

EFFECTS OF THE SOCIAL MEDIA INTERFERENCE FACTOR ON MEMORY CONSOLIDATION IN ADOLESCENTS

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The relevance of this study is due to the need to answer the question of how the factors of digital medium affect the development of mental functions in the younger generation. The study was aimed to assess the effects of the social media interference factor on memory (auditory-speech and visual-figurative) consolidation in adolescents. The sample was 130 adolescents aged 11–17. The groups were formed based on the age stages (11–12, 13–14, 15–17 years). The study involved the use of the method for the diagnosis of the short-term auditory-speech and visual-figurative memory span. Viewing video content and reading the fragment of the fiction book were used as interference. A significant decrease in the short-term auditory-speech and visual-figurative memory span was observed in adolescents. The short-term memory span is reduced in the context of social media interference (prolonged continuous viewing the heterogenous visual-acoustic and visual-speech content). The high risk of the long-term memory loss due to the impact of the social media interference factor on memory consolidation in adolescents is empirically proven. The more the duration of the maximum continuous video stream and the total time the adolescents spend on Internet (including social media), the larger is the loss of information.

Keywords: short-term memory, auditory-speech memory, visual-figurative memory, interference, visual-acoustic content, visual-speech content

Author contribution: all authors contributed to study planning, literature analysis, data acquisition, analysis, and interpretation equally.

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ВЛИЯНИЕ ФАКТОРА ИНТЕРФЕРЕНЦИИ СОЦИАЛЬНЫХ СЕТЕЙ НА ПРОЦЕССЫ КОНСОЛИДАЦИИ ПАМЯТИ У ПОДРОСТКОВ

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Актуальность настоящего исследования обусловлена необходимостью поиска ответа на вопрос о том, как факторы цифровой среды оказывают влияние на формирование психических функций подрастающего поколения. Целью работы было изучение влияния фактора интерференции социальных сетей на процессы консолидации памяти (слухоречевой и зрительно-образной) у подростков. Объем выборки составил 130 подростков в возрасте 11–17 лет. Формирование групп осуществляли по возрастным этапам (11–12, 13–14, 15–17 лет). Исследование осуществляли с использованием методик диагностики объема кратковременной слухоречевой и зрительно-образной памяти. В качестве интерферирующего воздействия выступали просмотр видеоконтента и прочтение фрагмента художественного произведения. Установлено значимое снижение объема кратковременной слухоречевой и зрительно-образной памяти у подростков. В условиях интерферирующего воздействия социальных сетей (длительного непрерывного просмотра визуально-акустического и визуальноречевого контента гетерогенного содержания) происходит снижение объема кратковременной памяти. Эмпирически доказан высокий риск потери долговременной памяти под влиянием фактора интерференции социальных сетей на процессы консолидации памяти у подростков. Чем больше длина максимального непрерывного видеопотока, а также общая длительность нахождения подростков в интернете (в том числе в социальных сетях), тем больше объем потери информации.

Ключевые слова: кратковременная память, слухоречевая память, зрительно-образная память, интерференция, визуальноречевого контент, визуальноречевого контент

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For the first time in the history of civilization, the current generation of adolescents lives in two realities, the one mediated by technical devices (digital reality) and another one not mediated by technical devices. The micro- and macrocharacteristics of both realities affect the younger generation mental development. Modern psychologists must now start raising specific questions of how

the factors of digital environment affect the development of mental functions in the younger generation.

One of the popular theses on the theories of memory is the thesis that we are our memory. The issue of the impact of the factors of digital environment on memory processes in the younger generation is a specific research issue [1–8].

More than four and a half billion people all over the world (57.6% of the world's population) are active users of social media. Internet users on average spend 6 h 54 min a day online and are on 6–7 various social media (according to the Digital Global Statshot Report in partnership with We Are Social and Hootsuite, 2021).

Regardless of the legal and regulatory framework [9] (the children's use of Internet and social media is regulated by the the letter of the Ministry of Education and Science of the Russian Federation), as well as of the existing age limitations imposed by the social media and/or providers (for example, the TikTok user minimum age is 13 years), children find ways to bypass the established limitations. This significantly expands their access to the shared content with no age-restricted content.

The fundamental process of long-term memory formation referred to as consolidation occurs in many different types of memories, species and memory systems [2, 10, 11].

Initially, the memory is unstable and can be disturbed by several types of interference, including behavioral and pharmacological. Over time, the memory acquires resistance to these forms of interference due to consolidation [2]. Memory formation is a two-stage process. The first stage is a phase of short-term memory that lasts up to several tens of minutes. During this stage the memory is vulnerable to environmental influences: interference from new learning or alterations in gene expression. The phase of long-term memory, being a more stable structure formed 24 h after the engram emergence, constitutes the second stage of memory formation. A number of studies [10, 11] have shown that the consolidated memories that have passed the phase of long-term memory can also become labile, if a conditioned stimulus is applied after memory formation and stabilization. This reflects the process of memory reconsolidation [3, 5, 13].

Experimental studies of memory consolidation were focused on the time window of several hours after learning. Empirical evidence about the fact that memory consolidation in humans may take weeks, months or possibly years suggests that memory consolidation consists of various stages. The proof that different stages of consolidation depend on different cellular mechanisms and brain systems is represented by the findings of human and animal studies showing that hippocampal lesions usually disturb the recently acquired memories. However, the ability to recall past information is preserved.

System consolidation represents the changes associated with memory storage. Memory consolidation and storage involve activity in the hippocampus followed by such cortical areas as entorhinal cortex (CA1–CA3) and posterior parietal cortex [11]. A memory trace (engram) is formed in the hippocampus as a result of encoding information received from various sensory modalities. The incoming information is transformed into the integrated internal representation of the disparate elements of environmental perception that is interpreted and conceptualized by involving elements of past experience linked to actual experiences. Thus, internal representation is transformed into engram subsequently passing the stage of consolidation.

The method used in the study reported was developed based on the concept of working memory by B. B. Velichkovsky [4, 13] and the concept by K. V. Anokhin [14]. Memory, the higher mental function, is characterized by processuality and is implemented through memorizing. Memorizing ensures preservation of information content that goes through two stages (phases). The short-term stage is characterized by retaining the information stored in its fullest form (without losses or distortions of the content) over a short time. This is

a labile memory phase to which there corresponds retention of information trace in the form of the nerve impulse reverberation. The long-term stage of memorizing is characterized by reduction of the amount of information during the long-term storage without modification.

Consolidation that ensures the information content transition from the short-term to the long-term stage also involves further transformation of the information stored in accordance with the existing experience and addition of this information to the already existing information (incorporation into the system of long-term storage). The long-term memory involves preservation of the trace through consolidation and subsequent structural changes.

Working memory is a system of those cognitive processes that ensure rapid storage and processing of information. The working memory stores information using the mechanisms of short-term and long-term storage. Information is retrieved (this process is referred to as reconsolidation) from the long-term memory (that includes the system of images, system of symbols and signs, and the semantic system organized into holistic experience). Furthermore, information consolidated in prior experience is initially reconsolidated. Active reconstruction of information occurs during retrieval in case of memory reactivation that ensures information retrieval. Reconstruction is, in turn, accompanied by recategorization. Each round of recategorization is followed by reconsolidation (re-storing information). Each round of memory retrieval involves replacement of the old trace with the new content (the content could be partially or fully modified).

The interfering information (in our study this information is represented by the visual-acoustic and visual-speech content) occupies the short-term memory. This, in turn, results in consolidation of the initially limited information content.

The study was aimed to study the effects of the social media interference factor on memory consolidation in adolescents.

METHODS

The total sample was 130 in-school adolescents aged 11–17. Three study groups were formed based on age. The first one included 44 adolescents aged 11–12 (23 boys and 21 girls); the second one included 41 adolescents aged 13–14 (20 boys and 21 girls); the third one included 45 adolescents aged 15–17 (23 boys and 22 girls). The control groups also included adolescents of the specified age ranges: 46 people aged 11–12 (26 girls and 20 boys); 42 adolescents aged 13–14 (20 girls and 22 boys); 42 people aged 15–17 (23 girls and 19 boys). Inclusion criteria: screen time, i.e. the time spent on Internet, including social media, had to be at least 6 hrs a day.

The study was performed in three steps (Fig. 1).

Step one

The short-term auditory-speech and visual-figurative memory span was assessed together with the long-term memory span (delayed recall after 40 min); the experimental study of memory consolidation-reconsolidation during storage of figurative-symbolic information was performed. The short-term auditory-speech and visual-figurative memory span was assessed by the method of memorizing ten words proposed by A. R. Luria and the methods "Two Groups of Three Words", "Five Figures That are Hard to Verbalize".

The visual-figurative working memory span was assessed using the Block Span method [15].

Step two

The experimental study of interference in the form of viewing video content on the TikTok social media platform (experimental groups) or in the form of reading the fragment of the children's picture book (control groups) was carried out. Subjects in the experimental groups were offered to watch two series of videos. The first series consisted of 18 videos lasting up to 10 s or longer (the total length of this video content was 5 min). The videos for this series were selected based on the visual-acoustic features. The videos featured video content with some background music or other rhythmic melodic accompaniment, but no background speech. The second series was represented by 22 videos lasting 10–20 s (the total length was 5 min). These videos were selected based on the visual-speech features. The videos featured video content with the direct speech production.

After watching both series of videos (visual-acoustic and visual-speech ones) the subjects were offered to answer the following questions about the video: ordinal number of the video, semantic content, details, impression (in the like/dislike format).

Subjects in the control groups were offered to read several pages of text with pictures (the fragment of the book "Naksitrallid" by Eno Raud) silently (not aloud) within 10 minutes. After reading, the subjects had to retell the piece of text they had read as detailed as possible. Assessment was performed based on the following parameters: number of characters; sequence of actions committed by the main characters; number of semantic units in the retelling.

Step three

The process of auditory-speech and visual-figurative memory reconsolidation in the context of interference was assessed: such parameters as span, pace, precision, and duration of memory trace storage within the framework of auditory and visual modalities were reassessed using the method of memorizing ten words by A. R. Luria, and the methods "Two Groups of Three Words", "Five Figures That are Hard to Verbalize".

The methods of descriptive (mean and standard deviation) and comparative (nonparametric Mann–Whitney *U* test,

Wilcoxon signed-rank test, $p < 0.05$) statistics were used for quantitative data processing. The studied groups were compared based on the quantitative indicators obtained before (memory consolidation) and after (memory reconsolidation) the interference exposure.

RESULTS

Step one

When completing the task of assessing the short-term and long-term memory span and memory consolidation and reconsolidation in adolescents during the first phase of the study, we revealed the reduced memory span for all memory types in the groups of subjects. The maximum reduction of the short-term auditory-speech and visual-figurative memory span was observed in the groups of adolescents aged 11–12 (Fig. 2).

The maximum short-term memory span (for both auditory-speech and visual-figurative memory) was revealed in the experimental group of adolescents aged 15–17. Significant differences between three experimental groups of adolescents were observed. As for the short-term auditory-speech memory span, there were no significant differences only between the experimental groups of adolescents aged 13–14 and 15–17 in the fourth series to be recalled (immediate recall after the stimulus words) repeated for the fourth time ($p = 0.137$). The same results were obtained in the control groups. There were no significant differences in the short-term auditory-speech memory span between the control groups of adolescents aged 13–14 and 15–17 in the fourth series to be recall ($p = 0.132$).

When recalling two groups of three words, the decrease in the short-term auditory-speech memory span was observed in the group of adolescents. After the fourth series, two groups of three words were not available for recall in full. In the control and experimental groups of adolescents aged 11–12 one word per series (the last one) was available for recall. The other words named were the inflicted ones that are semantically similar to the stimulus words. Adolescents aged 13–14 in both groups recall two words of each group. The grouping principle was not followed: adolescents named together those two words that had been named in different groups during presentation. It should be noted that there was no substitution of words with

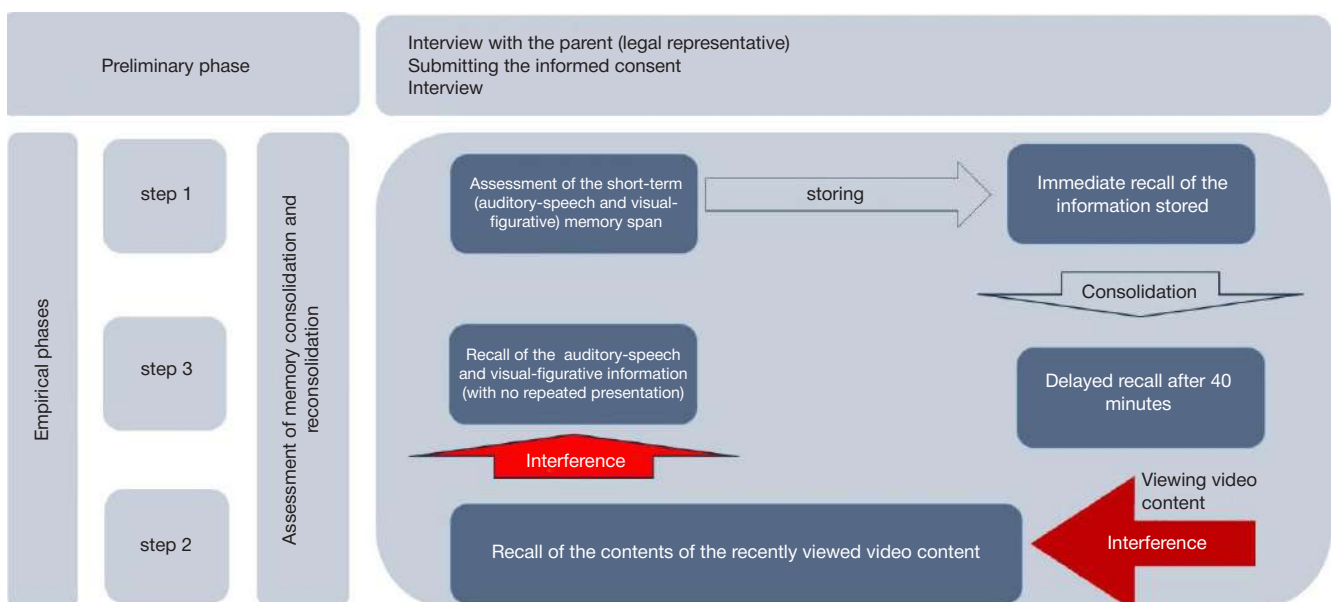


Fig. 1. Design of the study aimed at assessing the effects of the social media interference factor on memory consolidation in adolescents

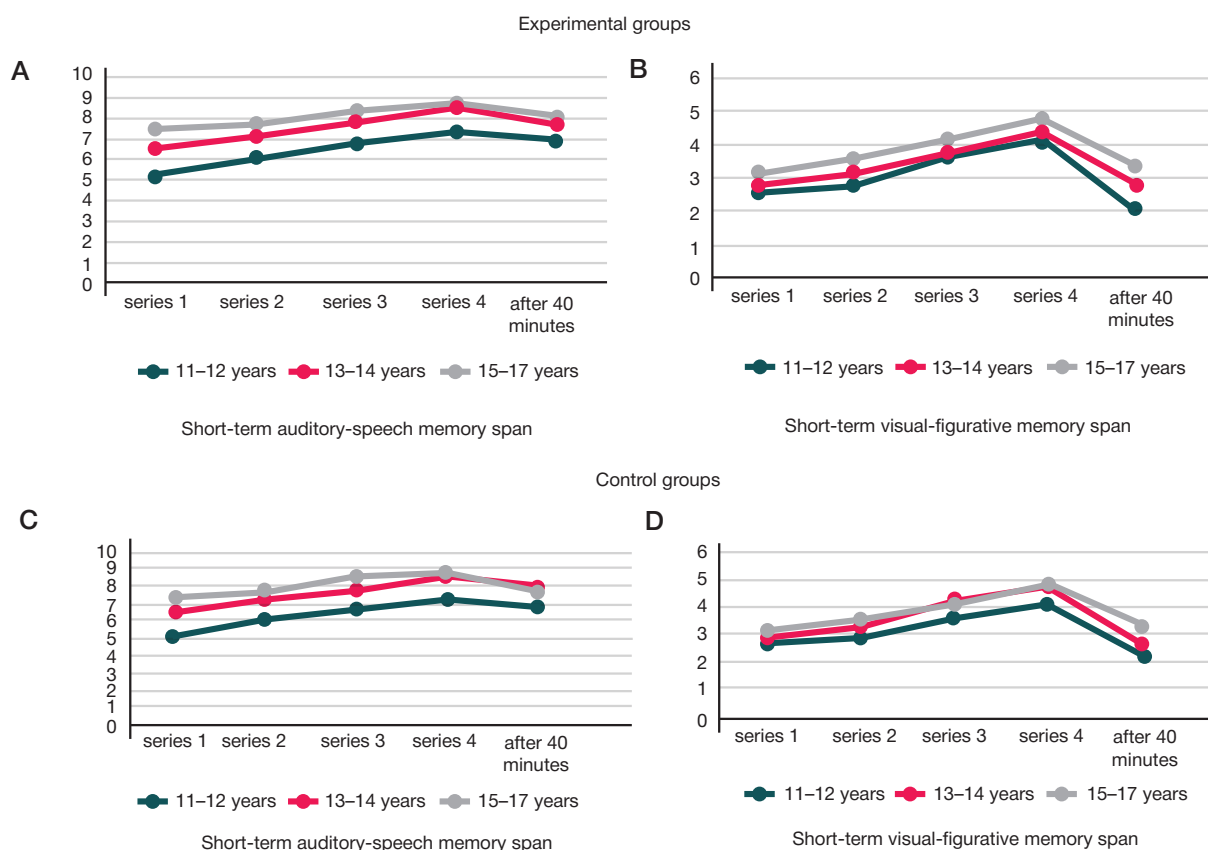


Fig. 2. Parameters of the short-term auditory-speech and visual-figurative memory span in adolescents

the semantically similar ones (typical for adolescents aged 11–12). As for adolescents aged 15–17, the subjects recalled correctly two words of the first group (the first and the last one) and all three words of the second group (out-of-order) after presentation of the fourth series.

A pairwise comparison of experimental and control groups in accordance with age ranges (adolescents aged 11–12 with the control groups of adolescents aged 11–12; adolescents aged 13–14 with the control groups of adolescents aged 13–14; adolescents aged 15–17 with the control groups of adolescents aged 15–17) performed when assessing the short-term auditory-speech and visual-figurative memory span revealed no significant differences.

The findings are also confirmed by the results of using the Block Span instrumental method. Thus, the initial decrease in the short-term memory span can be observed in adolescents who spend at least 6 hrs a day on Internet and social media. The maximum decrease in the short-term (both auditory-speech

and visual-figurative) memory span has been revealed in the groups (both experimental and control) of adolescents aged 11–12. The reduced span leads to the fact that the information content is simplified and reduced during the stage of storing, which, in turn, results in consolidation of the initially distorted information content. Distortions are reflected in simplification and reduction of the information stored. The average loss of original information is 44.16% of the total information content in the experimental group and 44.89% in the control group. The decrease in the short-term memory span is also typical for adolescents aged 13–14. However, in contrast to adolescents aged 11–12, the loss of semantic content is 32.56% in the experimental group and 33.04% in the control group. The form is substituted with equivalent or similar semantic content at the stage of consolidation. When recording auditory-speech information, adolescents of this group replace the stimulus words with semantically similar words or synonyms. The minimum decrease in the short-term memory span has been

Table. The average values of such parameters as idea, details, and impression for video content presented to the groups of adolescents

Groups of subjects	Parameters				
	Idea (number of semantic units)	Details		Impression	
		Number of characters	Number of objects	Like	Dislike
Visual-acoustic content (18 videos)					
11–12 years	11	8	6	15	2
13–14 years	16	14	12	10	8
15–17 years	24	18	16	9	9
Visual-speech content (22 videos)					
11–12 years	14	10	7	18	4
13–14 years	19	14	9	14	8
15–17 years	26	18	12	12	10

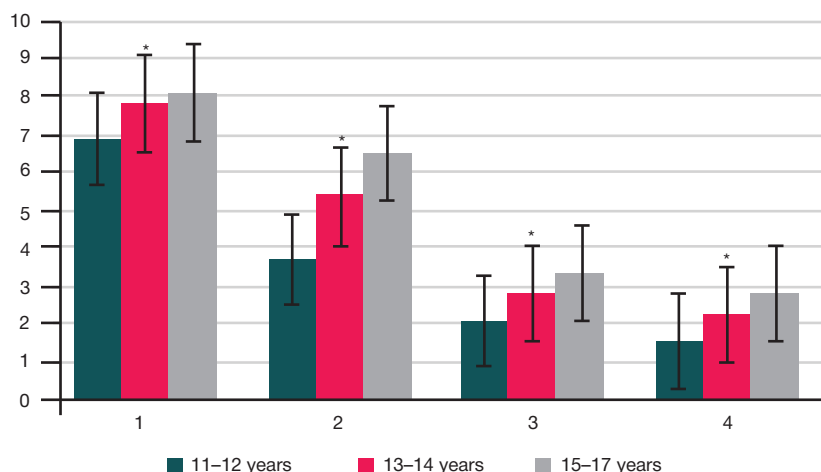


Fig. 3. Bar graph showing the average values of the auditory-speech and visual-figurative memory span obtained in the experimental groups after exposure to interference

revealed in the groups of adolescents aged 15–17. Furthermore, the distortion of information at the stage of storing is minimal. The loss errors are reported more often than in other groups: adolescents recall only a part of information content, with no distortions or substitution with semantically similar information.

Step two

The factor of interference was analyzed during the second phase.

The consolidated interfering content was assessed in the experimental groups of adolescents after viewing the 10-minute video content based on three parameters: idea (number of semantic units), details (number of characters, humans and animals, as well as the number of objects in the video), impression (whether the subject likes or dislikes the video). These parameters were assessed for each video constituting the video sequence (Table).

Imagine the qualitative structure of the consolidated content of the recently watched video content for two series (visual-acoustic and visual-speech content).

When watching both visual-acoustic and visual-speech content, adolescents of all groups show the loss of semantic content of the videos. When describing the recently watched pieces of video the subjects disrupt the video sequence (all the adolescents enrolled used the sequence that was different from the presented sequence when describing the contents and the characters of the video fragments). The contents of various video fragments is “mixed”: when describing semantic content of the video fragment, adolescents specify the characters and other objects from the other videos, either previous or subsequent ones. It is worth mentioning that adolescents most often describe the characters from the first two or three video fragments of the content, or from the last ones in the sequence demonstrated. This is a regular feature that corresponds to the edge effect.

In the experimental group of adolescents aged 11–12, the idea of single video fragment is formulated as a simple sentence or a phrase “noun + adjective”. Only 15% of video fragments (six videos) are available for description. The subjects usually specify the character of the video (human or animal), its action or trait. Furthermore, if the adolescent specifies the character, he/she does not specify the objects present in the video. And, vice versa, if the adolescent specifies the objects present in the video, he/she is unable to specify and describe the character. As for the impression criterion, the adolescents like 90% of

video fragments constituting both visual-acoustic and visual-speech content and note these as “interesting”, “funny”, “curious”, “zany”, “cool”, etc. The authentically established fact is that not the original content, but the emotional response to the content is recorded during consolidation or reconsolidation of video content. Adolescents do not identify information that have made certain impression. The subjects aged 13–14 in the experimental group use enlarged simple sentences that characterize the relationships between the characters of the video and external objects when describing the ideas of the recently watched video fragments, constituting both visual-acoustic and visual-speech content. Only 32% of videos (13) are available for description that constitute mainly the visual-acoustic content. Positive impressions predominate over negative ones by a ratio of 60/40. Adolescents conserve their impressions without recalling the semantic content and details of the video. In the subjects aged 15–17, the percentage of videos available for description increases to 48% (19 video fragments). This age group is characterized by the more precise and detailed description of videos. In contrast to other age group, these adolescents describe the details (characters and other objects) as precisely as possible.

Assessment of the social media interference impact on memory consolidation in adolescents shows loss of the significant amounts of information in the form of missing (the content of the part of videos is recorded only via impression with no semantic content or details) or distorted information (mixing the content of several viewed video fragments). The maximum losses of both visual-figurative and auditory-speech information due to interfering effects of social media are observed in the group of adolescents aged 10–12.

The content consolidated after reading the text was assessed in the control groups of adolescents based on the following parameters: number of characters; main characters' sequence of actions; number of semantic units in the retelling.

The consolidated content qualitative structure allows stating the semantic content distortion manifested in the disruption of the main characters' sequence of actions; actions of one character are attributed to another one; minor characters are lost. The details are missing in the description of events during retelling. The figurative-graphic information represented by the pictures seen when reading the fragment of the book is also modified. When describing the pictures, adolescents correctly specify the main characters. However, they make mistakes when describing actions committed by main characters or their location.

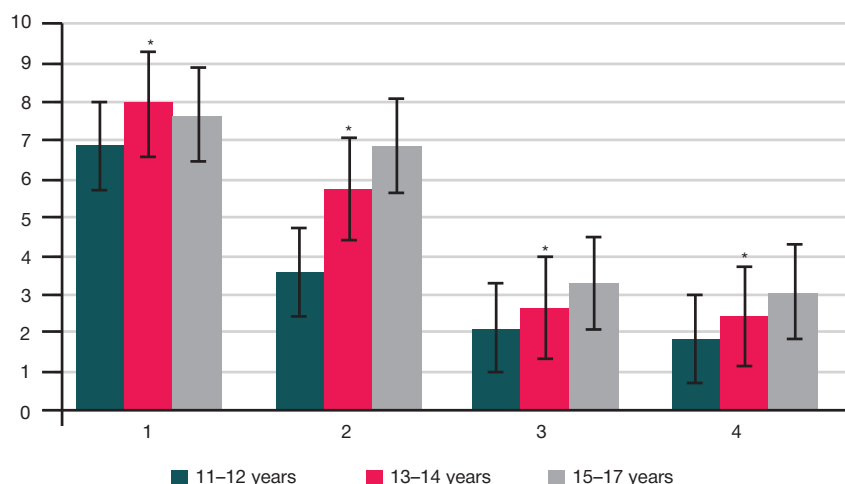


Fig. 4. Bar graph showing the average values of the auditory-speech and visual-figurative memory span obtained in the control groups after exposure to interference

The following specific features of the information consolidated observed in the control groups of adolescents should be noted. Adolescents of the control group aged 11–12 retell mostly in short simple sentences (consisting of 4–5 words on average). The number of semantic units is lower than the number of sentences: the same semantic content is represented using several sentences. When retelling, adolescents recall mostly the contents of the last 20–25 sentences they have read. In 90% of cases, retelling of the prior content is reduced to the description of the pictures watched. When retelling the recently read fragment of the book, adolescents aged 13–14 in the control group use enlarged simple sentences. They reproduce the semantic content that reflects interaction between the characters as dialogs. The semantic content is recalled in fragments and is correlated with the pictures found in the recently read pages. In the retelling, the detailed description of pictures predominates over the semantic content of the recently read text. The more precise and detailed retelling of the recently read fragment is typical for the 15–17 age group (control group). Adolescents of this group provide the most precise description of the characters' actions compared to other groups. The sequence disruptions observed in the retelling are minimal, the pictures are described using 5–7 sentences that are represented by mentioning the objects depicted and specifying their characteristics, without regard to the recently read text.

Assessment of the recently read text interference effects on memory consolidation in adolescents of the control groups shows distortion of the substantial amount of information. Distortions are manifested as the disrupted sequence of actions committed by the characters observed during retelling of the text and the lack of semantic correspondences between the recently read textual information and the pictures. The maximum distortions are reported in the control group of adolescents aged 11–12.

Step three

Reconsolidation of the auditory-speech and visual-figurative memory was assessed during phase three. After watching two series of videos (visual-acoustic and visual-speech content), adolescents of the experimental groups were offered to recall 10 words; groups of three words; and five images of the figures that are hard to verbalize together with the symbol (letter of Greek alphabet) they had memorized before watching. Adolescents of the control group were offered to complete a similar task after reading a fragment of the picture book.

A significant decrease in the amount and quality of the information recalled was observed in all experimental groups of adolescents during reconsolidation after exposure to the social media interference. Assessment of the significance of differences in the auditory-speech memory span values observed in the experimental groups of adolescents before and after exposure to interference revealed the significantly decreased values in the groups of adolescents aged 11–12 ($p = 0.026$), 13–14 ($p = 0.022$), and 15–17 ($p = 0.024$). Similar results were obtained when assessing the visual-figurative memory span. The maximum significant decrease in the amount of information recalled is reported in the experimental group of adolescents aged 11–12 ($p = 0.024$). The visual-figurative memory span is also decreased in the experimental groups aged 13–14 ($p = 0.022$) and 15–17 ($p = 0.021$) (Fig. 3).

The quantitative indicator of the amount of information recalled and the information content are modified in the context of social media interference. The group of subjects aged 11–12 replace the stimulus words to be recalled by the names of objects or produced speech (words) from the videos constituting the visual-speech content. Elements of the videos constituting the visual-acoustic content are also reported in the visual imagery recalled (particular movements resembling the contours of the figures recalled, contours of the displayed objects, etc.). In the group of adolescents aged 13–14 and 15–17, the qualitative transformation of the information recalled occurs primarily in the form of reduction. The interfering social media contents “blocks” the information content consolidated before the interference exposure. This, in turn, results in the loss of information content.

A significant decrease in the amount and quality of information recalled after exposure to the text reading interference is also reported in the control groups of adolescents. Assessment of differences in the auditory-speech memory span values obtained in the control groups of adolescents before and after the exposure to interference has revealed the significantly decreased values in the group of adolescents aged 11–12 ($p = 0.044$), 13–14 ($p = 0.049$), and 15–17 ($p = 0.047$). Similar results have been obtained when assessing the visual-figurative memory span. The maximum significant decrease in the amount of information recalled is observed in the control group of adolescents aged 11–12 ($p = 0.042$). The visual-figurative memory span is also significantly decreased in the groups aged 13–14 ($p = 0.044$) and 15–17 ($p = 0.044$) (Fig. 4).

In the context of interference provided by reading the text with illustrations, the quantitative reduction of the amount of information recalled is observed along with the modified

qualitative context. Adolescents aged 11–12 in the control group replace the stimulus words recalled with the names of objects presented in the illustrations to the text they have read. They also record the elements of illustrations in the recalled visual images. In the groups of adolescents aged 13–14 and 15–17, the qualitative transformation of the information recalled occurs primarily in the form of reduction. The interfering content of the recently read text “blocks” the information content consolidated before the interference exposure, just like the recently viewed video content. This is the cause of the information content loss.

Assessment of the significance of differences showed that the decrease in both auditory-speech and visual-figurative memory span was more pronounced in the experimental groups of adolescents where watching video content was used as interference compared to the control group where interference was provided by reading the fragment of the fiction picture book. In adolescents aged 11–12, significance of differences (p) between the indicators of auditory-speech memory was 0.021, and that of visual-figurative memory was 0.024; in adolescents aged 13–14, significance of differences between the indicators of auditory-speech memory was 0.024, while that of visual-figurative memory was 0.024; in adolescents aged 15–17 significance of differences in auditory-speech memory between the experimental and control groups was 0.019, and that of visual-figurative memory was 0.018.

The findings indicate more severe interfering effects of video content compared to reading textual information.

DISCUSSION

According to the review of domestic and foreign studies [15], the findings do not allow us to speak about the unified and consolidated effects extending to the whole population of children and adolescents. The authors of the review believe that the lack of definitive evidence of the effects of digital technology, including social media, is due to non-linear and differential effects. The power of these effects depends on the number of factors: individual characteristics, intensity of using the technologies, and socio-economic characteristics of the

child's environment. Our findings also confirm the adverse impact of the factor of continuous long-term video stream viewing. The more the duration of the maximum continuous video stream and the total time spent on Internet (including social media) by adolescents, the larger is the information loss.

The results of the study conducted confirm the earlier results [16]. The author points out to the fact that the efficiency of memory processes decreases within a year and a half since the start of mastering the Internet; the more prolonged online activity (over three years) leads to the increase in memorizing due to increased interaction of functional and operational mechanisms. Furthermore, the author believes that the methods used for processing of the material memorized become less differentiated and more automated with the increase in the duration of online activity. According to our empirical findings, the maximum decrease in the short-term (both auditory-speech and visual-figurative) memory span and substantial distortion of information due to interference are observed in the groups of adolescents aged 11–12. The 13–14- and 15–17-year-old subjects show less prominent reduction and distortion of information.

CONCLUSIONS

Adolescents aged 11–12, 13–14, and 15–17 show the decrease in the short-term (both auditory-speech and visual-figurative) memory span. The reduced short-term memory span results in impaired consolidation. The distorted information content is consolidated at the stage of storing. Either partial loss of information content (13–14 and 15–17 age ranges), or information content transformation in terms of form (for example, simplification) and the contents (for example, when recalling two series of three words, the stimulus words are recalled chaotically: words of one series are transferred to another series; the stimulus words are replaced by consonant words, the visual-figurative information is simplified and clarified) occurs.

Thus, the findings should be included in the programs of mental hygiene and development of the younger generation in the context of digital reality. The danger is not the digital reality itself, but its unconscious and uncontrollable effects on the fundamental mechanism that links the short-term and long-term memory systems.

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