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Exploring the Modality of Network-Type Thinking in Young Children with Picture Books

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Abstract

This study investigated the concrete modality of network-type thinking and knowledge entity formation of young children aged from four to six, employing the picture books. More precisely, we analyzed the techniques with which they associate words and concepts from read stories. As a result, it was demonstrated that the children substantially hire verbs and syntagmatic association when developing a knowledge network. In addition, it was also shown that six-year-olds recalled significantly more keywords than younger children when it came to syntagmatic (or "serial") thinking method. Furthermore, this paper indicates some of the future possibilities of the findings that are to be applied to the more effective selection of picture books in nursery school settings for their language development.

Keywords: Education, Language, Network-Type Thinking, Young Children, Picture Books

1 Introduction

The entity of human wisdom unleashes its utmost potential when there're sufficient rigid connections between one knowledge and another. Central Council for Education, Japan [1] mentioned that these components of the network, which are the collection of knowledge, are indeed learnt and acquired separately in each academic subject, however they should not be harnessed separately. Furthermore, the report pointed out that those are expected to be intimately linked with each other, emphasizing the essential nature of wisdom as a densely connected network rather than a collection of individual scattered pieces.

Notably, this point of view can be directly applied to discussing the modality of thinking process of human beings, which is termed *network-type thinking*. The central norm of network-type thinking is the philosophy where wisdom is regarded as the interwoven structure of individual

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units or fragments of what we learn, which we generally call knowledge. Hypothesizing this form of human wisdom and understanding, Kirimura *et. al.* [2] delineated a dynamic growth model of knowledge network, introducing three constructive phases of knowledge structure: propagation phase, mixing phase, and creation phase. By further elucidating these dynamics and its architectural complexity, there is potentially a high chance that we could bring this discovery to the field of early education to expect an acceleration of development in knowledge of young children as well.

To further describe the applicative prospect of the above assumption of human wisdom network creation modality, it is a good practice to attempt to comprehend how to develop children's knowledge network at school settings. To offer one example, it is relatively straightforward to understand that the educational efficacy is to be elevated by paying attention unceasingly to the connections between several topics being discussed. Likewise, we believe that this is also the case with language acquisition process for young children. It is considered that young children build up their mint knowledge structure exactly in the same way as the grown-ups, where the network is created by the emerging connections of nodes by edges. Explaining architectural compositions of this mechanism more in depth to prove this hypothesis is irrefutably of a great academic and societal value, since the linguistic ability underpins any task-processing capacity as we progress onto more advanced academic stages.

Based on the assumption that our thinking process is supported by a network-type structure, the question that must be answered with clarity is exactly how the nodes get connected by edges. To paraphrase, we have to work out what triggers one knowledge to be linked to another knowledge during the process of learning, in order to apply this young children's thinking modality to practical utilizations. When it comes to the knowledge network composition of adults, we already have certain materials to refer to, such as the report by Kadota and Ikemura [3]. According to it, our knowledge is bolstered by the ground of semantic relevance, which can be roughly subdivided into paradigmatic and syntagmatic relationships. The former refers to the relationship between words that can be substituted for each other in a particular context. For example, "cloud" can be substituted by "rain" in the context of weather, ergo their paradigmatic relationship. On the other hand, the latter refers to the relationship between words based on how they combine in sequence to form a sentence. To provide an example, "cloud" and "white" have a syntagmatic relationship as they can be arranged in a specific order to create some relevance (*e.g.* Clouds are white.).

Notwithstanding these detailed explanations about our network-type thinking pathways, it is less understood what this is like in children as of today, due to several factors in their cognitive natures that hinder the investigational attempts. For instance, their verbal expression technique is limited compared to that of adults, and children may rely more on intuitive reasoning rather than logical processes, making it hard for adults to follow their thought patterns [4][5]. In light of these obstacles on the way towards deeper insight into children's cognitive system, it is crystal-clear that we ought to introduce a sufficiently concrete methodology to allow for extensive and in-depth analyses. For this specific purpose, we shed light upon the use of picture books that are widely used in nursery school and kindergarten settings. In early educational settings, picture books are recruited for regular educational activities and are central to how young children broaden their lexicon and linguistic ability. Furthermore, picture books are shown to be effective in allowing children to familiarize themselves with complex concepts in a relatively simplified manner [6], emphasizing their benefits beyond the development of early literacy. Accordingly, these traits of picture books are believed to directly indicate the strong contributions to, and links with aforementioned network-type thinking in young children.

Additionally, our preceding research [7] showed that the arbitrary set of random picture books can be subdivided into certain groups each of which has semantic interrelatedness. In fact, after performing topic modelling on 303 picture books we collected, it turned out that they were broken down into 6 major subsets of semantic connections. Together with discussions above, it can be deduced that the picture books themselves are a semantic network composed of these subsets, and children construct a network of their own knowledge in their own way based on the provided large network of the picture books through the process of early exposure to them. In this sense, our research question converges to what is really meant by "in their own way".

Putting picture books in practice for the objective of this research of identifying the modality of knowledge network construction in young children, we devised a simple program of picture books reading at kindergarten; after reading two picture books in a row, we backtrack the memory of what children have seen or learnt to observe what and how many topic words they were able to list, as well as in what way they link these words, by adopting an appropriate interviewing method. The expectation after completing this investigation is that we figure out specific thought patterns of young children on classifying picture books, as well as associating one book with another, namely their network-type thinking blueprint.

2 Methods

We conducted the above-mentioned picture books reading program on 119 young children at several kindergartens in Japan, whose ages range from four to six years old during the period between October 2022 and March 2023. Detailed breakdown of children at each age and gender is summarized in Table 1.

Table 1: Breakdown of ages and genders of children we conducted the program on

	4-year-old	**5-year-old**	**6-year-old**
Male	4 (3%)	13 (11%)	36 (30%)
Female	8 (7%)	15 (13%)	43 (36%)

2.1 Survey Items

In the study conducted, two picture books were recited to the preschool children, and the nature of the connections between the keywords recalled from each book's content was examined. The survey items included the number and content of the keywords recalled from each picture book, as well as the number of keywords the children were able to link and the manner in which they made these connections.

The picture books used in the study were *Otsukai* (translation: Errands), written by Wakiko Sato, published by Fukuinkan Shoten (first edition 1993) [8], and *Thomas tidies his room*, written and illustrated by Gunilla Wolde, translated into Japanese by Nanako Tsubakihara, published by Dowakan Publishing (first edition 2008) [9]. The books were selected from a collection of approximately 2,000 picture books. In selecting the appropriate picture books, 4 criteria were considered: (i) The illustrations should be easy and clear enough to understand, allowing for the shared idea held amongst all children. (ii) Each book should be able to be read in under five

minutes. (iii) A variety of different objects should appear. (iv) The story should be easy to follow. Regarding criterion (i), the illustrations needed to be easy to understand to ensure that all children could have a common recognition. For criterion (ii), the aim was to keep the program's duration under 15 minutes, taking into account the children's attention span [10]. Criterion (iii) considered the need to avoid bias in the types of keywords drawn from memory, ensuring that the choice of the keywords did not become overly skewed. For criterion (iv), recognizing that keywords could be listed not only from the illustrations but also from the story itself, the stories were selected for their contextual simplicity, suitable for children's comprehension aged up to six.

As for the story of *Otsukai*, it features a girl who is sent on an errand. She prepares for anticipated difficulties such as rain and hunger, but her worries ultimately prove unnecessary as the clear blue sky lets in the sunlight soon after. The story includes various characters and objects such as a cat, a mouse, a candy, an umbrella, and a life buoy. On the other hand, *Thomas tidies his room* is about a boy searching for his teddy bear in his room, but getting distracted by other discoveries while continuing the search. The picture book features characters and objects like a bear, an elephant, a digger, a ball, and a hat. These two books were selected for reciting sessions in this study according to the above reasons and criteria.

2.2 Measurement Methods

The following procedures were conducted for data collection.

First of all, the children were informed that they were going to listen to two picture books, *Otsukai* and *Thomas tidies his room*, and were instructed to exercise attention to the contents of the books as they would be asked to recall what appeared in the stories immediately after each reading, all in a suitable and appropriate language. The children were further informed that the readings would take place in sequence, with *Otsukai* being read first, followed by *Thomas tidies his room* (the order was determined arbitrarily, however was maintained throughout the experiment) with a brief interview about the former in between, and that upon completion, they would engage in an activity where they would connect keywords from both books. To reduce any potential psychological anxiety, the study was framed as a "storybook connection game", and measures were taken to ensure a playful and relaxed environment. The readings were conducted for groups of one to four children at a time, but the subsequent interviews were done individually, with one investigator assigned to each child.

Second, following the reading of *Otsukai*, the children were asked to recall and orally provide keywords representing objects and events from the story. The terms recorded on this stage were referred to as "recalled keywords from *Otsukai*" in this study namely. The recall time was limited to two minutes according to the empirical pre-tuning based on preceding investigations, allowing for sufficient time for recalling activity while not coercing children into excessive mental fatigue. After two minutes, the same procedure was followed for *Thomas tidies his room*, and the keywords were recorded as "recalled keywords from *Thomas tidies his room*".

Lastly, the investigators asked the children to pick up a pair of two keywords from "recalled keywords from *Otsukai*" and "recalled keywords from *Thomas tidies his room*" that look suitable for semantic relatedness. For each pair a child picked up, a child was asked whether they were able to verbalize a connection between the two keywords. If the child agreed, the reasoning behind the association was recorded in a way they expressed it, a set of which was named "associations" in this study (some examples are shown in Table 2). Each keyword could only be used once, and this process continued until the child either reported no further connections or all keywords were used up to form pairs. For instance, if the child provided six "recalled keywords from

Otsukai" and five "recalled keywords from *Thomas tidies his room*", this can result in up to five connected pairs, and the session concludes. During the pairing phase, questions such as "Do you think these two keywords are related?" or "Can these two be connected?" were asked, with variations in phrasing chosen to best suit the child's understanding. We did not do an exhaustive search for every possible pair between two groups of keywords because this research preferred the spontaneous associations of keywords before children learnt to find regularity in doing so.

Table 2: Examples of how children associated two keywords from each book

	Recalled Keywords from:		**Association**
	Thomas Tidies His Room	***Otsukai***	
1	bear	cat	They are both animals.
2	ball	goggles	They both fit in the bag.
3	ball	pineapple	They are both round.
4	hat	hat	Hat appeared in both books.
5	bear	cat	They both eat fish.
6	bear	raincoat	Bear puts on a raincoat.

2.3 Analytical Methods

With regard to the content of the keywords, "recalled keywords from *Otsukai*", "recalled keywords from *Thomas tidies his room*", and "associations" were aggregated using techniques of text mining, such as word cloud to visualize any potential finding.

In addition to the above-mentioned contents of what each association signifies, we also delved into the number of these associations by age group to investigate the developmental difference of association capabilities. The numbers of "recalled keywords from *Otsukai*", "recalled keywords from *Thomas tidies his room*", and "associations" were counted based on the aforementioned investigation, and the mean ± standard deviation for each group was calculated.

Furthermore, the connections in the "associations" were categorized into two principal types. Referring to previous studies [11][12], the collected "associations" can be classified into paradigmatic semantic relations representing hierarchical relationships (*e.g.* cloud—rain) as "parallel" relations and syntagmatic semantic relations representing syntagmatic connections (*e.g*. cloud—white) as "serial" relations. The numbers of parallel and serial keywords were counted. Statistical analysis was performed employing statistical software package JMP (SAS Institute Japan, JMP®, Version 13.2.1. SAS Institute Inc., Cary, NC, 1989–2024.). For comparisons among three or more groups, analysis of variance (ANOVA) and multiple comparison tests with Bonferroni correction were used. The significance level was set at or below 5%.

2.4 Ethical Considerations

This study was conducted after obtaining approval from the Research Ethics Committee of Kobe Tokiwa University, Kobe, Japan. Prior to the study, both verbal and written explanations were

provided to the directors of the cooperating facilities, and measurements were conducted only at facilities that granted consent. During the study, where a child refused to participate or withdrew from the study halfway, participation was not forced, and such cases were excluded from the analysis.

3 Results

3.1 Contents of the Keywords

The "recalled keywords from *Otsukai*" and "recalled keywords from *Thomas tidies his room*" obtained from the survey were visualized using text mining technique. Fig. 1 shows the word cloud for the "recalled keywords from *Otsukai*", and Fig. 2 shows the word cloud for the "recalled keywords from *Thomas tidies his room*". Furthermore, the "associations" were summarized in the format of word cloud as well, which is shown as Fig. 3. In each diagram, be noted that the words of the same grammatical category were shown in the respective colors. For example, nouns were colored in blue, and verbs in red.

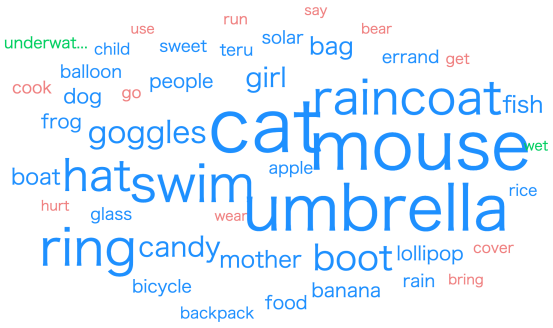

Figure 1: Generated word cloud of "recalled keywords from *Otsukai*"

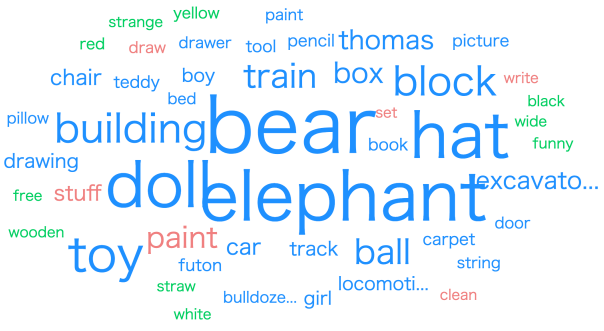

Figure 2: Generated word cloud of "recalled keywords from *Thomas tidies his room*"

Figure 3: Generated word cloud of "associations"

3.2 Association Count

Table 3 shows the statistics of the keyword and association counts, and Table 4 shows that by age group. For six-year-olds, the "recalled keywords from *Otsukai*" ($F_{2,116} = 15.4472$), "recalled keywords from *Thomas tidies his room*" ($F_{2,116} = 14.3649$), and "associations" ($F_{2,116} = 16.1027$) were all significantly higher compared to four- and five-year-olds ($p < 0.01$), where the critical value for $(df_1, df_2, \alpha) = (2, 116, 0.01)$ is 4.79.

Table 3: The statistical information of the recalled keywords and associations ($N = 119$)

	Recalled Keywords from:		**Association**
	Thomas Tidies His Room	***Otsukai***	
M ± SD	6.2 ± 2.4	7.7 ± 2.9	4.6 ± 2.9
Total Count	714	918	553
Maximum	13	17	13
Minimum	0	0	0

Table 4: The number of keywords and associations by age group ($N = 119$)

	Recalled Keywords from:		**Association**
	Thomas Tidies His Room	***Otsukai***	
4-year-old ($N = 12$)	4.8 ± 1.7	4.4 ± 1.6	2.1 ± 1.8
5-year-old ($N = 28$)	6.4 ± 2.5	4.8 ± 2.0	3.2 ± 2.2
6-year-old ($N = 78$)	8.5 ± 2.7	6.9 ± 2.4	5.5 ± 2.8

3.3 Paradigmatic and Syntagmatic Associations by Age Group

Overall, there were two main modalities to connect the keywords during their categorization process. One way was to link the keywords using a shared abstract concept (*e.g.* connecting "cat" and "bear" with "animals"), and the other way was to arrange the keywords together as a sequence (*e.g.* connecting "bear" and "raincoat" with "the bear puts on a raincoat"). The method of connecting keywords through abstract concepts was considered akin to paradigmatic semantic relations, which represent hierarchical relationships, and was classified as a "parallel" relation. The method of juxtaposing keywords together in line seemingly resembled syntagmatic semantic relations, which represent syntactic connections, and was classified as a "serial" relation.

To further examine the characteristics of cognition in early childhood, the numbers of parallel and serial connections were analyzed by age group. Fig. 4 shows the bar chart with error bars of the number of parallel connections by age. The mean ± standard deviation of parallel connections was 0.5 ± 0.7 for four-year-olds, 1.1 ± 1.3 for five-year-olds, and 1.2 ± 1.5 for six-year-olds, with no accountable significant differences between the groups ($F_{2,\ 116} = 1.8419$). Fig. 5 shows the chart of serial connections by age. The mean ± standard deviation of serial connections was 2.0 ± 1.3 for four-year-olds, 2.7 ± 2.0 for five-year-olds, and 4.1 ± 2.8 for six-year-olds. In fact, ANOVA results ($F_{2,116} = 7.4588$) indicated that six-year-olds had significantly higher values than four- and five-year-olds ($p < 0.01$). In a nutshell, while the average number of paradigmatic (parallel) connections did not significantly change with age, the number of syntagmatic (serial) connections tended to grow with age, according to our observation and analysis.

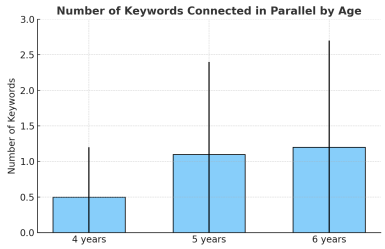

Figure 4: Paradigmatic association count by age group ($p < 0.01$)

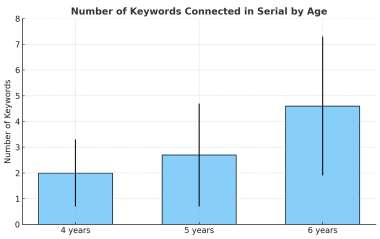

Figure 5: Syntagmatic association count by age group ($p < 0.01$)

4 Discussion

As of today, it remains relatively unclear how children in the early stages of language acquisition connect and associate words, and exactly how these connections are established. Clarifying the nature of these connections could be of great educational significance and can potentially contribute to further elucidating the educationally effective methodology of adults' communication

with children, in line with their intellectual development at critical period. This study developed a play-based program that tracks network-like thinking through storytelling and examined the nature of children's word connections. Common "recalled keywords from *Otsukai*" included nouns like cat, mouse, umbrella, float, and raincoat, while "recalled keywords from *Thomas tidies his room*" featured words like bear, elephant, doll, hat, block, and ball. On the other hand, many of the "associations" were verbs, such as play, put, eat, and wear, indicating that pre-school children tend to rely on verbs for word association, as shown in Fig. 3. Most commonly, children related keywords in a “linear” way, reflecting syntagmatic semantic relations, by linking words in a sequence, such as "the cat chases the mouse". Adults, in a stark contrast, tend to connect "cat" and "mouse" using paradigmatic semantic relations that involve hierarchical or categorical thinking, such as classifying both as "animals" or “mammals”. However, in the case of the children surveyed, many related "cat" and "mouse" through simple additive thinking, such as imagining the cat chasing the mouse.

Furthermore, a vast majority of the children linked animals with objects, often through expressions like "[animal] does something to [object]." This partly explains the predominance of verbs in the "associations" identified in Fig. 3. Only 10 out of the 553 associations made in fact connected "cat" with "mouse" in a parallel, paradigmatic way, and these were primarily found among six-year-olds. The survey suggested that most of the younger children anthropomorphize animals and objects, imagining them playing or living together with humans with human-like emotions, causing syntagmatic expressions to occur with high frequency. Subsequently, as cognitive development progresses, children begin to abstract animals into common classifications such as "animals" or "mammals" after these perceptual stages. Piaget [13] also argued that young children exhibit animistic thinking, attributing life-like qualities to inanimate objects, and explained non-living objects using knowledge of living creatures. In research related to naive biology in kindergarten-aged children, it has been reported that children typically acquire naive biology knowledge between ages four and six, and five-year-olds are shown to often have more biological knowledge compared to four-year-olds [14].

Besides, in this study, six-year-olds scored higher than four- and five-year-olds in terms of the number of general association links, which was found statistically significant. Uehara [15] in their review accounted that cognitive development in early childhood is strongly influenced by language development, with major progress occurring around age of four and having a significant impact on cognitive activity thereafter. The increase in the number of connected keywords can be considered to be supported by this explanation of cognitive development. Furthermore, six-year-olds showed a sharp increase in serial thinking, connecting words in such a way as "[animal] does something to [object]" more flexibly through animistic thinking, in which they attribute life or social aspects to various entities. On the other hand, while the average number of parallel connections, based on paradigmatic semantic relations, increased with age (from ages four to six), no statistically significant increase was admitted in the expansion of paradigmatic thinking. This finding hints at the fact that the acquisition of parallel thinking may occur after early childhood, and as a matter of fact, this agrees with the pre-existing researches [4][16][17]. The study was conducted from October to March, in the latter half of the academic year (note: an academic year starts in April in Japan), and more than half of the participants were six years old. Of the 553 total connected keywords, only 10 instances, as briefly mentioned above, where "cat" and "mouse" were connected as "animals" were observed, implying that children may acquire serial thinking and convert their knowledge into abstract concepts after starting elementary or primary schools.

Despite the above meaningful findings on this investigation, some limitations were being acknowledged. Firstly, the gender ratio of the surveyed children was inequal, which poses some

uncertainty to the obtained results. Factually, researches suggest that female children, particularly those between the ages of four and six, tend to exhibit more advanced language processing development compared to their male counterparts. Studies have shown that girls generally demonstrate earlier and stronger neural connectivity in key language areas, such as Broca's area (responsible for language production) and Wernicke's area (responsible for language comprehension) [18][19]. In the future investigational settings, it is desired that the environment with sufficient time and staffing resources to equalize the ratio is fully ensured. Moreover, it is indeed even more desirable to include month age for each surveyed child for future researches, in terms of identifying and elucidating spectrum of cognitive growth of children. Although this research did not fully delve into gory details of this in light of the relatively small number of sample data available and the very purpose of roughly describing the modality of children's network-type thinking, it would admittedly be a more precise locator of these contributory factors if we were to include these data all together.

Notwithstanding some acknowledged experimental and investigational issues this research faced as aforementioned, this research is an immensely significant precursor to the embodiment of the emerging field of education merged with informatics, that Takamatsu *et. al*. term eduinformatics [20][21][22]. The findings of the concrete modality of young children's network-type thinking, such as the primary use of syntagmatic, verb-based association technique, would lead to the deployment of the brand-new system that allows educators and nursery teachers to effectively choose picture books in a way children's thinking processes maximize the chance of new creation of the association links of knowledge, potentially being assisted by the mint large language models (LLMs) that are undergoing unprecedentedly rapid revolution today, and the appropriate algorithms and data structures born in the field of informatics.

5 Conclusion

Employing statistical analysis on the collected list of associated words given by pre-school children aged from four to six, this research demystified some of the hitherto unclear components of their network-type thinking modality. To wrap up the findings, we ascertained two important facts. First, the children heavily relied on verbs when it came to associating words in their minds, and the second one was that there was a statistically significant increase in syntagmatic association skills as one ages during these critical years of cognitive development.

Having roughly delineated a contour of the young children's network-type thinking process, which has been highly obscure thus far, is a consequential feat per se, however this also implied the extended future utilization of picture books in nursery school settings. Understanding the mechanism of knowledge network growth in young children serves as a good basis of many possible future applications, such as effective picture book selection method allowing us to unleash their intellectual potential, and powerful communication technique between them and us.

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