Research article

Pre-schoolers' visual perception and attention networks influencing naming speed: An individual difference perspective

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ABSTRACT

Naming speed is considered to be one of the essential components used to predict reading capacity in school. The current study examined how visual perception and attention networks influence naming speed, and analyzed the relationship between visual perception and attention networks. The total number of participants was 163 Thai preschool children between the ages of five and seven years selected through multistage random sampling. Visual perception, attention networks, and naming speed were assessed using the Developmental Test of Visual Perception 3 (DTVP-3), Attention Network Task (ANT), and Rapid Automatized Naming (RAN), respectively. Structural equation modeling was used to test naming speed hypotheses. The hypothesis of a causal model was supported by the evidence generated by this study. A direct positive association between both visual perception and attention networks to naming speed was observed. Compared with attention networks, visual perception had a higher significant effect on naming speed performance. Consequently, children who have higher visual perception are more likely to demonstrate a better naming speed performance. These results indicate that visual perception is strongly urged to naming speed, as doing so can help predict children's reading readiness before they start learning to read.

1. Introduction

Naming speed is the capability to respond orally to letters or digits, which involves recalling the verbal representations of abstract visual stimuli. Likewise, reading recruits the same cognitive, linguistic, and perceptual processes as naming speed. More than fifty years ago, Geschwind and Fusillo (1966) were the first researchers to state that naming speed was related to reading readiness. Evidence has shown that visual-verbal disconnection may contribute to an inability to percept and name colors or comprehend their names, resulting in reading difficulty (Araújo et al., 2015; García et al., 2018; Swanson et al., 2003).

Recently, numerous studies have provided support toward the postulation that naming speed is one of the most important predictors of reading performance (Logan et al., 2011; Luoni et al., 2015) and it has linked word recognition, word-reading accuracy, reading fluency, and reading comprehension in young children (McGrath et al., 2011; Nicolson et al., 2001). There are a variety of measures to evaluate naming speed, with one, rapid automatic naming (RAN), being widely used. RAN uses both non-alphanumeric (object and colour naming) and alphanumeric (letter and digit naming) stimuli (Denckla and Rudel, 1976; Neuhaus et al., 2001). The RAN test has been applied to identify children at risk of reading and learning difficulties, as well as to predict reading problems in Grades 1 and 2 preschool children (Schatschneider et al., 2004; Torppa et al., 2017). One of the recent studies using these measures investigated Finnish-speaking children. The study revealed that only reading deficit children, when compared with good readers/good spellers, were poorer in naming speed and letter knowledge (Torppa et al., 2017).

Meanwhile, naming speed and reading have been shown to be related because both constructs require serial processing and oral production of the names of stimuli, such as drawings of common objects, letters, or digits (Georgiou et al., 2013a). Several studies have shown that naming speed is involved in reading problems in children e.g. dyslexia, attention deficit hyperactivity disorder (ADHD), and autistic spectrum (Alves et al., 2016; Brock and Christo, 2003; Di Filippo et al., 2006; Rucklidge and Tannock, 2002). In addition, some studies found that children with

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reading difficulties had problems with naming speed, and scored low in naming objects and digits (Al Dahhan, Kirby and Munoz, 2016; Brizzolara et al., 2006). Although the performance on serial naming tasks is related to fluent reading, the influence of the other factors; both visual perception and attention, on naming speed has still been debated and under-investigated (Kruk and Luther Ruban, 2018; Visser et al., 2004).

Additionally, naming speed is possibly influenced by other important cognitive components, including visual perception, which is involved in dealing with the stimuli's non-symbolic and concrete properties (e.g., size, color, shape, texture, and sound). Visual perception can influence many areas of daily living, especially school performances for children (Jung et al., 2014). Visual perception was found to relate with reading skills, that is, the reading skills require of eye-hand coordination, figure-ground perception, visual closure, visuospatial ability, and position in space (Baluoti et al., 2012; Lipowska et al., 2011; Bellocchi et al., 2017). Visual discrimination and position in space inform the ability to recognize one letter or word from the surrounding ones, and to identify the letter in different positions (Woodrome and Johnson, 2009). Children who have visual perception problems at an early age are likely to face academic challenges and word recognition difficulty (Fraga González et al., 2014; Johnston et al., 2017). This finding implies that children who show poor visual perception performance are at risk for naming speed problems. Therefore, the current research aimed to investigate visual perception in relation to naming speed in young children.

Further, visual attention is regarded as another important factor influencing reading (van den Boer and de Jong, 2018). For example, children are required to sustain attention in order to focus on a word in a sentence or a story. This extends to children having to control their attention to speak continuously within a naming speed task (Bosse and Valdois, 2009). Moreover, they must be able to pay attention and hold it long enough to read and comprehend. While some children may be able to percept and discriminate between visual and auditory stimuli, they might be unable to acquire reading skills due to having difficulty sustaining attention on words, sentences, or instructions (Ebert and Kohnert, 2011; Jongman et al., 2015a, 2015b). Nonetheless, Georgiou et al. (2013b) examined naming speed and attention in children from kindergarten to Grade 1 and found an inconsistent evidence in that shifting attention was not related to naming speed. There is thus a need for further investigation into the relationship between attention and naming speed. Many research findings support that children with attention deficit hyperactivity disorder (ADHD) have limited naming speed, as children in ADHD groups have been found to be slower at object naming relative to control groups (Rucklidge and Tannock, 2002). Using RAN tasks in children with inattention symptoms between the ages of seven to 11 yielded a similar research result (Weiler et al., 2000). McGrath and his colleagues investigated naming speed by using only alphanumeric indicators – RAN letters and numbers – to predict single word reading in children with inattention and found the naming task to have no significant effect on performance in children showing ADHD symptoms (McGrath et al., 2011). Evidence has pointed to naming speed being linked to three attention networks: alerting, orienting, and executive control (attention) as indexed by the attention network task (ANT) (Fan et al., 2001; Rueda et al., 2004). The attention networks were operated to control thought, behaviour, and emotion via multiple cognitive processes, that is, alerting responses to detect targets in complex environments and sustain an alert state, orienting to regulate the focused identification and choosing of stimuli to direct attention, and executive monitoring of performance to achieve a goal (Fan et al., 2002; Geva et al., 2013).

There has been research into a number of aspects relating to the relationship between visual perception and attention. Jung et al. (2014) suggest that visual perception among children with ADHD and sensory processing disorder is lower than that of ADHD children without sensory processing disorder. To explain the link among visual perception, attention, and sensory processing problem, the brain navigation system may have to integrate the information from vestibular, proprioceptive, and visual senses in order to navigate our eyes from left to right across words, digits, or pictures on a screen or page. Both attention and sensory processing may influence visual perception, contributing to a delay in reading performances among children with ADHD (Jung et al., 2014).

Furthermore, Germano et al. (2013) investigated and compared the characterizations of the visual-motor perception of children with ADHD and children with good academic performance. The results showed that children with ADHD had lower scores relating to their performances in spatial position and visual closure (Germano et al., 2013). Moreover, some children with dyslexia who have problems with visual perception and a visual processing deficit also have attention problems (Bosse et al., 2007; Lobier et al., 2012). Likewise, Martinussen et al. (2014) demonstrated the direct influence of behavioral inattention on the proficiency of word reading, and the significant relation between naming speed and behavioral inattention in the classroom. A finding by Shanahan et al. (2006) shows that naming speed contributes to a high degree of comorbidity between ADHD and reading disorders in children (Martinussen et al., 2014; Shanahan et al., 2006).

According to the literature review of naming speed in children, factors influencing naming speed include figure-ground perception, visual closure, accuracy of attention, and executive control. To provide further clarification on this issue, this study examines how naming speed is influenced by visual perception and attention. As the young children participating in this study had not yet been introduced to an alphabet, the current study aimed to examine their RAN performances using only three types of stimulus materials: Colors, objects, and digits (Di Filippo et al., 2006). Visual perception was investigated using the DTVP-3, which consists of eye-hand coordination, copying, figure-ground perception, visual closure, and form constancy. The children's attention networks were investigated using the attention network task (ANT) for children (Rueda et al., 2004), which measures alerting effect, orienting effect, and executive control. It was of interest for us to find the significance of visual perception and attention on early detection of naming speed in young children. In short, this study examines the causal relationship between naming speed, visual perception, and attention among five to seven year-old children in Thailand. It was hypothesized that both visual perception and attention would influence naming speed and that visual perception and attention were also related. Our proposed model was developed using structural equation modeling (SEM) (Bollen and Noble, 2011) in order to examine the direct and indirect effects of naming speed and visual attention on naming speed and its indicators.

2. Methods

2.1. Participants and design

Participants included 163 Thai children, 81 boys and 82 girls, between 60- to 90-months-old (mean age = 72.60 months, SD = 7.27 months), recruited from kindergarten and Grade 1 in Thai government schools. All participants were right-handed. The participants' parents were asked to provide information about their family, such as parents' age, education, and socioeconomic status. The descriptive statistics regarding the children and their families show that there were 118 children (69.40%) in kindergarten and 52 (30.60%) in Grade 1. The mean age of the fathers during pregnancy was 33.27 years old (SD = 8.01), while the mean age of the mothers was 30.62 years old (SD = 6.10). The majority of parents had graduated with a bachelor's degree or higher (56 of the fathers (39.90%), 72 of the mothers (42.30%), and the fathers and mothers with at least one parent with a bachelor's degree (41.1%)). An average (median) monthly income per household for the current study was of 26,915 THB, the percentage of families with more than 50,000 THB was 29.4%, between 30,000 and 50,000 THB was 14.10%, between 30,0000 and 0 THB was 34.10%, respectively. Children reported to have poor vision, blindness, or neurodevelopment problems were excluded. Every participant received a sticker and some snacks after all testing had been completed. Ethical approval was granted by the

Ethics Committee of College of Research Methodology and Cognitive Science (RMCS), Burapha University. Before entering the experiment, a written consent was obtained from the parent or legal guardian, and also a verbal consent was obtained from children. All of the instruments and methodological details were discussed earlier.

2.2. Measures

2.2.1. Naming speed

Naming speed was assessed using RAN (Norton and Wolf, 2012; Wolf and Denckla, 2005). All naming speed tests consisted of five rows and ten columns of randomized objects, colors, and digits. Object naming consisted of five pictures, including a dog, book, hand, chair, and star; color naming consisted of five colors, including black, blue, green, red, and yellow; and digit naming consisted of five numbers, including 2, 4, 6, 7, and 9. In the three naming tasks, items were presented on pieces of paper measuring 11.69×16.53 inches. On each piece of paper, there were five rows with 10 items each, totalling 50 items. Each piece of paper was presented in front of each child. After a little practice, the children were asked to rapidly name the objects, colors, and digits. When the children said an incorrect word, the correct word was given. The same procedure was repeated for all of the objects, colors, and digits. The examiner recorded the time in seconds by using a digital watch, starting the timer when the child started to name the first item and stopping it when they named the last item. The three naming tasks were shown to be reliable (*Cronbach's alpha* $= 0.85$).

2.2.2. Visual perception

Visual perception was measured using the Developmental Test of Visual Perception, Third Edition (DTVP-3) (Brown and Murdolo, 2015; Hammill et al., 2013). The DTVP-3, an updated version of the DTVP-2 (Hammil et al., 1993), was designed to measure both visual perception (no motor response) and visual-motor integration ability, with no bias regarding race, gender, or handedness differences. The battery of five subtests was employed for identifying visual perceptual deficits in children, including specific learning disabilities, eye-hand coordination difficulty, and subtle neuropsychological deficits in children from 4 to 12 years of age. The DTVP is a suitable tool for investigating the link among visual perception, visual-motor integration, and reading (Bellocchi et al., 2017).

Children were asked to follow the instructions. In the first section, relating to eye-hand coordination, children were asked to draw precise straight or curved lines in accordance with visual boundaries. In the second section, on copying, simple figures in sequence were shown, and the children were asked to draw a picture of the figure in a space provided below the figure. The next sections were on figure-ground perception, visual closure, and form constancy and consisted of non-motor tasks. The figure-ground perception subtest showed stimulus figures which were complicatedly hidden, embedded in a confusing background, and the children were asked to find as many of the figures as they could on the page. In the visual closure subtest, the children had to match a complete figure to its identical, incomplete one embedded in a series of incongruous figures. This task required the children to mentally fill the gaps of the incomplete figures. Lastly, for form constancy, the target figure, sometimes presented in a confusing background, was shown to the children. They were asked to discriminate the target figure appearing in a different size, orientation, and/or color from other distractors. The raw score from each of the visual perception subtests was converted to a standard score, ranging from 0 to 20. *Cronbach's alpha* for the DTVP-3 as used in this study was 0.70.

2.2.3. Attention networks

Attention networks were evaluated using the ANT, children's version (Rueda et al., 2004), which was developed to measure the effectiveness of the three attentional networks in one cohesive task and is based on the original version developed by Fan et al. (2002). The index of the alerting network could be obtained by subtracting the reaction times in the double-cue no-cue conditions. Similarly, the index of the orienting was conducted comparing the central cue and spatial cue conditions. Finally, the difference in reaction times between incongruent and congruent trials was the indicator of the conflict effect, which was possibly the most important indicator in our study due to its closed relation to executive control. In the child version of the ANT, yellow fish targets and flankers are applied for the purpose of appropriately engaging children between four to 10 years of age. The task had four cue conditions (no cue, central, double, and spatial) and three flanker conditions (neutral, congruent, and incongruent). The varied combinations between cue and flanker conditions were randomly presented in three blocks, 48 trials each. Children were instructed to pay attention to the direction (left or right) of the target fish at the center of a horizontal string of other distracting fishes facing either left or right. They pressed the right or the left key to answer accordingly. They were allowed to practice on the first trial. The children spent approximately 20 minutes finishing all trials. Rueda et al. (2004) and Fan et al. (2002) reported relatively high immediate reliability for the scores of each attentional network in both children and adults. The overall accuracy, overall reaction time, alerting, orienting, and executive control were used as dependent measures.

2.3. Procedures

All children were administered the tests in three sections. In section one, naming speed, figure-ground perception, visual closure, and form constancy were tested. In section two, eye-hand coordination and copying were tested. Finally, the children's attention networks were evaluated in the last section. The total time per person was approximately 90 minutes or less. Each child was tested individually in the child's own school.

2.4. Statistical analysis

The IBM Statistical Package for the Social Sciences (SPSS) statistics version 23 was used for the data analysis. For attention network's reaction time, the median reaction time (RT) of each condition was used as a raw score for each participant. However, as the RTs for the attention network task were not normally distributed, outliers were removed. *RTs* over $+2$ *SD* for each condition were removed (9.44% of the data). The SEM was applied using IBM SPSS AMOS software version 22. The SEM was run on all the visual perception components, the attention networks, and naming speed components. Multiple indices were used to evaluate model fit, including $\chi^2/df = < 2.00$, $p_\chi > .05$, RMSEA $< .05$, CFI $> .90$, GFI $> .90$, AGFI $> .90$, IFI $> .90$, NFI $> .90$ and TLI $> .90$ (Hooper et al., 2008; Schreiber, 2017).

3. Results

3.1. Sample description

Table 1 presents the descriptive statistics for all measures used in this study. The total time in seconds of RAN was converted to standard score, enabling a comparison between each RAN subtest. Next, the mean scale score for visual perception measured by the DTVP-3 was converted from the raw score of each subtest. Lastly, attention network scores were collected from cue and flanker conditions. The three components relating to attention networks efficiency were computed. Alerting scores were calculated by subtracting median *RT* to double-cue trials from median *RT* to no-cue trials. Orienting scores were calculated by subtracting median *RT* in spatial-cue trials from median *RT* in central-cue trials. Finally, executive control scores were calculated by subtracting median RT for congruent trials from median *RT* for incongruent trials for each participant and session. Moreover, skewness, kurtosis and Mardia's multivariate kurtosis were analyzed. For normalization data, alerting and executive control were transformed to normality by using a two-step approach,

Table 1
Descriptive statistics for all indicators used in the study (N = 163).

Task	Mean (S.E.)	Min	Max	Skewness	Kurtosis	C.R.
Naming Speed						
RAN objects (score)	93.16 (1.23)	55.00	145.00	0.30	0.73	1.91
RAN colors (score)	89.53 (1.24)	55.00	130.00	-0.14	-0.32	-0.84
RAN digits (score)	96.45 (1.34)	55.00	133.00	-0.58	-0.15	-0.40
Visual perception						
Eye-hand coordination (score)	7.09 (.19)	1.00	12.00	-0.52	-0.24	-0.62
Copying (score)	14.16 (.32)	3.00	20.00	-0.31	-0.62	-1.63
Figure-ground (score)	10.18 (.23)	2.00	17.00	-0.45	-0.12	-0.32
Visual closure (score)	10.01 (.26)	4.00	19.00	0.37	-0.44	-1.14
Form constancy (score)	9.62 (.26)	1.00	20.00	0.55	0.29	0.75
Attention Network						
Accuracy (% accuracy)	83.56 (1.03)	45.00	100.00	-0.88	-0.15	-0.39
Overall reaction time (milliseconds)	1141.33 (11.59)	779.33	1455.58	-0.35	-0.39	-1.03
Alerting (milliseconds)	64.03 (8.63)	-441.67	366.33	0.09	-0.15	-0.39
Orienting (milliseconds)	31.67 (7.19)	-244.33	333.00	0.22	0.78	2.02
Executive control (milliseconds)	88.03 (10.74)	-527.50	400.50	0.03	-0.28	-0.74
Mardia's Multivariate Kurtosis					5.07	1.64

which offers to transform observed variables into normalization statistics (Templeton and Burney, 2017). A skewness index of less than three and a kurtosis index of less than 10 were used for normalization of probability distributions. Since the data for all variables had a normal distribution, the effect of variance-covariance among the variables was limited (Kline, 2011; Schumacker and Lomax, 2010).

3.2. Correlational analyses of the naming speed and all latent variables

Table 2 shows the Pearson's correlations between the latent variables used in the study. Not surprisingly, the highest positive correlations were detected in relation to object naming speed (for colors: $r = .67$; for digits: $r = .68$), but small to medium correlation coefficients were also obtained in relation to eye-hand coordination, figure-ground perception, visual closure, and form constancy. In addition, the alphanumeric task represented by the digit naming speed correlated significantly with most visual perception variables. However, the object naming speed did not correlate with the variables within the attention network task.

The three networks under the attention network task were found to be independent from each other. Indeed, Pearson's product-moment correlations were almost non-existent, with an insignificant correlation between alerting and orienting ($r = .12$), between orienting and executive control ($r = .04$), and between alerting and executive control ($r = .17$). Furthermore, overall accuracy had a negative relationship with overall reaction times ($r = -.01$). A negative relationship between speed and accuracy indicates that the children who produced more errors also had longer reaction times.

3.3. SEM analysis of the visual perception and attention networks effects on naming speed

To assess the incremental validity of naming speed, a model was specified in which the path between naming speed and visual perception was freely estimated. All fit indices were almost identical to the previous base model: $\chi^2 = 74.86$, $df = 60$, $p = .09$, RMSEA = .04, CFI = .97, GFI = .94, AGFI = .90, IFI = .97, NFI = .86 and TLI = .96. Addressing the research question, the R^2 for the prediction of naming speed by both visual perception and attention networks was 0.27. These results indicate that visual perception and attention networks explains approximately 27 percent of the variation in naming speed. It is noteworthy that the statistical significance of direct effects of visual perception and attention networks was on naming speed. The path coefficient between visual perception and naming speed was .38 ($p < .001$) and the path between attention networks and naming speed was .27 ($p < .05$), indicating that, in this model, both visual perception and attention networks had essentially equal explanatory power to predict naming speed. Notably, the direct correlation between visual perception and attention networks was at .24 ($p < .05$), showing that visual perception was significantly correlated with attention networks when represented by these five subtests. Concerning the use of the bootstrapping method in hypothesis testing, the beneficial bootstrapping allows us to produce pseudo-samples, which were estimated as 500 cases, resampling at the 95% bias-corrected confidence interval. The results showed that coefficients of naming speed and visual perception components deemed significantly, however, only alerting and reaction time in attention networks components did not reach a statistical significance as shown in Fig. 1.

Table 2
Pearson's correlations with Bonferroni's correction between the latent variables investigated in the study (N = 163).

	1	2	3	4	5	6	7	8	9	10	11	12
1. RAN objects	.78											
2. RAN colors	.67**	.81										
3. RAN digits	.68**	.65**	.78									
4. Eye-hand coordination	.24	.17	.24	.70								
5. Copying	.07	-.03	.17*	.17*	.72							
6. Figure-ground	.31**	.19	.36**	.28**	.28**	.61						
7. Visual closure	.26	.15	.28**	.32**	.39**	.56**	.57					
8. Form constancy	.18	.15	.21	.26	.16	.45**	.47**	.67				
9. Accuracy	.19	.22	.24	-.08	.14	.15	.11	.17*	NA			
10. Overall reaction time	.01	-.04	-.04	.06	.03	-.01	.10	.05	-.01	NA		
11. Alerting	.15	.06	-.01	-.01	.05	.09	.09	.04	.07	-.05	NA	
12. Orienting	-.03	-.08	-.16	.02	.04	-.02	.01	-.05	-.19	-.16	.12	NA
13. Executive control	-.02	.06	.07	-.03	.06	.10	.08	.28**	.29**	-.10	.16	.04

Note: *$p < 0.05$, **$p < 0.01$; *Cronbach's alphas* are in diagonal cells.

4. Discussion

While naming speed has been shown to be the core of reading failure, few studies have examined the association of visual perception with attention and naming speed. Both visual perception skills and attention have a significant effect on reading abilities in school-aged children (Bellocchi et al., 2013, 2017; Çayir, 2017). Meanwhile, investigations into rapid naming testing have had a long history since Denckla and Rudel (1976), with this area of study continuing to deserve attention (Alves et al., 2016). The effective development of visual perception skills requires a concerted focus on improving several abilities, one of which is naming speed processing. Children in preschool also need to develop good visual perception skills which are implicated in letter recognition and reading acquisition (Bellocchi et al., 2017), as well as attention. There were strong evidences suggesting that children who undergo attention-training programs in preschool and kindergarten have good reading experiences (Lehtimäki and Reilly, 2005; Bellocchi et al., 2013). Using SEM provides strong evidentiary support for investigating the impact of visual perception and attention on naming speed before children learn to read.

One of the prominent findings of this study is that visual perception is the most significant factor in predicting naming speed in children. It is consistent with the findings of Bellocchi et al. (2017), which also explored the relationship between reading and visual perception in children with dyslexia. Moreover, the findings from our current research show that visual perception positively correlates with naming speed. This has been previously supported by Sortor and Kulp (2003). They found that visual perception is a good predictor of children's reading level and their readiness to read (Sortor and Kulp, 2003). Furthermore, recent investigations into the relationship among all levels of visual perception, reading speed, and reading comprehension in first-grade children showed that higher reading speed, higher reading comprehension scores, and less reading errors were as a result of better general visual perception, motor-independent visual perception, and visual-motor perception (Memiş and Sivri, 2016). Another investigation into how visual perception factored into performance in school for children with autism, reported that visual perception affected school performance due to its high

function as a requisite for performing drawing, attention, reading, and other tasks (Vetrayan et al., 2015).

In this study, we also evaluated attention networks as related to naming speed performance. Several previous studies have shown a relationship between attention deficit and naming speed tasks, including objects, colors, and digits, support the findings from the present study (Alves et al., 2016; Shanahan et al., 2006; Whipple and Nelson, 2016). Children with ADHD have recently been shown to take a longer time to perform object and digit naming speed tasks relative to typical children (Alves et al., 2016). Moreover, children with ADHD performed significantly slower on measures of nonalphanumeric naming (objects and colors) than alphanumeric naming (letters/digits) (Whipple and Nelson, 2016). Other studies have further shown that attention deficit factors (e.g. attentional selection, spatial attention) influence processing speed/naming speed tasks (Shanahan et al., 2006; Ryan et al., 2017; Wang et al., 2017). Furthermore, our findings show that attention networks were more strongly affected by executive control, which could also predict naming speed. Similarly, findings by Thompson et al. (2015) showed that children who had good executive control were also the strongest in letter knowledge, phonological awareness, and rapid naming skills. Moreover, shifting attention from one item to the next may have a partial effect on RAN (Wolf and Bowers, 1999). This reflects the finding that the prosodic qualities in text reading may cause interruptions due to the allocation of attention to read away from processing word meanings in passages. Our finding confirms that attention networks also play an important role in support of naming speed performance in young children.

At the same time, our study provides support for the theory that visual perception has a strong relationship with attention networks, supporting the hypothesis that visual perception and attention networks may combine to affect naming speed or reading readiness in both children who have reading difficulties and those with an attention deficit (Alves et al., 2016; Whipple and Nelson, 2016; Willcutt et al., 2005; Wolf and Bowers, 1999). Wolf and Bowers (1999) proposed a model where RAN performance is influenced by attention and visual processes. Moreover, Willcutt et al. (2005) suggested that children with reading disorder (RD) and children with ADHD may share processing speed for both linguistic
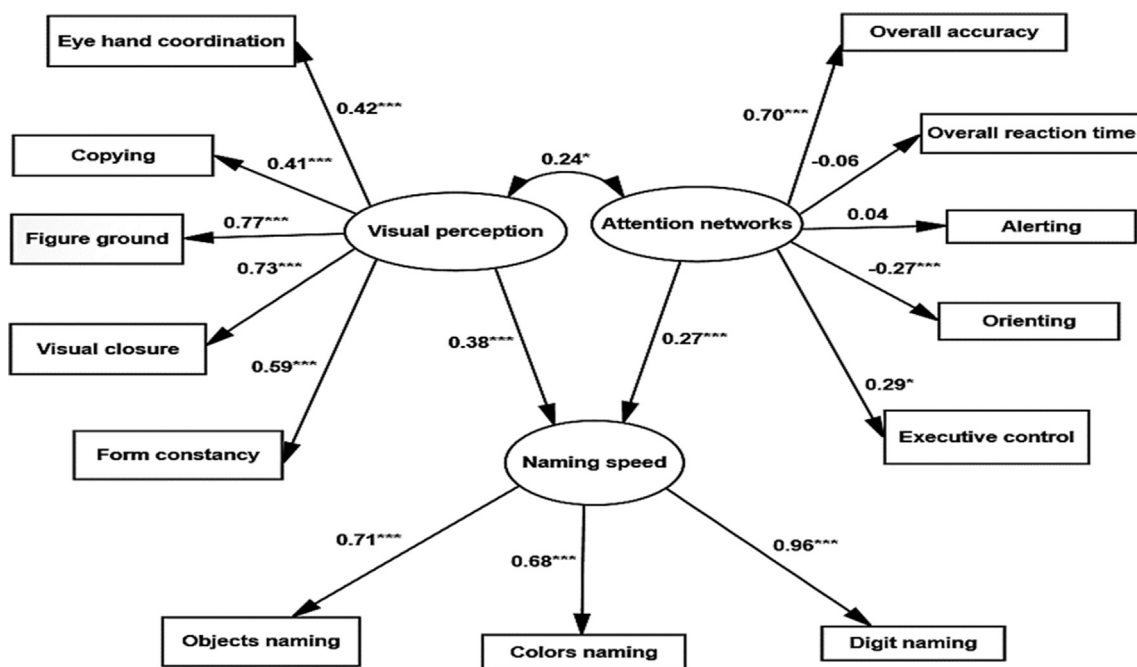

Fig. 1. Structural equation modeling of the relationship among the visual perception, the attention networks, and the naming speed in children. Note: Values represent standardized regression coefficients and 95% bias-corrected confidence intervals were presented in parentheses; *p < .05, **p < .01, *** p < .001.

and non-linguistic tasks as an underlying cognitive risk factor. This finding was supported by findings by Whipple and Nelson (2016), who investigated potential weaknesses in naming speed abilities in adolescents and adults with ADHD, RD, and comorbid ADHD/RD. They found that the ADHD-only group performed significantly faster overall on alphanumeric rapid naming. On the other hand, the RD and comorbid groups performed slower on alphanumeric and non-alphanumeric naming speed tasks. Meanwhile, Jung et al. (2014) confirmed the influence of sensory processing on visual perception in children with ADHD. In comparison to the children with ADHD, the ADHD children with sensory processing difficulties showed inferior performance on the Korean version of the Developmental Test of Visual Perception-2 (K-DTVP-2) designed to measure general visual perception, motor reduced perception, and visual-motor integration. Both visual perception and sensory processing play an interrelated role in completing cognitive tasks, such as matching shapes or objects, or tasks containing unfamiliar stimuli or subtle discriminations. For this reason, in reading, children with visual and attention deficits may not be able to recognize the letters or words they have encountered, or discriminate between the similar letters or words. In writing, letters or words might be written in reverse order. In addition, they might confuse left/right discrimination, which can also affect reading and writing later in life (Jung et al., 2014).

The main limitation of this study, which employed a cross-sectional design requiring a one-time data collection, arises when making inferences based on the individual SEM model. This relates to the generalizability of our findings. As our participants were preschool children who had not started learning letters, we excluded the task with letters from the RAN. Generalizations must be restricted to preschool children. Our results show that visual perception and attention networks are interconnected, and both of them correlate with naming speed. We suggest that future studies should explore additional factors, which possibly influence performance on naming speed. Phonological memory is a storage of phonological information, which is linked to its symbolic representation. RAN tasks require the retrieval of phonological information. Phonological awareness (PA) is the ability to attend, discriminate, and recognize spoken words, and it also plays a vital role with RAN as a consistent indicator of reading acquisition. Children had low scores on phonological memory, PA, and RAN in their preschool. Due to their low reading scores at 1st grade, the children with reading difficulties showed less improvement after reading intervention (Vellutino et al., 1996). That is, phonological memory and PA might have a relationship with naming speed. In terms of data collection, the amount of time taken to articulate each item's name is normally recorded in several studies. Interestingly, pause time (the amount of time spent for processing between items) might magnify the RAN elements related to reading (Norton and Wolf, 2012).

In conclusion, our findings suggest that visual perception and attention play the key roles in naming speed in preschool children. Accordingly, teachers should pay close attention to preschool children who struggle with RAN, because this may predict reading difficulty in those preschool children' near future. Such preschool children may have either visual perception or attention problems, or both. To scope out the problem, visual perception and attention tests should be administered consecutively following RAN tasks. After the problems related to the child's poor RAN score are identified, the teacher should provide an intervention tailored specifically for the preschool children.

Declarations

Author contribution statement

W. Ammawat: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

P. Wongupparaj: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

A. Attanak: Analyzed and interpreted the data; Wrote the paper.

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The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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