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A LITERATURE REVIEW OF THEORIES ON CHILD SPEECH AND LANGUAGE DEVELOPMENT FOR DESIGNING A SCREENING TOOL

(SOROTAN KAJIAN TEORI-TEORI MENGENAI PERTUTURAN KANAK-KANAK DAN PERKEMBANGAN BAHASA UNTUK MERANGKA REKA BENTUK ALAT SARINGAN)

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ABSTRACT

Screening for speech and language delays in children is not new and has been done for a decade. Currently, abundant validated speech and language delay screening tools are available in multiple languages in every part of the world. However, society and cultures heavily influence speech and language; therefore, a validated screening tool may only be appropriate for people with similar backgrounds, cultures, and norms. We reviewed multiple theories about speech and language areas in preschool children to formulate a conceptual framework for developing a new speech and language delay screening tool appropriate for use in Malaysia. Our panel of experts recommended theories in our literature review based on their expertise in speech and language in preschool children. Each theory was analyzed to extract important variables or domains to be included in the conceptual

framework. The Malay language was recommended as a medium for the new screening tool. Based on our literature review, we formulated a conceptual framework with four independent variables or domains: preverbal, receptive, expressive, and vocabulary. The dependent variables were speech and language delay. Age was identified as our moderating variable. Social interaction, culture, laws, and policies were mediating variables in our proposed conceptual framework. Our proposed conceptual framework was a guide for developing screening tools for speech and language delay in preschool children. The screening tool can be in the form of an interview questionnaire, physical examination, or parent-rated screening tool based on the researcher's needs and preferences.

Keywords: speech; child; preschool; language delay; development

ABSTRAK

Saringan untuk kelewatan pertuturan dan bahasa pada kanak-kanak bukanlah perkara baharu dan telah dilakukan selama sedekad. Pada masa ini, banyak alat saringan pertuturan dan bahasa yang disahkan tersedia dalam pelbagai bahasa di seluruh dunia. Walau bagaimanapun, pengaruh sosial dan budaya banyak mempengaruhi pertuturan dan bahasa. Oleh itu, alat saringan yang disahkan mungkin hanya sesuai untuk mereka yang mempunyai latar belakang, budaya dan norma yang sama. Pengkaji telah mengkaji pelbagai teori tentang perkembangan pertuturan dan bahasa dalam kanak-kanak prasekolah untuk membina satu kerangka konsep bagi membangunkan alat saringan kelewatan pertuturan dan bahasa baharu yang sesuai untuk digunakan di Malaysia. Teori-teori di dalam kajian ini telah disyorkan oleh barisan panel berdasarkan kepakaran mereka dalam menguruskan kes-kes kelewatan pertuturan dan bahasa dalam kalangan kanak-kanak prasekolah. Setiap teori yang disyorkan telah dianalisis untuk mengekstrak domain-domain penting untuk dimasukkan ke dalam kerangka konsep. Bahasa Melayu telah dipilih sebagai bahasa pengantar untuk alat saringan baru ini. Berdasarkan kajian literatur, pengkaji merumuskan kerangka konsep dengan empat domain: praverbal, reseptif, ekspresif dan perbendaharaan kata. Pembolehubah bersandar ialah kelewatan pertuturan dan bahasa. Umur dikenal pasti sebagai pembolehubah penyederhana. Interaksi sosial, budaya, undang-undang dan dasar telah menjadi pembolehubah pengantara dalam kerangka konsep yang kami cadangkan. Kerangka konsep ini merupakan panduan untuk membangunkan alat saringan untuk kelewatan pertuturan dan bahasa dikalangan kanak-kanak prasekolah. Alat saringan yang dibina boleh dibangunkan dalam bentuk soal selidik temu bual, pemeriksaan fizikal, atau alat saringan yang dinilai ibu bapa berdasarkan keperluan dan keutamaan penyelidik.

Kata kunci: pertuturan; kanak-kanak; prasekolah; kelewatan bahasa; perkembangan

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Introduction

Acquiring speech and language skills is a fundamental milestone in a child's early life, as it allows them to effectively communicate their thoughts, needs, and emotions, laying the foundation for their social, cognitive, and academic success. However, some children may experience delays or difficulties in developing these critical abilities, which can have far-reaching consequences (Hare & Bremner, 2016). Speech delay is a child's inability to produce sounds or form words at the expected developmental timeframe. In contrast, language delay describes a child's difficulty comprehending or expressing language appropriately for their age. It may manifest in delayed vocabulary acquisition, limited understanding of spoken language, and challenges in forming grammatically correct sentences. (Hare & Bremner, 2016). According to Bowen's classification, speech delay can be categorized as primary or secondary. Primary speech delay refers to cases where no specific causes or aetiology for the delay are known. On the other hand, secondary speech delay is identified when the delay is linked to other conditions, such as hearing and neurological impairment, behavioural problems, and developmental difficulties (Kumar et al., 2022).

Socioeconomic background is one of the primary causes of delayed language development in young children (Hare & Bremner, 2016). Children from lower socioeconomic backgrounds have fewer opportunities for exposure to rich language environments, which can impede language acquisition (Zhang, Wang, & Liu, 2023). Research has revealed a striking disparity in language exposure among young children from various socioeconomic backgrounds. According to Hassinger-Das et al., children from professional families typically hear 48 million words by age four, while those from low-income families only hear 13 million (Hassinger-Das, Toub, Hirsh-Pasek, & Golinkoff, 2017). Fewer acquisition of words will impact children's fluency in speech and language development. In addition to socioeconomic background, other risk factors for speech and language delay are male, bilingual environment, prolonged suckling habit, family history of speech and language delay, and chronic middle ear infection (Feldman, 2019; Kumar et al., 2022).

Environment and quality of interaction between caregivers and children also play a crucial role in children's speech and language development (Feldman, 2019). Language learning occurs within a social context, where children actively engage with their environment and the language models around them; thus, lacking a positive environment can potentially impair their growth in the speech and language domain. For example, social isolation during the COVID-19 pandemic resulted in a significant impact on speech and language development among preschool children and led to various speech-language-hearing disorders (Fernandes, Alpes, & Santos, 2024; Hsu & Wong, 2023). Parents play an important role in supporting children's language development by providing emotional support, engaging them in more conversations, and creating opportunities for meaningful interaction (Nora'Azian & Nurul Jamilah, 2024). Failure of parents to provide quality interaction and a supporting environment will result in major disadvantages for their children in speech and language development.

Approximately 2.5% to 11.9% of preschool children worldwide suffer from isolated or primary speech and language delays (Feldman, 2019). Our country lacks clear local prevalence data for primary speech and language delay. Most studies have focused on the prevalence of speech and language delay caused by other conditions such as autism, attention deficit hyperactivity disorder, and cerebral palsy. The lack of screening activities and a validated screening method for speech and language delays resulted in the unknown illness burden in a local setting. There is no set ideal age for screening speech and language delay, but it should occur sooner rather than later, before the age of four (Minor-Corriveau et al., 2018). The average age for children diagnosed with speech and language delay may range between two and eleven years old, but the peak prevalence is between two and five years old (Hoque, Akhter, & Mannan, 2021; Kumar et al., 2022). The American Academy of Paediatrics (AAP)

recommended that surveillance for speech and language delay should be conducted at every visit for children up to the age of 36 months. If any concerns arise, screening should be administered using standardized tools within this period to capture children with a delay (Wallace et al., 2015).

Needs For a New Screening Tool for Speech and Language Delay in Malaysia's Setting

Screening tools come in different types and forms, for example, questionnaires based on interviews between medical professionals and parents, a parent-rated questionnaire that reports children's progression through parents' daily observation, or a set of examinations conducted by medical professionals through direct observation of the children and physical examinations. Each screening tool has its strength in detecting speech and language delays in children. In Malaysia, primary health clinics are responsible for screening for primary speech and language delays. Our current approach to primary speech and language delay screening heavily relies on parent reporting and concern during their routine health clinic consultation with medical officers or community nurses, unlike screening for autism spectrum diseases that used a validated Modified Checklist for Autism in Toddlers (M-CHAT) as early as eighteenth month. Heavy burdens and attendance in primary health clinics will limit quality consultation between primary caregivers and parents. Thus, the needs and concerns of parents may be left unintentionally unattended. Therefore, children with primary speech and language delays may remain undetected and be denied early intervention and therapy. A validated screening tool will act as a checklist for the primary caregiver to ensure all the children are screened, and a parent-rated screening tool is suitable for use in primary healthcare settings to avoid an increase of burden to the healthcare workers.

Currently, abundant validated speech and language delay screening tools are available in multiple languages in every part of the world. However, society and cultures heavily influence speech and language; therefore, a validated screening tool may only be appropriate for people with similar backgrounds, cultures, and norms. Malaysia is a unique country of multiracial ethnicities, diverse social cultures and norms, and a multilingual population. Finding a present validated screening tool to adapt to these vast differences in culture is challenging and time-consuming. This is because language idiosyncrasies complicate translation and adaptation. For example, English uses many tenses, whereas Malay and Mandarin use fewer tenses, which are expressed differently (Chu et al., 2019). Thus, most screening tools are region-specific, and translating the validated screening tools to another language may have a different meaning than intended and lose their credentials. Therefore, developing a new screening tool is more appropriate to represent Malaysia's uniqueness.

Malay Preschool Language Assessment Tool (MPLAT) is Malaysia's only validated screening and diagnosis tool for speech and language delay. Screening can be conducted by a trained person for children between the ages of 4 to 6 years old. There is no set ideal age for screening of speech and language delay, but it should occur sooner rather than later, before the age of four (Minor-Corriveau et al., 2018). The average age for children diagnosed with speech and language delay may range between the ages of 2 and 11 years old, but the peak prevalence is between the ages of 2 and 5 years old (Hoque et al., 2021; Kumar et al., 2022). The American Academy of Paediatrics (AAP) recommended that surveillance for speech and language delay should be conducted at every visit for children up to the age of 36 months. If any concerns arise, screening should be administered using standardized tools within this period to capture children with a delay (Wallace et al., 2015). Thus, there is a valid reason for developing a new screening tool to screen children earlier.

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Malay Language as a Medium in A New Screening Tool

Malay, also known as Bahasa Malaysia, holds a significant position in Malaysia as the national language, playing a crucial role in shaping national identity and unity among the diverse population. Culturally, the Malay language serves as a symbol of identity for the Malay ethnic group and is closely intertwined with the broader Malaysian identity (Jambi, 2008). It serves as a medium for transmitting cultural narratives, traditions, and values, thus playing a vital role in preserving Malay heritage (Mohamad, Salleh, & Mohamad, 2022).

Moreover, the Malay language fosters social cohesion in Malaysia's multicultural society. Its use in interethnic communication promotes understanding and collaboration among different ethnic groups (Baharudin & Sadik, 2016). This is particularly important in a country with ethnic diversity, where effective communication can help prevent misunderstandings and cultivate harmonious relationships. The language's role in facilitating dialogue among Malaysians of various backgrounds is essential for maintaining social stability and promoting national unity (Mahamod et al., 2021). Its presence in popular media, such as television and literature, further underscores its cultural significance and helps shape the collective identity of Malaysians (Idrus et al., 2016).

Additionally, the incorporation of the Malay language in various domains, including healthcare and legal systems, highlights its practical importance in everyday life and governance (Pocock et al., 2020). Therefore, utilizing the Malay language in a new screening tool can benefit all ethnicities and races in Malaysia.

Conceptual Framework for a New Screening Tool for Speech and Language Delay

The development of a new screening tool required a solid conceptual framework to serve as the foundation. Developing a new screening tool requires a solid conceptual framework as the foundation. A conceptual framework provides an overall structure to systematically define the key concepts, their relationships, and the boundaries of a research area (Ullah, 2021). Varpio et al. defined conceptual frameworks as analytical tools with several variations and contexts that reveal areas where research is possible, indicate how to develop appropriate methodologies, and serve as a basis for choosing starting points for the needed research (Ullah, 2021). The conceptual framework should form the backbone of the screening tool development process, guiding the researchers to identify relevant concepts and domains, explore their interrelationships, and design appropriate tools to address research needs. A conceptual framework for developing a screening tool to detect speech and language delays in preschool children should consider the key components that need to be included, such as risk factors, developmental domains, and environmental settings.

An extensive literature review of the existing speech and language development theories, screening tools, and risk factors is crucial for developing a robust conceptual framework. Therefore, this study aims to conduct an integrative literature review to identify the key components to incorporate into a new screening tool for speech and language delays in preschool children based on existing speech and language development theories.

Methodologies

The abundance of child developmental theories in speech and language acquisition poses a challenge in determining which ones are most pivotal to include in a comprehensive review (Feldman, 2019). A Delphi method was employed in this study to address this problem. The Delphi method is a structured communication technique used to gather information and reach a consensus among a panel of experts on a specific topic (Deng et al., 2022). Four panels of experts were invited to participate in this study,

each with extensive knowledge of child speech and language development. Our panel of experts includes a public health specialist, a paediatrician, a speech pathologist, and a clinical psychologist. Our panel of experts was asked to share their perspectives on the theories they believe are fundamental to children's speech and language delay development. The discussion was held in online meetings and face-to-face meetings. After two rounds of discussion and feedback, the panel reached a consensus on the fundamental theories that should be included in this review. Each theory was thoroughly analysed and synthesized to formulate conceptual frameworks for a new speech and language screening tool for preschool children.

Results and Discussion

Literature Review of Fundamental Theories

Based on our discussion with a panel of experts, seven theories related to speech and language delay were selected to formulate our conceptual framework for developing screening tools for speech and language delay in preschool children. All these theories helped to identify relevant domains or variables in our conceptual framework. The list of the theories, their principal, and their relationships to speech and language areas are summarized in the table below.

Table 1: Summary of Theories related to Speech and Language

Theory	Principal of Theory	Relation to Speech and Language	Domain or Variable identified
Bronfenbrenner's Ecological Systems	Suggested that child development is influenced by multiple interconnected systems, ranging from the individual child to the broader societal and cultural contexts (Alwell & Cobb, 2009). The system is defined as the microsystem, mesosystem, exosystem, and macrosystem (Milan & Bridges, 2019).	- The microsystem, which includes direct interactions with caregivers and peers, plays a critical role in preverbal and early language development. Gros-Louis et al. found that mothers provide differential feedback to infants' prelinguistic sounds, which can enhance the child's vocal development and subsequent language skills (Gros-Louis, West, Goldstein, & King, 2006). - In the mesosystem, the interaction between microsystem environments such as preschool and home adds as catalyst for a rich environment to support vocabulary growth (Nora'Azian & Nurul Jamilah, 2024). - The exosystem and macrosystem influence language development through societal norms, policies, and cultural	- Preverbal - Vocabulary - Receptive - Expression - Environmental

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		practices. Provide language development through the social interaction process and enhance children's receptive and expressive language capabilities.	
Attachment Theory (Bowlby and Ainsworth)	Propose that children have innate need to form emotional bond or attachment. The quality of an infant's attachment to the caregiver will be determinant of their subsequent psychological and social functioning (Lopez, Mauricio, Gormley, Simko, & Berger, 2001)	Effective attachment help to stabilize children emotion and engage to more meaningful relationship and communication (Lopez et al., 2001) Effective communication help to improve children receptive and expressive domain of speech and language.	Social interaction Receptive Expressive Emotion
Development Milestone Theory	Proposed that every children has a series of predictable milestone achieved at specific age (Dosman & Andrews, 2012).	Development of speech and language can be predicted at a specific age and serve as a benchmark for children's developmental progression.	Age
Piaget's Cognitive Development Theory	Cognition development of children occurred in four distinct stage; Sensorimotor stage, preoperational stage, concrete operational stage, and formal operational stage. Through the progression of each stage, children acquire knowledge and skills (Rabindran & Madanagopal, 2020)	In the sensorimotor stage, children up to age 2 years old rely on sensory skills and motor action in daily routine. These preverbal skills act as introduction for children's speech and language acquisition In the later stage of cognition maturity, children begin to develop abstract, hypothetical, and deductive reasoning.	Preverbal skill Receptive skill Expressive skill Cognitive
Critical Period Hypothesis	The theoretical framework suggests specific time frames in human development during which certain skills and abilities can be most optimally acquired. It has been applied to various	Acquisition of speech and language skills in children is time sensitive. During this sensitive period, capabilities for children to acquire speech and language skills is optimized but waned after the sensitive period passed. Developmental milestone	Time Age

	domains, including language acquisition, sensory perception, and even the development of complex cognitive abilities. (Hartley & Lee, 2014)	theory is more practical and flexible as it allows children to catch up even after a specific milestone's expected age or time has passed.	
Vygotsky's Social Development Theory	Emphasized on the social and cultural context in the development of the individual. Children's thinking and meaning-making are socially constructed, emerging from their social interactions with their environment, which includes parents, peers, teachers, and the broader community. (Hartley & Lee, 2014)	- Social interaction and cultural context greatly influenced speech and language development in children.	- Social interaction - Cultures and norms
Universal Grammar (Chomsky)	The theory proposed language acquisition is not solely a product of environmental influences but rather that humans are biologically predisposed to acquire language through an innate capacity for linguistic competence(Hartley & Lee, 2014).	- Children are born with the ability to acquire language. The theory minimizes the importance of environmental and social interaction in speech and language acquisition. Highlighted genetic and biological factors.	- Genetic or biological

Theoretical Framework

Based on our discussion with a panel of experts, we agreed that Bronfenbrenner's ecological systems theory should serve as our main theoretical framework for formulating a conceptual framework for a new screening tool for speech and language delay in preschool children. Bronfenbrenner's Ecological System Theory was supported by other theories to fill the relevant item in each of the multi-layer systems in the theory. Figure 1 below shows our finalized theoretical framework for the study.

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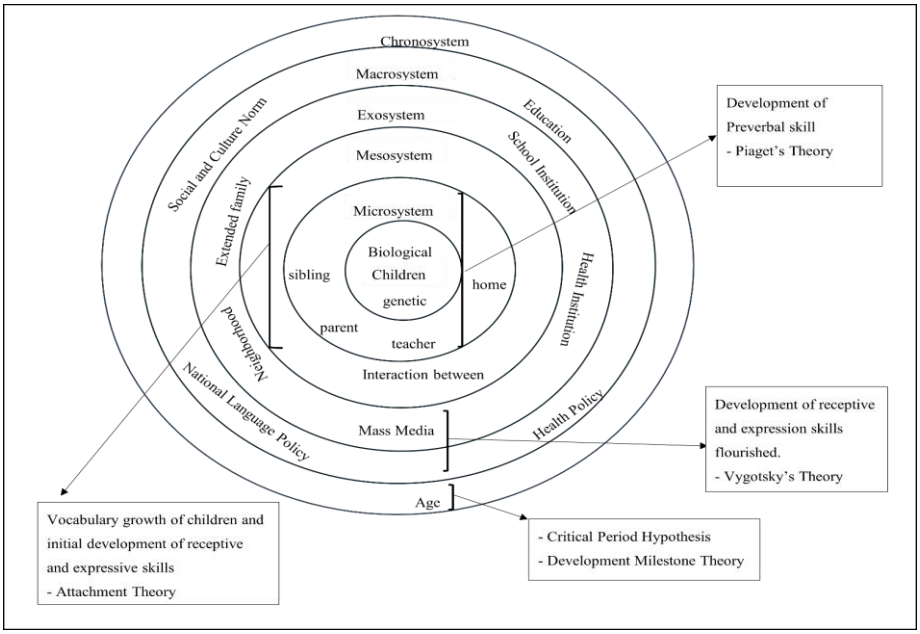
Figure 1: Bronfenbrenner's Ecological Systems Theory with Relation to Other Theories of Speech nd Language



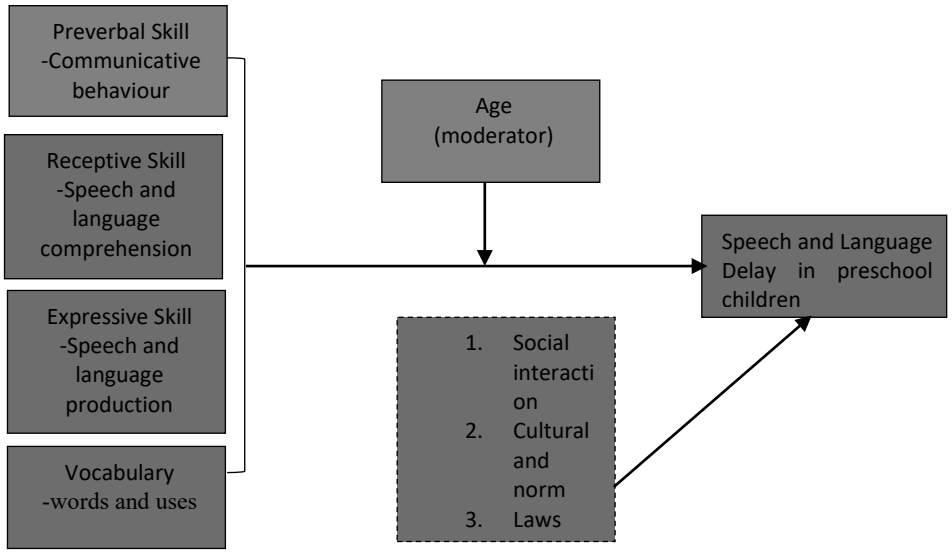
Our theoretical framework summarized findings and relations of the theories to speech and language development. In our first layer of the system, proposed by Chomsky's theory, a child is born capable of learning language. Age plays an important role in cognitive maturation for children to support their learning capabilities, as mentioned by the critical period hypothesis and developmental milestone theory. In the microsystem layer, a child's direct interaction with the closest person and environment helps nurture preverbal skills. This is supported by Piaget's theory of the sensorimotor stages. As we moved into the mesosystem layer, the vocabulary growth of the children is supported by the interaction component of the microsystem. In the exosystem and macrosystem layer, Vygotsky's theory and attachment theory highlight cultural and social importance in the development of children's receptive and expressive skills for speech and language acquisition.

Based on the relationship of all theories depicted in our theoretical frameworks, by using Bronfenbrenner's ecological systems, we could identify domains relevant to speech and language areas. Preverbal, receptive, expressive, and vocabulary domains were frequently discussed as important variables for children to acquire speech and language skills. Therefore, these domains can be used as benchmarks to screen speech and language delays in children. We also identified other domains or factors that heavily influenced speech and language development in children, such as social interaction, culture, and age, as our control variables for our conceptual framework.

Conceptual Framework

In formulating our conceptual framework, our dependent variable was speech and language delay as our focus to screen this developmental delay. Four important domains identified in theoretical frameworks were included as our independent variables: preverbal, receptive, expressive, and vocabulary. Age is identified as a moderator variable between independent and dependent variables. Other factors or domains identified in the literature review of the theories related to speech and language area were made as control variables for the dependent variables. Our conceptual framework is depicted in the figure 2 below.

Figure 2: Conceptual Framework for the Development of Screening Tool for Speech and Language Delay



Our main aim in this literature review is to build a conceptual framework to aid in developing a new screening tool for speech and language delay in preschool children. We reviewed selected existing theories to help identify important domains or variables to be included in our conceptual framework. Four main domains were identified: preverbal, receptive, expressive, and vocabulary.

Preverbal skills are a set of abilities that emerge before the onset of language and play a crucial role in shaping children's linguistic and cognitive development. These skills include perceiving and discriminating speech sounds, understanding basic concepts, and engaging in nonverbal communication through gestures and facial expressions (Neuman, 2015). Screening for preverbal skills can be conducted by observing a child's responses to various stimuli, such as their ability to orient to their name, follow simple instructions, and recognize familiar objects and events (Neuman, 2015). Children who exhibit delays or deficits in preverbal skills may be at risk for later language and literacy difficulties (Goldin-Meadow et al., 2014). Therefore, screening for preverbal skills is relevant to screening for speech and language delays in preschool children. An item can be built by assessing the child's communicating behaviour.

Receptive skills are another domain we proposed for screening speech and language delay. It is defined as the ability of children to comprehend and interpret a set of information. Examples of receptive skills include responding to one's name, following simple instructions, and identifying environmental stimuli. It is a natural process that occurs through countless daily interactions with caregivers (Grow & LeBlanc, 2013). Screening for receptive skills can be assessed by examining a child's speech and language comprehension. For example, a trained professional can observe a child's ability to respond to verbal cues, such as orienting to their name or identifying a familiar object. These skills can also be screened by providing a set of questionnaires to the guardian to gather information on the child's receptive capabilities at home through observation. Lacking receptive skills can also be associated with other diseases, such as autism or hearing problems. Therefore, these conditions must be ruled out before screening for speech and language is conducted.

Expressive skills are the ability to effectively communicate thoughts, feelings, and ideas through various means, such as language, facial expressions, and body language. (Denham, 2018). Thus, these skills are heavily influenced by the child's surrounding environment, culture, and social interaction. Preschoolers who effectively communicate their thoughts, feelings, and ideas can better navigate social interactions and form positive relationships with peers and teachers.

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Additionally, expressive skills are linked to academic outcomes, as children who can express themselves are more likely to engage in the learning process and succeed in the classroom. Expressive skills can be screened through direct observation, the interaction between the examiner and the child, or relevant questionnaires that measure children's speech and language production. Children with low ability with expressive skills can have social and academic difficulties. This child may also be prone to psychological problems in the future.

The vocabulary domain, encompassing the ever-growing repository of words that children acquire and master, is a fundamental component of their linguistic journey. It is a gateway to enhanced cognitive processing, effective communication, and meaningful social engagement. Research has consistently demonstrated that the size of a young child's vocabulary is a strong predictor of their future language proficiency, reading comprehension, writing skills, and overall academic achievement (Houston-Price, Howe, & Lintern, 2014; Silverman & Crandell, 2010). Children should possess at least 300 meaningful words by age two; by age 5, it expands to 5000 to 6000 (Houston-Price et al., 2014). Therefore, screening for this domain can be done quantitatively by measuring the amount of meaningful words children acquire at a certain age.

As in our conceptual framework, age is our moderating variable. The development of children in all four domains is closely related to age. Children will usually be able to reach their expected developmental milestones when they reach a specific age range. Therefore, we proposed that a new screening tool should have a targeted age range to ensure a constant effect of variables. We believe screening can be conducted at 18 to 24 months for several reasons. Firstly, children at this age shared a similar expected developmental milestone in all four domains proposed earlier. Secondly, expected developmental milestones in speech and language areas in this range of age are minimal but adequate to be used for the screened benchmark. Thus, a screening tool consisting of a questionnaire will be simpler, concise, and meaningful. Besides that, any observation or examination of children will be quicker and brief. Thirdly, a quicker and brief screening procedure will greatly benefit trained professionals, such as doctors in health clinics overcrowded with patients daily. This will reduce consultation time and avoid long waiting times for other patients. Lastly, early screening can lead to early intervention. Early intervention for speech and language delay in children significantly impacts children's growth and development. These are crucial to mitigate the potential long-term consequences of these delays, which can include social isolation, mental health problems, academic difficulties, and even unemployment later in life (Hare & Bremner, 2016). Furthermore, it will also help strengthen the bond between parent-child relationships and improve academic outcomes and social well-being.

Lastly, our conceptual framework included social interaction, culture, and policies as our mediating variables. This is because these variables greatly impact the preverbal, receptive, expressive, and vocabulary skills development in children, as suggested in the literature review. Children with a poor social and cultural environment may result in poor development of necessary skills and are prone to speech and language delay.

Conclusion

Our literature review proposes a conceptual framework for developing a new screening tool for speech and language delay in preschool children. We recommended that the screening tool be targeted at an earlier age, 18-24 months, including all the important domains of speech and language, and the screening tool must not neglect important factors such as social and cultural beliefs as these factors have a significant impact on speech and language development of preschool children. In Malaysia, the Malay language greatly influences social and cultural beliefs; thus, it should be prioritized as a medium of language for the new screening tool. Our conceptual framework served as a guide, and the

screening tool can be developed in various forms, such as questionnaires based on interviews between medical professionals and parents, a parent-rated questionnaire that reports children's progression through parents' daily observation, or a set of examinations conducted by medical professionals through direct observation of the children and physical examinations. The selection of types of screening tools will depend on the researcher's needs and preferences. However, as we mentioned previously, developing a new screening tool, such as a parent-rated questionnaire, is favorable to reducing the burden of trained professionals and helping parents or caregivers to report their observations accurately.

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