

Feedback-type interactive features in electronic storybooks enhance learning regardless of cognitive differences

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ABSTRACT

Electronic storybook applications with interactive features offer classroom learning benefits, but their effectiveness may vary due to individual differences as attentional and working memory processes affect their efficiency. Therefore, understanding how to apply interactive features without increasing cognitive load and decreasing efficiency is crucial to selecting applications beneficial for most students. Our study aimed to explore the effectiveness of the answer-until-correct (AUC) feedback-type interactive features. We tested whether these interactive features improve the learning outcomes in primary school children regardless of individual differences in core cognitive functions. Children ($M = 9.6$ years, $SD = 0.725$; $N = 100$) were exposed to a story in three groups. An interactive application group, a video group, and a picture group. Immediately after exposure, the children answered questions measuring recall performance. We also assessed the children's working memory capacity and attentional performance. Our results suggest that electronic storybooks with AUC-type interactive features promote learning regardless of individual differences in core cognitive functions. This makes them valuable tools in the classroom because they benefit students despite learning difficulties.

1. Introduction

Electronic storybook applications offer a fresh and promising way to support general knowledge acquisition. However, despite their increasing presence in classrooms and homes, research findings on their effectiveness are inconsistent (Furenes et al., 2021; Kucirkova, 2017). This inconsistency is particularly evident in studies examining interactive features. While these features are often engaging and potentially beneficial, they can also distract learners and interfere with effective information processing (Takacs et al., 2015). Children with less developed executive attention may be especially vulnerable to such distractions (Bali et al., 2023, 2025). This raises concerns about the universal applicability of these features in educational settings. A further challenge in this field is that many studies rely on a wide variety of storybooks and app types. They often do not account for individual differences among children (Bali & Zsidó, 2024). This methodological heterogeneity makes it difficult to compare results or develop generalizable guidelines. Additionally, the term “interactive features” encompasses a broad range of features – from puzzles and games to dictionaries, story-related tasks, and feedback mechanisms – each with potentially different effects on learning. As such, there is a clear need for

systematic evaluation of specific types of interactive features.

In the present study, we focus on one well-defined and pedagogically grounded type of interaction: answer-until-correct (AUC) feedback. AUC can be particularly beneficial as it is user-friendly and encourages children to re-evaluate their answers after each mistake. This process not only reinforces learning but also helps integrate new information (Mertens & Finn, 2022). Additionally, providing immediate feedback can enhance students' engagement and reduce distractibility regardless of task difficulty and, presumably, individual differences in cognitive abilities (Buetti & Lleras, 2016). In conclusion, our goal is to specifically assess the effectiveness of AUC feedback type interactivity within electronic storybooks. We expect that this type of interactivity will effectively promote learning and help students focus on the material. By isolating this specific interactive feature, our study seeks to contribute to more targeted recommendations for educational app design and to support teachers and parents in selecting effective learning tools.

1.1. Theoretical background

Electronic storybooks combine multimedia elements, such as animations, narration, and sound effects, with interactive features, making

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them appealing tools for early education (Varga, 2014). Multimedia elements such as narration, animations, background music, or sound effects convey information through at least two sensory modalities while guiding attention and facilitating the understanding of abstract words, complex emotions, and abstract phrases (Altun, 2018; Takacs et al., 2015; Takacs & Bus, 2016). In addition to multimedia elements, the properties of touchscreens expand the boundaries of incorporating multimedia into learning and allow the use of interactive features. Interactive features have an even greater potential than multimedia elements because they add relevant physical activities (Georgiou et al., 2021; Georgiou & Ioannou, 2021; Mavilidi et al., 2016; Mavilidi et al., 2018) and provide feedback (Fabio et al., 2019) that improves learning outcomes and contributes to a joyful learning experience (Çetin & Türkan, 2022; Kosmas & Zaphiris, 2023; Mavilidi et al., 2017; Son et al., 2020; Stapp et al., 2021). However, previous studies (Parish-Morris et al., 2013; Reich et al., 2016; Takacs et al., 2015) have often regarded interactive features as detrimental because they can be distracting and require users to shift their attention between tasks (such as dictionary functions or puzzles). This distraction may impede the integration of the information presented, potentially resulting in weaker learning outcomes.

Recommendations on what makes electronic storybook apps beneficial for all students are challenging tasks due to the mixed results of the large body of related research (Furenes et al., 2021; Kucirkova, 2017; Takacs et al., 2015). The mixed results are partly because the market for electronic storybooks is highly diverse, making comparisons extremely difficult (Kucirkova, 2017), especially because studies tend to use a diverse set of storybooks. Due to the lack of systematic testing of various features, it is difficult to create a truly effective digital learning environment that suits the needs of young learners. However, the difficulty in forming reliable recommendations is not only due to methodological inconsistency. A major contributing factor is that many studies overlook individual differences in cognitive processes, even though such differences—especially in working memory and attention—are likely to moderate how children engage with and learn from these apps (Bali et al., 2023, 2025; Makransky et al., 2021). This is especially true at a younger age (e.g., in elementary school) when the maturation of executive functions is still ongoing (Anderson, 2002; Best et al., 2009; Zelazo & Müller, 2010). Learning with electronic storybooks often requires children to process and integrate multiple types of information simultaneously (Ayres & Sweller, 2014; Mayer & Moreno, 2003). This can place significant demands on their working memory and attentional resources (Anmarkrud et al., 2019; Bali et al., 2023; Doolittle & Mariano, 2008; Wiley et al., 2014). Children with better working memory capacity can hold more information at a time (and, presumably, for a longer period) and integrate it more efficiently (Ayres & Sweller, 2014; Cowan, 2010; Wiley et al., 2014). In addition, executive attention has a crucial role in highlighting relevant information and ignoring irrelevant content while using these apps (Petersen & Posner, 2012). Given these challenges, it is not surprising that teachers often struggle to select appropriate applications (Vega, 2019). However, empirical research still often overlooks individual differences among children (Altun, 2021, 2022). This makes it difficult to develop design principles that are effective for all learners. Therefore, further research is necessary to identify interactive features that can support learning across a wide range of cognitive profiles.

Feedback-type interactions can be an effective tool for enhancing learning outcomes in electronic storybooks. Immediate corrective feedback offers information about whether an answer is correct, allowing children to self-correct by providing at least one cue related to the correct answer (Butler & Roediger, 2008). This type of immediate feedback also serves as reinforcement, helping to strengthen the memory of correct answers (Ernst & Steinhauser, 2012). Moreover, feedback-type interactions appear to be beneficial for a broader audience. This feature has the potential to emphasize the key points in the learning material, while minimizing delays and reducing the need for shifts in

attention. Consequently, the cognitive load is lower than that associated with other types of interactive features, which are crucial for successful information processing (Mayer & Moreno, 2003).

A key feature of answer-until-correct (AUC) feedback is that it promotes learner control, requiring active participation and self-correction. Unlike passive formats, such as watching videos or viewing static images, AUC feedback encourages children to evaluate their responses and revise them when needed. This process of repeated self-assessment fosters deeper cognitive processing and helps integrate new information (Chang & Li, 2019; Mertens & Finn, 2022). In addition, immediate feedback can increase students' engagement and learning motivation. It has been shown that engagement reduces distractibility regardless of task difficulty and, presumably, individual differences in cognitive abilities (Buetti & Lleras, 2016).

Consequently, we believe that answer-until-correct (AUC) feedback improves learning by engaging several well-established cognitive processes. When children actively try to recall information and correct their mistakes, they undergo retrieval practice, which strengthens their memory (Chen et al., 2018; Epstein et al., 2002). AUC interactions also minimize distractions by directing attention to one task at a time (Cain et al., 2009), thereby reducing cognitive load. Immediate corrective feedback reinforces accurate responses and boosts engagement (Ernst & Steinhauser, 2012), both of which facilitate deeper information encoding and support learning for a variety of cognitive profiles.

In the present study, we sought to test whether AUC feedback-type interactions have a beneficial effect on learning outcomes regardless of individual differences in WM capacity and attentional performance. Due to the lack of definitions of interactive features, it is difficult to determine what types of features are the most beneficial. This calls for a systematic assessment of interactive features and suggests that it is worth focusing on one specific type of interaction at a time. In the present study, we define interactive features as reader-triggered elements that require an active cognitive response, such as completing a task or re-evaluating an incorrect answer. This contrasts with multimedia features, which are automatically triggered (e.g., narration, animations, background music or sound effects) and do not require deliberate input from the user. The results might contribute to further recommendations on interactive features and might help teachers and designers utilize them in a way that is beneficial for learners regardless of individual differences.

1.2. Aims and scope

The aim of this study was to investigate whether a specific type of interactive feature—AUC feedback-type interaction—can enhance children's learning outcomes, regardless of their individual differences in working memory capacity and attentional performance. Our goal was to determine if this type of interactive features, designed with appropriate simplicity and relevance to the content, could support general knowledge acquisition in children. This is particularly important since electronic storybooks, when selected carefully, can be both engaging and educational (Higgins et al., 2019).

To achieve this, we compared three conditions: (1) electronic storybook app with AUC feedback-type interaction, (2) video presentation with animation, and (3) static illustrations. Static illustrations served as a non-digital baseline condition. The video and static conditions closely matched the content of the electronic storybook app, but neither included any interactive features. In the video condition, participants watched animated sequences (of the interactive features), while in the static condition, they viewed still images that depicted key moments from those animations. All materials were designed to be simple and directly related to the narrative content. We selected the video and static formats as control conditions to reflect more traditional or everyday learning situations, such as watching educational videos or reading illustrated books. Including these conditions allowed for a comparison with high ecological validity.

Prior research has identified AUC-type feedback as particularly beneficial, and in our design, it served as the primary form of interaction, therefore, we hypothesized that children would learn more effectively with this form of interactive features than with video or static formats. We also expected that animated videos would lead to better recall compared to static illustrations, due to the advantages of observational learning. Importantly, we anticipated that these effects would be consistent, regardless of individual differences in working memory and attention capacities.

The findings of this study have significant practical implications for educators, parents, and designers of digital learning tools. By focusing on a specific interactive feature that is grounded in pedagogical principles, our results can help identify tools that are both engaging and suitable for young learners' cognitive development. If AUC feedback is proven to be effective across a variety of cognitive profiles, it could become a reliable design element in educational apps and digital storybooks. This would support the creation of more inclusive, evidence-based learning tools that can be confidently utilized in both classroom and home environments.

2. Materials and methods

2.1. Sample

We recruited a total of 100 Hungarian children (55 girls) between 8 and 11 years ($M = 9.60$, $SD = 0.725$), from elementary schools. The required sample size was defined by calculating the estimated statistical power ($f^2 = 0.25$, $1 - \beta = 0.80$) utilizing the pwr package in R (Champely et al., 2017; R Core Team, 2020) for a general linear model including nine predictor variables. The effect size estimate was determined based on findings from previous studies (Bali et al., 2023, 2025). The analysis indicated that a minimum sample size of 73 was necessary; therefore, our study was adequately powered. All participating children were typically developing, with no reported neurological or other disorders according to their teachers and parents. Parents reported an average of 10.1 h ($SD = 8.97$) of weekly screen time for their children, and 73 of the children owned at least one device. One child was excluded from the study due to extensive prior knowledge of the topic presented. The children were randomly allocated to three groups: an interactive

Table 1

Descriptive data regarding demographic variables, device use practices, and cognitive variables separated by groups. The results of the statistical analyses performed to test group differences are also reported.

	Group	N	Statistics	
Sex	Picture	33 (15 girls)	$\chi^2(2) = 1.62$; $p = .445$	
	Video	33 (20 girls)		
	Interactive app	34 (17 girls)		
Device ownership	Picture	33 (21 yes)	$\chi^2(2) = 2.30$; $p = .316$	
	Video	33 (25 yes)		
	Interactive app	34 (26 yes)		
	Group	Mean	SD	Statistics
Age (years)	Picture	9.55	0.754	$F(2,97) = 0.163$; $p = .849$
	Video	9.61	0.747	
	Interactive app	9.65	0.691	
Maternal education	Picture	2.94	0.982	$F(2,94) = 0.01$; $p = .989$
	Video	2.91	0.995	
	Interactive app	2.91	0.843	
Weekly Screen time (hrs)	Picture	10.9	9.47	$F(2,96) = 2.52$; $p = .086$
	Video	7.36	7.39	
	Interactive app	12.1	9.48	
Device use (age)	The age from which children have started using devices regularly	Picture	6.53	$F(2,92) = 1.01$; $p = .367$
		Video	6.92	
		Interactive app	7.18	
ADHD Rating Scale-IV.	Inattention	Picture	5.30	$F(2,97) = 0.600$; $p = .551$
		Video	4.82	
		Interactive app	3.71	
	Hyperactivity/Impulsivity	Picture	3.27	$F(2,97) = 0.944$; $p = .393$
		Video	3.15	
		Interactive app	1.79	
Pieron Task	DI	Picture	6.99	$F(2,97) = 2.72$; $p = .071$
		Video	6.97	
		Interactive app	3.91	
Digit Span Task	Forward	Picture	7.70	$F(2,97) = 0.097$; $p = .908$
		Video	7.82	
		Interactive app	7.82	
	Backward	Picture	6.00	$F(2,97) = 0.813$; $p = .447$
		Video	5.73	
		Interactive app	5.59	
Verbal fluency	Correct answers	Picture	37.2	$F(2,97) = 0.511$; $p = .602$
		Video	36.5	
		Interactive app	38.5	

Notes: Maternal education: 1 = Elementary school, 2 = Vocational school, 3 = High school, 4 = University.

application group ($N = 34$), a video group ($N = 33$), and a picture group (which served as a control group, $N = 33$). The groups were matched on all relevant study variables, including age, maternal education, weekly average screen time, and device ownership. For descriptive data and exact statistical values, please refer to Table 1.

The study received approval from the Hungarian United Ethical Review Committee for Research in Psychology (reference no. 2023–06) and was conducted in accordance with the Declaration of Helsinki. Parents and teachers were informed about the study's details, and informed consent was obtained from the parents. All participating children verbally agreed to take part in the study.

2.2. Procedure

Each child participated individually in a quiet room at the children's school. The child was told that their participation was voluntary and that there would be no negative consequences for withdrawing from the study. Participation required the child's verbal consent. Additionally, the children were asked if they were familiar with the topic presented. Those who could speak coherently about the topic in two or three sentences were excluded from the data analysis. This criterion only affected one child.

We employed a between-subjects design, meaning that after a brief warm-up chat, the children were randomly allocated to one of three experimental groups: interactive app, video, or picture. In the interactive app group, children were introduced to the story through an interactive storybook application on a 6.5-in. smartphone. In this group, the children could explore the app while the story was presented using the read-aloud function. In the video group, the children held the smartphone and watched the storybook with the same narration, but they did not interact with the content. In the picture group, the

experimenter read the same narration aloud while showing the printed illustrations from the interactive storybook. Immediately after this exposure, the children answered 14 short questions. Their responses were recorded for later analysis. Following the short Q&A session, we measured their working memory capacity, attentional performance, and verbal skills. All children began with story exposure, followed by the short Q&A, while the order of the cognitive tests was counterbalanced to control for order effects. Each session lasted approximately 30 min. Only those children who could complete the 30-min session without interruption were included in the study. For the flowchart of the experiment see Fig. 1.

2.3. Study materials

2.3.1. The storybook

For the storybook exposure, we used a commercially available storybook (Let's Explore Ocean by Lonely Planet Kids) from the BOOKR Kids application (<https://bookrkids.com/>). The storybook had 11 pages, and one page included 16 words and 1 interaction on average. For an example page see Fig. 2. In addition, the book included a read aloud function (in the native language of the participants), and sound effects.

In the *interactive application group*, children used a tablet application where the story was presented through a read-aloud function. On each page, they heard a statement about animals, followed by multiple animal images. Children were asked to tap on the animal that matched the statement. They received immediate feedback (AUC feedback type) and could keep guessing until they selected the correct answer. In the *video group*, we recorded the interactive storybook to produce a non-interactive video version. This version included the same narration and visual content as the interactive version, with one animation per page showing the statement and the animal options. Instead of

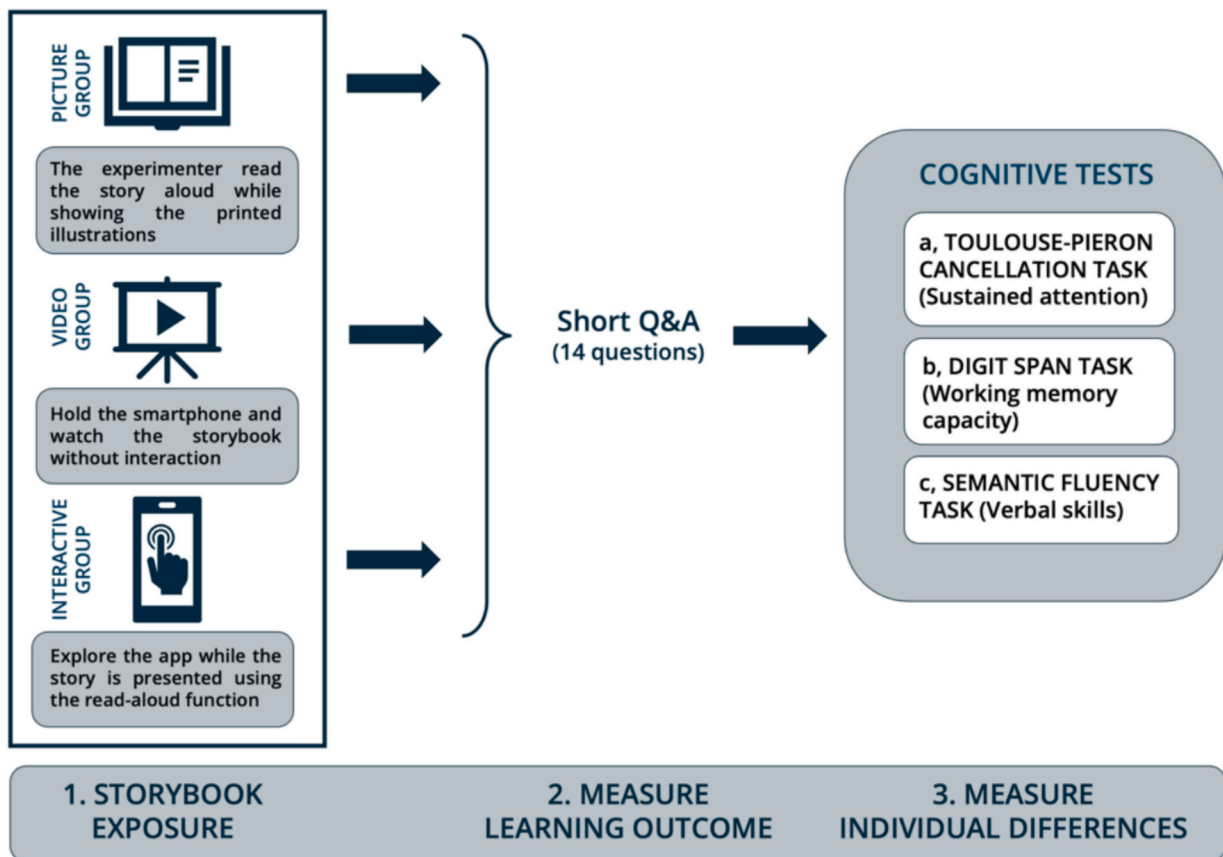


Fig. 1. The flowchart of the experiment. (1) The children were exposed to one of three storybook versions. (2) Immediately after exposure, they answered the Short Q&A. (3) Finally, they completed the tests measuring cognitive processes in a random order.

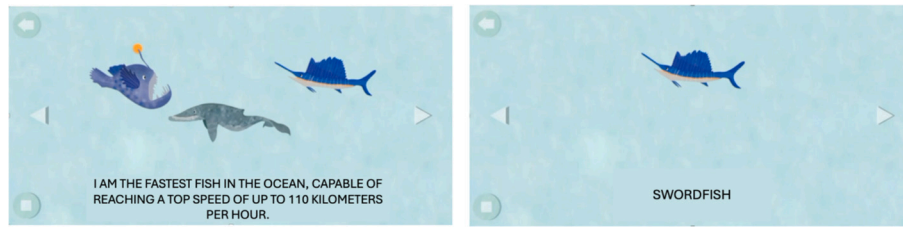


Fig. 2. A scene from the interactive electronic storybook “Let’s Explore Ocean.” This figure depicts a scene from the storybook *Let’s Explore Ocean* by Lonely Planet Kids, accessed through the BOOKR Kids application. The storybook is one of the interactive electronic materials used in this study. In this scene, children were prompted to choose one of three options based on the text. Selecting the correct answer allowed them to progress in the story, while incorrect choices offered the opportunity to correct themselves.

interacting with the content, the children watched a version where the correct animal was selected automatically, simulating the outcome of someone else’s choice. In the *picture group*, children viewed printed illustrations from the storybook while the same narration was read aloud by the experimenter. After each statement, the experimenter revealed the animal that matched the description. This condition included no animation and no interactivity. The storybook exposure lasted approximately five minutes in all three groups. To ensure consistency, the two mini games embedded in the original interactive version were skipped across all conditions. and for the comparison between conditions see Table 2.

2.3.2. Recall performance

In line with previous studies (see Furenes et al., 2021; Richter & Courage, 2017) we requested the children to answer 14 questions related to the plot of the storybook, referred to as the short Q&A. Some example questions included: “Which fish is the fastest in the seas?” and “Why do squids squirt ink?” This was done to assess their recall performance. The recall questions used during testing were based on the language of the storybook, however, were designed to avoid any potential cues or suggestions toward specific answers, while ensuring that the terminology and content remained consistent between the reading material and the test items. The answers were evaluated on a three-point scale, with scores ranging from 0 to 2 points, and were rated by three independent scorers. A score of 0 points was assigned for incorrect answers, 1 point for correct but incomplete answers, and 2 points for fully correct answers. The maximum possible score was 28 points, achievable by answering all 14 questions correctly. The scores obtained by the children ranged from 7 to 23.7 ($M = 15.8$, $SD = 3.81$). To evaluate the

agreement among the scorers, we used Kendall’s coefficient of concordance. The interrater reliability was found to be 0.948 ($p < .001$), indicating a high level of agreement among the scorers.

2.4. Cognitive tests

2.4.1. Sustained attention test

We used the Toulouse-Pieron cancellation task (TP) (Lima et al., 2023) to assess the attentional performance of the children. The TP is widely used to measure sustained attention from the age of 8 years (Chaharsooghi et al., 2011; Nedelescu et al., 2022). This task requires both resistance to fatigue and high levels of concentration. It consists of an A4 test sheet that portrays 400 figures overall in 20 lines with 20 figures per line. The children were asked to cross out as many target figures as possible and ignore the nontargets. The four target figures are presented in the header of the test sheet. The figures are squares with a line attached to them in 8 different positions. The task was timed and completed within 5 min, with the time being monitored by the experimenter. To evaluate performance, we recorded the number of attended figures in total (N), total errors (E), and total omissions (O). These measures were used to calculate the dispersion index (DI) using the following formula: $DI = (E + O) / N * 100$. A higher DI indicates poorer performance. In this study, scores ranged from 0 to 34.8 points. In earlier studies the test yielded for excellent test-retest reliability for the DI with a Pearson’s correlation coefficients of 0.877 ($p < .001$) (Lima et al., 2019).

2.4.2. Working memory capacity

The backward digit span task (Nagyne-Rez et al., 2008) was employed to measure the working memory (WM) capacity of the children. In this task, the children listened to a sequence of digits and were asked to repeat them first in the same order (forward version) and then in reverse order (backward version). After every two sequences, the number of digits increased by one. The task concluded if a child made errors in two consecutive sequences of the same length. We used the number of correctly recalled sequences as a measure of WM capacity, with higher scores indicating greater capacity. Children could earn a maximum of 16 points in each version. In this study, the scores ranged from 5 to 11 in the forward version and from 0 to 10 in the backward version. According to the official Hungarian manual (Nagyne-Rez et al., 2008), the test shows excellent reliability. The split half reliability takes a value of 0.83 for the forward version and 0.80 for the backward version, while the test-retest reliability shows a value of 0.76 for the forward version and 0.74 for the backward version.

2.4.3. Verbal skills

To control for the verbal skills of the children, we used the semantic fluency task (Sehyr et al., 2018; Socher et al., 2019). Children were asked to generate as many exemplars of a given category as they could under a predetermined time limit (one minute for each category). We used three categories, namely, ‘animals’, ‘fruits’, and ‘clothing’. The task lasted three minutes, one minute per category. As an indicator of

Table 2

Comparison of storybook presentation formats. The table summarizes the key characteristics of the three experimental conditions used in the study: Interactive App, Video, and Picture (Printed).

	Condition		
	Interactive App	Video	Picture (Printed)
Presentation mode	Tablet application	Video recording	Printed illustrations
Narration	Read-aloud function (native language)	Read-aloud (native language)	Read aloud by experimenter
Animations	Interactive animation	Automatic animation	None
Interactivity	Tap to select correct answer (AUC feedback)	None	None
Feedback	Immediate corrective feedback (Direct)	Observing someone receiving feedback (Indirect)	Immediate corrective feedback (Direct)
Learner control	High Child can explore and guess	None passive viewing	High Child can explore and guess
Exposure duration	5 min	5 min	5 min

vocabulary, we calculated the overall number of correct responses across the three categories. Subordinate and superordinate responses were considered correct, while variations in the same item (e.g., plural forms, colour variations) were not counted. The total number of correct responses for the three categories ranged between 18 and 71. The test has good psychometric properties; in this study, McDonald's ω was 0.611. To test reliability, we used the number of correct answers for each category.

2.5. Questionnaires

2.5.1. ADHD rating scale-IV

In addition to the cognitive tests the homeroom teacher (who spends most of the school day with the children) of each child completed in the ADHD Rating Scale-IV (Perczel-Forintos et al., 2005) to measure attentional mechanisms of the children. We asked teachers, not parents, to evaluate the children because it was important for comparability that children in the same class be assessed by the same adult. In addition, teacher ratings are more reliable and better predictors of a child's attentional performance than parental ratings are (Tripp et al., 2006). The questionnaire assesses inattention, hyperactivity, and impulsivity in children aged 5 to 18 years (McGoey et al., 2007) 18-item and consists of two subscales: inattention and hyperactivity/impulsivity. The items are rated on a 4-point Likert-type scale that ranges from 0 (never or rarely) to 3 (very often), indicating the frequency with which the described behavior occurred over the past six months. The scale demonstrates good psychometric properties. The McDonald's ω was 0.943 for the inattention subscale and 0.956 for the hyperactivity/impulsivity subscale.

2.5.2. Parental questionnaire

The parents completed a questionnaire that included demographic questions (age and sex of their children, maternal education), weekly average screen time and device ownership of their children.

2.6. Data analysis

Statistical analyses were performed using the JAMOV Statistics Program (Version 1.2.27.0 for Windows). Outliers were excluded, defined as recall performance scores on the short Q&A greater than ± 2.5 absolute deviations from the median (approximately 5% of all the collected data). All variables followed a normal distribution, as indicated by the absolute values of skewness and kurtosis, which were below 2.

First, we sought to explore the possible effects of demographic variables on general recall performance. We tested the relationships between recall performance and age, maternal education, weekly average screen time, and the age at which the children started using smart devices regularly (device use) via Pearson correlation analysis. We performed two additional independent sample *t*-tests to test the effect of sex and device ownership. This was necessary because we wanted to control for the possible nuisance effects of these variables when testing our hypothesis.

To test our predictions about the effects of the book format on recall performance, we used a general linear model analysis. The dependent variable was the score achieved on the Short Q&A, while the medium of the book (picture, video, or interactive app) was entered as a between-subject factor. Furthermore, the forward and backward digit span task scores, DI score, Inattention and Hyperactivity/Impulsivity subscale scores, and number of correct answers in the verbal fluency task were entered as independent predictors. Demographic variables showing a significant relationship with recall performance were also entered into the model (sex and maternal education both as independent predictors) to control for their effects. Follow-up pairwise comparisons were adjusted for multiple comparisons using Tukey's test. The statistical results are presented in a table to clearly describe the findings. The

dataset, which includes the computed study variables, is available on the Open Science Framework: https://osf.io/s5k4t/?view_only=fcd6f1e2c0bd4fdcfac0225ffec7a30e

3. Results

Regarding the demographic variables, we found that only maternal education and sex were associated with recall performance. Maternal education had a weak positive relationship with total Q&A; that is, higher education was associated with higher scores on the Short Q&A. We also found sex differences. Compared to girls ($M = 15$, $SD = 3.55$), boys ($M = 16.9$, $SD = 3.89$) scored higher on the Short Q&A. Other demographic variables showed no association with recall performance. Since maternal education and sex were related to the recall performance of the children, we included these variables in the GLM analysis. For the exact statistical values, see Table 3.

We hypothesized that multimedia elements and interactive features would improve recall performance compared to simple static illustrations, regardless of the individual differences in attentional mechanisms and WM capacity. We hypothesized that interactive features would have a greater impact than automatic multimedia elements or static pictures, due to the positive effects of feedback-type interactions. As anticipated, we observed a significant effect of the groups. Tukey-corrected pairwise comparisons indicated that participants in the interactive application group demonstrated better recall performance ($M = 17.5$, $SD = 3.12$) than did those in the picture group ($M = 14.8$, $SD = 3.90$). The recall performance of the video group ($M = 15.2$, $SD = 3.88$) differed neither from that of the picture group nor from that of the interactive application group. The distributions of the scores achieved on the short Q&A are reported in Fig. 3. For the exact statistical values, see Table 4.

As we anticipated, attentional mechanisms, working memory capacity, and verbal skills did not influence recall performance. We found no significant main effects or interactions for any of the measured variables, including the ADHD Rating Scale-IV, the backward and forward digit span tasks, and the semantic fluency task. Among the demographic variables, only the main effect of sex remained significant, showing that boys ($M = 16.92$, $SD = 3.89$) performed better than girls ($M = 14.99$, $SD = 3.55$) in general. The interaction for sex and maternal education was also nonsignificant, suggesting that sex differences are independent of book format. Our hypothesis was partially confirmed, as only members of the interactive (but not the video) group scored higher on the short Q&A than did members of the picture group, and the effect was independent of individual cognitive and demographic variables.

4. Discussion

Electronic storybooks with interactive features can enhance multimedia learning and significantly improve children's learning outcomes. They promote physical activity, increase engagement, and provide personalized feedback, making learning more effective (Fabio et al., 2019; Mavilidi et al., 2016; Mavilidi et al., 2018). However, these benefits depend on individual differences in cognitive processes (Bali et al., 2023; Wang et al., 2022; Wiley et al., 2014). Therefore, it is important to understand how to use these apps appropriately. As individual differences are often great between children in elementary school, it is difficult to find and design applications suitable for the individual needs of every student. General recommendations on multimedia elements (Mayer & Moreno, 2003) provide some guidance to designers and teachers; however, interactive features call for more precise recommendations. Regarding interactive features, previous studies have shown mixed results (Etta & Kirkorian, 2019; Furenes et al., 2021). Despite the supposed benefits, they can be distracting and might increase the cognitive load in the children (Takacs et al., 2015). Furthermore, the diversity of interactive features and the lack of precise definitions across different studies hinder the establishment of general conclusions (Kucirkova, 2017).

Table 3
The results of the Pearson correlations and independent samples t-tests test the effect of demographic variables (age, sex, maternal education, average weekly screen time, the age at which the children started using smart devices regularly, and device ownership) on recall performance in general. Significant correlations are labelled in italics.

	Age	Sex	Maternal education	Weekly screen time	Device use	Device ownership
Recall performance	$r = 0.070$ $p = .497$	$t(93) = 2.53$ $p = .013$; $d = 0.522$	$r = 0.209$ $p = .046$	$r = -0.068$ $p = .514$	$r = 0.000$ $p = .997$	$t(93) = -1.02$ $p = .413$

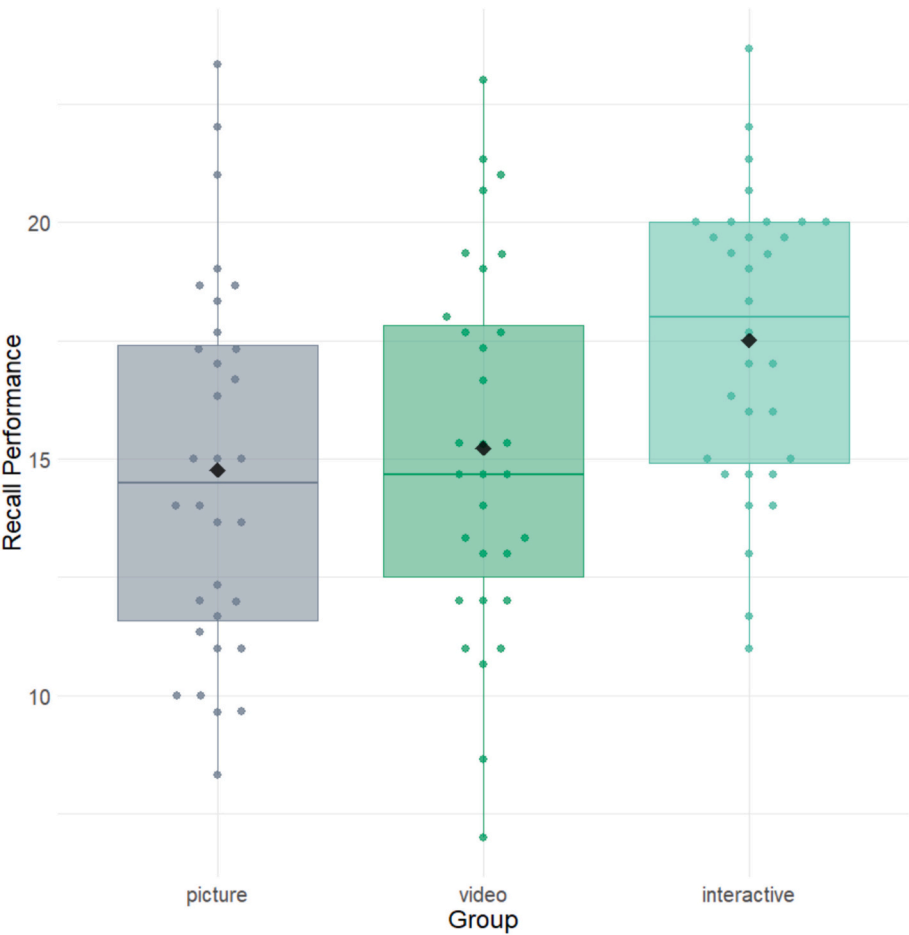


Fig. 3. The recall performance on the Short Q&A measured in three experimental groups: picture, video, and interactive app. The black diamonds represent the mean scores, while the colored dots indicate the actual scores achieved by the children.

The AUC feedback type interaction is a well-defined subtype and is potentially beneficial for students with a wide variety of cognitive abilities (Kim et al., 2017; Mertens & Finn, 2022). Therefore, we examined whether AUC-type interactive features can be more beneficial than multimedia elements and the static presentation of study material for a broader audience. As we predicted, AUC-type interactive features resulted in the best learning outcomes in elementary school children. Our findings underscore that interactive features with the right characteristics can be used for educational purposes regardless of cognitive differences. These results can guide teachers and parents in choosing suitable applications to facilitate general knowledge acquisition.

Children using the interactive electronic storybook recalled significantly more information on the short Q&A than those viewing static illustrations. Recall in the video group did not differ significantly from the static illustration group. These findings suggest that feedback-type interactions with corrective feedback have a stronger impact on learning than simply observing someone else's actions. These findings align with recent meta-analyses highlighting the effectiveness of AUC feedback (Chang & Li, 2019; Mertens & Finn, 2022). Immediate

corrective feedback enhances learning by reinforcing correct answers (Ernst & Steinhauser, 2012), increasing engagement (Chang & Li, 2019; Mertens & Finn, 2022), and promoting active involvement (Butler & Roediger, 2008). Together, these factors improve memory encoding and support better learning outcomes in interactive multimedia environments. These results suggest that the adoption of established educative practices is a good strategy for designing electronic storybooks with interactive features to promote learning. From a practical perspective, AUC-type interactive storybooks can be integrated into classroom routines in several ways. For example, they may be used in station-based learning, tablet-assisted learning, or as part of differentiated tasks designed to meet students' individual abilities. Interactive platforms, including tablets, interactive whiteboards, and tools like Genially, allow teachers to create and implement content across subjects such as literature, STEM, and second language learning. This approach enables teachers to take advantage of immediate corrective feedback and active engagement in the classroom, while also addressing individual learning differences.

Individual differences in working memory capacity and attentional

Table 4

Detailed statistical results for the general linear model with main effects, interactions, and pairwise comparisons. Significant effects are highlighted in italics.

The main effect of group	df	<i>F</i>	<i>p</i>	ηp^2
	2, 91	3.791	0.028	0.104

Pairwise comparisons	df	<i>t</i>	<i>p</i>	<i>P</i> _{Hukey}
Interactive - Picture	65	2.738	0.021	
Interactive - Video	65	1.643	0.235	
Video - Picture	65	0.930	0.624	

Main effects	df	<i>F</i>	<i>p</i>	ηp^2
Inattention	1, 91	1.637	0.205	0.025
Hyperactivity/Impulsivity	1, 91	2.182	0.144	0.032
DI	1, 91	0.401	0.529	0.006
Digit span Task (Forward)	1, 91	0.561	0.457	0.009
Digit span Task (Backward)	1, 91	0.017	0.896	0.000
Verbal fluency	1, 91	0.059	0.809	0.001
Maternal education	1, 91	0.477	0.492	0.007
Sex	1, 91	7.563	0.008	0.104

Interactions	df	<i>F</i>	<i>p</i>	ηp^2
Group*Inattention	2, 91	0.045	0.957	0.001
Group*Hyperactivity/Impulsivity	2, 91	0.321	0.727	0.010
Group*DI	2, 91	0.248	0.781	0.008
Group* Digit span Task (Forward)	2, 91	0.440	0.646	0.013
Group* Digit span Task (Backward)	2, 91	1.676	0.195	0.049
Group* Verbal fluency	2, 91	0.414	0.662	0.013
Group* Maternal education	2, 91	1.633	0.203	0.048
Group*Sex	2, 91	0.049	0.953	0.001

performance did not affect recall performance, confirming our second hypothesis. This finding supports our suggestion that feedback-type interactions have the potential to promote learning irrespective of individual differences. This particular type of interactive feature forwards information through a question and expects an attempted answer from the child, which is followed by personalized corrective feedback. This minimizes the need for sharing attention and task switching, which might reduce the risk of cognitive load (Ayres & Sweller, 2014; Mayer & Moreno, 2003). Consequently, AUC-type interactions are suitable for a broader audience, as they are cognitively less demanding for the children. These results can guide teachers and designers in building a digital environment that is beneficial for all students.

We also controlled for children's verbal skills, and we did not find any correlation in this respect. This demonstrates that verbal skills have not played a role in how children process information through storybooks or the extent to which they can report the knowledge they have gained through them. The effect of the book format was also independent of demographic variables. Although the sex of the children was associated with learning outcomes, this proved to be only a general effect. Overall, boys scored higher for all three book formats, indicating that sex did not influence how well children performed after using an electronic storybook. Considering these results, electronic storybooks (and AUC feedback-type interactions in particular) seem to be advantageous regardless of variables such as sex, maternal education, weekly screen time, or device ownership.

Despite the practical relevance of our findings, some limitations must be noted. First, we did not measure the time children spent with each book format. Therefore, we cannot determine how usage time may have influenced the results. In the future, it would be crucial to measure the time spent with the applications, as electronic storybooks also have the potential to support learning through self-paced learning (Tullis & Benjamin, 2011). Furthermore, the data collection did not occur during

regular classroom lessons. Therefore, while the results can be considered applicable to individual learning environments – such as home-based or independent study – they are only partially transferable to whole-class instruction. Nonetheless, we believe that the findings can still be effectively adapted to classroom settings that promote individualized or differentiated instruction. This can be achieved through tools like interactive whiteboards or tasks specifically tailored to students' individual abilities and interests. In addition, future studies should replicate this study in a more common context (e.g., during classroom learning). Future studies should also focus on the long-term effects of using electronic storybooks. We have limited knowledge of whether improved learning outcomes remain observable after the repetitive use of these apps or whether our results are simply a consequence of the novelty effect (Rodrigues et al., 2022). Children might become accustomed to the involvement of electronic storybooks, which would make these apps less appealing and attention-grabbing after a while. Longitudinal studies are also needed to explore the long-term benefits of using electronic storybooks which we have not addressed in the present study. Finally, our sample is not representative, as all the children were typically developing, which makes it difficult to draw general conclusions and recommendations. Future studies should include a specific sample of children with learning difficulties to understand how useful this feature could be for them. We might be able to utilize these tools to support the academic performance of these students.

5. Conclusion

Despite these limitations, our results indicate that well-designed electronic storybooks with AUC feedback-type interactions benefit children aged 8 to 10 years. They improve learning outcomes even for children with less mature sustained attention and working memory capacities. Teachers are sometimes not prepared to choose appropriate apps as an aid in the classroom (Vega, 2019). This is further complicated by the fact that educational apps such as electronic storybooks do not always deliver the expected outcome (Vaala & Lapierre, 2014). In addition, according to recent studies (Bali et al., 2023; Wiley et al., 2014) the efficiency of information processing through electronic storybooks is highly dependent on individual differences among children. It can be challenging to address individual needs when building a digital educational setting. Based on our results it can be assumed that implementing well-established pedagogical techniques as interactive features in electronic storybooks is promising. In the present study, we tested the impact of immediate AUC-type feedback on learning through an electronic storybook; however, further studies should address other techniques and other types of interactive features. Systematic testing of interactive features is crucial for forming clear recommendations on how to use them effectively without increasing cognitive load. Using simple multimedia elements and one AUC feedback-type interaction per page promotes comprehension and learning, regardless of individual differences in sustained and selective attention and working memory capacity.

CRediT authorship contribution statement

Cintia Bali: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Kriszta Zsanna Csibi:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Nikolett Arató:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **András Norbert Zsidó:** Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.actpsy.2026.106718>.

Data availability

I have shared the data on OSF, the link is available in the manuscript

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