Effects of Articulatory Consciousness Training in First Graders with a Reading Delay: A Randomised Control Trial

Abstract

This paper describes a randomised control trial (RCT) of a small group intervention targeting articulatory consciousness in first graders with a reading delay (control condition: $n = 57$, intervention condition: $n = 64$). The program in the intervention condition consisted of basic decoding and spelling tasks using articulatory cards to symbolise speech sounds. Training took place four times per week for five weeks. The control condition received "business as usual". The results show that the children in the intervention condition learned to use the articulatory symbols, but there were no effects of the intervention on reading and phonological awareness measures. Also, there was no relationship shown between initial phonological awareness skills and gains, or lack thereof, from the intervention.

Key words: reading, articulation, first grade, intervention, RCT

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The importance of the early identification of and early intervention in children with a reading delay is emphasised by both policy makers and schools to close the gap between at-risk children and typical readers. Because of this, in Norway, all first graders take a mandatory reading test after eight months of schooling. This national test is administrated in Norwegian, and the aim of the test is to identify children with a reading delay and to take early measures to prevent a negative trend in future learning trajectories. Here we evaluate the effects of an intervention programme aimed at children below the critical limit on this national test. The study was conducted in collaboration with the school administration in one municipality. The intervention was delivered in small groups and took place during the last weeks of the school year. The main goal of the intervention was to give the children beyond the critical limit a boost in reading and phonological awareness before the summer holiday.

Phoneme Awareness and Reading Instruction

Numerous studies show that phonological awareness, or more specifically phoneme awareness, is an important causal factor in the development of decoding skills (Ehri et al., 2001; Melby-Lervåg, Lyster, & Hulme, 2012; Suggate, 2016). Therefore, phonological awareness training has become a central part of basic reading instruction over the last 30–40 years in most alphabetic orthographies, including in Norway.

Norwegian is a Germanic language and can be categorised with medium orthographic consistency compared to Finnish and Italian in the consistent end of the continuum and English and French in the inconsistent end of the continuum (Landerl et al., 2013). Studies show that the predictors for learning to read (i.e. phoneme awareness, letter knowledge and rapid naming) are similar in consistent and inconsistent languages but that English-speaking children spend more time automatising their reading process than peers from more transparent languages (Caravolas, Lervåg, Defior, Seidlová Málková, & Hulme, 2013). Notably, in basic reading instruction, most first-grade teachers in Norwegian aim to use words with a consistent spelling pattern. However, words with inconsistent spelling occur in textbooks, and the children are therefore exposed to this from the very beginning of their reading development.

Speech and Articulation Problems as a Cause of Reading Difficulties

Phonological awareness training typically focuses on listening tasks, for instance, by ‘sounding out’ the phonemes. This presumably presupposes relatively rapid auditory processing, and it has been suggested that a focus on articulation may function as a supplementary and compensatory tool in phonological awareness training for children with phonological deficits. This is because articulation, either aloud or silent, is assumed to give sensory feedback and offer a concrete way to distinguish between sounds (Boyer & Ehri, 2011; Rosenthal & Ehri, 2011; Wise, Ring, & Olson, 1999).

Arguments for this are most clearly formulated in the motor theory of speech perception (Liberman & Mattingly, 1985; Liberman & Whalen, 2000). This theory creates the

backdrop of several intervention studies (see below). According to this theory, the fundamental elements in the perception of human speech are a combination of articulatory gestures (mouth movements) and speech sounds, which together constitute the identity of each phonetic element. Within this framework, articulatory consciousness training is therefore a natural part of basic reading instruction (Liberman, Shankweiler & Liberman 1989; Lindamood & Lindamood, 1998).

As for the relationship between orthography and articulation, the 'phonological recoding hypothesis' (Share, 1999) suggests that orthographic learning is the product of a natural, 'self-teaching' process. When exposed to novel words during text reading, children process the words from prior knowledge of the grapheme/phoneme correspondence and construct new orthographic connections. The aloud or silent articulation of the phonemes are thought to play a role in this recoding process, and studies have shown that suppressing the recoding process, for instance, in experiments where participants are to display concurrent articulation during silent reading , disrupts orthographic learning (de Jong, Bitter, van Setten, & Marinus, 2009; Share, 1999). Orally pronouncing novel words aloud during text reading has also been shown to enhance the student's memory in regard to both word meaning and the spelling structure of the words (Rosenthal & Ehri, 2011; Ehri, 2014). Although studies have supported the hypothesis of phonological recoding in orthographies with varying levels of transparency (such as Hebrew, English and Dutch), this may be limited to phonetic orthographies (Sahu 2000).

Another relevant perspective for the relationship between articulation and reading are the assumed connections between speech perception, speech production and the underlying phonological representations (Elbro, Petersen, & Borstrom, 1998; McBride-Chang, 1996; Sénéchal, Ouellette, & Young, 2004). The quality and distinctness of the phonological representations are vital in the development of phonological awareness (Elbro et al., 1998; Elbro & Jensen, 2005; Swan & Goswami, 1997) and have also been found to differ between different subgroups of language impaired children (Ramus, Marshall, Rosen & van der Lely, 2013). How the phonological representations are constituted and how different features contribute to the storing of these representations in memory is not clear. However, observational studies have found high correlations between speech perception and phoneme awareness (McBride-Chang, 1996; McBride-Chang, Wagner, Chang & Pressley, 1997), between articulation and speech perception (Sato, Troille, Ménard, Cathiard, & Gracco, 2013) and also between speech perception, articulation accuracy and phoneme awareness (Sénéchal et al., 2004).

Evidence for relations between reading and articulation has been investigated more directly in samples from different populations. Several longitudinal studies in samples of children with speech-sound disorders have shown that especially atypical speech-sound disorders in preschool children predict poor phonological awareness and reading delay in the early school years (Hayiou-Thomas, Carroll, Leavett, Hulme, & Snowling, 2013; Preston, Hull, & Edwards, 2013; Rvacheww, Chiang, & Evans, 2007). Correlations between poor articulation accuracy in preschool children and later reading problems are also reported in

other longitudinal studies of typically developed samples (Sénéchal et al., 2004; Thomas & Sénéchal, 2004).

However, that there is a correlation between articulation and reading does not imply a causal relationship. There are also several studies that do not support the notion that this reflects a causal relationship. Hulme, Nash, Gooch, Lervåg and Snowling, (2015) investigated the foundation of reading comprehension at eight years from a broad spectrum of language and speech measurements conducted when the children were three and five years old (N = 145). In this study, only language measures predicted later reading comprehension, and articulation accuracy measured at three years was not significantly related to later reading development. Rvachew and Grawburg (2006) compared two structural equation models of the correlations between speech perception, articulation, receptive vocabulary, phonological awareness and emergent literacy skills in a sample of 90 children (4–5 years old) with speech sound disorders. They found that speech perception and articulation were significantly correlated, but the analysis did not reveal any direct influence from articulation to phoneme awareness.

Intervention Studies on Articulation Consciousness Training

Although the articulation of speech sounds is indirectly embedded in most basic reading instruction programmes through reading-aloud exercises, studies that focus on instructional programmes with articulatory awareness as part of the basic reading instruction are rare. Most frequently cited in the literature is a programme called Auditory Discrimination in Depth (ADD) and a later version of the same programme called Lindamood Phonemic Sequencing (LiPS) (Lindamood & Lindamood, 1998; What Works Clearinghouse [WWC], 2008). This programme is inspired by the motor theory of speech perception and applies a multisensory approach to reading (Wise et al., 1999). The programme is constructed with learning activities that engage students in discovering the lip, tongue and mouth actions needed to produce specific sounds (WWC, 2008). Instructional means include mirrors and pictures of mouth movements in different positions. Adaptions of the original programme, some also including computer-assisted learning, have been tested in both the pre-reading phase and in reading-delayed samples.

As for studies of effect, Wise et al. (1999) compared the efficiency of three phonic-based computer assisted programmes in 122 second to fifth-grade children. Participants were all among the 10% lowest readers in their respective classes and were recruited from five schools in the same area. Children from three other schools in the area (n = 31) received regular reading instruction and served as controls. One experimental group received a programme with a focus on sound manipulation, another received a programme with a focus on articulatory awareness (ADD) and a third group received a combination of these two programmes. All participants received 40 hours of training in small groups over six months. The results showed that all intervention groups outperformed the controls on all reading and spelling measurements (significant effect size difference d = .73–1.73). The three groups had almost the same gains from interventions across grades and initial levels of phonological awareness and reading.

Castiglioni-Spalten and Ehri (2003) compared the efficacy of two intervention programmes, one based on the ADD (the mouth group) and one based mainly on listening tasks (the ear group) on 45 preschool children (mean age 5.9). Both programmes aimed to improve phonological awareness and reading readiness in children at the 'partial alphabetic' level of reading development according to Ehri's phase theory (1995). Participants were divided into equal triplets, and each triplet was randomly assigned to the ear group, the mouth group or the control group. Both experimental groups were individually taught by the same teacher and received same proportion of training. Controls remained in ordinary classrooms. The results indicated that both training types were efficient in promoting phonemic segmentation, enhancing the children's ability to spell and to segment words and pseudo-words. However, the articulatory group had reliably better effects on a task measuring the children's ability to use partial phonetic cues in reading (significant effect size difference d = .87).

Boyer and Ehri (2011) replicated some of the features from the 2003 study on a slightly larger and younger sample (n = 60, mean age 4.9). The main research topic was to compare the efficiency of phonological awareness training with and without a focus on articulation consciousness in respect to moving the children to the next level of development according to Ehri's theory, the partial alphabetic phase. The content of the two programmes was mainly as described for the 2003 study. The first group was taught to connect phonemes and pictures of articulatory gestures and then segment words first with pictures of articulatory gestures and then with letters. The second group was taught with letters and phonemes only. These groups were compared with a control group who received 'business as usual' instruction. The results showed that the two experimental groups both significantly outperformed the controls on all measures. Also significant was a better effect of training in favour of the articulatory awareness group for measures on phoneme segmentation, spelling, word reading and non-word repetition on the immediate post-test (significant effect size differences d = .79–1.12). However, when controlling for group differences concerning the total time spent on phonological awareness training in the two conditions, only the word reading measure remained significant at the seven day delayed post-test.

Torgersen, Wagner, Rashotte, and Herron (2003) compared two intervention programmes, both partly including computer-assisted learning, on a sample of first graders with a reading delay. The first programme was an adapted version of the ADD programme and the second programme, Read, Write and Type (RWT), provided explicit instruction in phonetic spelling and writing through engaging the children in learning activities. The participants were 150 first-grade students with low achievement in five elementary schools. At two schools, students were randomly assigned to either the ADD or the RWT programme. At three additional schools, students were randomly assigned to either the ADD group, the RWT group or a regular instruction control group. Instruction was delivered for seven months in groups of three children. During this time, the children received four 50-minute sessions per week. The results document similar effects from the training in the two intervention groups, with a small but not significant advantage in favour of the ADD

group on two measures on phonemic decoding. Both intervention groups significantly outperformed the control group.

In another study, Torgersen et al. (2010) replicated these findings in a design where first graders from three cohorts were recruited after a screening procedure each autumn and then randomly assigned to either ADD, RWT or a control condition. The results documented equal efficiency of the two intervention programmes, both significantly outperforming the controls on measures in phonemic awareness, phonemic decoding, reading accuracy, rapid naming and reading comprehension (significant effect size difference d = .37–.77). A follow-up test at the end of second grade showed similar patterns although some of the results at this time were non-significant.

Trainin, Wilson, Murphy-Yagil and Rankin-Erickson (2014) used another articulatory form of training material and examined the effect of two intervention programmes, both aimed to improve early reading skills. In total, 53 third-grade children with reading scores at least one year delayed from five schools in a low socio-economic status area were stratified by school and randomly placed in one of the two intervention conditions at their home schools. One programme, Word Work, aimed to teach the children how to decode and spell through a 'metaphonic' approach using articulatory awareness as a means to provide a conceptual understanding of the basic principles of alphabetic decoding. The other programme, Phonological Awareness Training for Reading, included traditional phonological awareness activities with a focus on segmenting, rhyming and blending and functioned as a control condition. Both interventions also included a component of reading fluency training. This was added from week three of the intervention and provided repeated practice in applying the skills learned in the groups. All training was delivered by graduate students from a local university and included three 45-minute sessions per week for 11 weeks. The results showed significant differences between the two programmes in favour of the Word Work condition in spelling and decoding (effect size difference d = .94), oral reading fluency (effect size difference d = .79) and metacognitive learning (effect size difference d = 1.1). For the phonological awareness measure, there was no significant difference between the two conditions.

A recent study from Sweden investigated the effect of a phonological training programme using an articulation card system called Fonomix (Fälth, Gustafson, & Svensson, 2017). The Fonomix material contains a number of different letter-sound combinations with corresponding pictures representing the specific articulation movement for each. The intervention sample was 69 preschool children that were divided, but not randomised, into a treatment and control condition. During the intervention year, the children assigned to intervention were trained in Fonomix, and the children in the control condition received the same amount of training in a whole language-based programme for preschoolers. For the analysis, the sample was divided into four subgroups based on pre-test scores. The results show a significant effect in favour of the intervention condition on all outcome measures (effect size difference d = 1.06–4.27). The results also documented that the 'at-risk' children showed the largest improvement from pre- to post-test on all measures compared to the other children.

Finally, a study evaluated the long-term effects of an intervention on third-grade children, also in Sweden (Wolff, 2016). The intervention programme entailed a multicomponent approach including phonemic decoding, reading comprehension strategies and fluency training. About 60% of the training sessions was spent on phonemic decoding and phonemic awareness tasks using both letter cards and cards with photographs of mouths pronouncing different speech sounds. This study found a sustained effect from the training after five years on word decoding (d = .37, p = .01) but no significant effects on the other outcomes. This can give at least some support to the use of articulation cards in programmes that aim to increase phonemic decoding skills.

The Current Study

As outlined above, most studies have compared the effects of articulatory consciousness training with other, more traditional approaches to phonological awareness training. However, in most studies the articulation consciousness training is embedded in programmes also emphasising listening tasks, letter-sound mapping and reading and writing exercises. Some of the programmes also include computer-assisted learning and metacognitive learning. Thus, the studies vary both in focus of instruction, sample composition, duration of training and quality of research designs. This makes the interpretation of the results somewhat difficult in respect to concluding on the unique contributions from the articulation consciousness training described. Few previous studies have used randomised samples, and in a review on the effectiveness of the ADD /LiPS programmes (WWC, 2008), only one out of 25 studies (the Torgersen et al. 2003 study) met the WWC evidence standards. In a more recently published report, WWC evaluated the effects of the LiPS programme on beginning reading (WWC, 2015). Here, two out of 48 studies were included due to the eligibility criteria. The WWC report concluded on a possible positive effect of the LiPS programme on reading comprehension and mixed effect on the alphabetic domain. Both conclusions are based on small amounts of evidence (WWC, 2015). Thus, both the mixed results from previous studies and the fact that the majority of the previous studies have used non-randomised designs underscore that it is important to do a randomised study.

In the present study, we aim to examine the effect of articulatory awareness training on first-grade children with a reading delay and randomise the children to produce a better design to draw conclusions about the effects. The current study also differs from the studies presented above in regard to the instructional material. Most studies described have used pictures of mouths in different positions. The material in the present study, Pictographic Articulatory System (PAS) (Kausrud, 2003), uses pictographic symbols of the speech sounds including a broader spectrum of phonological features, such as place, manner of articulation and acoustic cues. This material has been used in clinical practice on children with language disorders in Norway. The material has also been used by first-grade teachers in basic reading instruction both in full classes and for small-group delivery with positive results according to teachers' and parents' reports. However, there are no studies on the effect of the material, only a case study with one language-impaired child (Ottem &Kausrud, 2001). According to

this study the PAS symbols may have played a mediating and compensatory role by promoting the child`s ability to read traditional orthography.

In line with several of the previous studies on novice readers, the intervention programme in the current study integrates articulatory consciousness training in the training of phonological awareness. Compared with most other studies in this area, ours has a larger sample size and also randomisation. Moreover, in contrast to most of the studies cited above, the present study also measures the extent to which the children actually learn to use the articulatory symbols and examines how this is correlated to their progression in phonological awareness, letter knowledge and alphabetic reading.

The research questions in the current study are as follows:

- To what extent did the intervention programme succeed in teaching the children assigned to the intervention condition to use articulatory symbols?
- Will the children that receive an intervention programme with focus on articulatory consciousness improve phonological awareness skills compared with the children assigned to the control condition?
- Will the children that receive an intervention programme with a focus on articulatory consciousness improve alphabetic knowledge compared with the children assigned to the control condition?
- Will the children that receive an intervention programme with a focus on articulatory consciousness improve word reading compared with the children assigned to the control condition?

Method

Design

The design of the study is a randomised controlled trial with an intervention and a control group at each school, 28 clusters in total, with four to six children in each. Pre-tests were administered the week before intervention onset, and the post-tests took place after 20 hours of training. The measurements were administered by the first author and experienced research assistants. All testing sessions were audio recorded for reasons of fidelity.

Sample

A total of 129 first graders from a municipality outside Oslo were recruited based on their scores on the mandatory national reading test (see Figure 1 for an overview of the flow of participants in the study). The sample consists of 89 boys and 40 girls. Eighty-one (63%) have Norwegian as their first language, and 47 (36%) have another first language. Prior to the statistical analysis, we conducted an independent sampled T-test to consider whether it would be relevant to separate the sample from first language background in the analysis. The results from this analysis showed that there were no significant differences between children with Norwegian as their second language and children with Norwegian as their first language, neither on pre- nor post-tests. In further analysis, the sample was therefore considered as a whole.

The national test contains six subtests measuring phonological awareness, word reading, word spelling, letter knowledge and reading comprehension. The reliability for this screening test is not available at the subtest level, but the reliability for the test overall is coefficient alpha > .80 (UDIR homepage: https://www.udir.no/eksamen-og-prover/prover/rammeverk-for-kartleggingsprover-pa-1.-4.-trinn/krav/#reliabilitetskrav).

Since articulatory training in previous studies has been most promising for children with phonological problems (Trainin et al., 2014; Fälth et al., 2017), we set the inclusion criteria from the children's scores on the four subtests related to phonological skills and identified children who had scored below the critical limit on at least two of four subtests. The percentile for the critical limit is not available to the public, but it is usually around the 20% weakest scoring part of the sample. Schools with more than six children in this category were by the school administration in the municipality committed to participate in the study and conduct the intervention programme as part of the instruction (see Figure 1 for an overview of the flow of participants in the study).

For each school, the children were distributed in two conditions based on two procedures, as follows: in schools with more than 10 children meeting the inclusion criteria, we first selected 10 children by using a randomiser programme (randomiser.org). In the next step, these children were randomly allocated to an intervention group and a control group. For schools with fewer than 10 children, all children were randomised. The reason for only selecting 10 participants from each school was that a group size of five was considered the maximum possible for the teacher to follow up on through the programme. We also aimed to have an intervention and a control group of nearly the same size at each school. The final sample consisted of 14 intervention clusters and 14 control clusters, each with between three and five participants. All parents gave written consent for their children to participate in the study.

Intervention Materials and Procedure

The content of the programme can be described as an attempt to repeat the central principles in the basic reading instruction. However, instead of using alphabetic letters, the children were introduced to pictographic elements and taught how each speech sound was symbolised by these elements on articulation cards. The intervention programme aimed to increase the students' knowledge about the acoustic and articulatory features of each speech sound and thereby provide an alternative to auditory discrimination between phonemes. The Pictographic Articulatory System (PAS) symbols, which constitute the material used in this intervention, are based on all singular vowels and consonants in the Norwegian alphabet (Kausrud, 2003; Ottem, 2001). We aimed to avoid words with inconsistent spelling in the training sessions. This is because the PAS symbols represent single phonemes and are most convenient for the reading and spelling of words with a transparent spelling structure. Both the intervention material and the phonological awareness and reading tests conducted at pre- and post-tests therefore include transparently spelled words only. Figure 2 shows how the word ROSE, spelled in Norwegian, is depicted in PAS. For an overview of the PAS "Alphabet", see the supplementary material

The programme was constructed for the purpose of this study and consists of six learning activities, five activities for group work and one activity for individual work. The group activities were organised as a stepwise introduction to how to use the PAS symbols in representing speech sounds. First, the children were engaged in shared activities in exploring their own articulatory system, also using mirrors. Secondly, they learned the logic of the PAS system concerning how the articulatory and acoustic features of the sounds are represented in the symbols. Further, matching, spelling and reading tasks with the PAS symbols were also introduced. Additional materials for the shared activities included cards with words spelled in the PAS font and picture cards. The programme emphasises a collaborative atmosphere where the teacher and the children together investigate the PAS system and how to use the system in decoding and spelling. The teacher acts as a model for how to identify the articulatory and acoustic features of each speech sound, and the children also use mirrors to make the articulation more concrete.

The individual activities were different forms with fill-in transposition tasks. In this activity, the children read words written using the PAS system and were to transpose these words into alphabetic script. The programme has an increasing difficulty level that reflects the development from fluent and accurate knowledge of the PAS symbols to mastery of the symbols in reading and spelling (for details concerning the content of the programme, see the supplementary material).

The intervention was carried out at the children's local schools, and the teachers received three hours of group instruction in how to conduct the programme prior to the start of the intervention. The programme includes 20 training sessions of 40 minutes each. All teachers that delivered the programme were educated and experienced, some with additional training as special needs educators.

Fidelity

All participating teachers had to fill in a record form for each lesson and briefly describe how the intervention programme had worked for that particular session. All lessons were also audio recorded to document that the teacher had followed the predefined structure of the programme. The correlation between the teachers' reports and the audio-recorded lessons was nearly 100%. However, some schools reported that they had failed to deliver the programme as planned and had spent less time per week on the intervention, mainly due to teacher absence. The intervention groups in these schools received the same number of hours – 20 in total – but spent more weeks completing the whole programme. For some groups, the delivery of the programme was also shared between two teachers.

For each intervention group, we rated 10% of the recordings to examine how the teachers followed the programme and how the interaction in the groups worked out. The results from this rating indicate that all groups delivered the details of the programme as intended. However, the recordings revealed some problems with the group interaction in two groups, and this may have reduced the effects from the training in these groups.

Control Condition

The control condition in this study apply a “business as usual” approach. This means that the children got what the school usually provided children with a reading delay. All schools had to answer a questionnaire concerning the instruction of the children assigned to the control condition. The response rate was 85.7%. Six schools (50% of the answers) reported that the controls got some sort of special instruction in reading, spelling and phonological awareness during the weeks of the intervention. The content, organisation and dosage of this instruction varied between schools. One school reported daily individual lessons for all control children, and three other schools also offered individual instruction in addition to small-group instruction for the controls. Many schools had two teachers available for the first graders, and several schools also had school assistants present in the classrooms. This made it possible to use group instruction and tailor the reading instruction to individual needs.

Notably, in some schools the controls and the children in the intervention condition received instruction from the same teacher but at different times of the day; in other schools the delivery to the controls was given parallel to the intervention by another teacher. Importantly, the controls did not receive any of the instruction concerning the intervention materials. Because the assignment of the children to the two conditions was blinded to the professionals doing the post-intervention assessment, all children were shown two PAS symbols at the end of the measurement procedure and asked if they knew the symbols. The correspondence between the result from this check and the assignment key was 100%. This means that none of the children in the control condition had been exposed to the intervention material. The transposition test was added as a supplementary measure for those knowing the symbols.

The questionnaire for the teachers did not contain questions regarding instruction for those over the critical limit that remained in the classrooms. However, experience from a pilot study in several classrooms in the same municipality prior to the current study indicated that the general curricula across the classrooms included a broad spectrum of phonological awareness training and phonics reading exercises. It is also worth noting that in this municipality all first graders are offered a personal iPad, which is frequently used in the reading instruction and for practicing.

Measures

Screening Test

The national reading test is constructed as a group screening test and contains six subtests. For this purpose, only the four following subtests related to phonological skills are relevant:

- To identify sounds in words: phoneme position tasks (14 items)
- To segment sounds into words: picture-based tasks where the child must select a picture that corresponds to sounds read aloud (12 items)

- To spell words: the child must write and spell a word from a sentence that is read aloud (14 items)
- To read words: picture-based tasks where the children are asked to read a word silently and select the correct picture out of four (14 items)

Outcome Measures

Pre- and post-test measures were mainly constructed for the purpose of this study and were tests of letter knowledge, phonological awareness, reading accuracy, word-reading tasks and one test concerning the intervention material measuring the children's understanding of the pictographic symbols used. In the construction of the phonological awareness tests, we split the tasks into three sets. The reason for this was to be able to compare the potential effect of measures with measures that had different degrees of proximity to the material used in the intervention. The first set (trained words) consisted of words used in exercises in the intervention programme. These words are all nouns that are easy to depict, and all had a regular, transparent spelling structure – that is, no diphthongs, double consonants or compounded phonemes. The words were selected from a database of the 500 most frequent words in the Norwegian language (Norwegian list of word frequencies) and from the database 'Ordforrådet' (http://tekstlab.uio.no/ordforradet). This database also provides information concerning usage frequency and the ability for a word to be depicted.

The second set (untrained words) consisted of words that were matched to the trained words in phonological complexity, ability to be depicted and usage frequency. The third set consisted of pseudo-words, which were also matched to the other sets in phonological complexity. For the one-minute word-reading tasks, we used a similar procedure; here we constructed two lists of regularly spelled words. The first list (trained words) consisted of words used in the intervention exercises, and the second list (untrained words) was constructed to match the trained words but was not used in the intervention.

The third set of tasks (unrelated to the intervention tasks were two pseudo-word reading subtests from the Test of Word Reading Efficiency (TOWRE) battery (Rashotte, Torgersen, & Wagner, 1999). Reliability for all measures is reported in Table 1. For measures without time limits, we used coefficient alpha. For the other tests, the reliability measure is the correlation between equal tests (two word-reading tests and two pseudo-word-reading tests).

Letter knowledge

This test contains 48 items. All the letters in the Norwegian alphabet (24 in total) written both in uppercase and lowercase letters were presented to the children, who were asked to identify both the name of the letter and its corresponding sound. Reliability for both subtests (letter sound knowledge and letter name knowledge) is reported in Table 1.

Phonological awareness

Three different sets (trained words, untrained words and pseudo-words, respectively) were constructed, each set containing the following three subtests:

- Phoneme identification: e.g. ‘What is the first sound in ball?’
- Phoneme reduction: e.g. ‘What remains of the word ‘ball’ if you delete the ‘b’ sound?’
- Spoonerism: e.g. ‘What is ball with a ‘t’ first instead of a ‘b’?’

All subtests contain 12 items (36 per set) with increased levels of difficulty. The stop criteria were four consecutive errors in the first subtest, ‘phoneme identification’. The scoring was either right or wrong.

Decoding

The decoding measures contained three subtests (reading accuracy, one-minute reading of regularly spelled words and one-minute reading of pseudo-words).

Accuracy

Twenty-two pseudo-words with increasing difficulty were constructed for this task. The first words in the list were simple consonant-vowel (CV) words. The items had an increasing level of difficulty, ending in complex words with 14 letters and three consonant clusters. The children were asked to read the words as correctly as possible without any time limits. The stop criteria were four consecutive errors. When graphemes were either added, transposed or deleted, or if the reading was not fluent, this was defined as an error.

Regularly spelled words – trained

Sixty regularly spelled nouns were selected from a database of the 500 most frequent Norwegian words (Norwegian list of word frequencies). The words were then listed based on their level of phonological complexity. The first words were simple CV or VC words with two graphemes, followed by CVC words and then successively VCC, CVCV, CVCC and finally CCVCCV. Scoring was based on the number of correct words read in one minute. Words read in a phonologically acceptable way (i.e. if all graphemes were articulated) were scored as correct.

Regularly spelled words – untrained

The list of matched words was constructed using the same procedure and the same scoring criteria as described for the trained words.

Pseudo-words

The pseudo-word measures consisted of two translated versions of the TOWRE test – phonemic reading, set A and B. A child’s score was calculated based on the number of correct words read in one minute. Words read in a phonologically acceptable way (i.e. all graphemes were articulated) were scored as correct.

Transposition of pictographic symbols

The transposition test evaluated the progress in mastery of the articulatory elements in decoding and consisted of 24 listed pseudo-words with increased complexity, scripted in the font of the PAS system. The words all had a VC, CV, VCC or CVCV structure and consisted

of two to four symbols (letters). A child's score was based on the number of pictographic words transposed into correct alphabetic script in four minutes. Supplementary scoring also included the number of pictographic graphemes transposed correctly into alphabetic graphemes regardless of whether the word was spelled correctly.

Analysis

To evaluate the effects of the intervention, multi-level regression models were conducted for all the outcome measures. Here, the outcome scores for each measure at post-test were regressed on the scores at pre-test and the group dummy variable (experiment or control group). In these analyses, we used the restricted maximum likelihood (REML) estimator in Stata 16. Before deciding which level to include in the regression models for the various outcomes, we first calculated intra-class correlations for all the outcome variables using three-level homoscedastic partially nested mixed-effects models. In these models, between-school variance was estimated as the third level, and the between-intervention group variance was estimated in a partially nested fashion (as suggested by Flight et al., 2016) as the second level.

As can be seen in Table 1, the Intra Class Correlations (ICC) varied from .253 to redundant. In the following regression analyses, we included the third and/or the second level as long as it was not redundant. In all the analyses in which the partially nested second level was included. we also used the Satterthwaite degrees of freedom correction, as suggested by Candlish and colleagues (2018). Further, as the residual variances might differ across the two conditions in the partially nested models, we also estimated partially nested heteroscedastic models where the variances were measured separately for the two conditions. However, as the results did not differ from the homoscedastic partially nested mixed-effects models, we only report the results from the latter ones.

Results

Table 1 shows the descriptive together with Cohen's *d* between pre- and post-tests and the ICCs for the outcome variables. As shown in Table 1, all variables had acceptable normal distributions except for letter sound knowledge, where there were some ceiling effects.

As can be seen from Table 1, the children who received the intervention managed on average to transpose slightly less than half of the words (10.20 out of 24) in the transposition test. Supplementary scoring gave credit for each symbol correctly transposed even if the words were not fully spelled or wrongly spelled. The average scoring on this measure was 29.65 out of 66. Both these values were significantly different from zero; PAS words: $t = 12.76$ (62), $p < .001$ and PAS symbols: $t = 15.38$ (62), $p < .001$. However, as there was variation around these means (see Table 1), we used partial correlation analyses to determine whether this variation on the PAS test was associated with the post-tests of the outcome measures after controlling for the same test at pre-test. As can be seen from Table 2, there

were significant partial correlations between the transposition of PAS words and phonological awareness of untrained words and pseudo-word reading (TOWRE phonemic B). None of the other correlations was significant.

Effects from the Intervention

The fixed effects results from the multilevel mixed-effects models are shown in Table 2. As can be seen, no significant main effects were found from the intervention. Secondly, we analysed whether there were interaction effects between the pre-test scores on phonological awareness and the group variable on the post-test outcome. The results showed no significant interaction effects on the post-tests – that is, the gains, or lack thereof, from the intervention were unrelated to the initial phonological awareness skills.

Discussion

This study evaluated the effects of a five-week intervention targeting first graders below the critical limit on the mandatory national test in reading. The focus of the intervention was to examine whether introducing articulatory consciousness training in basic reading instruction can function as a bridge from sounds to alphabetic script and increase the children's phonological awareness and word-reading skills.

To examine whether the children had learnt the system that the articulatory consciousness training is based on, they were assessed with a transposition test. On this test, the children allocated to the intervention condition read pseudo-words written with the PAS symbols and were asked to translate the PAS 'pictographic words' by writing them in ordinary alphabetic script. Thus, in some ways the effects on this measure may be a prerequisite for the effects on the secondary outcomes, such as reading and phoneme awareness. The results show that, on average, the children's mastery of the symbol system was not fully automated. However, it should be noted that the extent to which the children learnt the symbol system varied (Table 2). Some of the participants scored near the ceiling level, while others showed less progress concerning automation of the system. These diverging results might reflect both individual differences among the children and factors concerning the implementation of the programme in the different schools.

When we examined whether the effects from the interventions was related to the extent to which the children had learnt to master the PAS symbols, the results were not clear. As shown in Table 2, we found significant relations between the transposition of words and two of the post-test measures. On these two measures, there was a small to moderate relationship between the PAS test and the phonological awareness tasks for untrained words and for the pseudo-word reading measure (TOWRE B). Also, these correlations were not present for the other post-test measures of the phonological awareness of trained words and pseudo-words nor for the other pseudo-word reading measures (TOWRE – A and Accuracy). Since these measures are highly similar to those for which there was a significant relationship, it can clearly be questioned whether this is a true and robust relationship.

Still, in spite of some effects on learning the symbol system in the intervention, there were no effects from the intervention overall: the control condition and intervention condition had similar gains on the secondary outcome measures. Also, there were no significant relationships showing that the poorer the phonological awareness skills, the larger the effects from the intervention.

Several factors may explain the lack of effect from the intervention on the outcome measures. The most apparent explanation is, of course, that the intervention does not work since we had some effects on the children's learning on the PAS symbols but no effects on the outcome measures.

Still, there also might be some alternative explanations for why this intervention was not effective in this study and that, perhaps, can contribute to nuance the conclusion that this intervention is not at all effective. One is that this intervention might not be effective for the group with reading difficulties that we have examined here (20% with the weakest phonological skills based on the national test). Many of these children did not have weak phonological problems, and they can score below the critical limit for several reasons. That said, what speaks against the notion that this lack of effect is sample-specific is that there was no relationship between the initial phoneme awareness skills and gains, or lack thereof, from the intervention. But it should be noted that the power of these kinds of analyses is rather weak since it only concerns those in the intervention condition.

Another possible alternative explanation for why the intervention did not work is the rather limited time spent on the intervention due to the complexity of the symbol system. Five weeks is short a time, and the intervention took place in the last weeks of the school year. In this period there are several national holidays, and this might have caused discontinuity in the delivery of the programme. As mentioned, there were also some implementation issues as some of the groups also met problems in delivering the programme in time. Problems with the social interaction in some of the groups may also have reduced the benefits from training.

Concerning the time limitation, it is also worth mentioning that the children in the intervention condition spent time on learning the new symbols of PAS, while the controls got 'more of the same' by continuing to take part in training inspired by the more traditional approach to phonological awareness training, either in the general classrooms or in training groups. Previous studies have noted that it takes more time to teach the children how to use articulatory cues as a supplementary tool in segmenting tasks compared to a 'letter only approach' (Boyer & Ehri, 2011). The results from the transposition test also show that not all the symbols were automatised at post-test, indicating that the training period may have been too short. From this perspective, it is possible that the training effect from the intervention could have increased with more time spent on the intervention. Other studies on the effects from articulatory training in similar populations, for instance that of Fälth et al. (2017), provided one year of training.

Finally, since all the children both in the intervention and control conditions improved from pre- to post-test, an alternative explanation for the lack of effect in favour of the intervention programme could be the quality of the instruction for the controls. Both the

results from the teachers' questionnaire and the experience from the pilot in the general classrooms prior to the intervention indicate that the controls received well-tailored phonological awareness training and reading instruction during the intervention period. Still, as mentioned, only 50% of the schools reported that the controls got some sort of special instruction in reading, spelling and phonological awareness during the weeks of the intervention.

Given that the control group also received high-quality, tailored instruction, the results from the present study are in line with previous intervention studies. Thus, as mentioned, previous studies have shown a similar size of effects from training in phonological awareness and basic decoding with and without a focus on articulatory consciousness (Wise et al., 1999; Torgersen et al., 2003, 2010). Since the post-test measures used listening tasks and word-reading tasks with alphabetic script, the content of the measures may also have favoured the children in the control condition who possibly spent more time on listening tasks and alphabetic decoding exercises during the intervention period than the children in the intervention condition.

Limitations

The study has several limitations. First, the study was conducted in collobaration with the school adminstration in the municipality. This means that the schools and teachers were commited to participate in the study. A post-study questionaire for the teachers revealed mixed additudes in regard to motivation to participate in the study. Although a large majority of the teachers gave positive responses on the evaluation of the intervention programme, negative attitudes prior to the intervention may have inflected the outcome in some of the groups. In the meetings with the school adminitration prior to the study onset, we could have specified that we wanted to avoid the recruitment of teachers with negative attitudes towards conducting external intervention programmes. A more motivated staff would possibly have improved the efficacy of the intervention in some of the groups.

Since the learning of the new symbols in the intervention condition in itself appeared to be time consuming, this may have prevented the children from getting enough time to apply the articulatory counciousness in reading and spelling exercises during the intervention period. We could therefore have added additional post-tests looking for delayed effects in the intervention condition. Since the intervention took place in the last weeks of the school year and since the school office for ethical reasons wanted to break the assignment into the two conditions after the intervention period, this was not possible.

Another issue concerns the curricula-based measures applied for the pre- and post-test assesments. The study intended to measure the effects on near and distal measures and evaluate any transfer effects to pseudo-words both on phonological awareness tasks and on reading tasks. The near transfer tasks were directly based on the words used in the intervention material, while the distal measures were matched to the words used in the

intervention material but were different words. Since the intervention material partly used pictures, the words selected both for the phonological awareness tasks and the word-reading tasks were depictable, high frequency nouns. This may have caused a high degree of overlap with words often used in the basic reading instruction in the classrooms and might partially explain the lack of effect on both the taught and distal words in the experiment condition. We could perhaps have controlled for this by including word knowledge in the pre-test measures. Hovewer, this would have extended the time spent on the measurement procedure, which was undiserable for both practical and ethical reasons.

The sample was based on the weakest first-grade readers in one municipality. Inclusion criteria were established to select children with a presumed phonological deficit. However, the results from the individual pre-tests show that the sample is quite heterogeneous and includes children with minor problems concerning phonological awareness skills. The national test is administered in full classrooms, and the instructional procedure is standardised, not allowing additional assistance. This may have included some false positives in the sample, considering that these children are young and not familiar with formal testing procedures. We could have changed the inclusion criteria after the individual pre-tests and randomised the sample from more restrictive criteria concerning phonological awareness, but this would have reduced the sample size. A smaller sample would have reduced the power of the statistical analyses. For ethical reasons, the school administration in the municipality also desired less restrictive criteria for inclusion in the intervention programme since many resources the weeks after the mandatory test were spent on the intervention programme.

Conclusions and Future Directions

The results from the current study indicated that training with a focus on articulatory consciousness was as effective as the ‘business as usual’ delivery to first graders in this municipality. The most apparent conclusion from this is that the intervention was not effective. However, it should be noted that the control condition in this study might have had an intervention dosage similar to the intervention group but with different content. An alternative interpretation of the results is therefore that phonological awareness training both with and without a focus on articulation consciousness are equally effective to facilitate basic decoding skills in novice readers. This conclusion is in line with the main conclusions from most previous research on similar populations (Boyer & Ehri, 2011; Torgersen et al., 2003, 2010). To investigate the effect of articulatory consciousness training from the perspective of compensation, further studies should consider a more clinical sample with severe problems in regard to phonological skills.

Figure 1**.** Flow of Participants

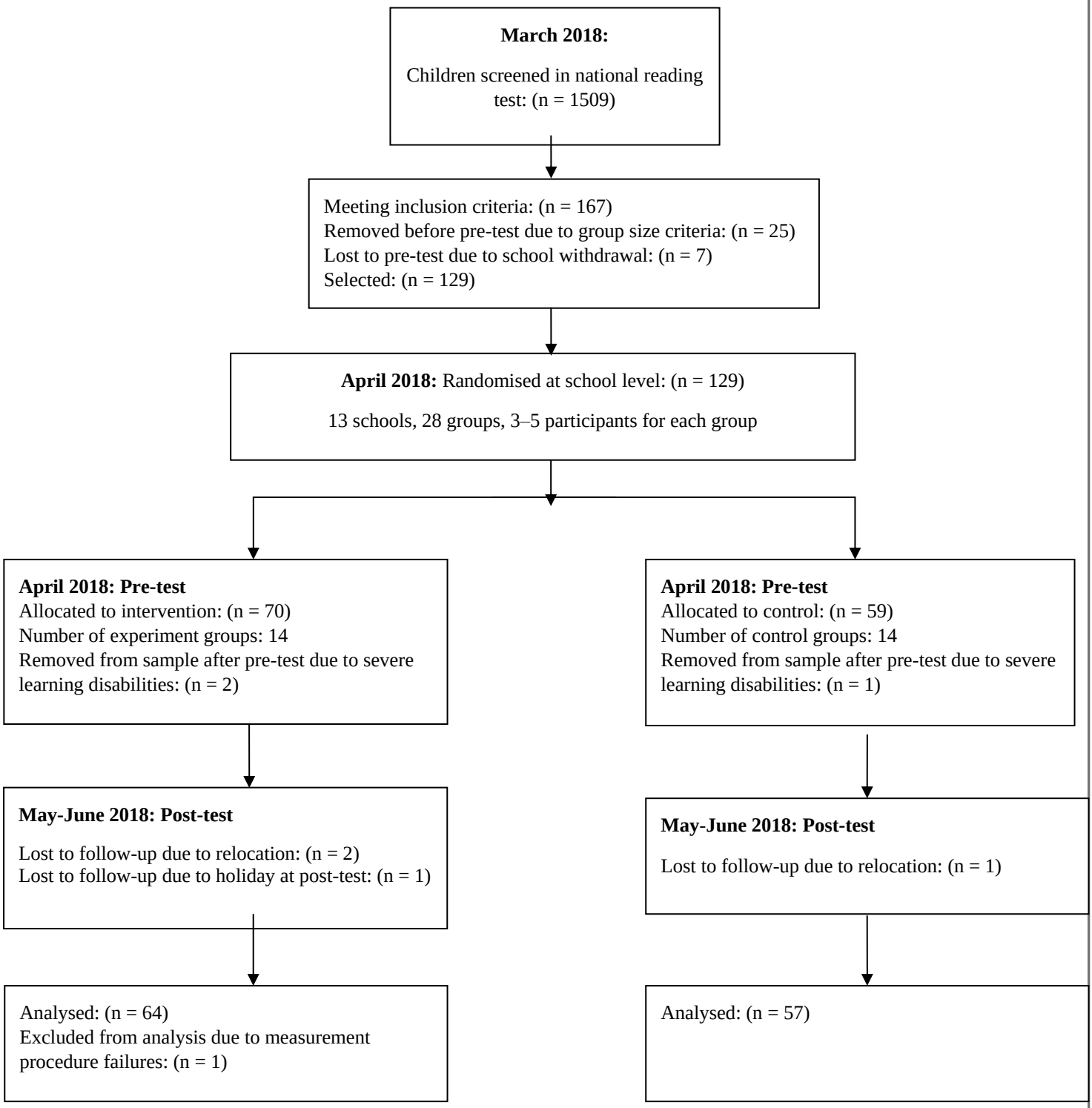

Figure 2

Pictographic Symbol System (PAS)

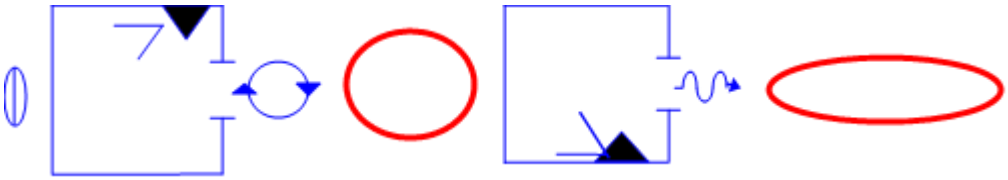

Figure 2. PAS ‘spelling’ of the word ROSE [ˀ ru:sə] (spelled in Norwegian): Blue script for consonants and red script for vowels. Consonant cards contain indicators for voice, placement of tongue and acoustic cues. Vowel cards symbolise the shape and the opening of the mouth when pronouncing a vowel.

Table 1.

Means, standard deviations, range, reliability and effect size for the sample (N = 121).

Measure	Intervention Condition (SD)	Min-max	Control Condition (SD)	Min-max	α	Cohens *d*	ICC	
							School level	Partial intervention level
Letter sound								
Pre-test	19.89(5.20)	3-24	20.75(4.84)	3-24	.92[a]			
Post-test	22.57(3.05)	8-24	22.22(2.87)	10-24	.87 [a]	.22	.252	<.001
Letter name								
Pre-test	15.14(6.37)	0-24	16.47(6.85)	2-24	.91 [a]			
Post-test	18.01(5.70)	0-24	19.98(4.57)	7-24	.91 [a]	-.24	.052	.092
Phonological awareness – trained words								
Pre-test	9.72(6.79)	0-24	11.22(7.23)	0-28	.93[a]			
Post-test	15.28(6.49)	2-28	15.31(7.04)	0-34	.90 [a]	.15	.190	<.001
Phonological awareness – untrained words								
Pre-test	8.98(6.87)	0-24	10.65(6.70)	0-23	.93[a]			
Post-test	12.51(6.44)	0-27	13.71(6.70)	2-28	.90 [a]	-.06	.075	<.001
Phonological awareness – pseudo-words								
Pre-test	7.63(6.38)	0-22	9.31(6.83)	0-28	,923[a]			
Post-test	11.34(5.72)	2-24	12.71(6.2)	0-29	,894[a]	-.06	.201	<.001
Word reading – trained words								
Pre-test	9.71(5.99)	0-24	10.44(5.74	1-27	,83[b]			
Post-test	13.59(6.91)	2-29	15.31(7.62)	2-35	,91[b]	-.07	.033	<.001
Word reading – untrained words								
Pre-test	7.93(6.04)	0-23	9.85(6.38)	0-25	,83[b]			
Post-test	10.71(6.66)	0-27	13.71(7.65)	0-31	,91[b]	-.13	.041	<.001
TOWRE phonemic A								
Pre-test	7.80(5.78)	0-20	9.85(6.38	0-25	,79[b]			
Post-test	11.34(5.67)	2-24	13.10(6.04)	0-28	,90[b]	.003	<.001	.050
TOWRE phonemic B								
Pre-test	5.63(4.97)	0-17	7.37(5.67)	0-24	,79[b]			
Post-test	9.84(5.36)	0-26	11.52(5.74)	0-25	,90[b]	-.006	.052	.006
Accuracy								
Pre-test	5.38(4.22)	0-17	5.47(4.07)	0-16	,84[a]			
Post-test	9.03(5.39)	0-21	8.17(4.20)	0-21	,88[a]	.19	.130	<.001
Transposition of PAS symbols	29.65(15.30)	5-66						
Transposition of PAS words	10.20(6.34)	0-24						

Note: [a] = Coefficient alpha; [b] = Pearson's correlation; Cohens *d* = difference between the intervention condition and the control condition in standard deviation units controlled for pre-

test. PAS symbols unknown to the children before intervention and transposition tests therefore only present at post-test.

Table 2.

Partial correlations between the transposition test and the outcome measures at post-test (n = 62).

	Transposition of PAS Words		Transposition of PAS Symbols	
	Correlation	*p* - value	Correlation	*p* - value
Measure				
Letter sound	.245	.057 n.s.	.162	.212 n.s
Letter name	.018	.889 n.s.	.084	.521 n.s
Phonological awareness – trained words	.116	.367 n.s.	.098	.450 n.s.
Phonological awareness – untrained words	.267	.036 *	.153	.234 n.s.
Phonological awareness – pseudo-words	.161	.210 n.s.	.227	.077 n.s.
Word reading – trained words	.179	.167 n.s.	.090	.492 n.s.
Word reading – untrained words	.119	.361 n.s.	.131	.316 n.s
TOWRE phonemic-A	.082	.529 n.s.	.098	.451 n.s.
TOWRE phonemic-B	.275	.032*	.243	.059 n.s.
Accuracy	-.243	.057 n.s.	-.190	.138 n.s.

Note: * = $p > .05$; n.s. = non significant values $p = > .05$

Table 3.

Effects of the treatment: Unstandardized regression coefficients, standard errors, p values and 95% confidence interval. Fixed effect estimates controlled for pre-test.

	Reg. coef.	*S.E.*	*p value*	*Confidence interval (95%)*
Letter Sound[a]	.698	.426	.101 n.s.	-.137, 1.533
Letter Name[b]	-1.193	.770	.134 n.s	-2.778, .392
Phonological Awareness – trained words[a]	1.158	.842	.169 n.s.	-1.576, 3.705
Phonological Awareness – untrained words[a]	-.318	.981	.746 n.s	-2.240, 1.605
Phonological Awareness – pseudo-words[a]	-.342	.807	.672 n.s.	-1.923, 1.239
Word Reading – trained words[a]	-.343	.824	.677 n.s.	-1.957, 1.271
Word Reading – untrained words[a]	-.935	.874	.291 n.s.	-2.697, .827
TOWRE Phonemic A[c]	-.016	.735	.983 n.s.	-1.460, 1.491
TOWRE Phonemic B[a]	-.370	.769	.631 n.s.	-1.88, 1.238
Accuracy[a]	.915	.672	.173 n.s.	-.402, 2.232

Note. [a] Fixed effects results from a two-level mixed-effects model with school as the second level. [b] Fixed effects results from a three-level regression homoscedastic partially nested mixed-effects model with the intervention groups in the treatment arm as the second level and

school as the third level. [c] Fixed effects results from a two-level regression homoscedastic partially nested mixed-effects model with the intervention groups in the treatment arm as the second level.

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Supplementary Material

Intervention Programme

The programme for the 40-minute sessions was structured in blocks of learning activities (six in total). Each activity lasted for 10–15 minutes, and for each session the children were engaged in three different activities. The choice of activities for each session during the five weeks followed a predefined structure from the level of complexity, as follows: Week one: Learning activity 1, 2 & 3; Week two: Learning activity 2, 3 & 4; Week three: Learning activity 2, 3, 4 & 5; Weeks four and five: Learning activity 4, 5 & 6 (see description of the content of each learning activity below). Learning material for the sessions include pictographic element cards (PAS cards) (see Figure 2) and larger cards (A5 format) with printed PAS words (nouns) on one page and an illustration of the present word on the other side. These cards were available in three versions marked with red, green and blue according to level of difficulty. Blue cards consisted of two- or three-letter words, green cards consisted of four-letter words and red cards consisted of longer words, also including consonant clusters. All words used regular spelling and avoided double consonants. The individual tasks (the word sheets) also consisted of three versions from the same criteria as described. Additional material were picture cards from Lotto or Memory boxes, already available in the classroom, and mirrors.

Description of the Instruction

1. **Learning to ‘feel’ the sounds**

The teacher has a stack of picture cards and a mirror. The children pick cards in order and identify the first sound of the pictured word while looking at their own mouths in the mirror. The teacher models how to identify the articulatory and acoustic identity of the present sound.

2. **Learning the PAS symbols**

First, the teacher explains and models by drawing a PAS card and saying out loud how she interprets the symbols by focusing on the pictographic elements: ‘Where does the air come out ?’ , ‘Is the voice on or off ?’, ‘Where is the tongue placed?’.

Afterwards are the children in turn invited to do the same.

3. **Matching**

Image cards are placed on the table with the image side up.

Selected pictographic element cards (PAS cards) are placed face up and cards are drawn by the children in turn. The child is then asked to pronounce the sound depicted on the PAS card and match the card to the correct picture on the table from the first sound. Activity continues until all children have tried. In this task, the teachers were recommended to start with the less

complicated symbols and add more cards when the children seemed to have understood the principle.

4. **Read and write with the PAS cards**

The children close their eyes, and the teacher puts up a word with the PAS cards.

The first child reads it aloud, and the task is then repeated until everyone has tried it.

The teacher adjusts the degree of difficulty in putting up the words according to her knowledge about reading level of each participant. The teacher models and scaffolds the decoding process.

As a variation, the children may also in turn be able to spell words with the PAS cards, and the teacher or another student then reads the word aloud.

5. **Reading PAS words**

Material: Cards with words printed in the PAS font with illustrations of the target word on the reverse of the card as an answer.

The cards are stacked with the PAS characters up and are drawn by each child in turn.

The children read the word aloud sound by sound and segment the word, and then turn the card to check the illustration.

6. **Individual tasks with worksheets**

The tasks consist of two versions of sheets, both with two columns. In the first column are words written with the PAS font, and in the second column the children are to transpose the words into alphabetic script. The second columns contain either silhouettes that indicate the shape of the alphabetic letters as a support (easiest) or dashes to indicate the number of letters (more difficult).

Figure 1 ***The PAS «Alphabet»***

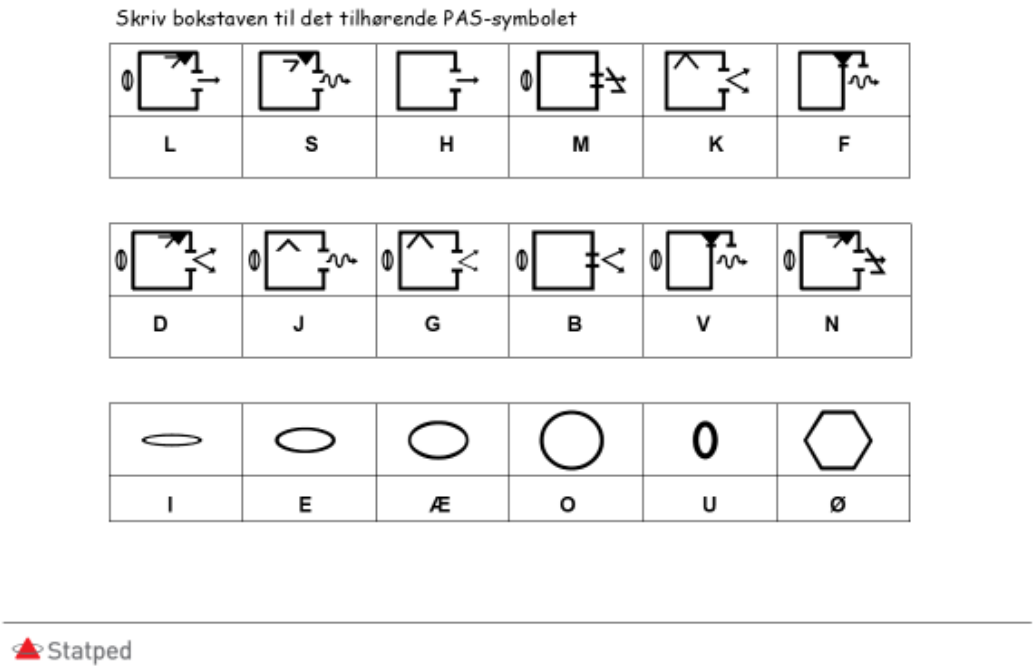

Figure showing correct transposition of all current PAS symbols into Norwegian letters.