Contextual Modulation of Adult–Child Language Interaction: Semantic Network Connectivity and Children’s Vocabulary Development

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Abstract: Word learning encompasses the understanding of interconnected clusters of words, where the comprehension of one word aids in the learning of another. Semantic networks, which have a long history in cognitive science, are commonly employed to explore these semantic relationships. However, limited research has been conducted on adults’ use of semantically relevant conversations in the field of early childhood education, and there is insufficient information regarding contextual factors influencing the development of semantic networks. The present study investigated the extent to which the use and effectiveness of semantically relevant conversations vary across activity contexts. This study analyzed data from the Home-School Study of Language and Literacy Development (HSLLD) Corpus available in the CHILDES database, focusing on a subset of 62 children. This study utilized four statistical features to describe the structure of semantic networks: short path length, diameter, density, and clustering coefficient. The following findings emerged: (1) Book reading displayed a significantly greater diameter than toy play and mealtime, indicating that there exist specific pairs of concepts or words within its semantic networks that are notably more distant from each other than in the other two activity settings. (2) Toy play exhibited a significantly greater density in comparison to book reading and mealtime, suggesting a higher degree of overlap or interdependence among the concepts within its semantic networks. (3) Book reading demonstrated a significantly greater clustering coefficient compared to toy play and mealtime, signifying the existence of cohesive word communities or groups of words characterized by dense internal connections. (4) Adults’ use of semantically relevant conversations during book reading was positively associated with children’s lexical diversity.

Keywords: early childhood education; language-learning environment; contextual modulation; vocabulary development; computational linguistics; network science

1. Introduction

During the first three years of life, children learn hundreds, even thousands, of words [1]. What are the factors that contribute to early vocabulary development? Studies conducted in laboratories have identified individual factors influencing word learning, including cross-situational word learning [2], social cue use [3], and syntactic bootstrapping [4]. But in the laboratory, the contribution of individual factors to vocabulary development is typically measured for one or a small handful of words [5]. These laboratory studies do not directly answer inquiries about the developmental composition and sequence of vocabulary growth across many different children in their natural learning environments.

While some studies have made efforts to forecast word learning outside laboratory settings, they have mostly focused on examining a single factor: the frequency of a child’s exposure to language spoken by caregivers [6]. However, the process of word learning is not solely about forming associations between objects and their labels and adding them...
one by one to the mental lexicon [7]. Words exist in a sea of other words, and the semantic relations among these words are crucial in understanding and interpreting language [8].

Thus, vocabulary development involves grasping interconnected clusters of concepts, where understanding one concept facilitates the learning and comprehension of another [9]. For example, when encountering the word “dog”, children not only retrieve the meaning or understanding associated with that single word but also access all the pertinent knowledge they have acquired over time. A dog is a pet with fur and four legs and it barks. To assist in their comprehension of the text or speech, children may also have access to words commonly used alongside “dog”, such as “bone” and “run” (Figure 1). In this view, the process of language comprehension in children necessitates more than just possessing an extensive vocabulary (i.e., a wide range of words in their lexicon). It also requires that those words stimulate rich, interconnected networks of conceptual knowledge [10].

Vocabulary depth, also referred to as word knowledge networks, plays an explanatory role in understanding and processing human language [7,10]. The term “word depth” refers to the quality of knowledge individuals possess about words, rather than simply the quantity of words known [11]. While certain viewpoints on vocabulary depth highlight richness of knowledge for individual word representations [12], depth can also be understood as the interconnected networks of semantic knowledge that form the foundation for word labels. In this view, similar concepts are linked together based on shared semantic associations [11].

Semantic networks are often used to investigate these semantic relations [13]. The idea of semantic networks has a long history in the field of cognitive psychology, with the advance of graph theory and its application to cognitive processes and social networks [7,8,13]. In these networks, words are represented as nodes, and they are interconnected through links that signify semantic associations.

Steyvers and Tenenbaum suggested semantic networks expand through the mechanism of preferential attachment [13]. In a child’s lexicon, words that have a high degree of connectivity are likely to attract more words over time (i.e., rich-get-richer scenario). In other words, children tend to acquire new words that are semantically relevant to known words compared to words that are not related [9]. The concept of preferential attachment can also provide an explanation for the commonly observed Matthew effect [14], suggesting that children who possess extensive prior knowledge about words have a greater ability to rapidly acquire new word knowledge.

In contrast, Hills et al. suggested semantic networks expand through the mechanism of preferential acquisition [15]. Word learning is influenced by the connectivity of words

![Figure 1. Semantic Network. The boxes of different colors signify distinct categories of words.](image-url)
in children’s learning environments, not by the existing connectivity of words known. In other words, learning is shaped by features present in the input irrespective of how prior knowledge is structured. For instance, concrete nouns that are densely connected in the input are more easily acquired due to their contextual diversity, which facilitates easier meaning disambiguation [16,17].

Both proposals are important and have different implications for our understanding of the role of lexical networks in vocabulary acquisition. On the preferential attachment proposal, vocabulary acquisition is driven by known words that have strong connections to other known words [9]. As new words are added to children’s lexicons, their vocabulary depth expands, leading to the enhanced semantic differentiation and reorganization of semantic networks [13]. When a child possesses a deep understanding of words, those words tend to have a greater number of connections to more words, resulting in more nuanced and elaborated meanings. On the preferential acquisition proposal, children display sensitivity toward highly connected words [8]. Children come across a word in various situations, each of which presents multiple possible meanings, and ascertain the meaning of the word by choosing from those meanings which consistently recur in different contexts [16]. Words that are highly interconnected are likely to appear in diverse speech and referential contexts, and it becomes easier to understand their relevant meaning or reference due to the numerous shared contexts with other relevant words [15].

Deep word knowledge, in contrast to superficial knowledge gained through fast mapping, is built gradually over time [18]. Therefore, it is crucial to begin intentionally cultivating this knowledge during the early years. However, there has been scant research on the depth of vocabulary in the field of early childhood education, with limited information about contextual factors influencing the development of semantic networks. Language may be taught during activity settings such as book reading, toy play, and mealtime and these contexts may involve different materials and environments facilitating the use of semantically relevant conversation, with each context possibly contributing in different ways [19]. But the extent to which different activity settings during conversation may be especially important for promoting lexical diversity needs further attention [20].

A framework rooted in Michael Halliday’s theory of Systemic Linguistics Approach (SLA) [21] offers researchers a means to systematically explore the interplay between linguistic form and meaning across various social contexts, utilizing the concept of register variation. Registers are distinguishable through specific linguistic features and functions, serving distinct intellectual and societal objectives [22]. These registers encompass lexical and grammatical features of language that exhibit variation across different situations and events [20,23]. Consequently, SLA conceives of language as a “social semiotic”, a system of signs whose meaning arises not intrinsically but due to their integration within context [24].

Research guided by the SLA perspective has primarily focused on investigating the contextual influence on semantic information. This topic has been approached from both structural (e.g., lexical diversity, syntactic complexity) [20,25,26], and functional standpoints (e.g., the types of language usage) [22,27,28]. Nevertheless, no prior attempts have been made to investigate the nuances of semantic networks within diverse activity contexts. Based on the SLA perspective, the present study investigates (1) if adults’ use of semantically relevant conversation varies across activity settings (book reading, toy play, and mealtime); and (2) the extent to which the effectiveness of adults’ semantically relevant conversation within each type of activity setting on children’s expressive language skill. Specifically, this study focuses on semantic components of adult–child interaction using network science algorithms.

2. Materials and Methods

2.1. Dataset

The current study analyzed the Home-School Study of Language and Literacy Development (HSLLD) Corpus [29], which is available in the CHILDES database. Commencing in 1987, this study examined contextual factors influencing language development in a
group of English-speaking children from lower-income families residing in urban centers within the northeastern United States. Originally, 86 children were annually visited in their homes from ages 3 to 5, with additional follow-up visits occurring in their 2nd- and 4th-grade years. Transcripts were collected during various activities, including book reading, toy play, mealtime, and narrative/experimental tasks. For the current study, we focused on the data collected when the children were 3 years old, specifically examining a subset of 62 children for whom complete data were available in these activity contexts. A total of 248 adult–child conversational interaction sessions were transcribed and subsequently verified by a second transcriber. This process was conducted in its entirety using the Codes for the Human Analysis of Transcripts (CHAT) transcription system, accessible through the Child Language Data Exchange System (CHILDES).

The recruited families, all of whom were English speakers, encompassed a diverse spectrum of cultural, racial, and educational backgrounds. Of them, 67% identified as White, 15% as African American, and 6% as of Hispanic heritage. A significant portion of the mothers, constituting 25% of the sample, indicated that they had not completed high school. Roughly 50% reported having achieved a high school diploma, while the remaining 25% disclosed having pursued some form of post-high-school education. Additionally, half relied on a parent’s earnings as their primary source of income, while the other half depended on government assistance programs such as Aid to Families with Dependent Children (AFDC). Half of the families were characterized as single-parent households [29].

The study encompassed four distinct conversational settings. First, during the book-reading session, mothers and children read *The Very Hungry Caterpillar*, a beloved children’s book authored by Eric Carle [30], known for its vibrant illustrations and simple language. Second, during the toy play session, mothers were asked to engage in unstructured play with their children using a selection of toys provided by the experimenter, including painted blocks, small toy cars, a tea set, utensils and dishes, a school bus with tiny figurines, a toy baby bottle with a disappearing milk effect, a parrot puzzle, toy telephones, and an optiscope, from which the mother and child could choose. While these play sessions could extend up to 40 min, they typically averaged between 10 to 15 min in duration. Third, during the mealtime session, recordings of natural mealtime conversations were collected. At the conclusion of the home visit, a blank audiotape was provided for families to record their typical mealtime interactions. Fourth, during the elicited report session, mothers were tasked with prompting their children to recount a past experience to the investigator. The elicited report session served as a measure of the children’s lexical diversity [29].

2.2. Measures

Semantic network algorithms measured semantic relatedness of words or concepts used in adult–child conversations. There are four statistical features used to describe the structure of semantic networks: short path length $L$, diameter $D$, sparsity $S$, and clustering coefficient $C$. Each measure is detailed in the next section.

Children’s expressive language skill was measured during the elicited report setting, wherein mothers were asked to encourage their children to share some past experiences with data collectors. A type–token ratio (TTR) was used as a metric to measure lexical richness or vocabulary diversity. This metric helps determine whether a child tends to repetitively use the same words or a child uses a variety of different words to communicate. A TTR is calculated by dividing the number of unique words (types) by the total number of words (tokens) in a specific language segment. Obtaining a language measure in a naturalistic setting with a caregiver, rather than a standardized assessment, holds value due to the child’s increased familiarity and comfort, as supported by stable elicited report results over time and a significant relation with future receptive language skills [31,32].

2.3. Analytic Strategy

In the current study, semantic network algorithms were used to investigate: (1) static features of words’ connectivity within networks during book reading, toy play, and meal-
Network science offers an intuitive and adaptable framework for representing and capturing the interdependence between entities, enabling the modeling of interconnection patterns [13]. In the context of semantic network analysis (SNA), community detection algorithms derived from network science are utilized to establish semantic concepts [8]. In particular, the present study gathered word associations through the construction of a network, wherein the topology mirrors the co-occurrence patterns of words. This approach draws its foundation from collocation analysis, a widely used domain within corpus linguistics [13,33,34].

To begin, we introduce specific terms from graph theory and provide an overview of the statistical characteristics employed to describe the structure of semantic networks. Semantic networks are built upon the foundation of graph theory, which consists of a set of nodes representing entities and a set of edges or arcs connecting pairs of nodes. When an arc or an edge connects two nodes in a semantic network, they are commonly referred to as neighbors. A neighborhood in this context is a subset of nodes that includes a single node and all of its neighbors.

Four primary statistical properties are commonly utilized to characterize the structure of semantic networks: short path length (L), diameter (D), density or sparsity (S), and clustering coefficient (C) [8,13]. The short path length (L) is related to the diameter (D): L represents the average shortest path length between all pairs of nodes in a network, whereas D represents the maximum of these distances among all pairs of nodes. It indicates that, on average, it takes L steps to move from one node to another, but at most D steps are required (Figure 2).

The density (or sparsity) (S) of a semantic network is calculated as the number of edges a node possesses divided by the total number of possible edges that a node could have [35]. It is expressed as:

$$\frac{\text{Actual Connections}}{\text{Potential Connections}} = \frac{m}{n(n-1)/2} \quad (1)$$

where \(n\) represents the number of nodes and \(m\) represents the number of edges in the network. In a dense network, nodes belonging to a specific community or group are more likely to establish connections with other members within the same community than with nodes outside of that community. That is, in a dense network, information tends to spread or diffuse more readily within the network, rather than being transmitted through a specific path from one node to another. According to Pereira et al. [36], networks with lower densities cover a wide range of distinct ideas or topics, and there is less overlap or
interdependence between them. In other words, semantic networks characterized by lower densities typically exhibit a greater abundance of concepts compared to networks with higher densities.

The clustering coefficient (C) or transitivity in a network is a metric that quantifies the tendency of nodes to form clusters or groups [35]. A high clustering coefficient indicates the presence of communities or groups of nodes that exhibit dense internal connections. In other words, C represents the probability that two neighbors of a randomly chosen node are connected to each other or the extent to which the neighborhoods of neighboring nodes overlap. In accordance with Watts and Strogatz [37], the clustering coefficient (C) is calculated by obtaining the average, across all nodes i, of the quantity:

\[ C_i = \frac{2T_i}{k_i(k_i - 1)} \]  

\( T_i \) refers to the count of connections between the neighbors of a given node i. That is, \( T_i \) represents the number of edges that directly link the neighboring nodes of i to each other. \( k_i(k_i - 1)/2 \) refers to the maximum number of connections that could exist between the neighbors of i if they were all interconnected in a complete subgraph. Here, \( k_i \) denotes the degree of node i, which indicates how many edges are directly connected to this specific node [13]. On the right side of Figure 3, none of the nodes has neighbors that are also each other’s neighbors, resulting in a C of 0. In the middle of Figure 3, there is one realized connection and two missing connections, yielding a C of 1/3. On the left side of Figure 3, C reaches its maximum value of 1 in a fully connected network where each node is directly linked to every other node [35,37].

A small-world structure is a common network pattern found in a variety of systems, such as semantic memory [38]. It is characterized by having a high clustering coefficient (C) and a relatively low or moderate short path length (L), in comparison to random graphs with similar size and density. Cognitive models suggest that C and L have an impact on the activation of associations between concepts. In particular, when C is higher and L is lower (or moderate), it increases the likelihood of forming a greater number of associations between words [39].

The present study aimed to investigate the variations in the structure of semantic networks across different activity settings (book reading, toy play, and mealtime) using repeated-measure ANOVA. Four key statistical properties (short path length, diameter, density, and clustering coefficient) were employed to characterize the structure of semantic networks, revealing significant associations with cognitive performance indicators [39,40]. Additionally, we hypothesized that children would exhibit higher levels of expressive language skill when the semantic networks within each activity context demonstrate high values of clustering coefficient (C) and low or moderate values of characteristic path length.
A small-world structure is a common network pattern found in a variety of systems, indicating a small-world structure. To analyze this relationship, generalized linear modeling was employed.

3. Results
3.1. RQ 1. Does Adults’ Use of Semantically Relevant Conversation Vary across Activity Settings (Book Reading, Toy Play, and Mealtime)?

Semantic networks were constructed based on three sources of semantic knowledge: book reading, toy play, and mealtime (Figures 4–6). The analysis of these semantic networks focused on four properties: short path length (L), diameter (D), density (S), and clustering coefficient (C). These statistical features provided distinct insights into the structure of the networks.

![Figure 4. Semantic Network in Book Reading.](image)

![Figure 5. Semantic Network in Toy Play.](image)

![Figure 6. Semantic Network in Mealtime.](image)
3.1.1. Short Path Length and Diameter

While the short path length showed no significant difference across different activity settings ($F(1.74, 64.43) = 0.92, p = 0.39, AKP’s Delta = 0.65$) (Figure 7), the diameter (i.e., maximum path length) exhibited a significant difference ($F(2.00, 74.00) = 5.52, p = 0.00, AKP’s Delta = 0.65$) (Figure 8). Semantic networks demonstrated the highest diameter during book reading ($M = 7.79$), followed by mealtime ($M = 7.16$) and toy play ($M = 7.13$). Yuen’s post-hoc test further confirmed that book reading displayed a significantly greater diameter in comparison to both mealtime and toy play. During book reading, there exist specific pairs of concepts or words in the semantic network that are significantly more distant from each other than in the other two activity settings. This indicates that the topics explored during book reading may cover a broader and more diverse range compared to those discussed during toy play and mealtime.

All three networks exhibited remarkably short average path lengths and diameters relative to their sizes. For example, in the semantic networks associated with book reading, the average path length was only 2.45, and the diameter was only 7.79. That is, at most, 7.79 associative steps (regardless of direction) were required to connect any two words within the lexicon.

![Figure 7. Network Structures: Short Path Length (Book Reading, Toy Play, and Mealtime). The red line in the semantic network represents a short path length.](image-url)
3.1.2. Density

The analysis showed a significant difference in density across the different activity settings, $F(1.88, 69.51) = 11.11, p < 0.001$, AKP’s Delta = 0.71. Figure 9 displays the results, indicating that the semantic networks had the highest density during toy play ($M = 0.02$), followed by mealtime ($M = 0.01$) and book reading ($M = 0.01$). Yuen’s post-hoc test revealed that toy play had a significantly higher density compared to both mealtime and book reading, indicating that there was more overlap or interdependence between the concepts in the semantic network [36]. In contrast, book reading and mealtime had significantly lower densities than toy play, indicating a greater abundance of distinct ideas or topics in their semantic networks. It is also worth noting that all three semantic networks were sparse, with a word being connected to only an average of 1.5% of the total number of words. This implies that a significant portion of the words in the networks had relatively few direct connections to other words.

3.1.3. Clustering Coefficient

The clustering coefficient varied significantly across different activity settings, $F(1.91, 70.68) = 27.74, p < 0.001$, AKP’s Delta = 1.00. Figure 10 displays the results, indicating that the clustering coefficient for semantic networks was highest during book reading ($M = 0.37$), followed by toy play ($M = 0.29$) and mealtime ($M = 0.28$). Yuen’s post-hoc test revealed a significantly higher clustering coefficient in book reading compared to toy play.
play and mealtime. The clustering coefficient for semantic networks in book reading was significantly higher than zero, suggesting the presence of word communities or groups of words that display dense internal connection (i.e., small-world networks). This type of network structure is conducive to semantically relevant conversation because it allows for efficient communication and information flow within individual word clusters.

Figure 10. Network Structure: Clustering Coefficient (Book Reading, Toy Play, and Mealtime).

3.2. RQ 2. Do Children Show a Higher Degree of Expressive Language Skill, When Adults Engage in More Semantically Relevant Conversation within Each Activity Context?

A linear model was conducted to examine if adults’ use of semantically relevant conversation within each type of activity setting was related to children’s expressive language skill (Table 1). The clustering coefficient for the semantic networks in book reading was significantly and positively associated with children’s vocabulary development ($\beta = 0.19$, $se = 0.10$). The analysis showed that the impact of semantically relevant conversations on children’s lexical diversity depended substantially on activity context.

Table 1. Vocabulary Development and Adults’ Use of Semantically Relevant Conversation Within Each Type of Activity Setting ($n = 59$).

<table>
<thead>
<tr>
<th>Type–Token Ratio (TTR)</th>
<th>$\beta$</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.04</td>
<td>0.10</td>
</tr>
<tr>
<td>Child Characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.19 +</td>
<td>0.10</td>
</tr>
<tr>
<td>Male</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>Conversation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clustering Coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Book Reading</td>
<td>$0.35^*$</td>
<td>0.16</td>
</tr>
<tr>
<td>Toy Play</td>
<td>$-0.19$</td>
<td>0.14</td>
</tr>
<tr>
<td>Mealtime</td>
<td>$-0.24$</td>
<td>0.16</td>
</tr>
<tr>
<td>The Number of Nodes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Book Reading</td>
<td>0.35</td>
<td>0.45</td>
</tr>
<tr>
<td>Toy Play</td>
<td>0.60</td>
<td>0.39</td>
</tr>
<tr>
<td>Mealtime</td>
<td>$-0.22$</td>
<td>0.49</td>
</tr>
<tr>
<td>The Number of Edges</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Book Reading</td>
<td>$-0.24$</td>
<td>0.46</td>
</tr>
<tr>
<td>Toy Play</td>
<td>$-0.50$</td>
<td>0.35</td>
</tr>
<tr>
<td>Mealtime</td>
<td>$-0.07$</td>
<td>0.44</td>
</tr>
</tbody>
</table>

$+ p < 0.10; ^* p < 0.05$; data are standardized.
4. Discussion

The first aim of the present study was to examine if adults’ use of semantically relevant conversations varies across activity settings (book reading, toy play, and mealtime). The second aim was to investigate the extent to which the effectiveness of adults’ semantically relevant conversations within each type of activity setting on children’s expressive language skill. In the inferential analyses, the following findings emerged: (1) The diameter of semantic networks in book reading was significantly greater than that of toy play and mealtime, indicating that certain pairs of concepts or words are notably more distanced from each other when compared to the other two activity settings. (2) The density of semantic networks in toy play was significantly greater than that of book reading and mealtime, suggesting a heightened level of interdependence or overlap among the concepts within its semantic networks. (3) The clustering coefficient of semantic networks in book reading was significantly greater than that of toy play and mealtime, implying the presence of cohesive lexical communities or groups of words characterized by their dense internal connections. (4) Adults’ use of semantically relevant conversations during book reading was positively related to children’s lexical diversity.

In the semantic networks observed in toy play and mealtime, information was found to diffuse from one word to all other words. However, in the semantic networks observed in book reading, there was a tendency for edges to connect words within the same community, forming dense clusters. Additionally, within these dense communities, several words were observed to have connections with words in other potentially distant communities, acting as bridges that connect smaller clusters or “islands” of words. Indeed, small-world structures have been observed in many other mature semantic networks [37]. Small-world characteristics enable local structure while facilitating global access, allowing easy movement and transition between clusters [13]. These small-world properties are believed to contribute to efficient cognitive processes such as processing, word retrieval, and word categorization [9,15,38].

While it is widely acknowledged that adult semantic networks exhibit small-world characteristics [8,13], only a limited number of studies have explored their variations across different contexts and the significance of semantic network structure in child language acquisition [26,41]. The findings of the current study demonstrated a relation between the degree to which adults engage in semantically relevant conversations during activities, particularly those that facilitate semantically relevant conversation (such as book reading), and children’s vocabulary development. Picture book reading provides a wide range of opportunities for engaging in semantically relevant conversations promoting children’s language skills, which may not naturally occur during mealtime or toy play.

This finding aligns with previous research, which has shown that picture books provide rich opportunities for building conceptual knowledge [42]. According to the Systemic Linguistics Approach [21], picture book texts and conversations centered around books may incorporate linguistic elements that are not commonly found in colloquial language. This exposure to abstract and semantically relevant words during book reading is particularly crucial because later reading comprehension relies on an understanding of low-frequency and sophisticated interconnected word meanings [7].

This finding is also in line with previous research, which has shown that book reading offers a context in which caregivers and children share a joint topic focus [42,43]. This activity creates opportunities for children to engage in semantically relevant conversations, moving beyond mere perceptual attention and involving conceptually focused discussions [29]. As the book remains a constant presence, the need to hold the topic in mind while constructing a related utterance is reduced, resulting in decreased cognitive demands of generating a related utterance [44]. Additionally, book reading is characterized by analytic discussions about words, the meanings of texts, and comprehension-related topics, which help children develop a greater appreciation for books and become more actively engaged in discussions [7,29,42–44].
The present study holds significant implications for both practice and research. First, the current study raises concerns about relying solely on general measures of ECE quality measures. Up until now, various stakeholders in the ECE field have collaborated to define and measure quality by using descriptions generated from classroom-level ratings of teacher–child interactions. These ratings are typically obtained through tools such as Early Childhood Environment Rating Scale (ECERS), Classroom Assessment Scoring System (CLASS), and Early Language and Literacy Classroom Observation (ELLCO). While these measurement tools have proven to be useful and more user friendly than language-intensive approaches [20], they only account for a relatively small portion of the variation in language and literacy outcomes. The findings of this study add to the existing evidence supporting the importance of semantically relevant conversations that prioritize vocabulary depth. In particular, the semantic network algorithm was found to effectively capture the significant proximal processes that contribute to children’s lexical diversity. Considering AI-driven measures beyond the general classroom-level ratings may enhance our understanding of children’s language learning environments.

Second, the results may have implications for improving caregiver education models. The present study raises doubts about the current approaches to fostering children’s language skills, particularly those focusing on enhancing the systems-level general environment through professional development of caregivers. Most current models emphasize global strategies while paying little attention to the differences across activity contexts. Caregivers also talk at, rather than with, children in some settings [27,45]. This could be one of the reasons why interventions typically have limited success in improving the use of high-quality language input [20,43].

Caregivers are expected to adapt their practice simultaneously across activity contexts, possibly leading to minimal change in their caregiving performance. In this regard, some researchers advocate for more targeted approaches to professional development since adjusting caregiving strategies is difficult [20,43]. The present results indicate caregiver education efforts could be adapted to capitalize on the natural variation in effectiveness occurring across activity settings. A promising approach would be to design and implement professional development models that would leverage on caregivers’ strengths by maximizing the effectiveness of language exchanges within activity contexts more conducive to using semantically relevant conversations. Given that such investigations are rare in the ECE field, additional research on context-specific caregiver education programs would contribute substantially to the ECE literature.

There are some significant limitations to the current study. First, our study is constrained by the absence of a standardized language measure, due to our reliance on secondary data analysis. This limitation is rooted in the scope of publicly accessible data within the CHILDES database. Second, the network models employed in this study do not address several aspects of semantic networks, including the potential disappearance of semantic links. Future research could focus on examining the evolution of semantic networks over time. Third, the present study focused on investigating semantic networks in the specific contexts of book reading, toy play, and mealtime, with a particular emphasis on semantic connections and expressive vocabulary. The extent to which these findings are domain-specific (e.g., semantic, phonological, and syntactic connections), the choice of vocabulary measure (receptive vs. expressive), and their applicability to different cultures and languages are still areas that require further research. Fourth, the current study is exploratory in nature and does not allow for causal inference. This study cannot show causal relations between semantically relevant conversations and children’s expressive language skill because the quality aspects are not manipulable by the researcher and cannot be randomly assigned. However, this research offers some insight into how a causal study can be designed in future studies.
5. Conclusions

Early care and education (ECE) quality research often overlooks the contextual aspects of children’s language experience [27,45]. There is still a lack of knowledge about how the effectiveness of caregivers’ instructional practices varies depending on specific activity contexts [20]. The present study employed innovative computational approaches to investigate how the use and effectiveness of semantically relevant conversations differ across different activity contexts.

While some studies have attempted to predict word learning in naturalistic settings, they have primarily focused on investigating a single factor: the frequency of words used in conversations. Words exist in a sea of other words, and the semantic connections among them is pivotal for understanding and interpreting language. Therefore, word learning involves grasping interconnected clusters of words, where understanding one word supports in learning another. Semantic networks are widely used to probe these semantic associations. Nevertheless, there has been limited exploration of how adults utilize semantically relevant conversations in the realm of early childhood education, and there is a dearth of information regarding contextual elements that influence the formation of semantic networks.

Drawing from the Systemic Linguistics Approach (SLA) perspective, this study delved into the extent to which the use and effectiveness of semantically relevant conversations vary across different activity contexts. The findings from this study underscore a link between the degree of engagement in semantically relevant conversations by adults during activities, particularly those that facilitate such conversations (like book reading), and the development of children’s vocabulary. This suggests that caregiver education efforts could be tailored to leverage the natural variation in effectiveness observed across different activity settings. Furthermore, the findings of this study contribute to the existing body of evidence emphasizing the significance of semantically relevant conversations that prioritize vocabulary depth. Specifically, the semantic network algorithm adeptly captures the significant proximal processes influencing children’s vocabulary development, and exploring AI-driven assessments beyond the global classroom-level evaluations may deepen our insight into the language-learning environments for young children.

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