

The Effects of Presented Media Types on Spatial Cognition Task Performance in Preschool Children

Bokyoung Kim *

Yun Hyun Pack

Soon Hyung Yi

Seoul National University

As the use of digital media is becoming more universal and is being used in early-childhood education, understanding the effects of digital media on development is required. The purpose of this study was to examine whether child performance on a spatial cognition task depends on the type of media used to present the task and if the effect of media type is different depending on child's age and sex. To do this, a spatial cognition task set (consisting of direction, rotation, symmetry, conjugation, and part/whole tasks) was prepared, and these tasks were presented to 60 3-, 4-, and 5-year-old children using paper- and tablet-based measures. Our results showed that the correct answer rate of task performance differed significantly when completing the task on a tablet than when completing the task on paper. Generally, response times when completing the tasks on a tablet was significantly shorter than when completing the tasks on paper. Although there was no interaction between the type of media and age, and partial interaction was found between the type of media and sex. This result implies an influence of digital stimulation on child performance on the spatial cognitive task. This study provides a basic understanding for follow-up studies to examine the consequences of exposure to digital stimulation.

Keywords: digital stimulation, media effect, presentation media, spatial cognition, task performance

The development of the technology in modern society has largely changed information delivery and the mediums used to evaluate children in early-childhood education. The emergence and expansion of digital media in the form of video, animation, and photos has made it possible to use digital media for various educational activities instead of paper media. Teachers are providing children with instructive content through video, computer, tablets, and more. The use of the digital media appears in early-childhood

education area and in child evaluation. In the past, child abilities were often assessed with paper-and-pen testing, but recent tests have been made using digital, interactive media.

Despite the expansion in the use of digital media, our understanding of the effect of digital media on children remains obscure. Children who use digital media can be influenced by it in various ways. Although the possibility that children remain unaffected cannot be excluded, it seems plausible that visual or cognitive influences and concentration- and fatigue-related effects might exist. Childhood is a critical period for development in various ways. The effects of digital media during this period might be more severe than during other time points and might

* **Corresponding Author:** Department of Child Development & Family Studies, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul, 08826, Korea.
E-mail: bokyoungk@gmail.com

affect later development. Therefore, it is necessary to assess the effect of digital media on child cognition and task performance to utilize digital media effectively in early-childhood education.

In the educational field, various studies regarding the effect of digital media have focused on the educational aspects of using digital media rather than the effect of the stimulation of digital media. Several education-engineering studies have discussed the influence of this media type on educational achievement (Cho, 2000; Jung, Kim., & Nah, 2013; Mayer, 1997; Paivio, 1986; Park, 2001; Park & Jeon, 1999). These studies have focused on how to deliver educational content to students through digital media and have contributed to developing effective use of digital media (Lee, 2010; Wood, Pillinger, & Jackson, 2010; Zucker, Moody, & McKenna, 2009). However, these studies do not provide information about the effect of digital media in terms of digital stimulation.

Other studies have attempted to understand the direct effects of digital media. Some researchers have tried to describe the fundamental effect of analog and digital stimulation (Chon, 2006, 2011; Kim & Yi, 2014; Lee, 2011; Miratech, 2001; Tewksbury & Althaus, 2000). This was done through the study of presenting the two-dimensional equal static stimulation using paper media and digital media. For example, researchers have presented the same articles to adults using digital and paper media and have subsequently measured reading speed and content remembrance rate (Lee, 2011; Miratech, 2001; Tewksbury & Althaus, 2000). Another study delivered a fairy tale to children through an electronic book and a paper book (in which there was no voice or animation) and measured the level of understanding of the story (Kim & Yi, 2014). In addition, in several neurophysiological studies, participant eye movements (Miratech, 2001) and the brainwaves (Chon, 2006, 2011) have been measured after presenting the same articles or advertisements using digital and paper media. These studies attempted to reveal the effects of digital stimulation by controlling the content and video elements of the media used.

However, these studies have been limited.

First, only a few studies have demonstrated the effects of media itself. Moreover, the results of the aforementioned studies are inconsistent; as such, it is difficult to draw conclusions. For example, in the studies by Miratech (2000) and Tewksbury and Althaus (2000), although the iPad reading group read more articles during the allocated time than the paper reading group, their article remembrance rate was lower. However, in the study by Lee (2011), the article remembrance rate of the smartphone newspaper group was better than that of the paper newspaper group. In the study by Kim and Yi (2014), the story understanding of the children of e-book group was not significantly different from that of the paper book group. These inconsistent results could be due to differences in the screen size of the media, character size, or the number of characters per screen that were used in each study (Kruk & Muter, 1984; Rubens & Krull, 1985). Therefore, to understand the exact effect of media type, more studies designed to minimize the perceptual difference of the screen and paper should be conducted.

Second, previous studies using brainwave measurement have provided strong neurophysiological evidence for the effect of digital media stimulation on attention and arousal (Chon, 2006, 2011; O, 2011). However, some influential elements included in these studies make the interpretation of the effect of the media itself unclear. For example, in the studies by Chon (2006, 2011), college students were assigned to a paper newspaper group and a digital newspaper group, and their brainwaves were measured while students were reading the newspaper. The paper newspaper group showed higher arousal, concentration, and brain activity in some regions (i.e., parts of frontal lobe and parietal lobe) compared to the digital newspaper group. The authors suggested that this result reflected that less energy is used in the brain when people use digital media compared to analog media. However, the lower concentration and arousal level found in the digital newspaper reading group could be attributed to another factor: the subjects were instructed to read the

articles by controlling the mouse. Several studies (Benest, 1991; Schwarz, Beldie, & Pastoor, 1983) have pointed out that the scrolling function can be a factor that might distract readers. This is because the subjects' eyes do not focus on certain characters but keep moving following the moving characters during scrolling. Therefore, other potentially influential elements need to be removed to verify the essential influence of analog and digital stimuli.

Third, previous studies aimed at investigating the effects of media have presented the reading material or story understating task through both types of media. However, a task aimed at the perceptual level might be more appropriate than a linguistic task, as interpreting and understanding the symbolized language requires thinking processes with more stages. For example, the reading task requires a series of thinking processes to comprehend the meaning of each word and to understand the meaning of the whole sentence by recognizing and deciphering the characters. In addition, a story-understanding task requires high-dimensional thinking processes to accept the auditory stimulus, interpret it, connect the story, and comprehend the causal relationships. On the other hand, a task that requires the recognition of a stimulus and some mental manipulations of the given stimulus includes fewer thinking stages than a language task and will be affected more directly by the nature of the media itself. Therefore, using a task at the perceptual level is required to ascertain the effect of digital media on cognition.

One task that requires recognition of a stimulus and mental manipulation is the spatial cognition task. This task measures the ability to recognize and comprehend the position or direction of a stimulus, spatial movement, continuity of form, and such. It includes subtasks such as direction, rotation, symmetry, conjugation, and part/whole. The media effect verification using the spatial cognition task can establish how digital media influences child cognition and mental manipulation. If the decline in attention and arousal level of the digital media condition found in studies by Chon (2006, 2011)

is the result of the digital stimulation itself, and not of other factors, the arousal- and concentration-related effects caused by the digital stimulus might be predicted to be present in the performance of the spatial cognition task. To address the limitations of previous studies, the present study aimed to minimize the perceptual difference between the paper and screen, to exclude other device operation elements such as scrolling, and to examine how differences of the presented media influenced child spatial cognition task performance.

In addition, sex and age might influence the effects of digital stimulation on child task performance. This is because children of different ages and sexes have different cognitive characteristics; as such, the effects of the external stimuli can differ. Few studies have examined whether the effects of media differs by age or sex.

Taking these elements together, the present study aimed to assess whether the performance on a spatial cognition task by 3-, 4-, and 5-year-olds differed depending on the types of the media presented and whether the effects were influenced by age or sex. A spatial cognition task set consisting of subdomains—direction, rotation, symmetry, conjugation, part/whole—was developed, and child performance was measured after these tasks were presented through paper and tablets. The research questions of this study are as follows: (a) do children perform differently on a spatial cognition task depending on whether the task is presented on paper versus digitally? and (b) does the effect of media type depend on age or sex?

Method

Participants

In this study, 60 3-, 4-, and 5-year-old children, who had never used tablets before were recruited in a kindergarten in Gyeonggi, Korea. The researchers explained the contents and procedures of the experiment and obtained consent about the participation of the children from the children's parents. A separate

preliminary survey confirmed that not all of the spatial cognition tasks used in this study were suitable for 2-year-old children; thus, 2-year-olds were excluded from the study.

Of the 60 children, 30 were male and 30 were female. The average age of the 3-year-olds (10 male; 10 female) was 43.2 months, range = 38–47. The average age of the 4-year-olds (10 male; 10 female) was 55.2 months, range = 52–59. The average age of the 5-year-olds (10 male; 10 female) was 64.6 months, range = 60–70.

Spatial Cognition Task Tool Components

Direction task tool. The direction task tool was designed based on earlier studies (Jedrysek, Klapper, Pope, & Wortis, 1972; Piaget, 1956). The direction task tool consisted of a left–right task and an up–down task. Images that were familiar to children such as a rabbit or an apple were used in each task. A left–right direction task tool was made by placing the image in the center and placing other images on the left and right. An up–down direction task tool was made by placing the image in the center and placing other images at the top and bottom.

In the practice session, the researchers asked the children to confirm the direction name by identifying their dominant hand and the alternate hand. Thereafter, children were asked to identify the image to the right or left of the middle image. In the testing session, the children were asked about the direction task without the direction confirmation of both hands. The same procedure was used for the up–down direction task. Considering the low articulation levels of young children, the children were instructed to respond to the indicated direction by words or indicating with their hands. The response reaction was scored as 1 only when all three questions of each direction task set were answered correctly. If children answered one or more questions incorrectly, their responses were scored as 0 to exclude the possibility that they answered correctly by chance.

Rotation task tool. The rotation task tool was designed based on earlier, related tools (Choi &

Lee, 2006; Piaget & Inhelder, 1971; Rosser, Ensing, Clider, & Lane, 1984). The rotation task tool consisted of a right-rotation task (90° to right) and a left-rotation task (90° to left). In this study, images which were familiar to children, simple, and contained a direction were selected as the stimuli for the rotation task. Each task had a standard image at the top and three option images (including the correct answer) at the bottom.

In the practice session, the researchers demonstrated the rotation trial with a piece of paper (4.5 × 5.0 cm), on which the sample image was printed. The researchers then asked the children to find the same figure as the rotated image from the options. This was done to allow the children to become familiar with the task. In the testing session, the children were asked to indicate which shape would appear if they turned the standard image to the right or left. They were instructed to rotate the standard image mentally and to choose the rotated image from the response items. The children's response times (correct/incorrect) and response times were recorded.

Symmetry task tool. The symmetry task tool was created for this study. The symmetry task tool consisted of a Y-axis symmetry task and an X-axis symmetry task using images that were familiar to children, simple, and contained an implied direction. Each task contained the standard image at the top, with three option images (including the correct answer) below.

In the practice sessions, the researchers presented an example task to the children and explained which image would be symmetrical to the standard image by covering and turning their hands over. The researchers allowed the children to find the symmetrical image of the example item in the response items. This allowed the children to become familiar with the task. In the testing session, the children were asked to say which shape would appear if the standard image were flipped left/right or up/down. The children were asked to conduct the task mentally and to choose the image in the response items. Their responses (correct/incorrect) and response times

were recorded.

Conjugation task tool. The conjugation task tool was made in a similar way to the rotation and symmetry task tools. Previous study findings related to child conjugation cognition performance are sparse; as such, the most basic-level task to measure child conjugation cognition ability was created. The conjugation task tool was composed of a left–right conjugation task and an up–down conjugation task. In the conjugation task tool, a black rectangle would form when the pieces of a presented stimulus and correct answer stimulus were put together. The boundary of the separated pieces included simple curves and straight lines. The standard image was placed at left in the left–right conjugation task and at the top in the up–down conjugation task. Three response options (including the correct answer) were placed on the opposite side.

In the practice sessions, the researchers presented the example task to the children and asked which shape fit with the standard image. The researchers asked the children to choose the correct answer from the response items. After allowing the children to become familiar with the task through the practice session, the testing session was conducted in the same way. The children's responses (correct/incorrect) and response times were recorded.

Part/whole task tool. The part/whole task tool was created for this study. Although the Wechsler Intelligence Scale for Children contains a finding-missing-part task, this task measures the ability to distinguish between the essential and non-essential parts of an object (Wechsler, 2003). As such, it was not applicable to this study. For this study, animal images familiar to children were selected as the stimulus images. The tool was made by creating a blank in a space in the image of the animal and placing three images that could be used to fill in the space (including the correct answer) below. The image was presented in black-and-white to control for the influence of color.

In the practice sessions, the researchers asked the children to indicate (from the answers

provided) which partial image should be inserted in the blank space. This allowed the children to become familiar with the task; subsequently, the testing sessions were carried out in the same way. The children's responses (correct/incorrect) and response times were recorded.

All subtasks consisted of four stimuli sets. One set was used in the practice sessions, and three were used in the testing sessions. The items considered to be too difficult for the children were excluded. The validity of the tool was verified by two early-childhood experts with a master's degrees and two daycare-center teachers. The spatial cognition task sets were printed on A4 paper and were saved on the tablets as image files. Task trials were scored 1 if a child answered correctly and 0 if they answered incorrectly. The average correct answer rate was calculated by averaging the response scores on the three testing sets. The time that children listened to the questions and responded was measured as response times, and the average response times were calculated by averaging the response times of the items to which they responded correctly.

Procedure

A preliminary survey was conducted before conducting the main survey to assess the suitability of the spatial cognition task sets and to determine how much time would be needed for the task. This survey was conducted with 9 children randomly selected from the kindergarten in Gyeonggi. Based on the preliminary survey, the level of the spatial cognition task sets were generally appropriate for 3-, 4-, and 5-year-olds, and the time required for total task performance was about 20 min. After the preliminary survey, some difficult-level tasks were replaced by more basic-level tasks, and the researchers' questions were simplified to aid children understanding. Moreover, the demonstration of the real piece for rotation task was adopted to help child understanding.

To confirm the suitability of the spatial cognition task sets presented on tablets, a secondary survey was conducted with 15

children (5 each of the 3-, 4-, and 5-year-olds) using the iPad 2. Based on the secondary survey, the spatial cognition task sets presented on the tablets were deemed appropriate for 3-, 4-, and 5-year-olds.

The main survey was carried out twice to determine whether child performance differed depending on the media type presented. In the first survey, the spatial cognition task sets were presented on paper; in the second survey, it was presented on tablets. To minimize child development and practice effects, the surveys were presented 2 weeks apart.

In the first survey, the spatial cognition task sets (27 tasks in 5 areas) were presented on paper. The 60 children were tested in a quiet kindergarten rooms and completed each task trial following researcher instructions. A research assistant measured child task response times using a stopwatch. The items were randomized to control the order effect. The researchers recorded child response reactions and response times. The time required for the survey was about 20 min per child. In the second survey (with the same 60 children), the spatial cognition task sets were presented to the children on tablets following the same procedure. The time required to complete the survey was about 20 min.

Data Analysis

The collected data were analyzed using IBM SPSS (v. 20). The statistical analyses included descriptive statistics, repeated measured ANOVAs, and paired sample *t*-tests. To examine differences between child performance on the spatial cognition task sets using different media and to establish whether the effect of media differed by child age and sex, a repeated measured ANOVA was conducted. Because the interaction effect between media type, age, and sex was found to be significant, a simple main-effect analysis was conducted using a paired sample *t*-test to investigate the results more precisely.

Results

Child Direction Task Performance in Relation to Media Type

To examine whether the spatial cognition task performance depended on presentation type (while controlling for age and sex), a repeated measured ANOVA was conducted for each task; child age and sex were between-subject factors, and media type was the within-subject factor. A main effect of media type was found when considering the correct answer rate of the left–right direction task, $F(1, 54) = 4.31, p < .05, \eta_p^2 = .07$, and the total direction task, $F(1, 54) = 5.84, p < .05, \eta_p^2 = .10$. These results are displayed in Table 1. The correct answer rates when using tablets was significantly higher than the correct answer rate when using paper media in the left–right direction task and the total direction task. This result is in line with the results of previous studies (Lee, 2011; Miratech, 2001; Tewksbury & Althaus, 2000), which showed that adults' reading performance differs depending on the type of media through which the content was displayed. Our findings imply that paper and digital stimuli can have different effects on child cognitive performance.

Regarding the response time in the direction task, the main effect of media was found to be significant in the left–right direction task, $F(1, 4) = 21.53, p < .05, \eta_p^2 = .84$, the up–down direction task, $F(1, 44) = 47.58, p < .001, \eta_p^2 = .52$, and the total direction task, $F(1, 45) = 23.30, p < .001, \eta_p^2 = .34$ (see Table 1). The tablet participants showed a significantly shorter response times compared to paper participants in the left–right direction task, the up–down direction task, and the total direction task. These results could be due to the contents skimming phenomenon during iPad article reading revealed from a study by Miratech (2001) and the decline of cerebral concentration and alertness during digital media use confirmed in studies by Chon (2006, 2011). That is, children can respond more

quickly as they are consuming less energy when performing tasks using digital media. Although the interaction effect between the media and age in the response times of the left–right direction task was found to be significant, this result had no practical meaning, as there were too few subjects in each age group to warrant further analysis. No further main effects or interaction effects were found in relation to correct answer rates and response times in the direction task.

Children’s Rotation Task Performance in Relation to Media Type

Regarding performance of the rotation task, the main effect of media type on performance accuracy was significant for the right-rotation task, $F(1, 54) = 7.52, p < .01, \eta_p^2 = .12$. The correct answer rate of paper participants was significantly higher than that of the tablet participants (see Table 1). This result show the opposite pattern to our findings in the correct answer rate of the left–right direction task

Table 1
Children’s Spatial Cognition Task Performance on the Presentation Media

Task	Subtask	Media	Correct answer rate		Response time	
			<i>M</i> (<i>SD</i>)	<i>F</i>	<i>M</i> (<i>SD</i>)	<i>F</i>
Direction	Left–right	Paper	.22(.42)	4.31*	2.78(2.03)	21.53*
		Tablet	.37(.49)		1.52(.54)	
	Up–down	Paper	.83(.38)	3.00	1.86(.73)	47.58***
		Tablet	.88(.32)		1.21(.45)	
	Total	Paper	.53(.30)	5.84*	2.02(.86)	23.30***
		Tablet	.63(.33)		1.40(.58)	
Rotation	Right-rotation	Paper	.58(.41)	7.52**	2.35(1.33)	.15
		Tablet	.43(.45)		2.14(2.19)	
	Left-rotation	Paper	.51(.46)	.05	2.36(1.38)	12.73**
		Tablet	.52(.45)		1.68(.79)	
	Total	Paper	.55(.40)	2.22	2.40(1.23)	3.33
		Tablet	.48(.43)		1.89(1.14)	
Symmetry	Y-axis	Paper	.60(.42)	.08	2.36(1.09)	6.32*
		Tablet	.62(.34)		2.03(1.04)	
	X-axis	Paper	.39(.45)	6.55*	1.99(.80)	.09
		Tablet	.52(.44)		1.79(.79)	
	Total	Paper	.50(.38)	2.53	2.28(.91)	4.18*
		Tablet	.57(.34)		1.99(.82)	
Conjugation	Left–right	Paper	.94(.21)	6.95*	1.93(.61)	25.16***
		Tablet	.86(.22)		1.52(.45)	
	Up–down	Paper	.86(.21)	3.18	1.87(.74)	3.63
		Tablet	.91(.20)		1.71(.65)	
	Total	Paper	.90(.17)	.47	1.92(.60)	14.19***
		Tablet	.88(.19)		1.64(.57)	
Part/Whole	Finding-missing-parts	Paper	.92(.15)	.54	2.54(.99)	8.27**
		Tablet	.94(.16)		2.19(.85)	

Note. The response time is given in seconds.
* $p < .05$. ** $p < .01$. *** $p < .001$.

appearing in each media condition. This finding can be interpreted based on several studies that showed that the stimulus of digital media might affect cognitive task performance (Lee, 2011; Miratech, 2001; Tewksbury & Althaus, 2000).

Regarding the response times of the rotation task performance, a significant difference between conditions appeared only in the left-rotation task, $F(1, 26) = 12.73, p < .01, \eta_p^2 = .33$. The tablet participants showed a significantly shorter response time than the paper participants (see Table 1). This result reflects the same pattern as the direction task response time in relation to media type. Again, this finding suggests the possibility that arousal or attention change due to the digital stimulus influences performance (Chon, 2006, 2011). There were no other significant main effects or interaction effects in relation to the correct answer rate or response time in the rotation task.

Children's Symmetry Task Performance in Relation to Media Type

Regarding symmetry task performance, a main effect of media type in relationship to correct answer rate of the X-axis symmetry task was found, $F(1, 54) = 6.55, p < .05, \eta_p^2 = .11$. As is shown in Table 1, the correct answer rate of tablet participants was significantly higher than that of the paper participants. This result is similar to that of the correct answer rate of the direction task according to media type. The analog stimulus has natural light-reflected wavelength, while the digital stimulus has diffused wavelengths from the digital media. This difference can have a different effect on perception or cognitive activity, as suggested by earlier research (Lee, 2011; Miratech, 2001; Tewksbury & Althaus, 2000).

Regarding the response time of the symmetry task performance, a significant difference between media types was present in the Y-axis symmetry task, $F(1, 34) = 6.32, p < .05, \eta_p^2 = .16$, and the total symmetry task, $F(1, 38) = 4.18, p < .05, \eta_p^2 = .10$. The tablet participants

showed a significantly shorter response time compared to the paper participants (see Table 1). This result shows a similar pattern to the response time of the direction task and rotation task in relation to media type. As discussed before, it is possible that the change of cerebral arousal, attention, and brain activation, which appeared during the use of digital media, influences the response speed of the performance. Other significant main effects or interaction effects did not appear in the correct answer rates and the response times of the symmetry task.

Children's Conjugation Task Performance in Relation to Media Type

Regarding performance on the conjugation task, the main effect of media type on correct answer rate of the left-right conjugation task was significant, $F(1, 54) = 6.95, p < .05, \eta_p^2 = .11$. As is shown in Table 1, the paper participants showed a significantly higher correct answer rate than the tablet participants in the left-right conjugation task. Although this result is similar to the pattern of the right-rotation task's correct answer rate, it is the opposite pattern to the correct answer rate of the left-right direction and X-axis symmetry tasks. This result is linked to the former discussion, which mentioned that digital media stimuli might influence child performance on spatial cognition tasks.

Regarding the response times of the conjugation task performance, the main effect in relation to media type was significant for the left-right conjugation task, $F(1, 52) = 25.16, p < .001, \eta_p^2 = .33$, and the total conjugation task, $F(1, 54) = 14.19, p < .001, \eta_p^2 = .21$. The tablet participants showed shorter response times than the paper participants for these tasks (see Table 1). This result is similar to the response time patterns and is linked to the former discussion mentioning how digital media stimulus might influence arousal and attention. No other main effects or interaction effects were found to be significant in this task.

Children's Part/Whole Task Performance in Relation to Media Type

Regarding the part/whole task performance, the interaction between media type and sex in relation to correct answer rates of the finding-missing-part task was found to be significant, $F(1, 54) = 4.83, p < .05, \eta_p^2 = .08$. Conducting a simple main-effect analysis to further examine this interaction (see Table 2), it was found that the correct answer rates of tablet participants were significantly higher than those of the paper participants for boys. The difference in correct answer rates in relation to media type was not significant for girls. This difference in the effect of media type according to sex did not appear in the task performance of other areas. However, this finding might suggest evidence that boys are more sensitive to digital stimuli. More empirical evidence and theoretical discussions are necessary to argue that boys are more sensitive to the digital stimulus than girls.

A significant difference was found for response times in relation to media type for the finding-missing-part task, $F(1, 54) = 8.27, p < .01, \eta_p^2 = .13$. As is seen in Table 1, the response times of tablet participants were significantly shorter than those of the paper participants. This result is in line with the response time pattern of the other area tasks, which implies an effect of digital media on child performance on the spatial cognition task.

Discussion

The possibility that child cognition can be affected differently depending on media type is well established (Chon, 2006, 2011; Lee, 2011; Miratech, 2001; Tewksbury & Althaus, 2000). However, in previous studies, the essential differences between media types is not readily apparent. This raised the importance of verifying the effects of media types at the perceptual level rather than at the level of interpretation and understanding the language required to complete the task. The necessity to examine whether the effect of different media types differs depending on child age and sex has also been raised. This study focused on a spatial cognition task set, which was presented on paper and using tablets to 60 3-, 4-, and 5-year-old children at two time points.

From the results of this study, several conclusions can be drawn. First, child performance on the spatial cognition task set differed depending on the media type presented in. The correct answer rate of the children in the tablet condition was higher (in the left-right direction task and X-axis symmetry task) and lower (in the right-rotation task and left-right conjugation task) than in the paper condition. The response times of tablet participants was significantly shorter than the paper participants. The fact that the correct answer rates of task performance was higher or lower during the tablet-based assessment can be interpreted in several ways. Children might concentrate better

Table 2

Simple Main Effect Analysis of the Interaction Effect Between Media Types and Sex in the Correct Answer Rates of the Finding-Missing-Parts Task

Sex	Media type	<i>M</i>	<i>SD</i>	<i>t</i>
Boys (<i>n</i> = 30)	Paper	.90	.16	-2.69*
	Tablet	.97	.10	
Girls (<i>n</i> = 30)	Paper	.94	.15	.90
	Tablet	.91	.19	

* $p < .05$

during task performance, or their concentration could decrease, despite being aroused and excited. It is also possible that concentration and alertness differed in different tasks. Previous research measuring brainwaves has shown that the effect of digital media on task performance can result from a decline in concentration, alertness, and brain activity (Chon, 2006, 2011). However, as this pattern of correct answer rates in relation to media type differed by task, it is difficult to interpret the factors influencing performance. A more precisely designed follow-up study is necessary.

Second, the effect of media type does not appear to depend on child age and only partially differs depending on child sex. The fact that performance differences by media type was only found for boys in the finding-missing-parts task raises the possibility that digital stimuli might affect boys more. However, careful attention needs to be paid to this interpretation, as sex differences were only found in one task. Future studies should explore this finding.

This study had several limitations. First, this study conducted tasks using both types of media with the same group of children. Although the interval between the two testing sessions was 2 weeks to minimize the children's development and the practice effect, these effects cannot be excluded completely. Nevertheless, given that the correct answer rates in the second testing session did not increase or decrease suggests that our results cannot be explained only by learning or the practice effect. A more precise test design will be required to confirm the effects of media type more clearly.

Second, this study was carried out using an ethological measuring method. Although this study tried to measure task performance more precisely by dividing the performance into correct answer rates and response times, it was difficult to interpret the performance results because of the limitations of the ethological method. Follow-up studies using a neurophysiological method to measure attention, concentration, and eye movement could provide more comprehensive evidence.

Despite these limitations, the findings from

this study are significant by beginning to reveal the essential influence of media type. Although many studies have intended to determine the effect of digital media by focusing on the function of the digital media, few studies have examined the effects of media itself, and findings from available studies tend to be inconsistent. The findings from the present study provide empirical data and provide discussion points about relevant issues. These findings also remove potentially confounding elements. In particular, these findings offer new information about the effects of different media types on child cognitive performance by using a spatial cognition task instead of a language task. Finally, these findings illustrate the effects of different media types and how such effects differ by child age and sex.

In sum, this study showed that the 3-, 4-, and 5-year-olds' performance on a spatial cognition task differed depending on the type of media used to present the task, suggesting that a digital stimulus can affect the brain function of a child. Because child brains are more plastic than adult brain, child cognition might be more strongly affected by new stimuli or be better able to adapt to new stimuli. How child and adolescent brains (which are increasingly subjected to digital media) are affected by such stimuli and how it will be reflected in terms of cognitive performance is a question that requires further investigation. The results of this study can be used as a basis for follow-up studies on how child cognition is influenced when exposed to digital media while growing up.

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