Research Article

Effectiveness of Multisensory Approach in Enhancing Phonological Awareness, Speech Intelligibility, and Consonant Accuracy in Children with Speech Sound Disorders: A Single-Subject Study

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Short running title: Effectiveness of Multisensory Approach in…

Highlights:

- FONEMZ multisensory approach improves phonological awareness in children with SSD
- Intervention increases speech intelligibility and correct consonant percentage
- Findings support clinical use of multisensory approach for Persian children with SSD

ABSTRACT

Background and Aim: Speech Sound Disorders (SSD) are associated with deficits in phonological awareness and reduced speech intelligibility. This study aimed to investigate the effectiveness of multisensory approach in enhancing phonological awareness, speech intelligibility, and the percentage of correct consonants in children with SSD.

Methods: A single-subject design was employed, structured into three phases. The study included three children aged 5 to 5.11 years with SSD who received intervention using the FONEMZ approach. Data analysis was conducted using visual analysis, Percentage of Non-overlapping Data (PND), Improvement Rate Difference (IRD), and the two-standard deviation (2SD) test.

Results: The multisensory approach effectively improved phonological awareness, speech intelligibility, and the percentage of correct consonants in children with SSD.

Conclusion: The findings highlight the significance of multisensory and interactive methodologies, particularly individualized therapy sessions, in facilitating phoneme acquisition and enhancing speech performance in children.
Trial Registration Number: The study was registered in the Iranian Registry of Clinical Trials on 4 November 2024 (IRCT20230403057804N4).
Keywords: Speech sound disorder; phonetics; Persian people; child; language

Introduction

Speech is a complex process requiring the precise coordination of respiratory control, the palato-pharyngeal valve, the laryngeal mechanism, and articulatory movements. Disruptions in this coordination can lead to Speech Sound Disorders (SSD), which are among the most prevalent communication impairments in children [1]. SSD is characterized by difficulties in accurately producing speech sounds, which may stem from structural anomalies, sensory deficits, neurological conditions, or unknown causes [2]. If left untreated, these disorders can negatively impact children's social interactions, academic progress, and long-term psychological well-being [3].

Speech intelligibility, defined as the degree to which a speaker's verbal output is understood by listeners, is a critical aspect of communication. Children with moderate to severe SSD often experience reduced intelligibility, which, in turn, affects their social and academic participation [4]. Notably, Phonological Awareness, the ability to recognize and manipulate phonetic structures, has been strongly linked to both speech intelligibility and literacy development [5]. Research indicates that children with SSD tend to exhibit weaker PA skills, which can further hinder their ability to acquire reading and writing proficiency [6, 7]. Therefore, addressing both speech production and phonological awareness deficits is essential for improving overall communication outcomes in children with SSD [8].

Traditional therapeutic approaches for SSD focus on articulation, phonetic corrections, or motor-based interventions [9]. However, recent research highlights the potential benefits of multisensory learning techniques, which engage multiple sensory modalities to enhance speech and language acquisition [10]. By incorporating visual, auditory, and kinesthetic cues, multisensory interventions may offer a more effective means of improving phonological processing and speech production.

The FONEMZ program is a structured multisensory intervention designed to enhance phonological awareness and speech production through the integration of auditory, visual, tactile, and kinesthetic cues. Each phoneme is represented by a unique visual symbol, facilitating phoneme discrimination and sound-symbol mapping. Previous studies have reported improvements in speech production, phonemic awareness, and early literacy skills following FONEMZ intervention [10]. A key feature of the FONEMZ approach is the one-to-one correspondence between each visual symbol and its associated phoneme, which simplifies sound-symbol mapping and reduces the complexity. The study by Pieretti et al. demonstrated that the implementation of the FONEMZ program resulted not only in improved accuracy of speech sound production, but also in significant enhancement of phonemic awareness and emergent literacy skills in children [10]. While previous studies suggest that phonological awareness training can improve speech outcomes [10, 11], there remains a significant gap in research regarding the application of FONEMZ, particularly in non-English-speaking populations. Given the linguistic and phonological characteristics of Persian, investigating the efficacy of this approach in Persian-speaking children with SSD is essential.

Single-Subject Experimental Designs (SSEDs) are particularly suitable for evaluating intervention outcomes in clinical populations because they allow each participant to serve as their own control, thereby reducing interindividual variability and facilitating detailed assessment of treatment effects [12].

Thus, this study aimed to evaluate the effectiveness of multisensory approach for improving phonological awareness and speech articulation in children with SSD. Although phonological treatment approaches such as the FONEMZ program have shown promising results in improving phonological awareness and speech expression in English-speaking populations, there was still a significant research gap regarding their effectiveness in languages with different phonological structures, such as Persian. This study hypothesized that phonological awareness-based approaches may not only improve phonological skills but also lead to more accurate speech sound production. Accordingly, this study assessed and treated of three children through a phonologically based multisensory approach, following the principles of the FONEMZ program. By addressing this research gap, the study sought to contribute to evidence-based practices in speech therapy, particularly in multilingual and diverse linguistic contexts. In addition, the single-subject design enabled researchers to evaluate the effectiveness of the

approach by focusing on the individual and closely examining the individual's behavioral and functional changes in response to the phonological therapy approach. This design also allowed for re-evaluating the effectiveness of the approach by analyzing the trend and rate of behavioral change over time.

Methods

This single-subject study was conducted following approval from the Ethics Committee and registration in the Clinical Trials Registry.

Study design

This study employed a single-subject ABA design within a clinical setting. The primary objective was to evaluate the effect of the multisensory approach on phonological awareness and speech intelligibility in children diagnosed with SSD.

Participants

Three children with SSD participated in the study. Participants met the following inclusion criteria and exclusion criteria. Participants were required to meet the following inclusion criteria: 1) A confirmed diagnosis of phonological SSD established by a qualified speech-language pathologist based on the Diagnostic Evaluation of Articulation and Phonology (DEAP) and informal connected speech assessment; 2) Age between 5 years 0 months and 5 years 11 months, as documented in clinic records or confirmed through maternal inquiry; 3) Persian as the child's dominant language, as determined by maternal report; 4) Absence of coexisting conditions, including intellectual disability, cerebral palsy, seizures, head trauma, sensory impairments (e.g. hearing loss), or other neurological disorders, as verified through medical records or maternal report, and clinical screening conducted by a qualified speech-language pathologist. The clinical screening included informal assessment of hearing status, oral-motor structure and function, and general cognitive-communicative abilities during structured tasks and connected speech. Participants were excluded if: 1) The family declined to continue participation throughout the study; 2) The child was unable to cooperate or continue participation in the research process.

Letter knowledge and phonological awareness in the late preschool period are predictive of reading skills in the early primary years [13], and reading abilities are also related to children's speech production difficulties, such that a reduction in speech errors is associated with improvements in reading skills [14]. These findings highlight the importance of interventions targeting phonological awareness and speech production skills in preschool children before errors become consolidated and formal schooling begins. Therefore, the age range of 5 to 5.11 years was selected due to the sensitivity of this period for implementing educational interventions.

A total of 12 children diagnosed with SSD were identified through a review of medical records at a speech therapy clinic. Of these, five met the age criteria, and their parents were contacted for potential enrollment. Two parents declined participation, resulting in the final selection of three children who met the inclusion and exclusion criteria. Table 1 presents the demographic characteristics of the participants and their baseline (first datapoint) scores on speech intelligibility and phonological awareness measures.

Phonological processes exhibited by participants reveal distinct trends of speech simplification. Participant 1 employed the largest number of processes, including voicing (/p/), stopping (multicentre fricative and affricate such as /tʃ/, /f/, /ʒ/, /x/, /dʒ/, /z/, /ʃ/, /s/, and /v/), fronting (/k/, /g/, /q/), and medial consonant deletion. In contrast, participant 2 had a reduced set of processes, predominantly fronting (/q/, /k/, /g/) and stopping (/ʒ/). Participant 3 showed the simultaneous occurrence of fronting (/ʃ/, /g/, /k/, /tʃ/), glottal substitution (/dʒ/, /q/), and stopping (/v/, /f/). In general, participant 1 showed broader simplification strategies than the rest.

Instruments

Diagnostic evaluation of articulation and phonology-Persian version

Speech production was assessed using the Persian version of the DEAP, a standardized instrument with established validity and reliability in Persian-speaking children [15].

The phonological and oral-motor subtests were used to identify phonological processes and rule out structural or motor-speech impairments.

Visual cards

Researcher-developed visual cue cards based on Persian phoneme shapes were used to support phoneme identification, production, and phonological awareness.

Phonological awareness assessment

Phonological awareness was assessed using the Phonological Awareness Test, a valid and reliable Persian instrument [16]. For the target age group, subtests assessing onset identification, rhyme identification, recognition of words with the same initial and final phonemes, and phoneme blending were administered [16].

Speech intelligibility assessment

Speech intelligibility was assessed using the Persian version of the Intelligibility in Context Scale (ICS), a validated parent-report measure for children aged 4–6 years. Responses are rated on a 5-point Likert scale (1=never, 5=always). The test-retest reliability of the scale is 0.82, and its internal consistency is 0.89, both considered satisfactory [17].

Intervention

A multisensory intervention based on the principles of FONEMZ was implemented in Persian. Therapy progressed hierarchically from phoneme identification and discrimination to syllable and word production. To carry out the treatment, a set of cards representing Persian phonemes (visual phoneme symbols) was designed; some images of the cards are provided in Appendix A. Visual phoneme symbols were paired with auditory targets to strengthen phonological representations and speech production. Activities incorporated auditory, visual, tactile, proprioceptive, and motor cues. Intervention intensity and target phonemes were individualized according to baseline performance and phonological severity.

Procedure

In the present study, the multisensory intervention was based on the principles of the FONEMZ program and served as the primary therapeutic approach. The program was adapted for Persian phonemes using a set of researcher-developed visual symbols. Given that phonological SSD typically involves pattern-based phoneme errors that reduce segmental accuracy and intelligibility, and that these same underlying deficits are associated with weaknesses in phonological awareness, an intervention capable of strengthening phoneme-level representations was required. FONEMZ was therefore selected because its multisensory, phoneme-focused structure directly targets phoneme representation, discrimination, and production, supporting simultaneous improvement in intelligibility and phonological awareness.

Approximately 20 individuals with speech production disorders were initially selected from speech therapy centers affiliated with Hamadan University of Medical Sciences. After applying the inclusion and exclusion criteria, 3 children were enrolled in the study. Three Persian-speaking children, aged 5 to 5.11 years, diagnosed with phonological SSD, confirmed by the Persian DEAP and supplementary speech analysis, were selected through convenience sampling. Their parents provided written informed consent before SSD study participation. The study procedure was explained to the parents of individuals who met the inclusion criteria, and in order to obtain caregiver consent, a consent form was provided to the parents and duly signed. This study was conducted in three phases, following an ABA single-subject experimental design.

Phase A (Baseline) lasted three weeks and included one assessment session per week. During this phase, no intervention was provided. Phonological awareness and speech intelligibility were assessed by a speech-language pathologist on three occasions, and all sessions were recorded for subsequent transcription and phonetic analysis. Phase B (Intervention) consisted of 15 treatment sessions delivered over three weeks (30 minutes per session, five sessions per week). Phonological awareness and speech intelligibility were reassessed after sessions 3, 6, 9, 12, and 15. The intervention followed a hierarchical multisensory framework. Initially, children were introduced to colored visual symbols representing target phonemes and were encouraged to identify and imitate the corresponding sounds. Once phoneme recognition was established, the phonemes were practiced in consonant–vowel combinations. Subsequently, children were trained to identify the initial phoneme of spoken words by selecting the appropriate phoneme symbol. In the final stage, children identified the initial sound of pictured words and selected the corresponding phoneme symbol. Auditory, visual, tactile, and motor cues were integrated throughout all intervention activities.

The follow-up phase (phase A) lasted three weeks. No intervention was provided during this period, and participants were reassessed once weekly to examine maintenance of treatment effects.

Data analysis

To rigorously evaluate treatment efficacy within the single-subject experimental framework, a multimethod approach was adopted. The analysis incorporated visual inspection, nonparametric effect size indices, including the PND and the IRD, as well as the 2SD method. These strategies were selected due to their appropriateness for small-sample, repeated-measures designs and their robustness in the absence of parametric assumptions.

Data were analyzed using visual inspection and three commonly used single-subject effect size indicators: PND, IRD, and the 2SD method [18]. These measures were used to evaluate treatment-related changes across baseline, intervention, and follow-up phases. The PND represents the proportion of intervention-phase data points that exceed the most extreme baseline value. PND values above 90% indicate a very effective intervention, values between 71% and 90% indicate an effective intervention, values between 51% and 70% indicate questionable effectiveness, and values below 50% indicate an ineffective intervention [19].

Results

To assess the effects of the intervention, visual analysis, PND, IRD, and the 2SD test were conducted. The following sections detail the findings from these analyses. Table 2 summarizes the intervention effects for each participant across all outcome measures based on the percentage of non-overlapping data (PND), improvement rate difference (IRD), and the 2SD method.

Visual analysis results

Visual inspection of the data demonstrated positive changes across most outcome measures following intervention (Figures 1–7). Improvements were particularly evident in speech intelligibility, percentage of correct consonants, recognition of words with the same final phoneme, and rhyme identification. Although the magnitude of change varied across participants, the overall pattern suggested a beneficial effect of the multisensory intervention.

Performance in onset identification and phoneme blending showed greater variability. While some participants demonstrated noticeable gains, others exhibited only modest improvements, indicating that these skills may require longer intervention periods or additional phonological training. In contrast, speech intelligibility and consonant accuracy improved consistently across participants and remained relatively stable during follow-up.

The maintenance of gains observed during the follow-up phase suggests that the intervention effects were not limited to the treatment period and may have contributed to more stable phonological representations and speech production skills. Overall, visual analysis supported the effectiveness of the intervention across the majority of assessed variables.

Effect size analysis

The results of the PND, IRD, and 2SD analyses generally corroborated the findings obtained through visual inspection. Strong treatment effects were observed for speech intelligibility, percentage of correct consonants, and recognition of words with the same final phoneme across participants. Improvements in rhyme identification and onset identification were also evident, although the magnitude of change varied among individuals.

The most variable outcome was phoneme blending, for which intervention effects differed across participants. Nevertheless, the overall pattern of results indicated that the multisensory intervention produced meaningful improvements in several aspects of phonological awareness and speech production. Findings from the 2SD analysis further supported the statistical significance of most observed treatment effects.

Discussion

The treatment, which was applied as a comprehensive intervention, has demonstrated potential in enhancing phonological awareness, speech intelligibility, and consonant accuracy in young children with SSDs. This study aimed to evaluate the efficacy of the multisensory approach in improving these skills in three children with articulation disorders. The findings suggest that the intervention had positive effects, highlighting the potential benefits of individualized, multimodal treatment approaches in clinical practice. The observed improvements may reflect the role of multisensory phonological training in strengthening phoneme representations and facilitating more accurate speech production. Results indicated that the multisensory approach facilitated improvements in recognizing words with the same initial phoneme in children 1 and 3, while all three participants showed gains in recognizing words with the same final phoneme and in rhyme identification. Improvement in

onset identification was observed only in the first participant, whereas all three children demonstrated progress in phoneme blending during the intervention phase, although this trend remained stable throughout.

These findings align with prior research. Hesketh et al. reported that phonological awareness therapy improved onset identification in children with SSDs, albeit among a limited number of participants, which is consistent with the present study [20]. Onset identification appears to be a more complex phonological task requiring additional training for substantial progress. Additionally, Farag et al. found that phonological therapy and phonological awareness training enhanced recognition of words with identical initial and final phonemes, as well as phoneme blending, in children with Specific Language Impairments (SLI) and co-occurring SSDs [11]. Pieretti et al. demonstrated that a multimodal FONEMZ approach effectively improves phonological awareness, including rhyme identification and awareness of initial phonemes in words. Visual tools such as FONEMZ symbols have been shown to enhance phonemic awareness by helping children differentiate and understand phonemes more effectively [10]. The integration of visual, auditory, and kinesthetic cues may enhance phonological learning by providing multiple pathways for encoding and retrieving speech-related information.

In addition to phonological awareness, the findings of this study indicate improvements in consonant accuracy. The percentage of correct consonants increased across all three participants during the intervention phase, suggesting that treatment implementation positively influenced consonant production. This result is consistent with previous studies. For instance, Pieretti et al. reported that the FONEMZ approach significantly enhanced children's production skills compared to multisensory and conventional treatment methods [10]. Similarly, Hesketh et al. found that phonological awareness-based interventions improved consonant accuracy, with comparable gains observed across different treatment approaches [21]. In another study, Farag et al. noted significant improvements in consonant accuracy among children with SLI and SSD following language treatment that incorporated phonological therapy or phonological awareness training [11]. Differences in treatment response across participants may be related to variations in baseline severity, phonological skills, and individual learning characteristics. While multisensory interventions have shown promise in improving consonant production, several factors, such as SSD severity, the presence of comorbidities, individual treatment needs, and participant-specific characteristics, can influence treatment effectiveness. Further research involving larger, longitudinal studies is needed to comprehensively assess the long-term benefits of such interventions. Despite these promising findings, several limitations must be acknowledged. The single-subject design limits the generalizability of the results. Additionally, individual factors such as baseline phonological skills, cognitive abilities, and motivation may have influenced outcomes. Future research should employ larger, randomized controlled trials with follow-up assessments to evaluate the long-term effectiveness of the multisensory approach.

The results of this study suggest that multisensory interventions such as FONEMZ can enhance phonological awareness, speech intelligibility, and consonant accuracy in children with SSDs. These findings underscore the importance of individualized treatment approaches and the integration of visual, auditory, and kinesthetic cues in speech therapy. Future research should explore the long-term effects of the multisensory approach and its adaptability across different linguistic and clinical populations.

Conclusion

The findings suggest that a multisensory phonological intervention based on FONEMZ may improve phonological awareness, consonant accuracy, and speech intelligibility in Persian-speaking children with Speech Sound Disorders (SSD). Although the results are promising, larger controlled studies are needed to confirm effectiveness and determine long-term outcomes.

Ethical Considerations

Compliance with ethical guidelines

Ethical approval for this study was obtained from the Research Council of Hamadan University of Medical Sciences under the ethics code IR.UMSHA.REC.1403.529 and the scientific code 140307246269. The study was also registered in the Iranian Registry of Clinical Trials (IRCT) Registration No. IRCT20230403057804N4. Informed consent was obtained from all participants prior to their inclusion in the study.

Declaration of generative AI and AI-assisted technologies in the writing process

Generative Artificial Intelligence (AI) tools, including ChatGPT-4.0 (Anthropic), were utilized exclusively for refining language, checking grammar, and enhancing stylistic quality. The AI was not involved in the conception, design, data collection, analysis, or interpretation of the study. The authors accept full responsibility for the manuscript's accuracy, originality, and integrity.

Data availability

The datapoints obtained and analyzed during the current study are available from the corresponding author on reasonable request.

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Authors' contributions

MSS: Study design, drafting the manuscript; KB: Study design, drafting the manuscript; SM: Statistical analysis, interpretation of the results, drafting the manuscript; MC: Statistical analysis, interpretation of the results, drafting the manuscript; SZ: Acquisition of data, interpretation of the results, drafting the manuscript.

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Table 1 .Gender, age and percentage values of the variable measured at first datapoint during baseline phase in the study population

Participant number	Gender	Age (years)	Word recognition with the same initial phoneme	Speech intelligibility	Word recognition with the same final phoneme	Correct consonants	Onset identification	Rhyme identification	Phoneme blending
P1	**Male**	5.1	60	62.85	40	72.83	60	50	70
P2	**Male**	5.4	60	82.85	50	85.54	100	50	70
P3	**Female**	5.6	40	60.00	30	32.05	90	40	60

P1; participant 1, P2; participant 2, P3; participant 3

Table 2. Percentage of nonoverlapping data and improvement rate difference for each participant and variables

Variables	Participant	PND (%)	IRD (%)	Interpretation (PND)	2SD result
Word recognition (same initial phoneme)	P1	20	34	Ineffective	Not effective
	P2	40	100	Ineffective (PND)/effective (IRD)	Not effective
	P3	100	100	Very effective	effective
Speech intelligibility	P1	100	100	Very effective	effective
	P2	80	80	Effective	effective
	P3	100	100	Very effective	effective
Word recognition (same final phoneme)	P1	100	100	Very effective	effective
	P2	100	100	Very effective	effective
	P3	100	100	Very effective	effective
Percentage of correct consonants	P1	100	100	Very effective	effective
	P2	100	100	Very effective	effective
	P3	100	100	Very effective	effective
Rhyme identification	P1	100	100	Very effective (PND)/limited (IRD)	effective
	P2	80	80	Effective	effective
	P3	80	80	Effective (PND)/limited (IRD)	effective
Onset identification	P1	80	80	Effective	effective
	P2	80	80	Effective	effective
	P3	80	80	Effective	effective
Phoneme blending	P1	0	0	Ineffective	Not effective
	P2	100	100	Very effective	effective
	P3	0	0	Ineffective	Not effective

PND; percentage of non-overlapping data, IRD; improvement rate difference, P1; participant 1, P2; participant 2, P3; participant 3
PND interpretation: >90%=very effective, 71–90%=effective, 51–70%=questionable, <50%=ineffective

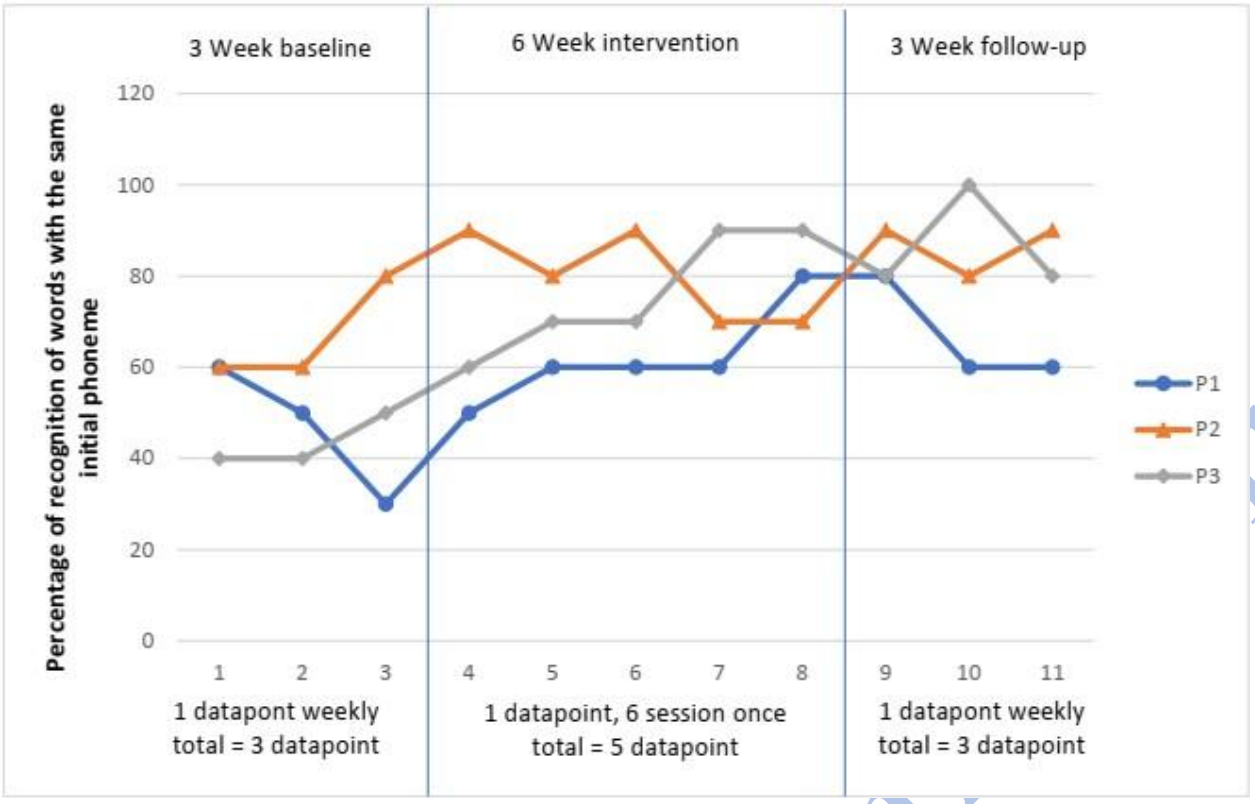

Figure 1. The percentage of recognition of words with the same initial phoneme across three study phases for the three participants. P1; participant 1, P2; participant 2, P3: participant 3

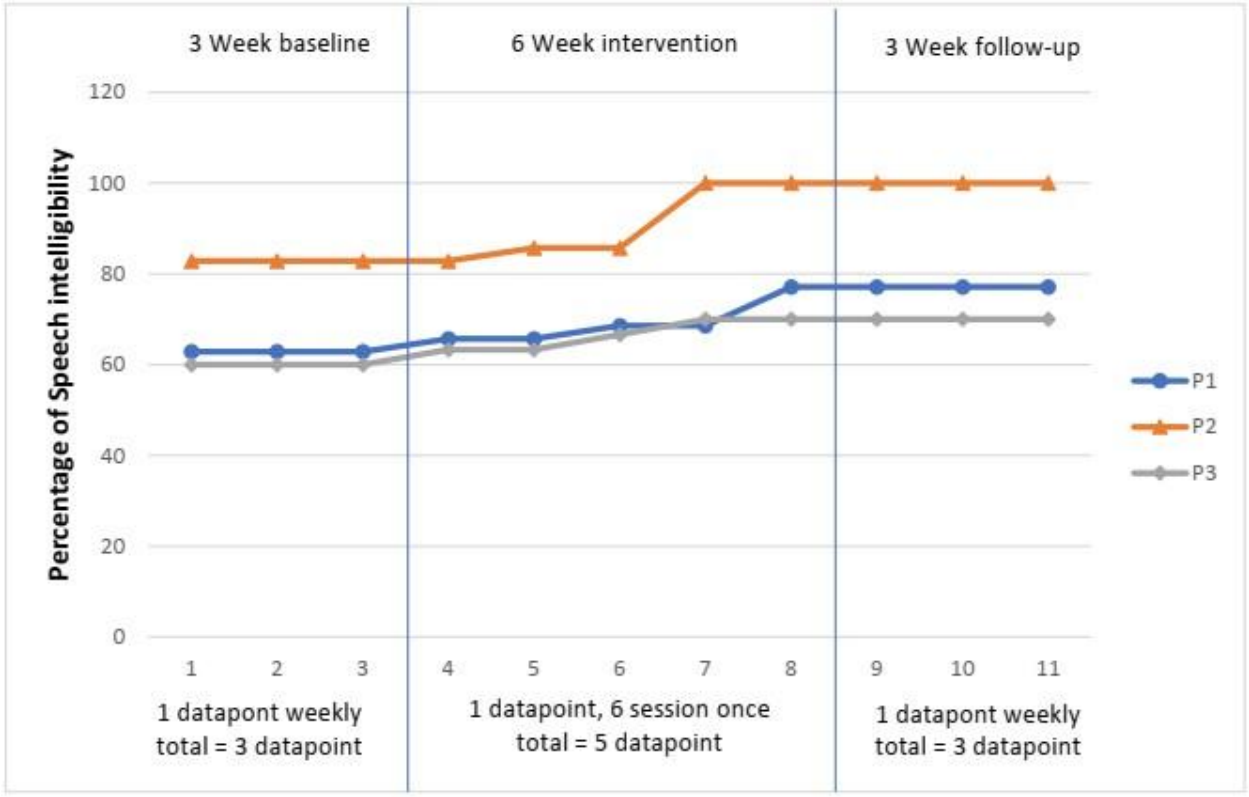

Figure 2. The percentage of speech intelligibility across three study phases for the three participants. P1; participant 1, P2; participant 2, P3; participant 3

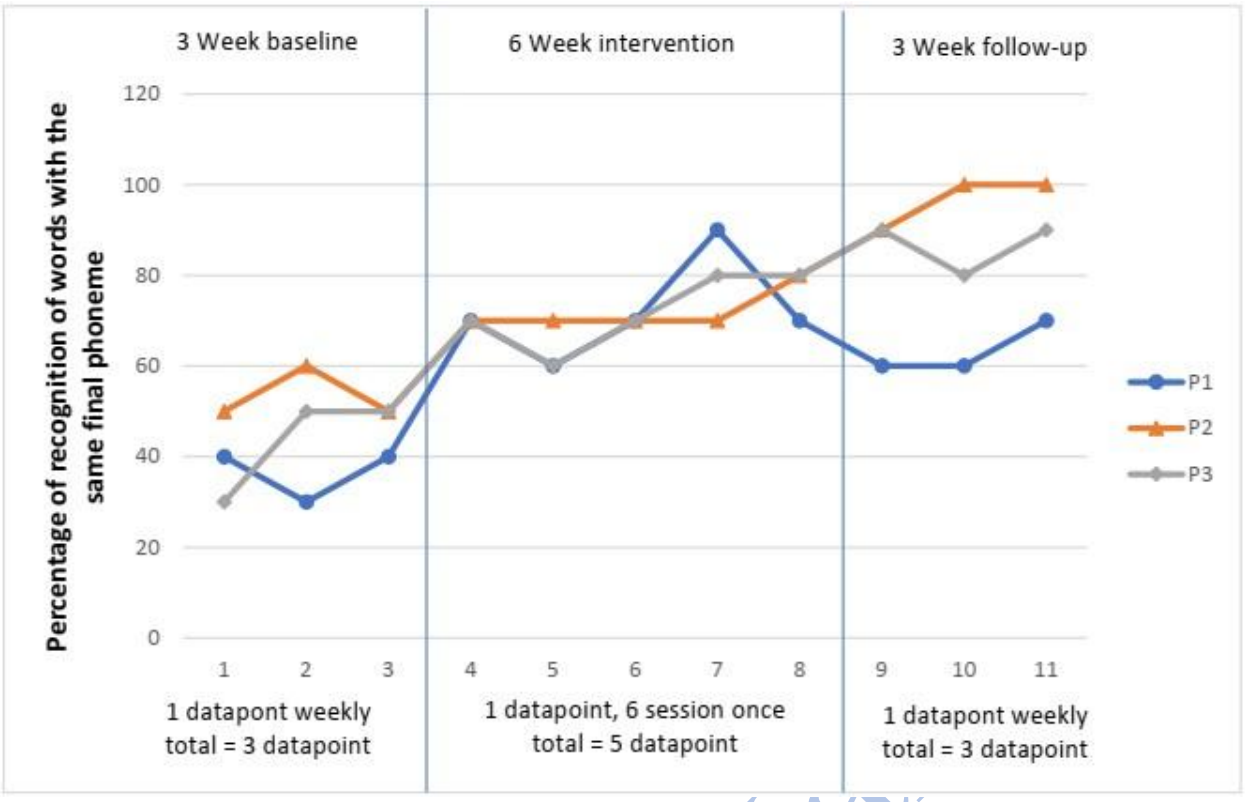

Figure 3. The percentage of recognition of words with the same final phoneme across three study phases for the three participants. P1; participant 1, P2; participant 2, P3; participant 3

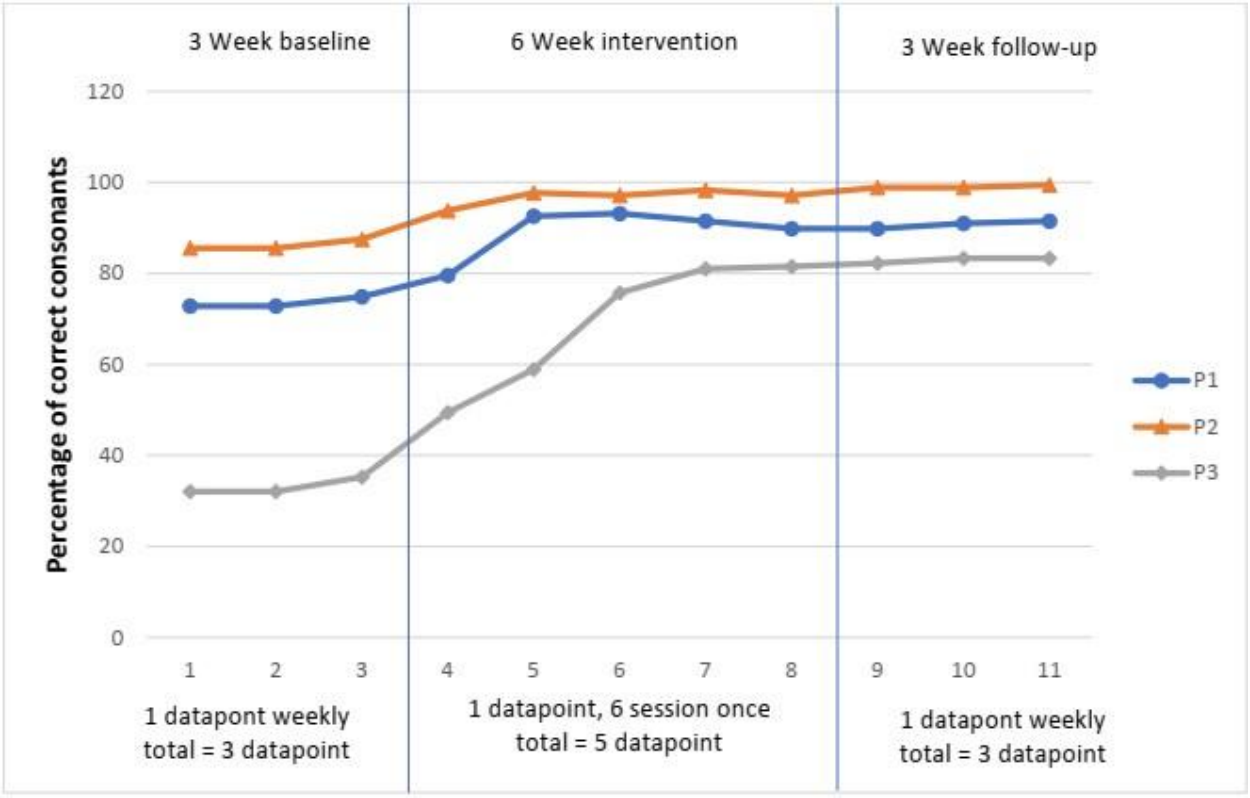

Figure 4. The percentage of recognition of correct consonants across three study phases for the three participants. P1; participant 1, P2; participant 2, P3; participant 3

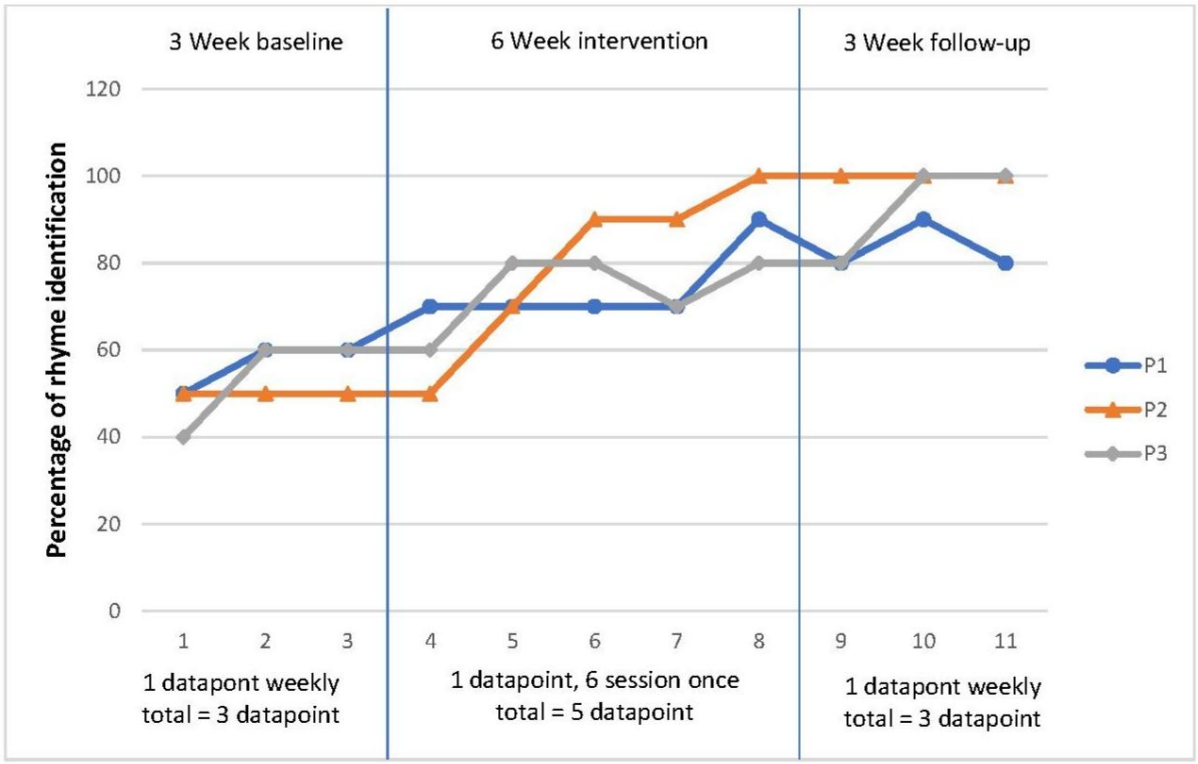

Figure 5. The percentage of rhyme identification across three study phases for the three participants. P1; participant 1, P2; participant 2, P3; participant 3

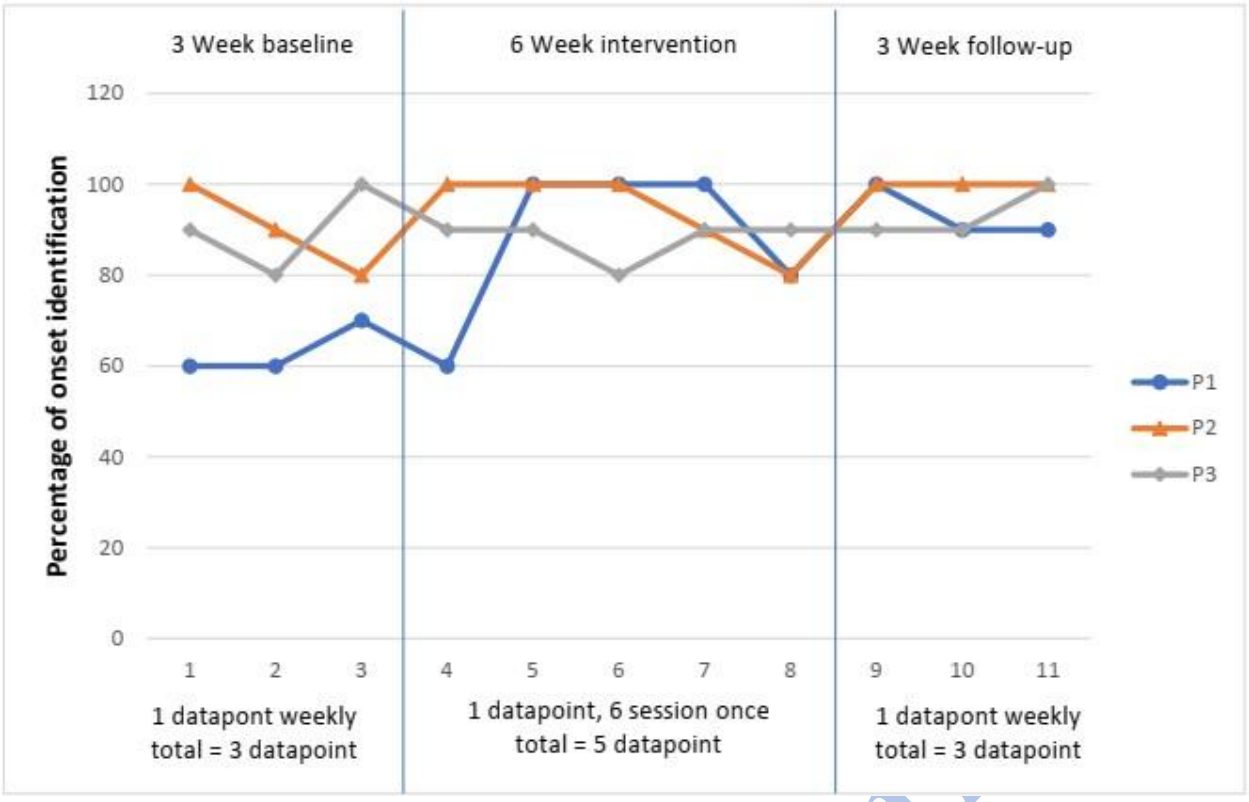

Figure 6. The Percentage of onset identification across three study phases for the three participants. P1; participant 1, P2; participant 2, P3; participant 3

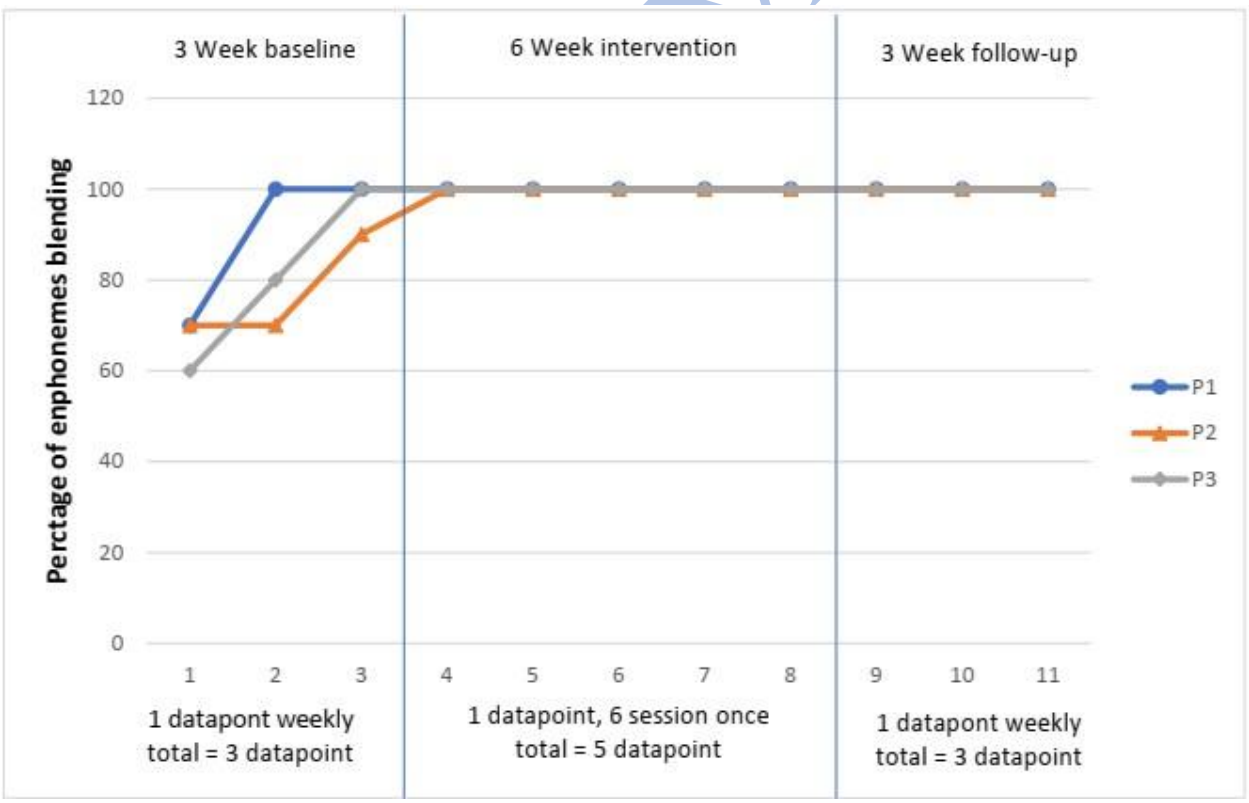

Figure 7. The percentage of recognition of phoneme blending across three study phases for the three participants. P1; participant 1, P2; participant 2, P3; participant 3