

Text Mining of Evidence on Infants' Developmental Stages for Developmental Order Acquisition from Picture Book Reviews

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Abstract

Herein, we study infants' reactions associated with the ordering of development mediated by picture books. We propose an approach that detects evidence on infants' reaction types from reviews of picture books. Existing developmental psychology research reports that infants' development occurs in a specific order; i.e., infants react according to their developmental stages. These existing findings must be extended because limited literature exists on studying picture books and infants' developmental order. However, the conventional approach in developmental psychology is time- and labor-consuming. Furthermore, existing findings show no information on the characteristics of picture books, making it harder to reproduce existing findings. To solve this problem, we collect infants' reactions by extracting the descriptions of infants' reactions from online reviews of picture books. Additionally, we investigate the characteristics of picture books that are related to these infants' developmental reactions. We collect over 150 reactions for each of the four types of reactions selected for the analysis and obtain typical characteristics of picture books for three reactions among the four types of selected reactions and find the proposed approach based on text mining of picture book reviews to be highly effective.

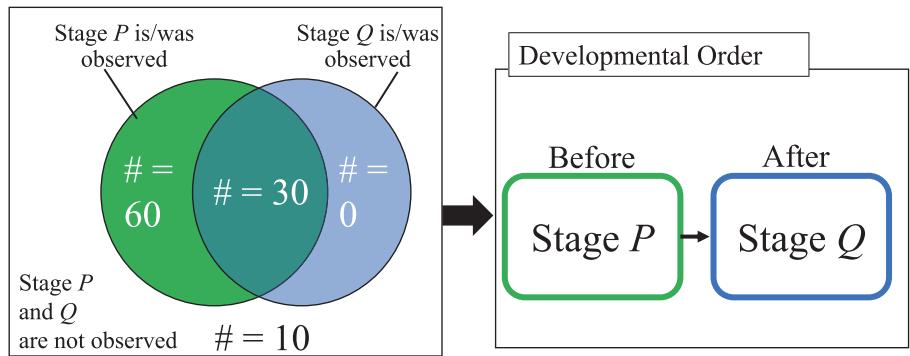
1 Introduction

Typically, educational books focus on specific subjects to be voluntarily learned such as science and sociology. However, picture books differ in the

sense that because they are efficient in infants' cognitive development (Pardeck, 1986). They do not focus on specific educational subjects with their style of expressions, i.e., funny stories and pictures. Although the readers of picture books are parents or childcare personnel who read the books for infants who have yet to achieve literacy. The target audience comprises infants who perceive and interpret the incoming stimuli of the book being read to them and the pictures shown in the books. Thus, picture books differ from other educational books in the sense that those who read them are separated from those who perceive them.

Developmental psychology research states that infants exhibit various cognitive reactions to external stimuli based on their developmental stage (Sully, 2000; Piaget, 1962; Leslie, 1987; Walker-Andrews and Kahana-Kalman, 1999). Infants express such cognitive reactions when picture books act as the stimuli. Furthermore, considering that infants cannot understand the printed letters of picture books, this tendency of reacting to pictures might be amplified to a certain extent.

Herein, we investigate infants' reactions related to the ordering of development mediated by picture books. We propose an approach that detects evidence on infants' reaction types by applying the text mining technique. In this area of research, existing research on developmental psychology (Ishikawa and Maekawa, 1996) has reported that there is a specific order of infants' development, and infants react according to their developmental stages. Ishikawa and Maekawa (1996) focused on the ordering of infants' development mediated by picture books.



E.g., when the result of studying the reactions of 100 infants is as shown above, it can be interpreted as follows:
 "When the stage *Q* is observed with an infant *I*, the stage *P* is always observed with the infant *I*"

The result in the left can be represented as above.

Figure 1: Overview of Ordering Analysis (Airasian and Bart, 1973)

Their findings include valuable insights regarding infants' developmental order, however, there are limitations to these findings: (i) no subsequent research exists based on infants' developmental order that is closely related to picture book reading, and (ii) existing findings include no information on the characteristics of picture books, making it harder to reproduce existing findings. Thus, extending these existing findings is necessary. However, the conventional approach in developmental psychology is quite time- and labor-consuming.

To investigate how the stimuli of picture books induce various reactions in infants, we apply the text mining technique to numerous reviews on picture books written by parents or childcare personnel. However, reviews on picture books have different characteristics compared with general book reviews. Such reviews include descriptions of an infant's reactions as well as descriptions of the reviewer's impressions of the book. Of these, descriptions of an infant's reactions are informative from the perspective of developmental psychology research. Thus, we analyze such descriptions extracted from picture book reviews. Furthermore, we focus on the infants' reactions related to the ordering of development mediated by picture books. We propose an approach that detects pieces of evidence of the types of infants' reactions by applying text mining. In addition, we investigate the characteristics of picture books that are closely related to those infants' developmental reactions. Specifically, we collect over

150 reactions for each of the four types of reactions selected for the analysis and obtain typical characteristics of picture books for three reactions out of the four types of selected reactions. We believe the proposed approach based on text mining of picture book reviews is highly effective.

2 Study of Infants' Developmental Order related to Picture Book Reading

In developmental psychology research, there is a specific order of infants' development, and infants show reactions in accordance with their developmental stages. Ishikawa and Maekawa (1996) focused on the relationship between the infants' developmental stages and the characteristics of picture books or the interaction induced by them. Ishikawa and Maekawa (1996) showed that there is a specific order of infants' development in the picture book readings and daily lives. For example, they indicated that before an infant learns how to turn pages and return to the proper page when he/she notices that he/she skipped a page, he/she who had not cared about skipping pages experiences preliminary stages such as "prefer picture books showing concrete daily life items and very few stories and sentences" and "prefer picture books having repetitive construction of pictures and sentences." To discover such types developmental orders, a questionnaire survey was conducted with 858 mothers having infants aged up to 74 months. In this survey, the participants were asked whether each of the 124 stages were observed

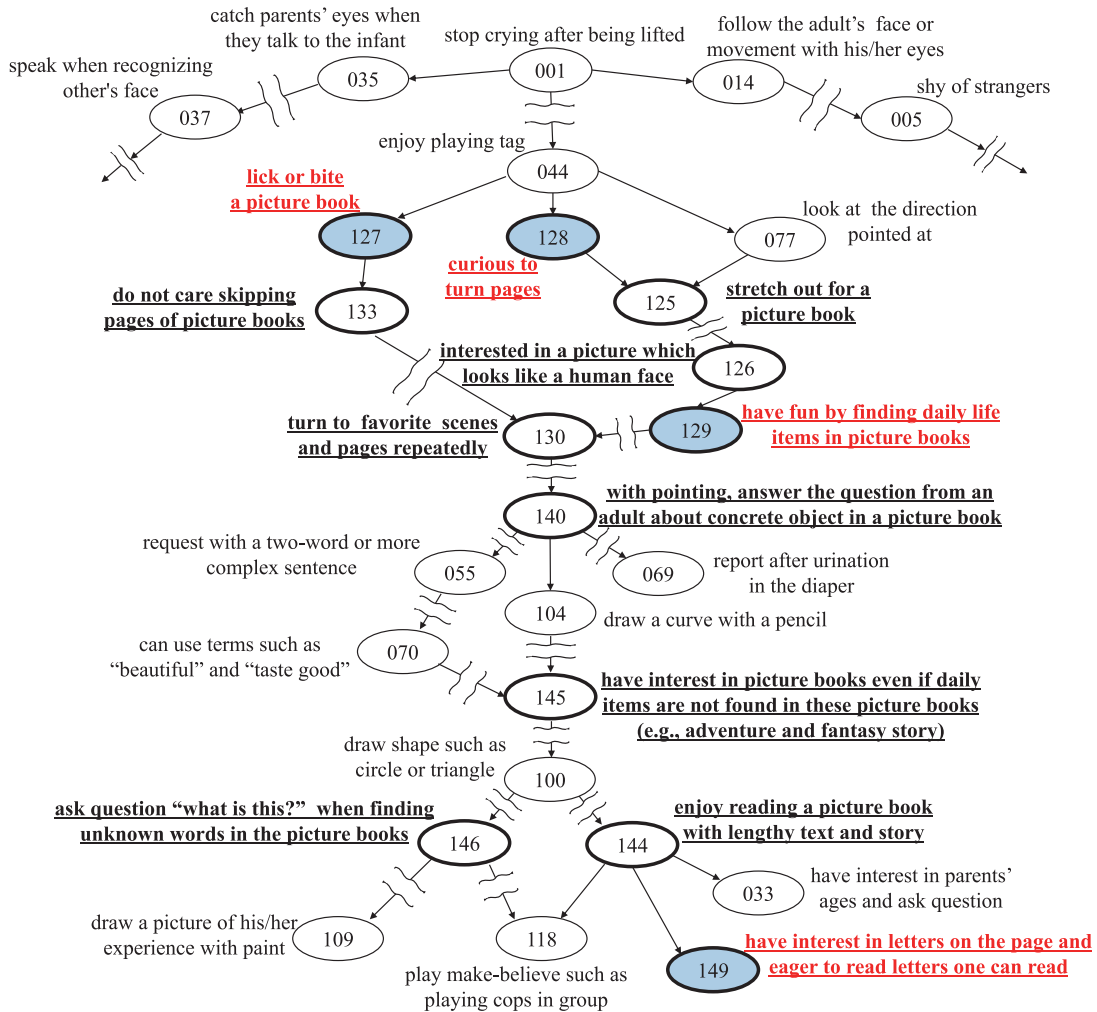


Figure 2: Excerpts of Developmental Stages and their Order (Ishikawa and Maekawa, 1996) (underlined stages are those related to picture book reading)

in their infants. The 124 stages include 25 stages regarding picture book reading and the remaining 99 stages concern the infants' daily lives such as "speak when you recognize someone's face." For each of the 124 stages, the participants select one of the following three answers: "is observed," "was observed," and "is not observed."

Ishikawa and Maekawa (1996) applied the ordering analysis technique (Airasian and Bart, 1973) to the result of this survey. They obtained the acquisition order of which stage comes first among those observed stages. Figure 1 shows the overall idea of the ordering analysis technique using the diagram notation and describes the situation wherein one stage P precedes another stage Q according to the numbers of infants observed throughout the survey.

Figure 2 illustrates the excerpt of the result of the ordering analysis shown by Ishikawa and Maekawa (1996). The developmental stages are located as the earlier stages mentioned above and the later stages described below. The arrow in Figure 2 indicates that the stage at its endpoint follows the one at its starting point. Regarding picture book reading, 12 are underlined in Figure 2 among the 25 stages.

3 Purpose of this Paper

In general, the following limitations of developmental order exist in the work of Ishikawa and Maekawa (1996). (i) The scale of the developmental order proposed by Ishikawa and Maekawa (1996) is insufficient. (ii) Ishikawa and Maekawa (1996) included no information on which picture books were read

when infants showed specific reactions corresponding to a certain developmental stage.

To resolve (i), of the 124 developmental stages, clear developmental orders were detected in only 98 stages. For the remaining 26 stages, orders were not detected. It is unclear whether the orders detected in the 98 developmental stages discovered by Ishikawa and Maekawa (1996) are sufficient to exhaustively understand the orders among all developmental stages. Thus, the survey of Ishikawa and Maekawa (1996) needs to be reproduced and developmental stages that were not covered within their survey (Ishikawa and Maekawa, 1996) have to be included, and then an additional survey for discovering orders among newly detected developmental stages has to be further conducted. However, the conventional approach of the research of developmental psychology based on questionnaire surveys is time- and labor-consuming.

The issue of (ii) is another reason that renders the conventional approach of developmental psychology research time- and labor-consuming. To reproduce the survey of Ishikawa and Maekawa (1996), identifying which picture books were read when infants showed specific reactions corresponding to a certain developmental stage is necessary. For example, in the case of the developmental stages such as “prefer picture books that have concrete objects without stories and sentences” (developmental stage no. 135) and “enjoy reading a picture book with lengthy text and story” (developmental stage no. 144), preparing picture books that satisfy the requirements provided within the description of each developmental stage is necessary. However, Ishikawa and Maekawa (1996) included no information on which picture books were read in the results of the questionnaire survey.

Regarding the discussion above, this study proposes how to collect evidence on the infants’ reactions related to the ordering of development mediated by picture books by applying the text mining technique to picture book reviews. To analyze the infants’ reactions, text data of reviews on picture books were collected from EhonNavi,¹ a website specializing in picture books. For the typical developmental stages related to picture book reading

¹<http://www.ehonnavi.net> (in Japanese)

(a) Principal Information

Start date of the service	Number of titles	Number of unique users per month	Number of members	Number of reviews
Apr. 2002	81,500	987,500	605,600	398,600

(b) Distribution of the Numbers of Reviews According to Infants’ Age

Age of infants	0	1	2	3	4	5	6
Number of reviews	8,984	16,318	27,856	33,443	29,930	26,328	21,825

Table 1: Overview of EhonNavi

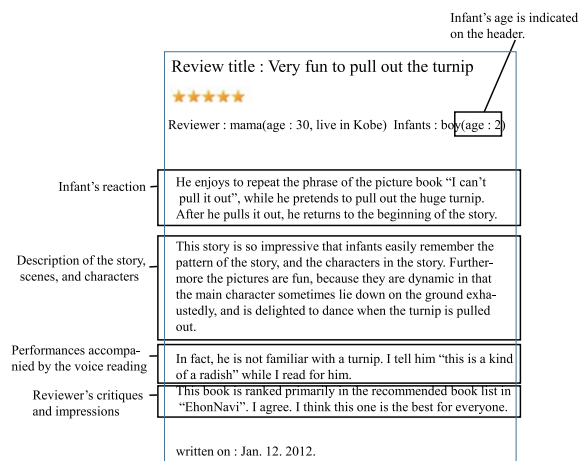


Figure 3: An Example of a Review

that were studied in Ishikawa and Maekawa (1996), we illustrate the procedure and the results of mining the evidence on the infants’ reactions related to the ordering of development mediated by picture books from the collected reviews. Collecting the characteristics of picture books related to those infants’ developmental reactions from online reviews on picture books is easy. This is an advantage of the proposed method based on text mining from online reviews on picture books over the conventional approach based on questionnaire surveys in developmental psychology research.

4 Website Specializing in Picture Books

To analyze the infants’ reactions, text data of reviews (written in Japanese) on picture books were collected from EhonNavi, a website in Japan specializing in picture books. EhonNavi provides information concerning picture books such as their publishers, authors, and descriptions. It also provides numerous reviews written by the parents or childcare personnel. The number of picture books included in

EhonNavi is about 81,500. The number of reviews is approximately 398,600 as of June 2020 (shown in Table 1). There are other popular websites with numerous book reviews as well, such as Amazon² and Booklog.³ Of these, EhonNavi has a unique characteristic in that its reviews are elaborate, thus reflecting the reactions of those who read the books as well as those who perceive them in detail. Additionally, another characteristic of EhonNavi showed that the age of the infant is attached to each review. All these characteristics are important for our work aimed at detecting the infants’ reactions following their developmental stages. Therefore, we have used the reviews provided on EhonNavi for the analysis conducted herein. Figure 3 shows an example of a review on EhonNavi: the header of each review includes the age of the infant to whom the reviewer reads the picture book.

5 Mining Evidence on Infants’ Developmental Stages related to Picture Book Reading from Reviews

5.1 Estimating Frequency Distribution of Infants’ Reactions per Age

Of the 25 developmental stages regarding picture books studied in Ishikawa and Maekawa (1996), this study focuses on the four stages described in Table 2. They are frequently observed in picture book reviews collected from EhonNavi. These four stages are shown with blue circles and red letters in Figure 2. Of these four stages, stages 127, 128, and 129 are those observed for infants aged at early months, whereas stage 149 is the one observed for infants older than the former. For infants aged between 0 to 6, we estimated the frequency of the infants’ reactions observed from the picture book reviews on EhonNavi. Figure 4 shows the corresponding distributions. Thus, we describe the procedure of collecting the reviews and semi-automatically estimating the frequency of infants’ reactions in those collected reviews as follows:

Step 1. For each of the four stages, the row “search words” in Table 2 shows words used that we search for reviews which include descriptions by the reviewers satisfying the “manual criterion” of the corresponding stage. Here, we assume that a denotes the age group ranging from 0 to 6 years. In addition, we assume that q denotes a search word (e.g., “lick

(舐め)”) or more than one search word concatenated with “and” operator (e.g. “mouth and put (口 and 入れ)”) listed at each subrow in the “search words” row of Table 2. Therefore, for each pair of the age a and the search word q , we collect reviews including those search words. We denote $h(a, q)$ as the number of collected reviews.

Step 2. For each of the four stages, we consider the row “manual criterion” of Table 2. We examine whether the reviews collected in step 1 satisfy the criterion. This means whether the collected reviews include descriptions of infants’ reactions satisfying the condition of the corresponding developmental stage. Here, for each pair of age a and search word q , we denote $n(a, q)$ ⁴ as the number of reviews randomly sampled for the procedure of manual examination, whereas $n_c(a, q)$ denotes the number of reviews that satisfy the criteria listed in Table 2.

Step 3. For each pair of age a and the search word q , we estimate the frequency $\hat{n}_c(a, q)$ of infants’ reactions in those collected reviews as

$$\hat{n}_c(a, q) = h(a, q) \times (n_c(a, q) / n(a, q))$$

Finally, we illustrate the estimated frequency distribution in Figure 4. For each of the four stages, we sum up the estimated frequencies $\hat{n}_c(a, q)$ throughout all search words q as below and obtain the estimated frequency $\hat{n}_c(a)$ for each age a .

$$\hat{n}_c(a) = \sum_q \hat{n}_c(a, q)$$

For each of the four stages with the estimated frequency distribution per age, Figure 4 shows the periods in months wherein the pass rate⁵ reported in Ishikawa and Maekawa (1996) is greater than or equals to 70% and is less than 80% (denoted as “70%–80%”), or greater than or equals to 80% (denoted as “≥80%”). From Figure 4, the periods in months where the pass rate of Ishikawa and Maekawa (1996) is greater than or equals to 80% mostly overlap with the peak in the estimated frequency distribution per age from the reviews. Regarding the peaks in the estimated frequency distribution per age, the estimated frequency is almost ≥90. The number of observations is sufficient when

⁴Herein, when $h(a, q) \geq 30$, $n(a, q)$ is fixed as 30 for all pairs of a and q . Otherwise, $n(a, q)$ equals to $h(a, q)$, i.e., all collected reviews are manually examined.

⁵In Ishikawa and Maekawa (1996), the pass rate is defined as the ratio of the answers “is observed” and “was observed” out of the overall answers in the questionnaire survey.

²<http://www.amazon.co.jp> (in Japanese)

³<http://booklog.jp> (in Japanese)

Stage No.	127	128	129	149
Stage description	lick or bite a picture book	curious to turn pages	have fun by finding daily life items in picture books	have interest in letters on the page and eager to read letters one can read
Search words (English translation of Japanese search words)	lick (舐め)	turn (めくる)	have fun (喜ぶ)	letter and read and not adult (文字 and 読む and not 大人)
	bite (噛)	turn and hand (めく and 手)	bus and have fun (バス and 喜)	letter and read (字 and 読)
	mouth and put (口 and 入れ)	turn and self (めくる and 自)	train and have fun (電車 and 喜)	letter and self (文字 and 自)
		turn and page (めくる and ページ)	dog and have fun (犬 and 喜)	letter and read (文字 and 読)
		flipping (べら)	cat and have fun (猫 and 喜)	letter and self and read (字 and 自 and 読)
		rifle (ばら)		
Manual criterion for judging whether the case written in the retrieved review satisfies the condition of the corresponding developmental stage	An infant actually licks or bites a picture book.	An infant has an interest in contents other than the letters such as pictures, pop-up and lift-the-flap and tries to turn pages to find them. This criterion excludes cases where an infant turns pages in order to read letters in picture books by himself/herself.	An infant is pleased to discover correspondence between concrete objects in the real world and pictures in a picture book.	An infant reads and understands letters constituting sentences in a picture book.

Table 2: Words used in Searching for Picture Book Reviews including Cases Satisfying Each Developmental Stage

compared with the number of participants with the answers as “is observed” and “was observed” in the questionnaire survey of Ishikawa and Maekawa (1996).⁶ Because the peaks of the frequency distribution per age estimated from the reviews and those of the distribution of the pass rates of Ishikawa and Maekawa (1996) are overlapping and the numbers of observations within the reviews are sufficient, then the picture book reviews are informative enough at least for the four stages studied herein.

5.2 Estimating Pass Rates per Age

Next, we estimate the pass rate for each age and four stages from the picture book reviews. Here, we collect reviews written after the picture book b is read for each pair of the picture book b and the age a . We denote $n_r(b, a)$ as the number of the collected reviews. Additionally, we denote $n(b, a)$ ⁷ as the number of reviews randomly sampled for the procedure of manual examination. Here, $n_c(b, a)$ denotes the number of reviews that satisfy the criteria listed in Table 2. Then, for each pair of the picture book b and the age a , we estimate the frequency $\hat{n}_c(b, a)$ of

⁶The numbers of participants with the answers as “is observed” and “was observed” are 110 for stage 127, 88 for stage 128, 66 for stage 129, and 102 for stage 149.

⁷In this paper, when $n_r(b, a)$ is greater than or equals to 30, $n(b, a)$ is fixed as 30 for all the pairs of b and a . Otherwise, $n(b, a)$ equals to $n_r(b, a)$, i.e., all the collected reviews are manually examined.

infants’ reactions in the collected reviews as

$$\hat{n}_c(b, a) = n_r(b, a) \times (n_c(b, a) / n(b, a))$$

Finally, we estimate the pass rate $pr(a)$ for age a for each of the four stages. We add the numbers $n_r(b, a)$ of the collected reviews and the estimated frequencies $\hat{n}_c(b, a)$ throughout all picture books b as shown below. Further, we obtain the estimated pass rate $pr(a)$ as their rate for each age a .

$$pr(a) = \sum_b \hat{n}_c(b, a) / \sum_b n_r(b, a)$$

Figure 4 shows the distribution of the estimated pass rates for each of the four stages. We observe that the pass rates estimated from the reviews are lower when compared to those reported in Ishikawa and Maekawa (1996). This is because not all parents described what they observed in the reviews. The fact is that only those parents who observed certain evidence of the developmental stages of their infants write the observed evidence in the reviews. The distributions of the pass rates estimated from the reviews coincide with the distributions of the pass rates reported in Ishikawa and Maekawa (1996).⁸

⁸Of the four stages, the distribution of pass rates estimated from the reviews for stage 129 has higher pass rates in the higher ages from 4 to 6 years when compared with the distribution of the estimated frequency. This is because the estimated frequencies for those higher ages are small, which causes much higher pass rates.

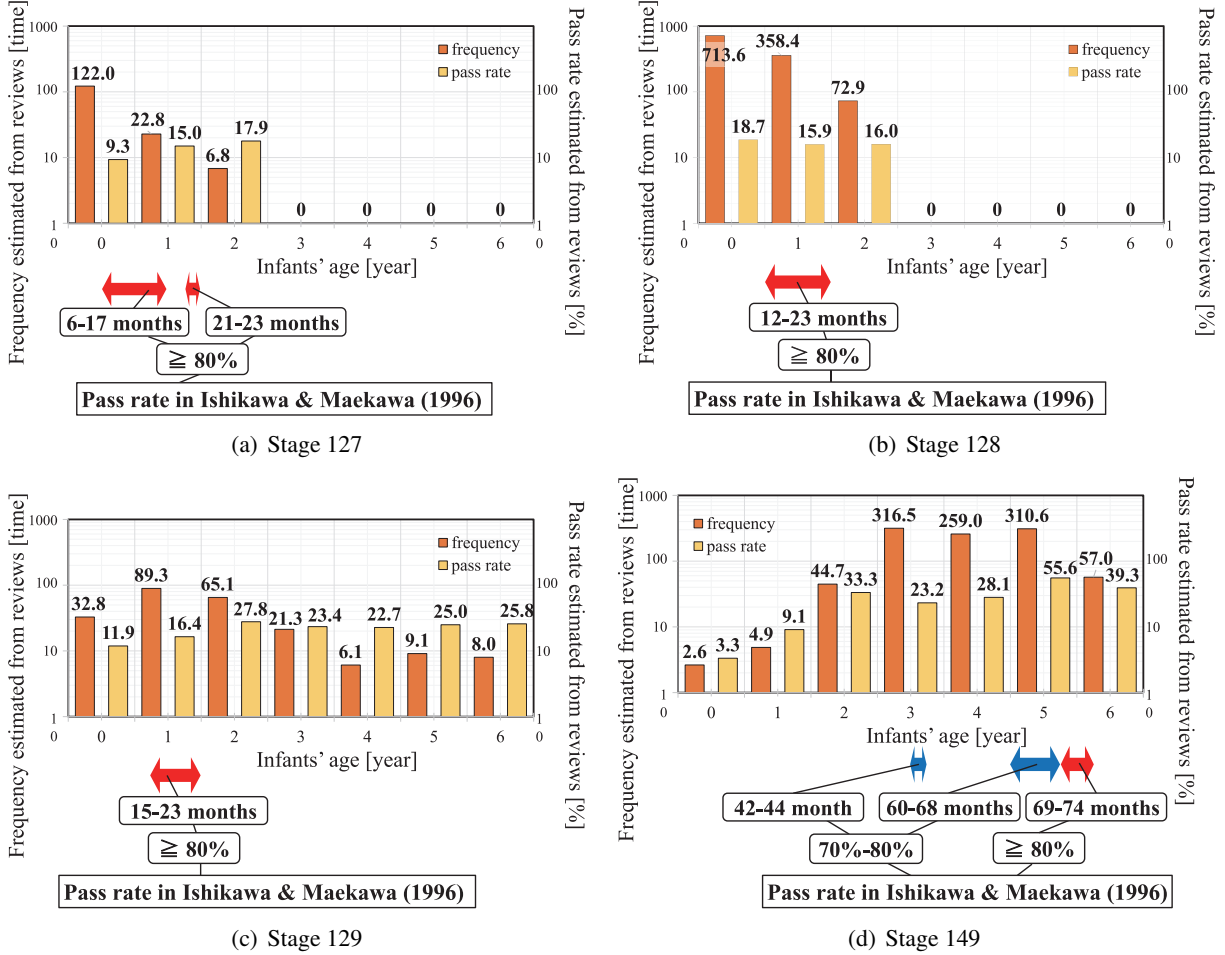


Figure 4: Frequencies and Pass Rates of Infants' Reactions Estimated from Reviews and Pass Rates in Ishikawa and Maekawa (1996)

5.3 Analyzing the Characteristics of Picture Books

The major advantage of the proposed approach based on text mining of picture book reviews is that it is easy to collect the characteristics of picture books that are read when infants show specific reactions corresponding to a developmental stage. Thus, this section studies the characteristics of picture books that are read when the reactions corresponding to stages 128, 129, and 149⁹ are observed from the four stages. For each of the three stages, let B_0 denote the set of picture books b that satisfy the

⁹Infants' reactions that are specific to stage 127, i.e., "lick or bite a picture book," usually have no strong relation to any specific characteristics of picture books, but are observed when picture books of any type are read, when suitable for infants around the ages of 3 years or younger. Thus, we discard stage 127 for the analysis on the characteristics of picture books.

following condition:

at least one review (written after the picture book b is read) is manually examined in step 2 of the previous section, and the review includes descriptions of infants' reactions satisfying the condition of the corresponding developmental stage.

Furthermore, we examine the characteristics of each picture book $b \in B_0$ such as "vehicles in the book," "animals in the book," "lift-the-flap book," "secure binding book," "colorful," and "featuring words" as shown in Figure 5. For each of the examined characteristics, we count the number of picture books satisfying the characteristics. Finally, we consider the characteristics that have the number greater than or equal to 5 picture books and illustrate them in Figure 5 with infants' age as the vertical axis. In addition, the three developmental stages 128, 129, and

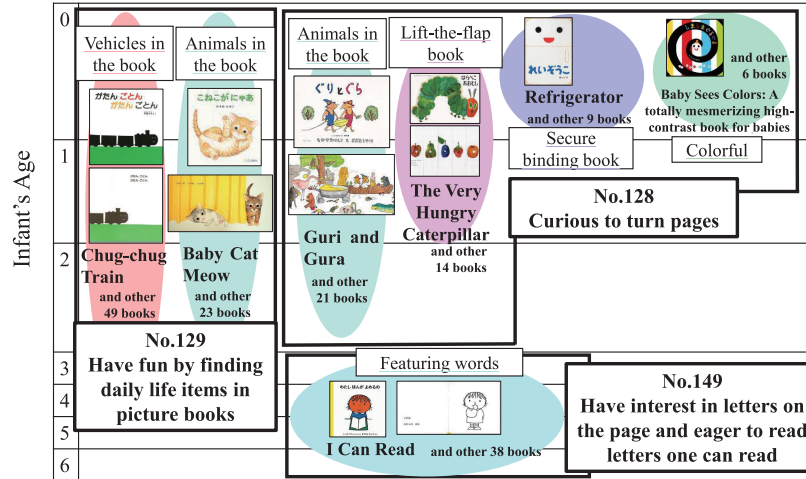


Figure 5: Typical Characteristics of Picture Books for Each Developmental Stage

149 illustrate the areas covering the corresponding characteristics. It is clear to understand the layout of characteristics shown in Figure 5, as the stage 128, “curious to turn pages,” is observed in the picture books with characteristics such as “colorful,” “secure binding book,” and “lift-the-flap book.” The stage 129, “have fun by finding daily life items in picture books,” is observed in picture books with the characteristics such as “vehicles in the book” and “animals in the book.” Further, the stage 149, “have interest in letters on the page and eager to read letters one can read,” is observed in picture books with characteristics such as “featuring words.”

6 Related Work

Previous work on analyzing infants’ developmental reactions detected from reviews on picture book reading includes an earlier work on how to detect infants’ major nine developmental reactions from reviews based on a simple keyword matching approach (Uehara et al., 2015). Further, later works considered on pointing behavior (Uehara et al., 2016) or hand/finger gestures (Uehara et al., 2017). Some focused on the relationship between characteristics of picture books and infants’ developmental reactions (Baba et al., 2017a) and clustering of picture books (Baba et al., 2017b). The proposed approach is novel when compared to previous works on analyzing infants’ developmental reactions detected from reviews on picture book reading. This is because we focused on the study of Ishikawa and

Maekawa (1996) that concentrated on the ordering of infants’ development mediated by picture books. The proposed approach shows how to detect evidence on infants’ developmental stages related to the ordering of development mediated by picture books from reviews. Related work includes studies on picture book recommendations based on the similarity of storylines of picture books, infants’ interest, and language developmental stages (Hattori et al., 2016; Yasuo et al., 2017). Their approach is based on the texts and pictures of picture books themselves but not on reviews of picture books.

7 Conclusion

In this work, we studied the infants’ reactions related to the ordering of development mediated by picture books. We proposed an approach that detects evidence on the types of infants’ reactions from reviews on picture books. We further examined the characteristics of picture books that are related to those infants’ developmental reactions. Future work includes scaling up this study into the remaining 21 developmental stages studied in the work of Ishikawa and Maekawa (1996). For the remaining 21 stages, the proposed approach based on search words applies to a few of them. Furthermore, another approach based on characteristics of picture books (e.g., “picture book with a relatively long story”) also applies to other types of stages.

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