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Predictors of successful Picture Exchange Communication System training in children with communication impairments: insights from a real-world intervention in a resource-limited setting

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ABSTRACT

Background Children with communication impairments—such as autism spectrum disorder or global developmental delay—face significant challenges affecting their emotional and behavioural development. The Picture Exchange Communication System (PECS) is an augmentative communication tool designed to enhance their skills. However, its effectiveness can vary in resource-limited settings. This study aimed to identify predictors of successful PECS training among children with communication impairments in such environments.

Methods This retrospective study analysed records of 61 children with communication impairments who underwent PECS training at Siriraj Hospital in Bangkok, Thailand, from 2020 to 2023. Success was defined as achieving PECS phase 3 proficiency and a Clinical Global Impression–Improvement score of 1–3 after 1 year. Logistic regression identified predictors of successful outcomes based on demographic, clinical, family and training-related factors.

Results After 1 year, 46% (28 out of 61) of the children achieved successful PECS outcomes. Significant predictors of success were lower severity of communication impairment (Clinical Global Impression–Severity ≤4; adjusted OR= 15.24, p = 0.002), higher frequency of PECS sessions (>6 times per year; OR = 9.11, p = 0.010), higher family income (≥20,000 baht per month; OR = 9.83, p = 0.024) and frequent home practice (≥3 times per week; OR = 7.02, p = 0.066).

Conclusions In resource-limited settings, factors such as severity of impairment, intensity of intervention, socioeconomic status and caregiver involvement significantly influence the success of PECS training. Tailored interventions and strategic resource allocation are crucial to optimise communication outcomes for these children.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The Picture Exchange Communication System (PECS) is a widely used augmentative and alternative communication method for children with autism spectrum disorder or other developmental disorders, but evidence of its effectiveness in resource-limited settings is scarce.

⇒ Previous research has suggested that baseline language abilities, communication severity and therapy intensity can influence PECS outcomes.

WHAT THIS STUDY ADDS

⇒ Unlike previous studies that focused primarily on PECS phase progression, this study uniquely defines 'success' using both mastery of PECS phase 3 and measurable improvements in social communication.

⇒ In a real-world, resource-limited context, lower severity of impairment (Clinical Global Impression–Severity; CGI-S), more frequent PECS training sessions, higher family income and consistent home practice emerged as strong predictors of successful outcomes.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Clinicians can use communication severity (CGI-S≤4) to prioritise referrals and personalise intervention intensity.

⇒ Emphasising frequent in-hospital sessions and robust caregiver support for home practice can improve communication gains even in settings with limited resources.

INTRODUCTION

Communication is a fundamental skill for human development and learning. However, certain paediatric populations experience communication impairments that hinder their ability to express themselves and comprehend their environment. One such group is children with autism spectrum disorder (ASD), which has a prevalence as high as 1 in 36 children.[1] Other groups

affected by communication impairments include those with global developmental delay (GDD) or intellectual disabilities (IDs).

Language deficits in children can precipitate emotional and behavioural problems. A meta-analysis by Yew and O'Kearney demonstrated that children with communication challenges have a 2.26-fold increased risk of externalising behaviours compared with peers with typical communication skills.[2] These behaviours include aggression, defiance, self-harm and property destruction. This may be attributed to their inability to communicate needs effectively, leading to misaligned caregiver responses and triggering frustration and aggressive emotions.[3] Concurrently, communication impairments hinder participation in social activities and peer interactions, contributing to internalising behavioural issues such as depression and anxiety.[4] Yew and O'Kearney's study also indicates a 1.84-fold higher risk of internalising behavioural problems in these children compared with those with normal communication abilities.[2]

Speech therapy is essential for children with communication impairments to promote language development and mitigate associated emotional and behavioural issues. However, its efficacy depends on multiple factors, including the age at intervention, intensity and frequency of therapy, family involvement, utilisation of advanced technologies, and the severity of the child's communication deficits.[5 6] In some instances, speech therapy alone may be insufficient to fully develop communication skills or address the accompanying behavioural and emotional challenges.

To address these challenges, augmentative and alternative communication (AAC) systems are employed. AAC provides tools and methods to assist individuals with severe communication difficulties in expressing themselves effectively.[7] Among the various AAC methods, the Picture Exchange Communication System (PECS) is widely used.

PECS was developed by Andy Bondy and Lori Frost in 1985 to help individuals with communication impairments, particularly children with ASD or other developmental disorders, communicate more effectively. It involves using picture cards to express needs or thoughts, reinforced by principles of positive reinforcement and a supportive learning environment.[7–10] Numerous studies have demonstrated that PECS enhances requesting and initiating communication skills in children with autism[8 9] and reduces inappropriate behaviours such as repetitive actions and negative expressions.[10]

Previous research has identified various factors influencing PECS training outcomes. Koudys *et al* examined predictors such as initial language abilities and found that children with higher baseline skills progressed further in PECS phases.[11] However, studies focusing on resource-limited countries are scarce, highlighting a gap in understanding how resource limitations impact PECS effectiveness.

Since 2020, the Division of Child Development and Behavior at the Department of Pediatrics, Faculty of Medicine Siriraj Hospital, has implemented PECS training for children with communication impairments. This programme includes children with autism, GDD or hearing impairments who face challenges with speech therapy. Despite the growing number of patients needing PECS training, the hospital has only one trained instructor responsible for both PECS training and other developmental stimulation programmes, leading to prolonged waiting times. Moreover, not all children benefit from PECS, and some fail to achieve the targeted communication goals.

This study aimed to identify specific predictors associated with successful PECS training outcomes in children with communication impairments. By understanding these predictors, we can inform strategies to optimise intervention programmes in resource-limited settings. The findings may help develop criteria for patient referrals, reduce waiting times and improve overall training outcomes.

MATERIALS AND METHODS

Study design and population

This retrospective chart review aimed to identify predictive factors associated with the success of PECS training among children with communication impairments. We included paediatric patients who underwent PECS training at the Department of Pediatrics, Siriraj Hospital, between 2020 and 2023. Eligible participants were children who had completed at least 1 year of PECS training during this period and had complete medical records.

The required sample size was calculated using G*Power software, assuming an OR of 2.62 based on prior research,[11] a type I error rate of 0.05 and a power of 80%. This calculation resulted in a minimum of 55 participants. To account for potential data loss, we added 10%, bringing the total to 61 participants.

PECS training procedure

PECS training follows a structured progression designed to develop communication skills step by step. It consists of six phases, each focusing on different aspects of functional communication:[9]

Phase 1: Basic exchange—The child learns to exchange a single picture for a desired item.

Phase 2: Increasing spontaneity—The child learns to travel to a communication partner to exchange pictures independently.

Phase 3: Picture discrimination—The child learns to select from two or more pictures to request desired items, demonstrating the ability to distinguish between different symbols.

Phase 4: Sentence structure—The child learns to construct simple sentences using a picture-based communication strip (eg, "I want+item").

Phase 5: Responding to questions—The child learns to answer "What do you want?" using their picture exchange system.

Phase 6: Commenting—The child expands communication skills by using pictures to describe things, answer questions or make observations.

Among these phases, phase 3 is a critical milestone, as it marks the transition from basic picture exchange to intentional communication through picture discrimination. Mastery of this phase is essential for developing functional communication skills beyond simple requests. Therefore, achieving proficiency in phase 3 is often used as a key criterion for defining successful PECS training in previous studies.[8 11]

Since PECS is a structured programme, all children begin at phase 1 and progress sequentially through the phases based on their individual learning pace. Training is conducted systematically to support children in mastering phase 3 and beyond.

To facilitate this progression, structured PECS training sessions are implemented in a clinical setting.

In routine practice, PECS training sessions were conducted at the hospital every 4 weeks, though scheduling varied depending on parental compliance. Each session lasted 45–60 min, adjusted to the child's engagement and progress. During these sessions, therapists focused on reinforcing PECS use, assessing progress and introducing higher-level skills when appropriate.

Given the crucial role of home-based reinforcement in PECS training, parental involvement was an integral part of the intervention. During each hospital session, parents received individual coaching from therapists, focusing on PECS implementation strategies, reinforcement techniques and ways to generalise PECS use in daily routines. Caregivers were encouraged to practise PECS daily as part of the child's routine communication, with each session typically lasting 15–30 min, depending on the child's engagement and response. To track adherence, parents were asked to maintain a logbook, recording how many days per week PECS was practised and in which daily situations it was implemented. These records were reviewed during follow-up visits to provide guidance and address challenges in home implementation.

Data collection

After obtaining ethical approval, data were meticulously extracted from medical records using a standardised data collection form to ensure consistency and accuracy. The information collected comprised the following:

- Demographic details: The children's sex and their age at the initiation of PECS training.
- Clinical characteristics: Developmental and behavioural diagnoses, severity of impairments, comorbidities and concurrent treatments.
- PECS training details: Frequency of PECS training sessions at the hospital and frequency of PECS practice at home.

Pretraining and post-training language development was evaluated using the Denver II Developmental Screening Test. The developmental quotient (DQ) was calculated as the developmental age divided by the chronological age, multiplied by 100.[12] Social communication outcomes and the severity of communication impairments were assessed using the Clinical Global Impression–Severity (CGI-S) and the CGI–improvement (CGI-I) scales.[13] To ensure reliability and minimise variability, the same developmental-behavioural paediatrician performed both assessments.

In routine clinical practice, patients are scheduled for follow-up every 4–6 months, and at each clinical visit, these assessments are conducted to monitor progress. However, for this study, only preassessment data (before initiating PECS training) and postassessment data (1 year after training began) were analysed to ensure consistency in evaluation time points.

The CGI-S scale was used to assess the baseline severity of each child's communication and social impairments. This scale rates severity on a 7-point rating:

- Normal (1): The child frequently uses spontaneous communication behaviours for diverse purposes, including initiating and maintaining interactive exchanges across various contexts.
- Borderline (2): The child uses expressive language for interactive social communication but occasionally demonstrates one-sided or awkward interactions.
- Mild (3): The child can request, initiate and take turns fluently in familiar contexts.
- Moderate (4): The child occasionally initiates requests or expresses opinions with support but lacks social intent for sharing information.
- Marked (5): The child predominantly communicates through simple requests or labelling, often only in response to prompts and initiates communication primarily in highly motivated or repetitive contexts.
- Severe (6): The child seldom attempts communication, and when attempts are made, they often involve unusual vocalisations or echolalia without communicative intent.
- Most severe (7): The child exhibits minimal to no observable communication behaviours.

The CGI-I scale was used to assess changes in communication and social skills postintervention. This scale also employs a 7-point rating:

- Very much improved (1): Significant and consistent progress in social communication, accompanied by a noticeable reduction in CGI-S.
- Much improved (2): Clear and consistent progress in social communication, potentially with a reduction in CGI-S.
- Minimally improved (3): Some observable improvement in communication, though CGI-S may remain unchanged.
- No change (4): No discernible improvement in social communication.

- Minimally worse (5): Minor regression or loss of previously acquired communication skills, insufficient to increase CGI-S.
- Much worse (6): Clear regression in natural communication skills, potentially corresponding to an increase in CGI-S.
- Very much worse (7): Significant and substantial regression in communication skills, leading to a notable increase in CGI-S.

Both scales have demonstrated moderate to strong inter-rater reliability, with weighted kappa values of 0.517 for the CGI-S and 0.650 for the CGI-I.[13] Their inclusion allowed for a comprehensive evaluation of the severity of communication impairments at baseline and enabled tracking of meaningful changes following PECS training.

The criteria for success in PECS training were defined as achieving proficiency in PECS phase 3 and obtaining a CGI-I score between 1 and 3. While PECS phase 3 measures a child's ability to differentiate and select symbols to request items, it does not fully capture broader social communication improvements.[9 14] Many children may learn to exchange pictures correctly but struggle with spontaneous communication, turn-taking or social interaction beyond requesting. The CGI-I scale addresses this limitation by providing a clinician-rated measure of overall social communication progress. By integrating both measures, this study ensures that success is not solely defined by reaching a technical milestone in PECS but also by demonstrating real-world communication gains that reflect meaningful behavioural change.

Statistical analyses

Data were analysed using IBM SPSS Statistics, V.26 (IBM). Descriptive statistics summarised demographic and clinical characteristics. Categorical variables were presented as frequencies and percentages, while continuous variables were expressed as means with SD or medians with IQRs. Differences between the successful and unsuccessful groups were evaluated using χ^2 or Fisher's exact tests for categorical variables and independent t-tests for continuous variables.

Variables with p values ≤0.1 from univariate analyses were included in a multivariate logistic regression model using the backward stepwise method to identify independent predictors of successful PECS training. Adjusted ORs with 95% CIs quantified associations. Receiver operating characteristic curve analyses were performed for significant continuous variables—specifically, the CGI-S score, receptive language DQ, and expressive language DQ—to determine optimal cut-off points and assess predictive accuracy using the area under the curve (AUC).

Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

RESULTS

Participant demographics and clinical characteristics

From 2020 to 2023, 110 children with communication impairments participated in PECS training at Siriraj Hospital. Among these, 61 children met the eligibility criteria for inclusion in this study, which required completing at least 1 year of PECS training and having complete medical records (table 1). All 61 eligible participants were analysed, with no missing data throughout the study process. The median age at the initiation of PECS training was 5.92 years (IQR: 4.59–7.71 years). Among these children, 35 (57.4%) were male, and 26 (42.6%) were female. The vast majority, 59 children (96.7%), had IDs or GDDs. Additionally, 34 children (55.7%) were diagnosed with ASD, and 10 (16.4%) had hearing impairments. Prior to PECS training, the median receptive language DQ was 24.00 (IQR: 16.67–34.52), and the median expressive language DQ was 18.75 (IQR: 11.57–29.13).

PECS training outcomes

1 year after initiating PECS training, 35 children (57.4%) achieved proficiency in phase 3 or higher of the system (table 2). According to the CGI-I scale, 29 children (47.5%) demonstrated significant improvement in social communication, indicated by CGI-I scores between 1 and 3. Post-training assessments revealed minimal changes in language abilities. The median receptive language DQ increased to 27.27 (IQR: 16.34–41.40), while the median expressive language DQ increased to 19.05 (IQR: 11.66–30.00). The median differences for receptive and expressive language DQs were 0.00 (IQR: 0.00, 4.89) and 0.00 (IQR: –3.60, 3.80), respectively.

Relationship between PECS phase and CGI-I scores

A cross-tabulation was conducted to examine the relationship between PECS Phase three proficiency and social communication improvements, as measured by CGI-I scores (table 3). Among the 61 participants, 35 (57.4%) achieved PECS phase 3 or higher, while 29 (47.5%) demonstrated significant improvement in social communication (CGI-I scores 1–3).

Of the 35 children who attained PECS phase 3 or higher, 28 (80.0%) had CGI-I scores between 1 and 3, while 7 (20.0%) had CGI-I scores between 4 and 7. Among the 26 children who did not reach phase 3, 1 (3.8%) had CGI-I scores between 1 and 3, whereas 25 (96.2%) had CGI-I scores between 4 and 7.

Predictive accuracy of key variables

Receiver operating characteristic curve analyses were conducted to evaluate the predictive accuracy of key pretraining factors. The CGI-S score, receptive language DQ and expressive language DQ demonstrated significant predictive value for training success.

The CGI-S score yielded an AUC of 0.781 (95% CI: 0.661 to 0.900, p<0.001), indicating good predictive accuracy. At a cut-off of ≤4, the CGI-S score had a sensitivity

Table 1 Baseline demographic and clinical characteristics of participants before Picture Exchange Communication System training

Demographic characteristics	Descriptive results (N=61)
Child-related factors	
Sex	
Male	35 (57.4)
Female	26 (42.6)
Age (years)	
<6	31 (50.8)
≥6	30 (49.2)
Communicable disease	
ASD	34 (55.7)
ID/GDD	59 (96.7)
Hearing impairment	10 (16.4)
Coexisting conditions	
ADHD	22 (36.1)
Cerebral palsy	4 (6.6)
Genetic disease	13 (21.3)
Receptive language (DQ)*	24.00 (16.67, 34.52)
Expressive language (DQ)*	18.75 (11.57, 29.13)
CGI-S	
1	0
2	0
3	1 (1.6)
4	25 (41.0)
5	20 (32.8)
6	13 (21.3)
7	2 (3.3)
Treatment-related factors	
Received speech therapy	57 (93.4)
Received occupational therapy	39 (63.9)
Received physical therapy	8 (13.1)
Frequency of PECS training at the hospital (times per year)	
1–3	5 (8.2)
4–6	22 (36.1)
7–9	23 (37.7)
≥ 10	11 (18.0)
Frequency of PECS practice at home (times per week)	
0	2 (3.3)
<1	1 (1.6)
1–2	14 (23)
3–5	4 (6.6)
6–7	40 (65.6)
Caregiver-related factors	
Caregiver sex	
Male	6 (9.8)
Female	55 (90.2)
Caregiver age (years)†	44.26±7.67
Caregiver educational level	
Below bachelor's degree	23 (37.7)
Bachelor's degree and above	38 (62.3)
Family monthly income	
<20,000 baht	13 (21.3)
≥20,000 baht	48 (78.8)
Number of children in the house	
1	40 (65.6)
2–3	21 (34.4)

Data are presented as numbers (percentages).
*Data are presented as medians (IQRs).
†Data are presented as means±SDs.
ADHD, attention deficit/hyperactivity disorder; ASD, autism spectrum disorder; CGI-S, Clinical Global Impression–Severity; CP, cerebral palsy; DQ, developmental quotient; GDD, global developmental delay; ID, intellectual disability; PECS, Picture Exchange Communication System.

of 70% and a specificity of 82% for predicting successful PECS training (figure 1). The receptive language DQ had an AUC of 0.672 (95% CI: 0.535 to 0.809, p=0.014); a cut-off of ≥21 provided a sensitivity of 71.4% and a specificity of 52% (figure 2). The expressive language DQ showed an AUC of 0.686 (95% CI: 0.551 to 0.820, p=0.007); at a cut-off of ≥17, it achieved a sensitivity of 71.4% and a specificity of 61% (figure 3).

Comparison between successful and unsuccessful groups

Participants were categorised into 'successful' and 'unsuccessful' groups based on achieving PECS phase 3 proficiency and obtaining a CGI-I improvement score between 1 and 3 (table 4). Of the 61 participants, 46% (28 children) were classified as successful, while 54% (33 children) were classified as unsuccessful. Significant differences were observed between the two groups.

Success rates differed by sex. Female participants were more likely to succeed compared with males (57.1% vs 30.3%, p=0.035). Regarding diagnoses, children with ASD were less likely to achieve success than those without ASD (39.3% vs 69.7%, p=0.017). Conversely, children with hearing impairments showed a higher success rate than those without hearing impairments (28.6% vs 6.1%, p=0.034).

Higher pretraining expressive language DQ scores (≥17) were associated with success (71.4% vs 39.4%, p=0.012). Similarly, receptive language DQ scores (≥21) were also significantly associated with success (75.0% vs

Table 2 PECS training outcomes after 1 year

Demographic characteristics	Descriptive results
The final phase of the PECS training procedure after 1 year	
1	17 (27.9)
2	9 (14.8)
3	21 (34.4)
4	12 (19.7)
5	2 (3.3)
6	0 (0)
CGI-I	
1	1 (1.6)
2	16 (26.2)
3	12 (19.7)
4	32 (52.5)
5	0 (0)
6	0 (0)
7	0 (0)
Receptive language (DQ)*	27.27 (16.34, 41.40)
Expressive language (DQ)*	19.05 (11.66, 30.00)
Median difference in receptive language DQ*	0 (0.00, 4.89)
Median difference in expressive language DQ*	0 (–3.60, 3.80)

Data are presented as numbers (percentage).
*Data are presented as medians (IQRs).
CGI-I, Clinical Global Impression–Improvement; DQ, developmental quotient; PECS, Picture Exchange Communication System.

51.5%, p=0.059). Additionally, lower CGI-S scores (≤4) were strongly associated with success (71.4% vs 18.2%; p<0.001; table 4).

In terms of treatment factors (table 4), children who did not receive occupational therapy exhibited a higher success rate compared with those who received it (75.8% vs 50.0%, p=0.037). A higher frequency of PECS training sessions at the hospital (>6 times per year) was significantly associated with increased success rates (82.1% vs 33.3%, p<0.001). Similarly, regular PECS practice at home (≥3 times per week) was strongly correlated with success (92.9% vs 54.5%, p=0.001).

Among caregiver-related factors, children whose caregivers had a bachelor's degree or higher were more likely to achieve successful outcomes (75.0% vs 51.5%, p=0.059). Moreover, higher family income (≥20,000 baht per month) was significantly associated with success (92.9% vs 66.7%, p=0.013).

Table 3 Cross-tabulation of the final PECS phase and CGI-I scores after 1 year of PECS training procedure

The final phase of the PECS training procedure after 1 year	CGI-I scores 1–3 (improved)	CGI-I scores 4–7 (not improved)
Phase 1–2 (n=26)	1 (3.8)	25 (96.2)
Phase 3–6 (n=35)	28 (80.0)	7 (20.0)
Total (n=61)	29 (47.5)	32 (52.5)

Data presented as numbers (percentage).
CGI-I, Clinical Global Impression–Improvement; PECS, Picture Exchange Communication System.

Multivariate predictors of PECS training success

Multivariate logistic regression analysis using a backward stepwise approach identified four key predictors of successful PECS training (table 5). First, lower severity of communication impairment, indicated by CGI-S scores ≤4, significantly predicted success (adjusted OR=15.24, 95% CI: 2.75 to 84.49, p=0.002). Second, a higher frequency of PECS training sessions—more than six times per year—was also a significant predictor (adjusted OR=9.11, 95% CI: 1.71 to 48.56, p=0.010). Third, higher family income (≥20,000 baht per month) was associated with greater odds of success (adjusted OR=9.83, 95% CI: 1.35 to 71.78, p=0.024). Lastly, frequent home practice of PECS, defined as three or more times per week, showed a trend towards significance (adjusted OR=7.02, 95% CI: 0.88 to 56.13, p=0.066).

DISCUSSION

In this study, approximately 46% (28 out of 61) of the children achieved success in PECS training after 1 year. Success was defined as reaching proficiency in PECS phase 3 and demonstrating significant improvement in social communication, indicated by CGI-I scores between 1 and 3.

The cross-tabulation analysis revealed that 80.0% of children who attained PECS phase 3 or higher showed significant social communication improvements (CGI-I scores 1–3), reinforcing the importance of progressing to this phase. However, 20.0% of these children did not demonstrate notable CGI-I improvements, indicating that achieving PECS milestones alone does not guarantee broader social communication gains. Conversely, nearly all children (96.2%) who did not reach phase 3 remained in the CGI-I 4–7 category, with only 3.8% showing measurable improvement. These findings highlight the need for a multidimensional approach in assessing PECS effectiveness, considering both functional picture exchange proficiency and overall social communication development.

Compared with previous studies, our success rate is somewhat lower. For instance, Koudys *et al*[11] reported that 57.1% (12 out of 21) of participants mastered PECS skills after the intervention. It is important to note that the criteria for success in their study differed from ours, which may contribute to the disparity in success rates.

In Koudys *et al*'s study,[11] success was primarily defined by the highest PECS phase attained by participants, without considering improvements in social communication or other functional outcomes. Specifically, they focused on

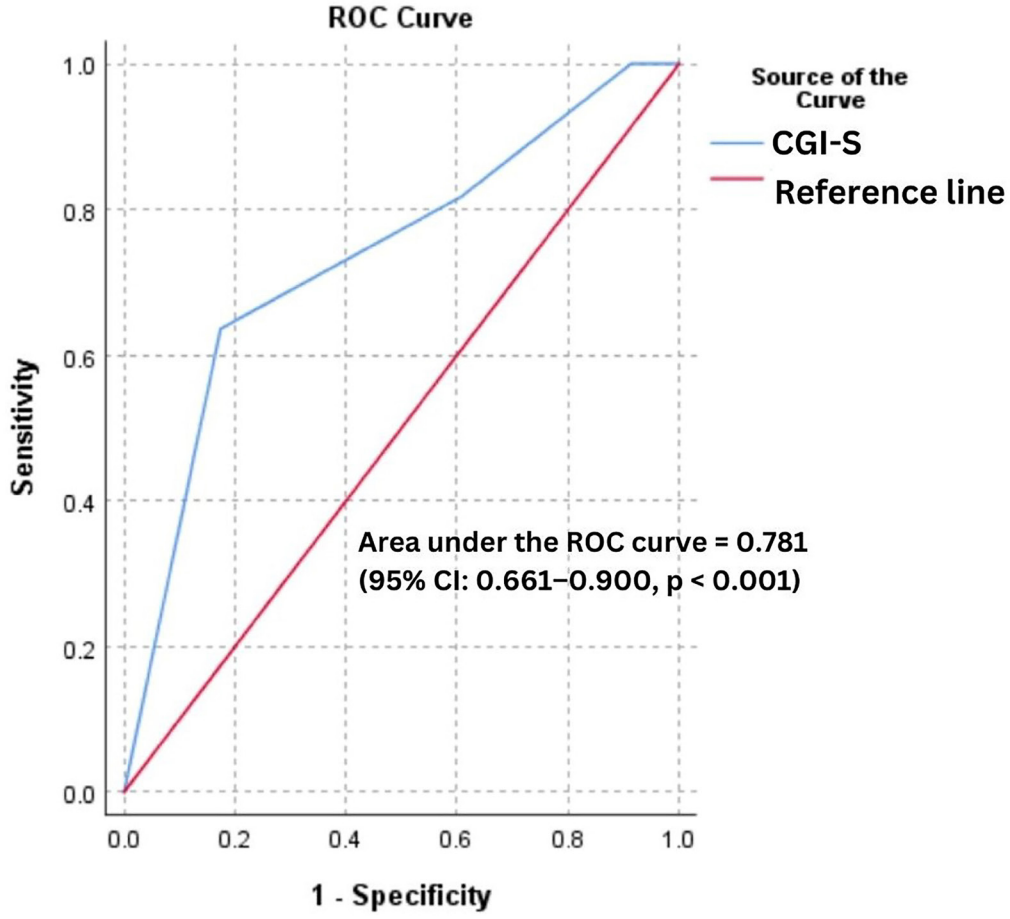

Figure 1 Receiver operating characteristic (ROC) curve for predictive accuracy of Clinical Global Impression–Severity (CGI-S) scores in determining Picture Exchange Communication System training success.

progression through the PECS phases as the sole indicator of success. In contrast, our study employed a dual criterion for success: participants were required not only to achieve proficiency in PECS phase 3 but also to demonstrate significant improvement in social communication skills, as measured by the CGI-I scale.

By incorporating the CGI-I score into our success criteria, we set a higher threshold for successful PECS training. The CGI-I scale assesses the degree of improvement in a patient's condition throughout treatment, providing a broader evaluation of functional gains beyond mere progression through PECS phases.[13] Therefore, our stricter definition of success likely contributed to a lower overall success rate compared with Koudys *et al*'s findings.

Variations in success rates may also be influenced by differences in participant characteristics. Our study included a high proportion of children with severe communication impairments and coexisting conditions such as IDs and GDDs. These factors can make PECS training more challenging and may affect the rate at which children progress through the PECS phases and improve in social communication.[11]

Our findings indicate that lower severity of communication impairment, higher frequency of PECS training at the hospital, higher family income and frequent home practice are significant predictors of successful PECS training outcomes.

The severity of communication impairment, assessed using the CGI-S scale, emerged as a strong predictor of success. Children with less severe impairments (CGI-S≤4) were significantly more likely to achieve proficiency in PECS phase 3 and demonstrate substantial improvements in social communication. This finding aligns with previous research suggesting that initial impairment severity influences the effectiveness of communication interventions. For instance, Koudys *et al*[11] found that children with milder communication deficits were significantly more likely to attain higher levels of proficiency in PECS training. Similarly, Romski and Sevcik[15] emphasised that children with less severe impairments may acquire communication skills more rapidly through augmentative interventions. They noted that early introduction of AAC systems like PECS can lead to quicker communication gains in children who possess foundational levels of language comprehension and cognitive skills.

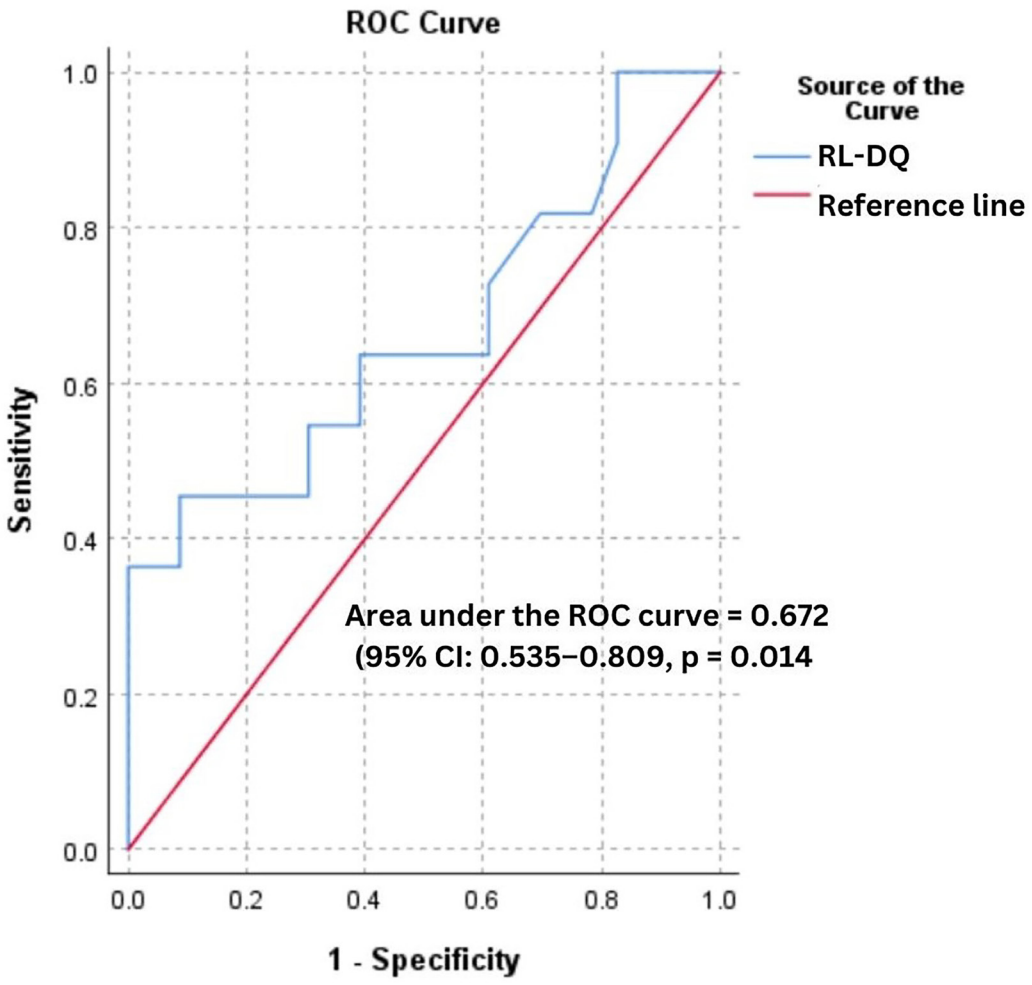

Figure 2 Receiver operating characteristic (ROC) curve for predictive accuracy of receptive language developmental quotients (RL-DQ) in determining Picture Exchange Communication System training success.

The frequency of PECS training sessions at the hospital also emerged as a significant predictor of success. Children attending more than six sessions per year were more likely to achieve positive outcomes. This underscores the importance of intervention intensity in AAC outcomes. Previous studies have highlighted that increased therapy intensity is associated with better communication outcomes in children with developmental disabilities.[5 16] Roberts and Kaiser[5] demonstrated that children receiving more frequent language intervention sessions showed greater improvements in language skills. Similarly, Yoder and Stone[16] reported that higher treatment intensity led to more significant language gains in children with ASD.

However, these earlier studies focused on intensive interventions delivered within a short time frame,[5 11 16] which differs from the real-world context of our study. In resource-limited settings like ours, where there is a shortage of qualified personnel to provide PECS training, the maximum feasible frequency was often just one session per month per patient. Additionally, our early implementation phase of PECS training coincided with the COVID-19 pandemic, further disrupting scheduled sessions for many patients. Despite these challenges, our findings emphasise that even in constrained circumstances, maintaining consistent training sessions with specialists remains crucial for optimising PECS outcomes.

Family income emerged as a significant predictor of successful PECS training, with children from higher-income families (≥20,000 baht per month) demonstrating greater odds of achieving favourable outcomes. Socioeconomic status influences access to resources, consistency in therapy attendance and the capacity to implement intervention strategies at home. Families with higher incomes may have greater flexibility to attend more frequent sessions and invest in supplementary materials or additional support services. Weisleder and Fernald[17] found that children from higher socioeconomic backgrounds are exposed to increased amounts

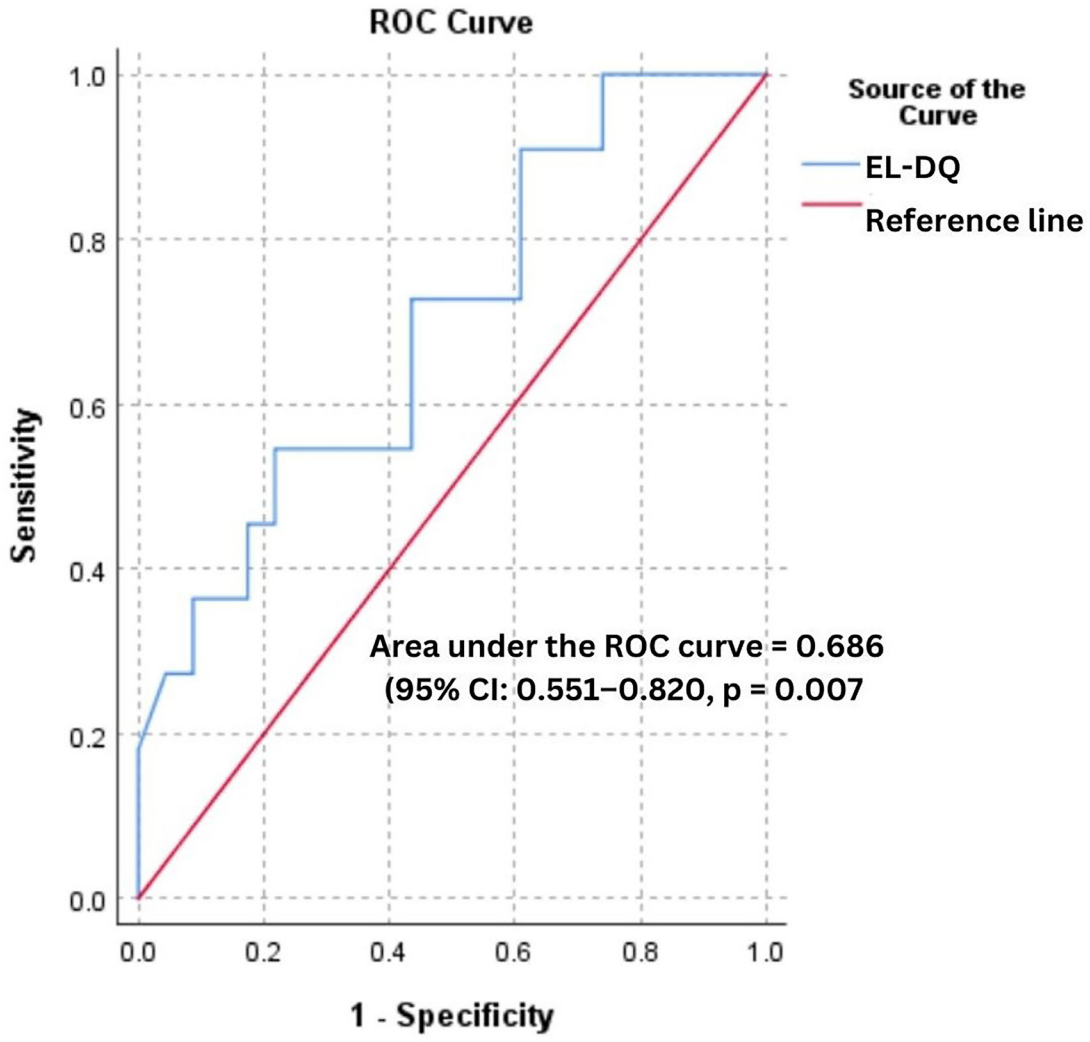

Figure 3 Receiver operating characteristic (ROC) curve for predictive accuracy of expressive language developmental quotients (EL-DQ) in determining Picture Exchange Communication System training success.

of child-directed speech, which enhances language processing efficiency and vocabulary development. Similarly, Hoff[18] noted that the quality and quantity of parental speech, influenced by socioeconomic factors, play crucial roles in early language development.

Frequent home practice of PECS (≥3 times per week) demonstrated a trend towards significance as a predictor of successful outcomes. Although not statistically significant in our multivariate analysis, the importance of caregiver involvement and home practice is well documented.[2 19 20] Active caregiver participation in AAC interventions can reinforce skills acquired during therapy sessions and facilitate the generalisation of communication abilities across settings. Kent-Walsh and Mcnaughton[19] emphasised that communication partner instruction, including training caregivers, enhances the effectiveness of AAC interventions. Similarly, Tamis-LeMonda *et al*[20] highlighted that maternal responsiveness and active engagement are critical for children's language development, suggesting that caregiver involvement can significantly impact intervention outcomes.

Our study also found that children with ASD were less likely to achieve success in PECS training compared with those without ASD. This finding may be attributed to the core social communication challenges inherent in ASD, which can hinder the acquisition and generalisation of PECS skills. Kasari *et al*[21] highlighted that children with ASD might require more specialised interventions tailored to their unique social communication deficits.

In contrast, children with hearing impairments demonstrated a higher success rate, suggesting that PECS may be particularly beneficial for this population. Notably, all participants with hearing impairments in this study used hearing aids, which likely facilitated their ability to process auditory cues and engage more effectively in PECS training. Previous studies have supported the role of hearing aids in augmenting communication skills, highlighting their contribution to improving speech

Table 4 Comparison of demographic and clinical characteristics between successful and unsuccessful PECS training groups

Demographic characteristics	Unsuccessful group (N=33)	Successful group (N=28)	P value
Child-related factors			
Sex			0.035*
Male	23 (69.7)	12 (42.9)	
Female	10 (30.3)	16 (57.1)	
Age			0.531
<6 years	18 (54.5)	13 (46.4)	
≥6 years	15 (45.5)	15 (53.6)	
Communicable disease			
ASD	23 (69.7)	11 (39.3)	0.017*
ID/GDD	33 (100.0)	26 (92.9)	0.207
Hearing impairment	2 (6.1)	8 (28.6)	0.034*
Coexisting conditions			
ADHD	13 (39.4)	9 (32.1)	0.557
Genetic disease	7 (21.2)	6 (21.4)	0.984
CP	4 (12.1)	0 (0)	0.118
Receptive language (DQ)			0.059*
<21	16 (48.5)	7 (25.0)	
≥21	17 (51.5)	21 (75.0)	
Expressive language (DQ)			0.012*
<17	20 (60.6)	8 (28.6)	
≥17	13 (39.4)	20 (71.4)	
CGI-S			<0.001*
≤4	6 (18.2)	20 (71.4)	
>4	27 (81.8)	8 (28.6)	
Treatment-related factors			
Received other treatment			
Speech therapy	30 (90.9)	27 (96.4)	0.618
Occupational therapy	25 (75.8)	14 (50)	0.037*
Physical therapy	7 (21.2)	1 (3.6)	0.060*
Frequency of PECS training at the hospital (time per year)			<0.001*
≤6	22 (66.7)	5 (17.9)	
>6	11 (33.3)	23 (82.1)	
Frequency of PECS practising at home (time per week)			0.001*
<3	15 (45.5)	2 (7.1)	
≥3	18 (54.5)	26 (92.9)	
Caregiver-related factors			
Caregiver sex			1.000
Male	3 (9.1)	3 (10.7)	
Female	30 (90.9)	25 (89.3)	
Caregiver age (years)†	44.88±7.99	43.54±7.34	0.500
Caregiver educational level			0.059*
Below bachelor's degree	16 (48.5)	7 (25.0)	
Bachelor's degree and above	17 (51.5)	21 (75.0)	

Continued

Table 4 Continued

Demographic characteristics	Unsuccessful group (N=33)	Successful group (N=28)	P value
Family monthly income			0.013*
<20,000 baht	11 (33.3)	2 (7.1)	
≥20,000 baht	22 (66.7)	26 (92.9)	
Number of children in the house			0.845
1	22 (66.7)	18 (64.3)	
2–3	11 (33.3)	10 (35.7)	

Data are presented as numbers (percentage), with percentages calculated by column unless otherwise specified.
*Statistically significant with p≤0.1.
†Data are presented as means±SD.
ADHD, attention deficit/hyperactivity disorder; ASD, autism spectrum disorder; CGI-S, Clinical Global Impression–Severity; CP, cerebral palsy; DQ, developmental quotient; GDD, global developmental delay; ID, intellectual disability; PECS, Picture Exchange Communication System.

perception and social interactions in children with hearing loss.[22 23] While research specifically on PECS for children with hearing impairments is limited, the broader body of evidence supports the utility of AAC interventions in enhancing communication skills across various developmental disabilities.[24] These findings emphasise the importance of addressing sensory deficits alongside communication training to optimise outcomes.

Furthermore, the observation that female participants were more likely to succeed in PECS training is intriguing. Some studies have reported sex differences in language development, with females often exhibiting advanced language skills compared with males.[25] Eriksson *et al*[25] found that girls tend to develop language skills earlier and have larger vocabularies than boys across different languages and cultures, which might contribute to better outcomes in communication interventions. However, the impact of sex on AAC intervention outcomes is less clear and warrants further investigation.

Although prior studies suggest that younger children often benefit more from early intervention due to greater neuroplasticity,[26 27] our study did not find a significant association between age at initiation and PECS training success. This finding aligns with the current understanding that there are no established guidelines on the ideal age for initiating PECS. Previous research has demonstrated that PECS can be effective across a wide age range, provided that interventions are tailored to the individual's developmental level and communication needs.[10 28] These findings highlight that age alone may not be a determining factor. Instead, factors such as intervention intensity, caregiver involvement and the individual's baseline communication abilities may play more critical roles.

Interestingly, the median difference in receptive and expressive language DQs was zero, with wide IQRs observed. These results suggest that while some children achieved substantial improvements, others showed minimal or no progress after 1 year of PECS training. This variability might be influenced by individual factors such as baseline language abilities, severity of impairments or training intensity, as previously discussed.[11] From a clinical perspective, these findings underscore the importance of personalised interventions and potentially increased training intensity, particularly for children demonstrating limited progress.

It is also important to note that almost all participants in this study were concurrently receiving speech therapy. Therefore, the lack of improvement observed in some children may be attributed to underlying factors. These factors include the severity of their primary condition, comorbidities or insufficient frequency of PECS practice

Table 5 Multivariable logistic regression analysis of predictors for successful PECS training outcomes

Potential variables	Adjusted OR	95% CI	P value
Frequency of PECS practice at home ≥3 times/week	7.023	0.879 to 56.131	0.066
Frequency of PECS training at the hospital >6 times/year	9.106	1.707 to 48.562	0.010*
CGI-S≤4	15.241	2.750 to 84.485	0.002*
Family monthly income ≥20,000 baht	9.830	1.346 to 71.783	0.024*

*Statistically significant with p≤0.05.
CGI-S, Clinical Global Impression–Severity; PECS, Picture Exchange Communication System.

both at the hospital and at home. These considerations highlight the need for tailored strategies to address individual barriers and optimise the effectiveness of PECS training.

Limitations

Several limitations of this study warrant acknowledgement. The retrospective design restricts our ability to establish causal relationships between the identified predictors and PECS training outcomes. Although the sample size was calculated to be sufficient, it was relatively small and drawn from a single institution, which may affect the generalisability of the findings. Reliance on medical records for data collection may have introduced information bias due to incomplete or inconsistent documentation.

A key methodological consideration in this study is the use of the Denver II Developmental Screening Test for language assessment. While Denver II is typically designed for children under 6 years old, its use was justified in this study as all participants had a language developmental level below 6 years. However, we acknowledge that Denver II has limitations. As a screening tool, it may lack sensitivity in detecting minor changes in receptive language skills, potentially leading to an underestimation of subtle improvements in communication abilities, particularly in older children with communication impairments. This limitation may affect the precision of language outcome measurements. Future research should consider integrating more comprehensive and standardised language assessment tools to improve measurement accuracy and capture nuanced changes in receptive and expressive language development more effectively.

Differences in success criteria across studies can significantly impact reported success rates. Our definition of success required both proficiency in PECS phase 3 and significant improvement in social communication, indicated by CGI-I scores between 1 and 3. This dual focus on functional skills and overall social communication outcomes diverges from studies such as Koudys *et al*[11] which evaluated success primarily based on PECS phase progression. This discrepancy may explain the lower success rate observed in our study. By incorporating the CGI-I as a complementary measure, we aimed to provide a more holistic evaluation of the training's impact, considering both functional milestones and clinical improvements in social adaptability. Although the CGI-I scale is not a standard outcome measure in PECS research, it was chosen to align with clinical priorities and enhance the applicability of our findings to real-world settings. This dual criterion offers a nuanced understanding of intervention success, emphasising the importance of assessing both skill acquisition and meaningful behavioural changes.

Our findings indicate that higher training frequency (>6 sessions/year) and more frequent home practice (≥3 times/week) were significant predictors of PECS training success. However, we did not account for all potential confounding factors, such as the quality of PECS implementation, therapist experience or aspects of the home environment beyond practice frequency, which may have also influenced outcomes. Additionally, while some participants continued training beyond 1 year, our study focused on a standardised 1 year period, limiting the ability to assess the impact of longer intervention durations.

Another limitation is that while our study included a substantial number of participants diagnosed with GDD/ID without ASD, we did not conduct a separate analysis to compare their outcomes with those of children with ASD. Our findings suggest that overall communication severity (CGI-S) and training frequency were stronger predictors of PECS success than diagnostic category alone. However, differences in cognitive and adaptive functioning between these groups may influence the rate and nature of progress in PECS training. Future studies should explore subgroup-specific outcomes to better understand the differential impact of PECS training on children with varying neurodevelopmental profiles.

We also did not account for all potential confounding variables, such as the quality of PECS implementation, therapist experience or aspects of the home environment beyond practice frequency. Additionally, while family income was analysed as a predictor of PECS success, we did not examine whether higher income was associated with more frequent PECS training sessions or greater home practice time. Socioeconomic status may influence access to intervention services and caregiver involvement, potentially impacting PECS outcomes. Future studies should explore the role of income as a mediator in PECS success, particularly in resource-limited settings. The CGI-S and CGI-I scales, while useful, are subjective measures and may be influenced by clinician bias. Future research should employ prospective designs with larger, more diverse samples and incorporate objective measures of communication outcomes.

Implications for practice

Our findings have practical implications for clinicians working in resource-limited settings. Given that the severity of communication impairment, as measured by the CGI-S, is a significant predictor of PECS training success, clinicians can use the CGI-S as a screening tool to identify children more likely to benefit from PECS training. By prioritising referrals for children with lower CGI-S scores (≤4), limited resources can be allocated more effectively to those most likely to achieve successful outcomes.

Conversely, factors such as the frequency of PECS training sessions at the hospital and the family's monthly income, while significant, are often beyond the direct control of healthcare providers. These factors are influenced by systemic issues such as staffing constraints, healthcare infrastructure and socioeconomic disparities. Therefore, in resource-limited settings, focusing on modifiable child-related factors like the CGI-S score may

be a more feasible strategy for optimising intervention outcomes within existing constraints.

CONCLUSIONS

Our study highlights key predictors of successful PECS training in children with communication impairments, emphasising the roles of impairment severity, intervention intensity, socioeconomic status and caregiver involvement. These findings contribute to a better understanding of how to optimise PECS interventions and support children in developing effective communication skills.

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