be significant constants.

## DISCUSSION

The main goal of this study was to determine the nature of the relationship between passive and active screen time of a child and phonological memory, to identify the nature of their influence on the level of its' development. With respect to the research questions we raised earlier, we draw the following conclusions based on our research data: (1) there is a difference between the developmental outcome for passive and active screen time in preschool children, (2) watching television has a pronounced negative effect on the development of phonological memory in preschool children, (3) interaction with smart electronic devices did not reveal a significant relationship with the level of phonological memory in preschool children, and (4) the level maternal education is a significant predictor for the development of phonological memory in preschool children.

Our results show that passive screen time is a significant predictor of the level of development of phonological memory in preschoolers: watching television negatively affects phonological memory in children; it was children with a long daily television viewing time that showed worse results in relation to the overall productivity of performing tasks on phonological memory. This is consistent with the results of Lin et al. (2015), where a significant predictor of time exposed to television was identified in children with delayed speech development, as well as with data where independent viewing of television by children was a significant predictor of speech delay (Chonchaiya and Pruksananonda, 2008). A longitudinal study by Madigan et al. (2019) supported the association between screen time and child development on a sample of almost 2,500 children from Canada. More time spent in media consumption at the age of 24 and 36 months was associated with worse performance in screening test, however, it should be recognized that authors used a complex parent-reported measure to evaluate children's developments across domains (social and communication, gross and fine motor, and problem solving). Phonological awareness was also proved to be negatively affected by passive screen time via watching television (Fröhlich et al., 2013). Due to the fact that  $p$ -values correction for multiple testing used in this study pointed that our correlation analyses results were insignificant, the present study results should be interpreted with caution. Indeed, before such corrections the results obtained could not be interpreted as considerable, as the correlation coefficients were rather weak (below 0.3, often below 0.2). The correction procedure revealed its' insignificance and highlighted that random noise as a possible explanation of the results obtained, although we have to admit that other statistical procedures revealed significant interrelations (e.g., regression analysis). We also emphasize that sample size and sample characteristics could be considered as one of the possible explanations: 122 preschool children participated in our

study. Furthermore, more precise questions on screen time and its' specifics and content could possibly improve our results: indeed, no significant relationship was found for active screen time variable. And consequently, more accurate understanding of phonological processing and phonological memory, in particular, may also be reflected in future research to consider possible effects of passive and active screen time in preschool children, since it is proved that some test on phonological processing components have better prediction power than others even when measuring the same component (Kilpatrick, 2012). Nevertheless, we believe that the value of this study is to provide preliminary evidence on the possible relationship between screen time and phonological memory in children.

At the same time, according to our data, the level of education of the mother, when is higher, it contributes more to the development of phonological memory as part of the development of speech and literacy. Parents with higher education spend less time in front of television than those with lower education (Guryan et al., 2008). Despite the fact that there are significant gender differences in the amount of time children spend watching television, according to our results, gender is not a statistically significant predictor of the level of development of phonological memory in preschool age. Our data are consistent with previous studies that showed the negative impact of watching television on cognitive, emotional, and executive functions (Lillard and Peterson, 2011; Yousef et al., 2014; Takeuchi et al., 2015). Albeit the negative outcome of television exposure (both specialized child content and adult content) is described for literacy and speech development (Zimmerman et al., 2007; Barr et al., 2010), some research emphasize there is no association between television exposure and language development (Schmidt et al., 2009; Bittman et al., 2011). Nevertheless, the current data on cognitive development outcome prediction depending on media consumption seems contradictory not only for language and literacy, but also for attention problems (Foster and Watkins, 2010; Conners-Burrow et al., 2011), executive functions (Linebarger et al., 2014; Nathanson et al., 2014), school readiness and class engagement (Pagani et al., 2010; Sharif et al., 2010) at different stages of ontogeny. Despite the scarcity of studies on the impact of television viewing by children on the development of speech and literacy, and in particular, phonological memory, in general, their results also indicate that there is a negative impact of television on their development (for review, see Kostyrka-Allchorne et al., 2017).

Research suggests that the use of smart screen technologies has a positive effect on the development of speech and literacy, and it is this part that we could not confirm in our study. The use of iPad apps by preschoolers to develop phonemic awareness is expressed in its best development and better language achievement (Bebell and Pedulla, 2015), while the characteristics of the applications are important in order to have feedback and play elements (van Gorp et al., 2016). All of the above brings us back to the problem of creating content for children's media consumption. A study by Linebarger and Walker (2005) emphasized that it was not so much television viewing as a whole that negatively affected speech development, as individual programs were associated with the worst vocabulary development and expressive language production. It is proved

that some educational program can enhance early literacy skills (Wright et al., 2001). Papadakis and Kalogiannakis (2017) in their review highlighted an increasing number of educational mobile applications and pointed that their pedagogical potential should be appropriately assessed. Furthermore, children learn rapidly multiple forms of activity with smart electronic devices, which facilitate the its implementation as educational tool. Nevertheless, application design should be taken into account in order to provide effective learning environment. According to cultural-historical approach, child's activity, possibility of interaction with peers or adults and feedback will be significant characteristics to be evaluated.

Franceschini and Bertoni (2019) in their manuscript argued that playing commercial video games can be beneficial for children with developmental dyslexia, since improvement in phonological decoding speed and phonological short-term memory were found, which is due to enhancement of cross-modal processing, so the effect on phonological memory was mediated by improvements in visual processing, through cross-modal or supra-modal mechanisms. Training phonological memory is proved to improve reading abilities in preschool children, and in particular, activities with unfamiliar phonological units repetition (Maridaki-Kassotaki, 2002). However, albeit both phonological awareness and phonological memory are significant predictors of reading skills, their influence is not identical at different stages of ontogeny. Therefore, Nithart et al. (2011) emphasize that phonological awareness is crucial in the kindergarten and phonological memory contributes more to the reading skills development in the first grade. Hence, phonological memory development increases in primary school at the same time with vocabulary enhancement. In addition, various phonological processing abilities were proved to be related with reading and with each other, and had different rates of development: for example, phonological memory had the slowest development rate (Wagner et al., 1994). Phonological memory is also associated with language production and syntactic complexity, in particular, and this relationship is mediated by articulation abilities (Adams and Gathercole, 1995).

Among the possible explanations for the patterns we have described, one can single out the fact that a longer television viewing time in children inevitably leads to a decrease in the amount of communication and play with parents and peers. It is communication that creates an enriching environment for the development of speech and literacy in a child. Since preschool age is critical for the development of mental functions, and in particular, speech, it is extremely important to enhance the possibilities of this period and use the opportunities for the development of language and literacy skills. The enriching environment in this case will be precisely the active interaction of the child with the environment, primarily social, through parents and peers. It is the imitation and use of the cultural model by the child that will give the developmental effect (Vygotzky, 1978).

The advantage of our study is the consideration of the problem of the development of phonological memory in preschoolers in the light of the child's active and passive screen time. Phonological memory remains a less studied component of

phonological processing in the development of speech and literacy, so it is critical to highlight its development. Albeit in our longitudinal study we did not identify the features of the progress of preschool age in the growth of phonological memory depending on the passive and active screen of time, we were able to identify the negative influence of passive screen time on its development, and also to consider the influence of other variables related with family context on this process.

Nevertheless, the study has a number of limitations that could affect our consideration of the level of development of phonological memory in preschool children, such as the characteristics of the content consumed, the features of the family context, in particular, the characteristics of the interaction between parents and children, as well as the educational environment of the kindergarten and the characteristics of the teacher's interaction with children. Indeed, in our study we only considered data on family characteristics provided by mothers, since traditionally in Russian culture they are the ones in charge of the education of the children, perhaps the fathers' answers that may also be provided should be taken into account. On the other hand, we have not given consideration to the content that children have access to, because our work is at an initial stage of a larger project. We will continue our longitudinal investigation in order to deepen our knowledge on interrelation of speech and literacy development with content that children can obtain through media such as television and/or smart electronic devices, and in particular, emphasize the difference between development outcomes in smartphones, computers and tablets preschool children users. Family context should be also taken into account, since the verbal input provided in family environment can be different. This factor depends not only on socio-economic status or education level that we already assessed, but also on parents' psychological characteristics (e.g., emotional well-being, attachment, aggression patterns, etc.) and family dynamics (e.g., communication quality and quantity, sibling interaction, home activities, etc.), in general. And finally, we suppose that educational environment may also have an influence on emerging literacy development, since the teacher's interaction with children is considered as specific kind of verbal input. This raises another research question: which context (family or kindergarten) contributes more in emerging literacy and speech development, and what is the ratio of these indicators at different stages of development? What kind of digital content and how much of it can be a part of nurturing environment at home and in kindergarten for phonological memory development? Is there any methodological framework that can facilitate the design of this type of content?

In terms of statistical analysis, the present study has the disadvantage of *p*-values correction for multiple testing results, indeed, our correlation analyses indices were reported as insignificant after the correction was performed. We suggest that sample volume should be considered as an explanation rather than random noise possibility, hence, previous research demonstrated interrelations between phonological processing elements and screen time in children. For this reason, we point out in the "Discussion" section that the results of the study

should be considered with caution. Further research is required for a more accurate understanding of the nature of individual differences in the level of phonological memory development in preschoolers.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

The studies involving human participants were reviewed and approved by The Ethics Committee of the Faculty of Psychology at the Lomonosov Moscow State University (the approval no: 2019/50). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

## AUTHOR CONTRIBUTIONS

NV was responsible for the methodological basis and understanding of the theoretical and practical significance of

the research. AV was responsible for the design development, conclusion of cooperation agreements with kindergartens and schools on the basis of which the test was conducted, and defining the diagnostic tools. DB was responsible for organization of the data collection process, training of the testers, protocol maintenance, quality control of the data collection, writing the relevant sections of the text, and participation in the data analysis. MG was responsible for the data collection, analysis of the received data, writing the individual parts of the text of the manuscript. AC was responsible for the data collection and writing the individual parts of the text of the manuscript. EO was responsible for the theoretical and empirical analysis of phonemic awareness development and selection of the methodological tools for its evaluation. All authors contributed to the article and approved the submitted version.

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**Conflict of Interest:** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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