



Breaking the reading code: Letter knowledge when children break the reading code the first year in school

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ARTICLE INFO

Keywords:

Children
Gender differences
Letter-sound knowledge
Longitudinal

ABSTRACT

The aim of this study was to examine when children learn to read and how learning to read depends on a foundation of alphabetic knowledge. 356 children aged 5–6 years completed assessments of letter-sound knowledge, i.e. the names and sounds of uppercase and lowercase letters of the Norwegian alphabet. Each child was tested at the start, the middle and the end of the school year. The time that each child broke the reading code was also recorded. The results indicated that 11% of the children knew how to read before starting school and 27% of the children did not learn to read by the end of the first year. The remaining children typically knew 21 uppercase letter sounds before they were first able to read, and only a few (<5%) knew less than 11 uppercase letter sounds when they broke the reading code. The average of all four letter-scores at the time they broke the reading code was 19 ± 5 letters (mean \pm standard deviation). Although letter sound knowledge was associated with the ability to read, it was not sufficient for breaking the reading code. 40% of children who knew 23 letter sounds or more, enough to read more than 80% of the most common Norwegian words, and 15% of children who knew all 29 letter sounds still could not read. Based on these data, it seems reasonable to advocate learning letter-sound correspondences early in the first year of school to form the best possible basis for breaking the reading code.

1. Introduction

Letter-sound knowledge has been found to be one of the most important factors for reading development (Bradley & Bryant, 1983; Dehaene, 2011; Ehri, Nunes, Stahl, & Willows, 2001; Nation, 2019; Solheim, Frijters, Lundetræ, & Uppstad, 2018; Sunde, Furnes, & Lundetræ, 2019; Tønnesen & Uppstad, 2015). Dehaene (2011) argues that letter-sound correspondences must be systematically taught, one by one and that the amount of such teaching is the best predictor of reading performance (p.26).

Research indicates gender differences in letter-sound knowledge when children enter school. When measuring the number of uppercase letter names, uppercase letter sounds, lowercase letter names and lowercase letter sounds that children knew, girls knew significantly more letters than boys (Sigmundsson, Eriksen, Ofteland, & Haga, 2017, 2018). This may be one of the reasons for the gender gap in reading shown in large scale academic assessment studies such as Programme for

international Student Assessment (PISA) 2015 in 15-year-old children (OECD, 2016). Based on current evidence, development of letter-sound knowledge seems to be a matter of dynamic interaction between nature and nurture, in the sense of a multicausal explanation (Stoet & Geary, 2013). This multicausal explanation may be related to both biological factors (Geary, 1996) i.e. maturational differences in the language capacities (Huttenlocker et al., 1991) and socio-cultural factors such as social - cognitive processes in which girls are advantaged (Geary, 2010). Gough and colleagues proposed a simple model for reading, the ‘Simple View of Reading’, in which reading skill is dependent on both decoding and comprehension (reading = decoding \times (linguistic) comprehension) (Gough & Tunmer, 1986; Hoover & Gough, 1990). From this perspective, decoding from graphemes to phonemes is at the core of reading skill. “Decoding is clearly not sufficient for reading. But at the same time, we argue that decoding is necessary for reading, for if print cannot be translated into language, then it cannot be understood” (Gough & Tunmer, 1986, p. 7). Nation (2019, p. 48) argues that “decoding can be

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<https://doi.org/10.1016/j.newideapsych.2019.100756>

Received 5 July 2019; Received in revised form 28 September 2019; Accepted 28 September 2019

Available online 31 October 2019

0732-118X/© 2019 The Authors.

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defined as the ability to identify words or print and linguistic comprehension as the ability to understand spoken language". Breaking the reading code, that is, acquiring a mapping from graphemes to phonemes, is of high importance for children as it marks the point at which they can start to read words with two and three letters and progressively more complex texts (Ehri et al., 2001 for an overview). However, it is important to be aware of the two factors decoding and comprehension. A skilled decoder is a reader who can read isolated words quickly, accurately and silently (Gough & Tunmer, 1986, p. 7). In this respect Gough and Hillinger (1980) claim that word recognition skill is fundamentally dependent upon knowledge of letter-sound correspondence rules. This is later supported by Milledge and Blythe (2019) who argue that both a word's orthography and phonology are critical for development of reading skill. Children with dyslexia experience deficits in phoneme awareness (Hulme & Snowling, 2016; Solheim et al., 2018). Piasta, Justice, and Petscher (2012) argue that setting benchmarks on a specific measurable skill may be important.

For English-speaking countries, the predictive relationship between letter knowledge and reading ability is well documented. However, research into this relationship for other alphabetic languages and countries has been called for (Foulin, 2005). In Norway, no formal reading or pre-reading instruction is given in kindergartens, and variability in children's letter knowledge at school entry is likely related to differences in their home environment (Mullis, Martin, Foy, & Hooper, 2017). When children start school, the instruction received is based on combining phonics and whole-word reading because of the semi-transparent nature of Norwegian orthography (i.e. more transparent than English, but less transparent than Finnish) (Seymour, Aro, & Erskine, 2003; Walgermo, Frijters, & Solheim, 2018a). The relationship between letter knowledge and breaking the reading code in native Norwegian speakers is not well documented in the literature. In this study we investigated this relationship in children following traditional Norwegian reading instruction in their first year in school.

2. Methods

2.1. Study design and participants

A total of 412 children, 186 girls and 226 boys, aged between 5 and 6 years were recruited for this study. The children were selected from 28 schools in the south of Norway in the school year 2002/2003 (convenience sampling from schools in a particular region of Norway that were invited to participate). In Norway, reading instruction for the first grade is still the same as in 2002/2003 (Ministry of Education, 2006; Norwegian Ministry of Education, Research and Church Affairs, 1997), and the results can therefore be applied to today's 5 and 6-years old. The language orthography was Norwegian Bokmål. The mean chronological age for the entire group at the start of the project was 6.1 (SD = 0.3) years; the overall range was 5.67–6.67 years. The entire sample reflected the population of children attending schools in the region and included children in a wide range of socio-economic backgrounds. The children were attending their first year in school. The schools varied in size and location (from urban to suburban) and included pupils with different sociocultural- and economic backgrounds. Exclusion criteria included; uncorrected visual deficit; behavioral, or neurological conditions; a history of learning difficulties or any other medical condition that could potentially interfere with the ability to carry out the tests.

All participants completed an assessment of letter knowledge ("Bokstavtesten"; Ofteland, 1992) in the start, middle and end of the first school year.

For 356 children the time of breaking the reading code was also recorded by their teacher. This study reports results for the sample of N = 356 children, 165 girls and 191 boys.

3. Measurements

3.1. Letter knowledge

The Norwegian alphabet is based on the Latin alphabet and identical to the Danish alphabet. Norwegian language is considered to have a semi-transparent orthography (Esmaeeli et al., 2017).

Knowledge of letter names and letter sounds was assessed using the Letter-sound knowledge test (LSK test; "Bokstavtesten"; Ofteland, 1992). The LSK test measures a participant's knowledge of the names and sounds of Norwegian uppercase letters ("A, B, C, ...") and lowercase letters ("a, b, c, ..."). The participant is presented with the grapheme of each letter of the alphabet in turn and is asked to verbally produce both the name and the sound (phoneme) of each letter. There are 29 letters in the Norwegian alphabet. Each name and each sound that the participant correctly produces is scored 1 point, for a maximum total score of 4×29 points = 116 points.

The LSK test takes about 10 min per participant. It has two sheets, one for the uppercase letters and one for the lowercase letters.

The convergent construct validity of the test battery was estimated by comparing the rankings of the test scores in a class of 20 Norwegian six-year-old children (mean age 6.05, SD 0.28) with the rankings of the same children based on an evaluation of their teacher. There was a close association between the rankings based on the teacher's evaluation and the rankings of test scores, with a Spearman rho correlation of 0.683.

The relative test-retest reliability of the test battery was estimated by the intraclass correlation coefficient (ICC (2,1); Shrout & Fleiss, 1979). The results indicated good reliability for individual test item scores, with ICCs between test and retest scores ranging from 0.985 to 0.992 (Sigmundsson et al., 2017).

Based on a questionnaire to teachers involved in the project, a common understanding about when a child *has broken the reading code* was established. "... a child *has broken the reading code* when it is able to read short one- and two-syllable words, in uppercase letters, with slow, almost hesitant decoding (close to fluent decoding). These words are without accumulation of consonants. Each child had a test sheet for the three test points, one for the uppercase and one for the lowercase letters. In addition, each teacher had sheets with one- and two-syllable words in uppercase letters and lowercase letters together with shorter sentences to test whether children had 'broken the reading code'. The approximate time (week of the year) at which each child was first observed to read short words was recorded on the test sheet by the teacher and taken as the operationalization of "breaking the reading code". Although a useful measure of reading ability at the behavioral level, the time-point measurement does not imply that learning to read entails a sudden insight or an abrupt reorganization of a child's cognitive resources. Whether learning to read occurs in stages (e.g. Gough & Hillinger, 1980) or proceeds by incremental acquisition of experiences giving rise to stage-like changes in behavior (e.g. McClelland, 1995), beginning to read short words is an observable behavior indicating progress towards reading proficiency.

3.2. Procedure

Full ethical review and approval was not required for this study in accordance with the national and institutional guidelines. However, the study was carried out in accordance with the recommendations of the Norwegian Centre for Research data and the Declaration of Helsinki.

Permission for data collection was obtained following a presentation of the project at a meeting for school leaders in the region, and principals of all participating schools were informed about the project. Prior to the data collection, information about the nature of the study was given in verbal form to the children and both in written and verbal form to their parents. Written informed consent was obtained from the parents of all participants prior to the study commencement. The participants were given an opportunity to withdraw from the test without providing the

reason. Identification numbers were used to maintain data confidentiality.

The assessment took place in a quiet room during normal school hours and was conducted in accordance with the LSK manual. All participants were tested individually by teachers that had been trained in the test protocol. Each child answered the test at three time points throughout the year: early in the school year (September), in the middle of the school year (January) and late in the school year (June).

Each test item was explained and demonstrated before the participants started.

3.3. Data analysis

For the statistical analysis, Matlab 2017b for Windows was used (Mathworks, USA). As several score distributions were non-normal, data was summarized using median and interquartile range (25th and 75th percentile) unless otherwise stated. From the letter scores at each of three time points, the letter score at the recorded time of breaking the reading code was estimated using linear interpolation for each child. Linear interpolation was performed using Matlab's interp1 function. Logistic regression was performed using Matlab's glmfit function with the logit link function. The non-parametric Wilcoxon rank sum test (equivalent to Mann Whitney U test) was used to test for significant differences between group medians.

The frequency of letters was computed from a list of the 10 000 most frequent Norwegian words based on 14.6 million words from Norwegian novels and newspapers collected by the project Aksis: Norwegian text archive (Aksis, 1998).

3.4. Results

To gain a deeper understanding of the importance of letter knowledge for the ability to read, we started by examining the time at which children were first reported to read. 11% of the children already knew how to read before entering school, whereas 27% of the children had still not broken the reading code at the end of the first year in school. The remaining 62% of children learned to read during the first year of school (Fig. 1A). The latter group typically broke the reading code at the beginning of the second semester, about half a year after starting school in August (5.8 ± 2.5 months; mean \pm standard deviation).

The proportion of girls and boys that learned to read during the first year in school was similar but slightly higher for girls (64% of girls vs 61% of boys). However, a larger proportion of girls than boys knew how to read at school entry (15% of girls vs 7% of boys). Consequently, a

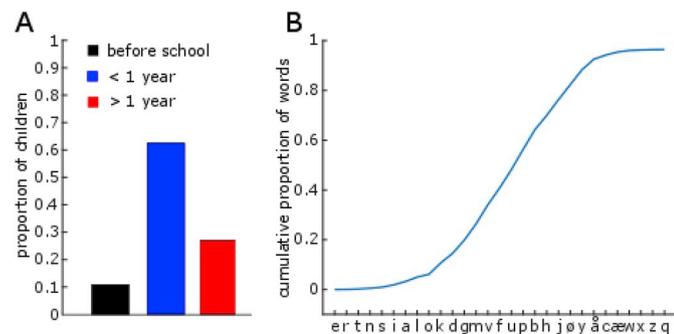


Fig. 1. A: Proportion of children who could read before starting school (black; 11%), children who learned to read during the first year in school (blue; 62%), and children who still could not read by the end of the first year in school (red; 27%). B: Cumulative proportion of Norwegian words that consist of the letters up to and including the letters on the x axis. Letters on the x axis are ordered according to their rate of occurrence in the 10 000 most frequent Norwegian words. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

larger proportion of boys than girls still did not read after one year (21% of girls vs 32% of boys).

3.5. Breaking the reading code

How many letter names and sounds do children typically know when they break the reading code?

For the group that learned to read during the first year in school (N = 203), we estimated the four different letter scores for each child at the time of breaking the reading code from linear interpolation using letter scores recorded at the three test times (September, January, June).

When they were able to fluently decode one- and two-syllable words for the first time, most children already had knowledge of 21 or more uppercase letter sounds (Table 1), which in principle is sufficient to read well above 80% of the most frequent Norwegian words (Fig. 1B).

Less than 5% of the children broke the reading code with scores lower than 11 uppercase letter sounds and less than 25% of the children broke the reading code with scores lower than 18 uppercase letter sounds (Fig. 2A). These scores are sufficient to read about 1500 and 6000 of the most frequent Norwegian words respectively (Fig. 1B).

Although the reading test was administered using uppercase letter words, uppercase letter score was highly correlated with lowercase letter score ($r = 0.82$; $p < 0.001$). Children scored significantly less on lowercase letters than uppercase letters when they learned to read and significantly less on sounds than names. There was no significant gender difference in letter scores at the time of breaking the reading code (Table 2).

3.6. Association between letter knowledge and being able to read

To understand how strongly letter knowledge was associated with the binary measure of whether a child could read or not, we performed a logistic regression analysis on the entire sample of children (N = 356) at all three time points, for a total of 1068 samples. The probability that a child could read significantly increased with the uppercase letter sound score ($t = 16$; $p < 0.0001$; $df = 1050$), and more accurately classified children into readers and non-readers than age or time in school. Similar results were obtained for letter names (Table 3).

However, knowing a large number of letter sounds was not sufficient for being able to read. 40% of children knowing 23 uppercase letter sounds, and 15% of children knowing all 29 uppercase letter sounds still could not read (Fig. 3A). The corresponding numbers for lowercase letter sounds were 20% and 5% respectively.

What discerns children who break the reading code from those who do not? An analysis of the 27% of children who still could not read after one year in school showed that as a group they knew fewer letters than the others already at school entry. However, at the end of the first year, this group's distribution of scores for uppercase letter sounds ranged from 4 to 29 and was close to uniform (Fig. 3B), indicating both a) that many children did not learn to read despite having acquired an adequate number of letter sounds, and b) that a group of children learned very few letters during the first year in school.

Taken together, these results affirm that A. letter knowledge is associated with, and a good predictor of, reading ability also in the Norwegian context, and B. reading words does not follow automatically

Table 1
Descriptive Statistics of Letter Knowledge at the Time of Breaking the Reading Code for Children who Learned to Read During the First Year in School.

Letter score	Median	Inter-quartile range	Mean	Std	N
Uppercase letter sounds	21	18–26	21	5.4	199
Lowercase letter sounds	15	11–20	16	5.8	171
Uppercase letter names	24	20–27	23	4.7	203
Lowercase letter names	17	12–21	17	5.8	172
Average letter score	20	16–24	19	5.1	203

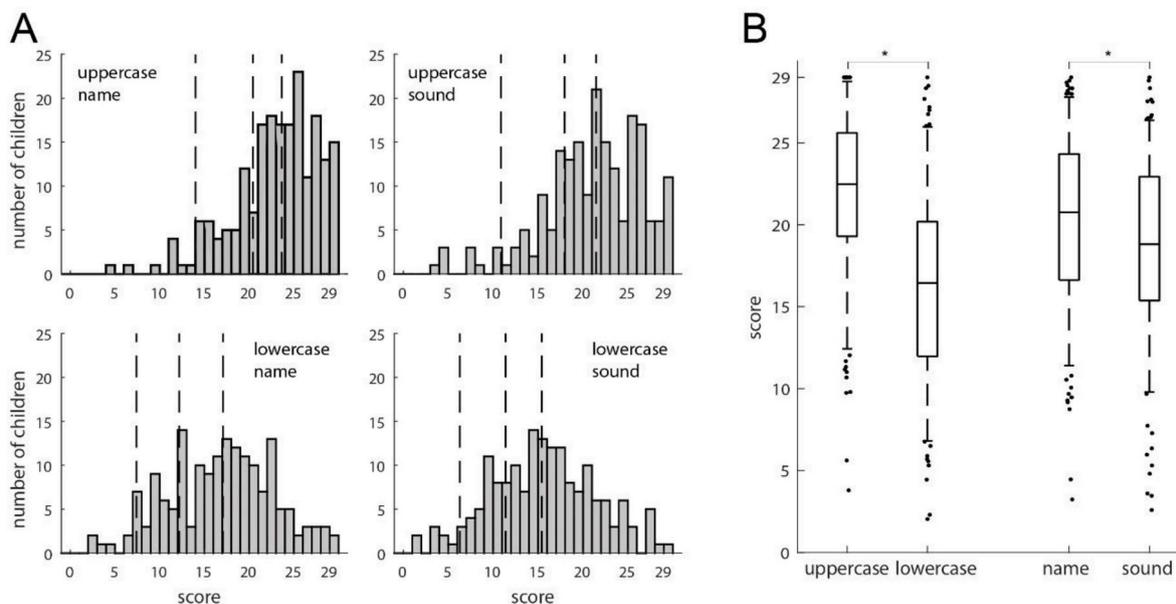


Fig. 2. Letter scores at the time of breaking the reading code. A: Distribution of estimated scores for uppercase letter names (upper left), uppercase letter sounds (upper right), lowercase letter names (lower left), and lowercase letter sounds (lower right) at the time of breaking the reading code for children who learned to read during the first year in school. 5th, 25th and 50th percentiles are indicated with striped lines. B: Children knew significantly more uppercase letters than lowercase letters (averaged over letter name and letter sound scores) and significantly more letter names than letter sounds (averaged over big and lowercase letter scores) at the time of breaking the reading code. Boxplots show median of data values (line in box), 25th and 75th percentile (box boundaries), 5th and 95th percentiles (whiskers), and outliers (jittered dots). * denotes significance at the 0.01 level. See text for details.

Table 2
Comparative statistics of letter knowledge at the time of breaking the reading code.

Comparison	Difference of medians	Significance
Uppercase – lowercase	6	$p < 0.001$
Name – sound	2	$p < 0.01$
Girl – boy		
Uppercase sound	0.4	$p = 0.42$
Average of letter scores	0.5	$p = 0.96$

Table 3
Classification of children into reader or non-reader with logistic regression.

Predictor	Correctly classified	Decision boundary
Uppercase letter sounds	85%	22 letters
Lowercase letter sounds	85%	17 letters
Uppercase letter names	84%	23 letters
Lowercase letter names	85%	18 letters
Time in school	72%	6.7 months
Age	69%	6.8 years

from knowledge of the Norwegian letter-sound correspondences. The ability to pull letter sounds together into words is an additional skill that requires phonetic awareness as well as deliberate practice to develop (e. g. Castles, Rastle, & Nation, 2018; Foulin, 2005; Rayner, Foorman, Perfetti, Oesetsky, & Seidenberg, 2001).

4. Discussion

In this study we examined when a sample of 356 Norwegian children broke the reading code and how this event was related to their knowledge of letter names and letter sounds.

4.1. Reading development during the first year in school

We found that 11% of the children had already acquired reading skills before entering school, suggesting that they had received sufficient deliberate practice and experience related to reading (Walgermo, Foldnes, Upstad, & Solheim, 2018b; Solheim et al., 2018; Castles et al., 2018; Nation, 2019). At the other end of the spectrum, 27% of the children, the majority of which were boys, did not learn to read during the first year in school (Fig. 1A). Walgermo et al. (2018a, b) argue that both literacy interest and reader self-concept are important for student’s learning and reading development. Considering that 5–10% of the population is commonly estimated to have some form of dyslexia or visual processing disabilities (Rodgers, 1983; Shaywitz, Fletcher, Holahan, & Shaywitz, 1992; Stein & Walsh, 1997), up to about a fifth of children may have lacked the necessary practice or motivation to develop reading skills during the first year in school.

4.2. Breaking the reading code

In this study we found that letter knowledge was highly predictive of whether a child had broken the reading code or not also in the Norwegian context. Most children knew at least 21 letter sounds, close to the full set of letters needed to read most of Norwegian text, before they started to read. In a study by Piasta et al. (2012), benchmarks of 18 uppercase and 15 lowercase letters identified in preschoolers (3–4 years old) were associated with successful literacy outcomes in first grade (5–6 years old). These results lend support to a large body of research advocating the importance of letter-sound knowledge for breaking the reading code and developing reading competency. Existing research has shown that children benefit from reading instruction when connections between phonemes and graphemes are taught explicitly (National Institute of Child Health and Human Development, 2000; Sunde et al., 2019). McBride-Chang (1999) argues that tasks like letter-sound identification, which required both letter recognition and sound isolation, may be the most optimal predictors of early reading success (p. 304). Dehaene (2011) claims that ‘teaching of grapheme-phoneme

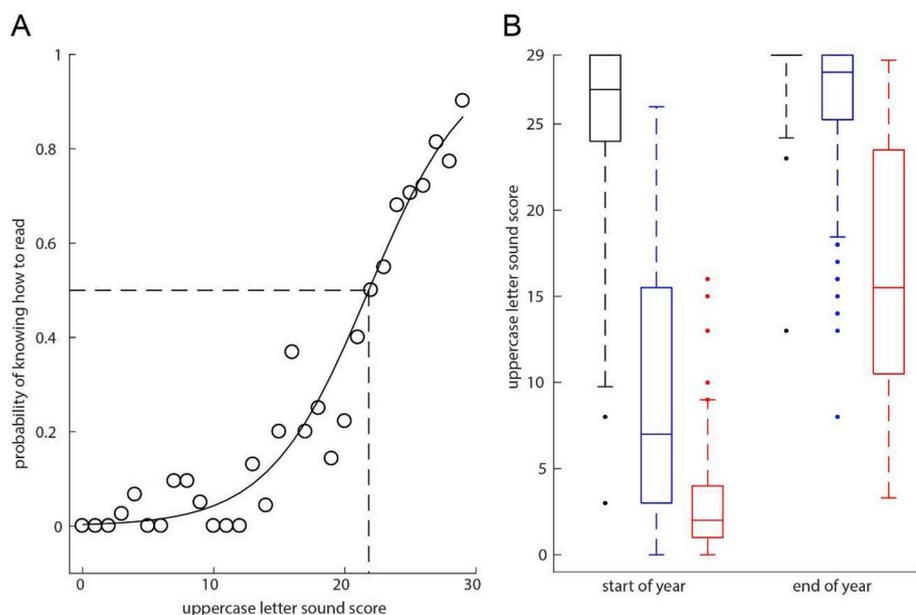


Fig. 3. A: Probability that a child could read as a function of the child's uppercase letter sound score based on logistic regression. Dotted line marks the threshold for predicting that a child can read based only on the child's uppercase letter sound score. For full letter knowledge (uppercase letter sound score = 29) the probability that a child could read was about 0.85. B: Comparison of uppercase letter sound score for groups of children based on when they learned to read (corresponding to Fig. 1A). Boxplots as in Fig. 2B. *Black*: Children who already knew how to read when they started school. *Blue*: Children who learned to read during the first year in school. *Red*: Children who did not learn to read during the first year in school. Note the wide range of scores of the latter group. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

correspondences is the fastest, most efficient way of making children efficient readers' (p.23). Ehri et al. (2001, p. 393) concluded after their meta-analysis that systematic phonics instruction should be implemented as part of the literacy program to teach beginning reading as well as to prevent and remediate reading difficulties.

The number of letter names and letter sounds were equally predictive of reading ability, consistent with the recent resurgence in research acknowledging the directly facilitating effect that learning letter names can have on reading proficiency knowledge (Foulin, 2005; Roberts, Vadasy, & Sanders, 2018). Indeed, some children in our study could read one- and two-syllable words with knowledge of only half the number of letters of the most typical child, suggesting that breaking the reading code is achievable with less letter knowledge than what is commonly the case. Correspondingly, we observed that even children who knew all the letter sounds did not necessarily read words, pointing to the importance of a third factor for reading ability. Although orthographically more transparent than English, Norwegian phonemes do not map directly to single letters. Reading ability depends on the co-development of letter knowledge, alphabetic decoding and phonetic awareness, including the non-trivial segmentation and association of continuous speech to phonemes (e.g. Castles et al., 2018). Practicing spelling, and decoding through reading carefully designed text ("decodable readers"; Treiman & Kessler, 2014) might promote the acquisition of additional letter sounds and accelerate reading ability. Investigating the effect of practicing reading at an earlier stage of letter knowledge has been pointed out as a worthwhile avenue for future research (Castles et al., 2018).

5. Conclusion

Based on the association between letter-sound knowledge and reading skill, it seems reasonable to advocate learning letters and their sounds early on in the first year of school, to ensure that children have equal opportunity to learn how to read (Nation, 2019). In a practical setting this could mean that all children should be measured on letter knowledge when they start school. Children who have broken the reading code should be given the right challenges for their skill/action capacity to further promote their literacy (Csikszentmihalyi, 2008). For those who have yet to break the reading code, effort should be put into acquiring enough letter-sound knowledge to start practicing decoding words (Hatcher, Hulme, & Ellis, 1994). As reading is the key to other keys in the educational systems, these should be prioritized tasks in the

first 1–2 years of school (Solheim et al., 2018).

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.newideapsych.2019.100756>.

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