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Evidence for Assembled Phonology in Beginning and Fluent Readers as Assessed with the First-Letter-Naming Task

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This study was aimed at clarifying word recognition in beginning (88 months) and fluent readers (university students). The major goal was to investigate the differences and similarities in word recognition of the two groups by using the first-letter-naming task as employed by Rossmeissl and Theios (1982). In three experiments, the factors affecting performance in this task were determined. Pronounceability appears to be the most important factor operative in the first-letter-naming task. The data also suggest that the effects obtained are due to response competition. Furthermore, the data indicate that the similarities in word recognition by fluent and beginning readers far surpass the differences and, more importantly, that word recognition of both fluent and beginning readers is mediated by phonology.

This study aims at clarifying the differences and similarities of word recognition in beginning and fluent readers. More specifically, the issue under investigation is whether or not there is a developmental shift to an expert way of reading that is different from the reading by novices.

The theoretical starting point is the "dual-route" model (Coltheart, 1978). The core of this model is the assumption that fluent readers have two independent routes at their disposal to read words. Via the "nonlexical" route, a word is read by means of discrete grapheme–phoneme correspondence rules, and only by activating the phonology of the stimulus can word recognition come about. This process is also called "phonologic

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mediation" or "assembled phonology." It is assumed that this nonlexical way of reading in an alphabetic writing system is used by beginning readers, when they learn to read, or by fluent readers who come across infrequent words (Seidenberg, Waters, Barnes, & Tanenhaus, 1984). The primary process in fluent readers is the lexical route, in which a direct match is established between the written word and its mental representation, caused by frequent confrontation with the word.

Adherents of the dual-route model state that the lexical route is a prerequisite if one is to read irregular (exception) words. The dual-route model dominated the eighties and survived a proposal for a purely lexical alternative suggested by Humphreys and Evett (1985). Recent publications (e.g., Lukatela & Turvey, 1990; Perfetti & Bell, 1991; Van Orden, 1987, 1991; Van Orden, Pennington, & Stone, 1990), however, have made the pendulum swing back (see Morton, 1985, p. 718). These studies appear to prove that even the most fluent readers read exclusively by phonologic mediation. A critical examination of the major assumptions of the dual-route model can be found in Van Orden, Pennington, and Stone (1990).

In this study we made use of the first-letter task to gain further insight into the word recognition processes of beginning and fluent readers. The first-letter task was developed by Rossmeissl and Theios (1982) and is a variant of the Reicher–Wheeler paradigm. The relevance of this paradigm for research in word recognition will become clear later.

In 1969, Reicher published his famous article on the "word superiority effect" (see also Wheeler, 1970). Letters and letter strings were presented tachistoscopically (35–85 ms) and were followed by a patterned mask. Subjects then had to identify a letter that had been presented in isolation or one that had appeared in the preceding letter string on a prespecified position. Identification of a letter was more accurate when it had been part of a word than when it had appeared in isolation or in an orthographically illegal letter string. This result was interpreted as evidence for parallel processing of letters in words. The word superiority effect has not only been established in adult fluent readers, but also in beginning readers as young as 98 months (Chase & Tallal, 1990).

In the first-letter task, Rossmeissl and Theios (1982) presented adult subjects with three types of stimuli: words, orthographically legal nonwords, and orthographically illegal nonwords (unpronounceable letter strings, which they called anagrams). The task for the subjects was to name the first letter of the stimuli. They reasoned that if letters in words are processed in parallel and if the orthographic context provides an independent source of information, then the identification of the first letter should be facilitated by a legal letter string (words and legal nonwords), but not by an illegal one. This hypothesis was confirmed by their data. First-letter naming of words (550 ms) and legal nonwords (553 ms) was significantly faster than that of illegal nonwords (562 ms). They regarded this as further evidence for a direct access model of word recognition. A model in which letters are processed serially from left to right (the assumption of the phonologic mediation route) would not have predicted an effect of orthographic legality. Thus, the effects found in the first-letter paradigm seem to suggest that words can also be identified without the use of grapheme–phoneme correspondence rules or, stated more explicitly, that fluent readers recognize words lexically.

The first-letter paradigm is very suitable for experiments with beginning readers, because it requires a response that young children find easy. If beginning reading is characterized by a serial process of grapheme–phoneme conversion (see above), then young children should not show the effect established by Rossmeissl and Theios (1982), because the orthographic context can only exert an influence when letters are processed in parallel. Experiment 1 is a replication and extension of the Rossmeissl and Theios (1982) first-letter experiment. Not only beginners but also fluent readers served as subjects. (The rationale for Experiments 2 and 3 is clarified following the presentation of Experiment 1.)

Because the experiments reported here were conducted in The Netherlands, a few remarks on Dutch orthography and reading-instruction methods are required. The Dutch orthography is neither as deep (a low correspondence between spelling and sound) as the English, nor as shallow (a high correspondence between spelling and sound) as the Serbo-Croatian. The most widely used reading curriculum (Veilig Leren Lezen, which translates into Learning to Read Safely; Caesar, 1979) stresses the importance of phonics instruction. Pure whole-word methods (Rayner & Pollatsek, 1989, pp. 348–356) have been used in the past, but were abandoned over 20 years ago because of unsuccessful results. Children in Grade 1 are taught the grapheme–phoneme correspondence rules and are confronted solely with regular words. After about 4 months of regular reading instruction most children can read all regular Dutch words by systematically applying the grapheme–phoneme correspondence rules.

The beginning readers who participated in this study were all instructed according to the same reading curriculum (Veilig Leren Lezen; Caesar, 1979), which has a rather rigid preprogrammed plan. Assessing the reading and spelling level of all children, who attended different schools, could therefore be reliably executed. All children were first graders who were tested on reading decoding, spelling, and verbal and non-verbal intelligence 6 months after formal reading instruction had started. Potential differences between groups could thus be tested on a number of variables. The experiments were executed after all children had had 8 months of formal reading instruction. All subjects (both the beginning and fluent readers) had Dutch as their mother tongue. None of the children suffered from obvious learning disorders, and they are all representative of the average Dutch child, attending regular schools.

EXPERIMENT 1

The main question of Experiment 1 was whether first-letter naming in beginning readers is also, as in fluent readers, facilitated by an orthographically legal context. Therefore both reader groups participated. The experiment aims at replicating and extending the results of Rossmeissl and Theios (1982). In the study of Rossmeissl and Theios, subjects were asked to specify the first letter of a string with its letter name. In our Experiment 1 (and also in Experiment 3) half of the adult subjects were asked to use the letter name to specify the first letter and the other half were asked to use the phoneme. The group of beginning readers all used phonemes to respond. This procedure was followed to justify both the comparison between the adult subject group of Rossmeissl and Theios and our adult group (letter naming) and the comparison between our beginning and fluent readers (phoneme naming). The procedure to have the beginning readers respond with letter names as well was considered undesirable, because, totally unfamiliar with this task, they could be expected to experience great difficulty with it. In contrast, phoneme naming, a very familiar task for Dutch first graders, is a rather unfamiliar task for fluent readers. Yet, they may be expected to manage this task.

Method

Materials. The total set of 72 stimuli consisted of 24 words, 24 legal nonwords, and 24 illegal nonwords. The word stimuli were taken from the first three instruction books of the children's reading course (Veilig Leren Lezen; Caesar, 1979). All word stimuli contained four letters and had a CV_1V_2C structure. The word stimuli served as the starting point for the construction of the nonword stimuli. By reordering the letters or introducing new letters and deleting old, but maintaining the initial one, legal nonwords (pronounceable and orthographically legal letter strings) and illegal nonwords (unpronounceable and orthographically illegal letter strings) were constructed. Appendix A shows the complete set of stimuli.

Procedure. The experiment was run on a Macintosh Classic computer. Subjects were told that stimuli would appear on the screen and that they had to name the first letter of each word and ignore the word they were part of. Beginning readers used the phoneme to specify the initial grapheme. Half of the group of adult subjects was instructed to use the letter name to specify their response (as in Rossmeissl & Theios, 1982), and the other half used phonemes to indicate their response, as the children did. Naming times were registered with a voice key and a millisecond timer. Each response was evaluated on correctness by the experimenter by pressing a key on the computer keyboard. Before the experimental session started, every subject received 10 practice trials.

Subjects. Both beginning and fluent readers served as subjects. From a population of 246 children in Grade 1 (mean score on a reading-decoding test was 29.7, $SD = 10.9$, Eén-minuut-test, Caesar, 1975), a group of 28 children (mean age 88 months, $SD = 3.9$; 11 boys and 17 girls) with a slightly above average score on the reading test (mean: 35, $SD = 9.2$) was selected. The experiment was run after 8 months of formal reading instruction. The group of fluent readers ($N = 40$) was recruited from the undergraduate population of the Department of Psychology at the University of Amsterdam.

Results

The results of the beginning and fluent readers were analyzed separately but are discussed simultaneously. We are aware that normally data from both reading groups should be analyzed together, but the variance in the data of the beginning readers is relatively large (a well-known problem) compared to that of the fluent ones. Consequently, the manipulations resulted in significant effects for the fluent readers only when their data were analyzed separately.

Before the data were analyzed, responses were removed from the data set for the following reasons: naming errors (children, .9%; adults, .7%), errors due to voice-key failure (children, 3.9%; adults, 1.7%), extremely long responses (more than 3 *SD* above the mean; children, 1.5%; adults, .9%), and extremely short responses (less than 100 ms; children, 0%; adults, .2%).

Beginning readers. Subject and item means were calculated for the three types of stimuli, and these means were the input for the statistical analyses.[1] A one-way analysis of variance (stimulus type: words vs legal nonwords vs illegal nonwords) on both subject and item means (F_1 and F_2, respectively) of the beginning readers revealed significant effects ($F_1(2, 54) = 15.70$, $p < .001$; $F_2(2, 69) = 7.04$, $p < .01$). A post-hoc analysis (Newman–Keuls) on the subject data showed a significant difference between words and legal nonwords and between words and illegal nonwords ($p < .01$ in both cases), but not between legal and illegal nonwords. A separate analysis on the legal vs illegal nonwords showed a significant difference on the subject, but not on the item analysis ($F_1(1, 27) = 4.37$,

[1] After Clark's (1973) seminal article on the use of the proper F test in psycholinguistics, researchers started to report *min* F', which enabled them to generalize beyond the materials used. This test treats both the subjects and the items as random effects in one and the same analysis. Shortly after Clark's publication, Wike and Church (1976) criticized the *min* F' test, because of being too conservative and therefore occasionally leading to Type II errors. As a consequence, researchers started to report both F_1 (subject analysis) and F_2 (item analysis) separately. The input for the item analysis are the computed item means collapsed over subjects, whereas in the subject analysis the subject means are computed by collapsing over items. In F_1 subjects are treated as a random and items as a fixed effect, whereas in F_2 items are the random factor and the subject factor is assumed to be fixed.

TABLE 1
MEAN FIRST-LETTER-NAMING LATENCIES IN MS FOR BEGINNING AND FLUENT READERS IN EXPERIMENT 1

	Response type		
	Beginning readers	Fluent readers	
Stimulus type	Phoneme	Letter	Phoneme
Words	756 (134)	465 (31)	508 (64)
Legal nonwords	790 (109)	469 (30)	518 (76)
Illegal nonwords	808 (123)	475 (29)	527 (75)

Note. SD in parentheses.

$p < .05$; F_2, $p > .25$). The subject means for the three stimulus types are presented in Table 1.

Fluent readers. A 2 (response type: letter vs phoneme) by 3 (stimulus type: words vs legal nonwords vs illegal nonwords) analysis of variance on the data of the fluent readers (see Table 1) revealed significant main effects on both the subject and item analysis. The main effect of response type indicated that responding with the letter was faster (469 ms, SD = 29) than with the phoneme (518 ms, SD = 71), $F_1(1, 38) = 7.91$, $p < .01$; $F_2(1, 69) = 263.41$, $p < .001$. The F values for the main effect of stimulus type were: $F_1(2, 76) = 12.18$, $p < .001$, and $F_2(2, 69) = 2.98$, $.05 < p < .10$. The interaction between stimulus type and response type was not significant ($F < 1$, in both subject and item analyses). The six interaction means are shown in Table 1.

Further investigation of the effect of stimulus type (a post-hoc Newman–Keuls analysis) showed that all conditions were significantly different from each other. The difference between words (487 ms, SD = 55) and legal nonwords (493 ms, SD = 62) was significant at the 5% level; the differences between words and illegal nonwords (501 ms, SD = 62) and between legal and illegal nonwords was significant at the 1% level.

A separate analysis (stimulus type: words vs legal nonwords vs illegal nonwords) on the data of the subjects in the letter response condition (to compare the results with those of Rossmeissl & Theios, 1982) showed that in this group the difference between words and legal nonwords did not reach significance. Adding the data from the subjects in the phoneme response condition increased the power of the test thus leading to a significant difference on this comparison.

Discussion

The results of the Dutch fluent readers in the letter response condition of Experiment 1 (see Table 1) replicate those of the English subjects of

Rossmeissl and Theios (1982). Naming the first letter was faster when it was part of a legal letter string (words or nonwords) than when part of an illegal nonword. The differences between conditions were almost exactly the same as the corresponding differences in Rossmeissl and Theios' study. The latency difference between illegal and legal nonwords was 6 ms, between illegal nonwords and words it was 10 ms, and between legal nonwords and words it was a nonsignificant 4 ms. The comparable data from Rossmeissl and Theios were, respectively, 9, 12, and 3 ms. What is peculiar, though, is the fact that the Dutch subjects were on average 85 ms faster than the English subjects. The reason for this cannot have been the amount of practice, because that should have favored the English subjects. They received 1008 trials, whereas the Dutch subjects only got 72.

The results of the total group of fluent readers, however, presented a slightly different picture. It is clear that the group who had to respond with the letter name was faster than the group that had to specify the phoneme, presumably because the latter group had to give a rather unfamiliar response. The overall data pattern shows that naming the first letter or phoneme of words is faster than of both legal and illegal nonwords, and that legal nonwords are processed faster than illegal nonwords.

That performance on legal nonwords is not statistically different from that on words in the letter condition (replicating the results of Rossmeissl & Theios, 1982), but worse in the phoneme condition might be due to a ceiling effect in the former situation. We believe that the difference between processing words and legal nonwords is real, but hard to detect in the first-letter-naming task. This assumption is not only corroborated empirically in a naming task by McCann and Besner (1987) but is also explicitly stated in most word-recognition models, for instance in Paap, Newsome, McDonald, and Schvaneveldt's activation-verification model (1982); Seidenberg and McClelland's PDP model (1989); and Van Orden, Pennington, and Stone's subsymbolic approach to word recognition (1990). The latent, but statistically unreliable, difference between legal nonwords and words became manifest in the more difficult phoneme condition.

The results of the beginning readers mimicked those of the total group of fluent readers. Naming the first letter of a word was clearly easier than that of legal and illegal nonwords. Furthermore, on the additional analysis it was shown that naming the first letter of legal nonwords was faster than that of illegal nonwords. It thus seems that the similarities between these groups of beginning and fluent readers surpass the differences. The most important difference between the data patterns of both groups concerns their overall latencies: beginning readers take almost 60% more time to come up with the response than fluent readers (785 and 494 ms, respectively).

From the above it seems safe to conclude that after 8 months of formal reading instruction, Dutch beginning readers have developed a process of word recognition that is rather similar to that of experienced readers. In both reader groups naming the first letter was facilitated when it was presented in an orthographically legal letter string. Furthermore, for both groups facilitation was stronger in a word context than in a legal nonword context. It is important to note that the similarity of the word-recognition processes of fluent and beginning readers is limited to the set of words the beginners have been exposed to. It would be unjustified to generalize the results to word recognition in general. If the orthographic-context interpretation of Rossmeissl and Theios (1982) holds, then these results suggest that beginning Dutch readers fairly quickly develop the skill to recognize words via the lexical route.

However, although the interpretation of Rossmeissl and Theios (1982) sounds plausible, there is an alternative explanation for their results (and, for that matter, for ours). Their interpretation points out identification as the locus of the effect, but it is also possible that the results reflect an effect of response competition.

When a literate subject is confronted with a rather familiar stimulus like a word, and, as we will assume, also with an unfamiliar letter string, he or she cannot avoid reading it. In the first-letter paradigm, however, the subject is not asked to read the stimulus, but to ignore it and to name its first letter. If it is indeed impossible to avoid processing the entire stimulus (in other words, this process is enacted automatically), it is plausible that naming the first letter is in fact hindered when it is part of a letter string. One additional assumption is needed for this explanation to apply to the data, namely that this processing has to come to an end before a subject can execute the required response. If indeed this process occurs automatically, this assumption is plausible.

This conception of mental processing in the first-letter task provides an alternative explanation of why subjects are faster in naming the first letter of a word than of an illegal nonword: automatic processing of a word terminates faster than the processing of an illegal nonword. Consequently, naming the first letter of a word can be accomplished faster than of an illegal nonword. Note that a "horse-race" model (Coltheart, 1978) would not necessarily predict more interference from an illegal letter string (but cf. Paap & Noel, 1991). In terms of that model, both processes, the one involving the entire stimulus and the one forced on by the task, are started simultaneously, but the letter-naming process does not have to await the outcome of processing the whole stimulus to produce a response. In case the processes proceed independently and the first-letter naming process terminates first, no interference from the "secondary" process has to be expected. In contrast to this view, we suggest that the subject *does* finish processing the whole stimulus prior to attending to the required response.

Two arguments support this response-competition interpretation, one anecdotal and one empirical. Both adults and children responded occasionally with the complete stimulus instead of the letter. After completion of Experiment 1 all adult subjects and some beginning readers reported that they could read the stimuli. The children seemed reluctant to admit this, because the experimenter had clearly indicated prior to the experiment that they were not supposed to read them. Reicher's subjects also reported that they sometimes were able to pronounce a nonword or turn a nonword into a word (1969, p. 279).

The empirical argument is based on experiments executed with fluent and beginning readers. In these experiments, beginning and fluent readers had to perform the same first-letter task as used here. However, in this case subjects were confronted not only with words and nonwords but also with single letters. Both the beginning and fluent readers were significantly and substantially faster naming a single letter than naming any other kind of stimulus, including words.[2]

According to the response-competition interpretation, naming a single letter should be faster than naming the first letter of any kind of letter string, because in the former case there is no response competition. The orthographic-context explanation (Rossmeissl & Theios, 1982), however, predicts *longer* naming times for single letters than for letters in words, because single letters lack a facilitating context. In other words, the single-letter effect does not support the identification interpretation of Rossmeissl and Theios (1982).

Rossmeissl and Theios (1982) explained the first-letter effect in terms of a facilitation mechanism (as we did before introducing the response-competition account). Although there is no explicit mentioning of the word "facilitation," it is clearly implied: ". . . it is assumed that orthographic knowledge provides an independent source of information helping to identify each of the letters . . ." (p. 448). Their experiment, however, does not really permit an interpretation in terms of facilitation because there was no neutral condition from which the direction of the effects

[2] A first-letter experiment was run with two groups of beginning readers (Grade 1: good and medium readers) drawn from a population similar to the one used in the experiments reported here. Stimuli used in the experiment were letters, words, pronounceable nonwords (legal and illegal), and unpronounceable nonwords. The main effect of stimulus type was significant, $F(3, 111) = 94.81$, $p < .001$. For both groups of readers naming an isolated letter (842 ms) was significantly faster than naming the first letter of any other stimulus type. The isolated-letter condition was in fact as much as 183 ms faster than the fastest letter-string condition. A similar experiment was executed with fluent readers. Stimuli in this condition were letters, words, pseudohomophones, and illegal unpronounceable nonwords. Again the main effect of stimulus type was significant, $F(3, 57) = 32.11$, $p < .001$. Naming an isolated letter (508 ms) was significantly faster than naming the first letter of any other stimulus type. The isolated-letter condition was 30 ms faster than the fastest letter-string condition.

could be assessed. The first-letter effect could thus just as well be explained in terms of less inhibition in the case of words and legal nonwords as compared to illegal nonwords. It is plausible that the single-letter condition (see Footnote 2) is the neutral condition from which the effects should be assessed. Because it was the fastest condition, the conclusion seems warranted that in all other conditions responding is inhibited.

If the first-letter effect is indeed caused by a process of response competition, the interpretation of the effect in terms of lexical word recognition should be re-evaluated. The suggestion of Rossmeissl and Theios that the first-letter effect is evidence for lexical reading can only be valid if the locus of the effect is in the identification process. If, on the other hand, the response-competition hypothesis holds, then Rossmeissl and Theios' data are not conclusive with respect to the issue of how word reading comes about.

To summarize so far, we began this investigation from the assumption that the first-letter effect might evidence lexical reading. We then argued that the common view that beginning readers typically read via a serial process of phonologic mediation would thus predict the absence of a first-letter effect for this reader group. In contrast, our data showed that beginning readers behaved similarly to fluent readers in this task. But instead of drawing the conclusion that these data show that both beginning and fluent readers read via the direct lexical route, we subsequently offered an alternative hypothesis, namely, that a process of response competition could be responsible for the effects in both reader groups. Ultimately then, the data may be quite compatible with the view that reading in both beginning and fluent readers is phonologically mediated.

In Experiments 2 and 3, the response-competition hypothesis was investigated further. In Experiment 2 we depart from the assumption that indeed response competition underlies the first-letter effect and focus on the nature of the competition process. More specifically, this experiment was aimed at revealing the variable or variables that cause the first-letter effect. Experiment 3 was designed to provide more direct evidence for the response-competition hypothesis. Along the way, support will be gathered for the view that assembling the phonology of letter strings is an imperative process whenever beginning and fluent readers encounter letter strings.

A major problem when trying to interpret the results of Rossmeissl and Theios (1982) and of Experiment 1 is that orthographic legality and pronounceability are generally confounded. Both Rossmeissl and Theios' and our orthographically legal letter strings were pronounceable, whereas the illegal ones were always unpronounceable. Later, it is shown that orthographic legality and pronounceability can be disentangled.

Careful inspection of the experimental materials suggests that the following four stimulus characteristics may be relevant for performance in

TABLE 2
RELEVANT FACTORS DETERMINING STIMULI USED IN EXPERIMENT 2

Example (Factor)	Stimulus type				
	Word zalf (salve)	Legal PSH zant (sand)	Illegal PSH zalv (salve)	Legal NW zulf	Illegal NW zfli
Lexicality	Yes	No	No	No	No
Orthographic legality	Yes	Yes	No	Yes	No
Phonologic lexicality	Yes	Yes	Yes	No	No
Pronounceability	Yes	Yes	Yes	Yes	No

Note. PSH, pseudohomophone; NW, nonword. Legal/illegal refers to orthographic legality.

the first-letter task: (1) *lexicality*: Is the letter string a word or not? (2) *orthographic legality*: Does the letter string obey orthographic rules? (3) *phonologic lexicality*: Does sounding out the letter string lead to a word? and (4) *pronounceability*: Is the letter string pronounceable? Orthographic legality correlates almost perfectly with pronounceability, but in the Dutch language it is possible to create orthographically illegal pseudohomophones that are yet pronounceable. Table 2 serves as the reference point for the description of the tests that can be executed to find out which of the above stimulus characteristics is (are) critical for performance in the first-letter task.

If the first-letter effect were due to lexicality, a significant difference should arise between naming the first letter of words and legal pseudohomophones. A test for orthographic legality involves the comparison of legal and illegal pseudohomophones. A test for phonologic lexicality compares legal pseudohomophones and legal nonwords. In the present design it is possible to test for pronounceability only when the test for phonologic lexicality and/or for orthographic legality fail. If phonologic lexicality turns out to be an irrelevant factor, the difference between illegal pseudohomophones and illegal nonwords is the proper test for pronounceability. If, on the other hand, the test for orthographic legality fails, the contrast of legal versus illegal nonwords is the appropriate one. To be able to test for pronounceability without having to rely on the negative outcome of any of the other factors would only have been possible if illegal pronounceable nonwords had been included in the materials.

EXPERIMENT 2

The main purpose of Experiment 2 was to establish whether the effects found by Rossmeissl and Theios (1982) and in our Experiment 1 are caused by the difference in orthographic legality or in pronounceability between the stimulus types used in those experiments, or perhaps by both. Experiment 2 was also aimed at testing the relevance of the factors lexicality and phonologic lexicality.

One remark on the procedure is in order. Prior to the experiment proper, the subjects were asked to read the word stimuli from which the legal and illegal pseudohomophones were derived three times to make sure that they were familiar with them at the onset of the experiment. Most of these words were relatively simple for this group of beginning readers, and the children may have seen them before, but they have not yet occurred in the reading curriculum so far. Earlier research (Bosman & de Groot, 1991; Reitsma, 1983; Reitsma & Vinke, 1986) indicates that only a few confrontations with a word are necessary to familiarize a beginning reader with this word. To check whether these "training" words had the same familiarity as well-known words (that *are* part of the reading curriculum), latencies on training words and well-known words were compared. In case of equal familiarity, these two stimulus types should show no significant difference on the first-letter task. The reason training words rather than well-known words were used to derive legal and illegal pseudohomophones from was that only the training words lent themselves for the construction of pseudohomophones of both types.

Method

Materials. A selection of 28 one-syllable words was made from a word list for children (Kohnstamm, Schaerlaekens, De Vries, Akkerhuis, & Froonincksx, 1981). All stimuli could be changed into pseudohomophones. In Dutch it is possible to construct pseudohomophones that are either orthographically legal (obeying Dutch orthographic rules) or illegal (violating Dutch orthographic rules). From these 28 selected training words, half were transformed into legal and the other half into illegal pseudohomophones (all pronounceable). The words also served as the starting point for the construction of nonwords. Half of the nonwords were orthographically legal and the other half were illegal (unpronounceable, also called anagrams). Finally, 14 well-known words were selected from the first three reading books of the regular curriculum of the children (see Materials section in Experiment 1). This led to six types of stimuli: 28 training words, 14 legal pseudohomophones, 14 illegal pseudohomophones, 14 legal nonwords, 14 illegal nonwords, and 14 well-known words (a total of 98). In every condition the letters b, d, f, g, h, k, l, m, n, p, r, s, v, and z served as the initial letter of one of the stimuli. The mean length of the stimuli in each condition was the same (4.4, $SD = .6$). Any emerging differences between conditions could thus not be due to differences across conditions in first letters or length. The stimuli used in Experiment 2 are listed in Appendix B. Two words appeared in the experiment that were removed later because their initial letter was a vowel, whereas the other ones were all consonants.

Procedure. The experiment consisted of two stages. In the first stage, beginning and fluent readers were asked to read the 28 training words 3 times in a random order, with the restriction that the same stimulus was never repeated without a different one interspersed. The experiment was run on a Macintosh Classic computer. Reading times were registered with a voice key and a millisecond timer and responses were evaluated by the experimenter.

Immediately after the training stage, the subjects took part in the first-letter task. Beginning readers responded by naming the first phoneme of every stimulus, and fluent readers by naming the letter name (details of the procedure and response evaluation are described in Experiment 1). Prior to both parts of the experiment, subjects received 10 practice trials.

Subjects. From a population of 241 children of Grade 1 a group of 20 children (7 boys and 13 girls; mean age: 89 months, $SD = 5.1$) was selected with a reading score that was above average (population mean: 28.8, $SD = 13.3$; sample mean: 46.6, $SD = 6.1$). The mean scores on two intelligence tests of the sample and the population were the same. The mean scores on a verbal intelligence test, assessed by a vocabulary test (RAKIT, Bleichrodt, Drenth, Zaal, & Resing, 1984), were 26.3 ($SD = 4.0$) for the population and 26.7 ($SD = 3.3$) for the sample, and on a non-verbal intelligence test (Standard Progressive Matrices, Raven, 1958) they were 24.5 ($SD = 10.1$) and 24.4 ($SD = 11.1$), respectively. The group of fluent readers ($N = 20$) was again recruited from the student population of undergraduates of the Department of Psychology at the University of Amsterdam. None of the subjects participating in Experiment 2 had been a subject in Experiment 1.

Results

Only the data of the main part of the experiment, the first-letter task, is reported because the training phase had only one purpose: to familiarize the subjects with a set of words, the "training" words. As in Experiment 1, the results of the beginning and fluent readers were analyzed separately but discussed simultaneously.

The data of the first-letter task were screened. As in Experiment 1, responses were removed for naming errors (children, 1.2%; adults, .15%), voice-key failure (children, 7.5%; adults, 3.4%), extremely long responses (more than 3 SD above the mean; children, 1.2%; adults, .7%), and extremely short responses (less than 100 ms; children, 0%; adults, 0%).

An analysis of variance with the factor stimulus type (training word vs legal pseudohomophone vs illegal pseudohomophone vs legal nonword vs illegal nonword vs well-known word) on the subject and item means revealed significant main effects on the subject analysis of both the be-

TABLE 3
MEAN FIRST-LETTER-NAMING LATENCIES IN MS FOR BEGINNING AND FLUENT READERS IN EXPERIMENT 2

Stimulus type	Beginning readers	Fluent readers
Training words	748 (134)	510 (51)
Well known words	750 (128)	515 (58)
Legal pseudohomophones	770 (157)	514 (51)
Legal nonwords	791 (160)	517 (56)
Illegal pseudohomophones	811 (132)	517 (56)
Illegal nonwords	880 (180)	532 (67)

Note. SD in parentheses.

ginning and fluent readers and a significant main effect on the item analysis of the beginning, but not on the one of the fluent readers: children, $F_1(5, 95) = 17.17$, $p < .001$ and $F_2(4, 65) = 9.93$, $p < .001$; adults, $F_1(5, 95) = 7.82$, $p < .001$, and $F_2 < 1$. The training condition was excluded from the item analysis, because the number of stimuli was twice as high as that in the other conditions.

Further analyses showed identical results on post-hoc analyses (Newman–Keuls) and planned contrasts. Only the results of the post hoc tests will be presented. All means are shown in Table 3. Beginning readers took significantly longer to name the first letter of an illegal nonword than that of any other stimulus ($p < .01$). Also, naming the first letter of an illegal pseudohomophone was significantly longer than for training words and well-known words and for legal pseudohomophones ($p < .01$). Fluent readers also named the first letter of an illegal nonword more slowly than that of any other stimulus ($p < .01$). For fluent readers no other differences between the stimulus types reached significance.

Discussion

Experiment 2 tested the potential relevance of four factors in the first-letter-naming paradigm, namely, lexicality, orthographic legality, phonologic lexicality, and pronounceability (see Table 2). It appeared that the variable lexicality was not an explanatory factor for either subject group, because there was no difference in first-letter naming times between words and legal pseudohomophones. The variable phonologic lexicality was not an explanatory factor in the beginning and fluent reader groups either, because the differences in naming times between legal pseudohomophones and legal nonwords were not significant. Only in the group of beginning readers did the factor orthographic legality appear to be of critical importance: in this group, but not in the adult group, naming the first letter of an orthographically illegal pseudohomophone was slower than of an orthographically legal one. The absence of the effect in the adult group suggests that with increasing fluency, the significance of the orthographic legality factor diminishes.

When comparing the data of the beginning readers of Experiments 1 and 2, a noteworthy aspect is that only in Experiment 1 did processing time for words and legal nonwords differ significantly, whereas these stimulus types did not differ reliably from each other in Experiment 2. This could have been caused by a general greater variability in Experiment 2. A post-hoc analysis of variance[3] on all conditions of Experiment 1 and the corresponding conditions of Experiment 2 of the group of beginning readers indeed shows that the difference between words and legal nonwords was now significant in the data sets of both experiments. This result replicates that of the total group of fluent readers in Experiment 1. In all subject groups, both groups of beginning readers of Experiments 1 and 2 and the fluent readers of Experiment 1, processing of words was faster than of legal nonwords, which in turn was faster than processing illegal nonwords.

If our assumption is correct that also for fluent readers processing of words is faster than of legal nonwords (see Discussion in Experiment 1), then it seems that a difference in processing words and legal nonwords is easier to detect with the first letter task in beginning readers than in fluent readers. We believe that differences between beginning and fluent readers mostly pertain to processing efficiency, that is, fluent readers process words and word-like stimuli faster than beginners, but not so much to differences in processing.

As can be seen when comparing Tables 1 and 3, latencies on words and legal nonwords in Experiments 1 and 2 are rather similar, whereas latencies on illegal nonwords are much longer in Experiment 2 than in Experiment 1. It is not clear why naming the first letter of illegal nonwords is particularly hard in Experiment 2. A suggestion is that the number of illegal nonwords in Experiment 1 (33.3%) was higher than in Experiment 2 (14.3%), causing the subjects to adopt different strategies in the two experiments.

[3] A 2 (experiment: 1 vs 2) by 3 (stimulus type: words vs legal nonwords vs illegal nonwords) analysis of variance on the subject means showed a significant effect of stimulus type, $F(2, 76) = 35.63$, $p < .001$ (the data of eight subjects from Experiment 1 were discarded to match the number of subjects in both experiments). All means differed significantly from each other (Newman–Keuls, $p < .01$). The main effect of experiment did not reach a significant level ($F < 1$). The interaction between experiment and stimulus type was also significant, $F(2, 76) = 7.10$, $p < .01$. It appeared that the RT in the illegal nonword condition in Experiment 2 (880 ms) was much higher than that in Experiment 1 (817 ms), whereas only small differences occurred between the word conditions in Experiments 1 and 2 (760 and 748 ms, respectively) and between the legal nonword conditions in these experiments (798 and 791 ms, respectively). The item analysis was not performed, because of the different number of stimuli in conditions.

Notwithstanding the above contrast, the results strongly suggest that pronounceability rather than orthographic legality (with which it has often been confounded), is the main factor underlying the first-letter effect. In both reader groups naming the first letter of an unpronounceable letter string was slower than for any other stimulus. Another conclusion, bearing on the question how word recognition comes about, is that both beginning and fluent readers cannot help generating the pronunciation of letter strings they are confronted with, even when these letter strings are highly irregular.

Having shown that pronounceability is the main determinant of performance in the first-letter task and, consequently, that assembling the pronunciation of letter strings is an imperative process that cannot be prevented (the subjects actually being asked to ignore the context when naming the first letter), our next experiment provided a more direct test of the response-competition hypothesis. If response competition indeed underlies the first-letter effect, it should be possible to reduce the effect by letting the output of the automatic pronunciation process converge with the required response, thus decreasing the competition between the two processes. This was the approach taken in Experiment 3.

EXPERIMENT 3

It was assumed above that responding in the first-letter task is delayed until the pronunciation of the complete stimulus is generated. If true, a match between the pronunciation of the first letter as part of the complete stimulus on the one hand and the required first-letter response on the other, should speed up responding. The reason is that, as compared to a situation in which no such match exists, the responses in this "congruent" condition are given a head-start. In Experiment 3, the responses in only one of the stimulus-group conditions are given this head-start. To ascertain that no other differences between conditions could account for any effect that might occur, only orthographically legal, pronounceable nonwords of three letters were used as stimuli.

Method

Materials. A set of 60 legal, pronounceable nonwords was created. Each stimulus consisted of one syllable containing three letters. The initial letter of a stimulus was always a vowel, and was an a, e, o, or u. Twenty stimuli had a VCC structure (for example "arg" [*a*rg]; "single-cluster" stimuli), 20 had a V_1V_1C structure (for example "aab" [ab]; "double-cluster" stimuli), and 20 had a V_1V_2C structure (for example "auf" [auf]; "mixed-cluster" stimuli). The pronunciation of the vowel in VCC-stimuli is about the same as that of this vowel in isolation. So if phonemes have to be produced as responses in the first-letter task, the VCC-stimuli constitute the congruent condition. The pronunciation of the double vowel in V_1V_1C

stimuli and that of the mixed vowel in V_1V_2C stimuli differs from that of the isolated V_1 vowel. However, the pronunciation of the double-cluster (V_1V_1) in the double-cluster stimuli is about the same as the pronunciation of the *name* of the first-letter in these stimuli. So if letter names have to be produced as responses in the first-letter task, the V_1V_1C stimuli constitute the congruent condition. A frequency count of words with an initial vowel in the first three books of the reading curriculum, indicated that the beginning readers had not had differential experience with these three types of initial clusters ($p > .35$). Appendix C shows the stimuli used in Experiment 3.

Procedure. This experiment was run on a Macintosh Classic computer. Beginning readers were told that nonwords would appear on the screen and that they had to name the first phoneme of each stimulus. As in Experiment 1, half of the adult subjects were instructed to use the letter name to specify the responses and the other half were asked to use the phoneme. Naming times were registered with a voice key and a millisecond timer. Every response was evaluated on correctness by the experimenter by pressing a key on the computer keyboard. Before the experimental session started, every subject received 10 practice trials.

Subjects. Both beginning and fluent readers served as subjects. From the same population as in Experiment 1, two groups of beginning readers (21 medium and 20 poor readers) with a mean age of 89 months (SD = 5.0) were selected. None of these children (21 boys and 20 girls) participated in Experiments 1 and 2. The mean on the reading test (Caesar, 1975) of the medium readers was 25.3 (SD = 4.9) and of the poor readers it was 15.2 (SD = 2.2). The difference between these means was significant, $F(1, 39) = 70.62$, $p < .001$.

To ascertain that no other differences than those due to reading level could be responsible for any differences between the results of medium and poor readers that were to emerge, the results of a verbal (RAKIT; Bleichrodt et al., 1984) and a non-verbal intelligence test (Standard Progressive Matrices; Raven, 1958) were taken into account. There was no significant difference between the poor and medium readers on the verbal intelligence test ($.10 < p < .20$), but the difference on the non-verbal test was significant, with the medium readers being superior (medium readers, 26.3, SD = 9.2; poor readers, 20.6, SD = 4.6), $F(1, 39) = 6.27$, $p < .05$. The effect of the non-verbal intelligence factor will later be tested in a statistical analysis.

The fluent readers taking part in this experiment were 40 students from the Department of Psychology at the University of Amsterdam. Again these subjects had not taken part in Experiments 1 or 2.

Results

The results of the beginning (children) and fluent readers (adults) are analyzed and discussed separately. As in Experiments 1 and 2, responses

TABLE 4
MEAN FIRST-LETTER-NAMING LATENCIES IN MS FOR BEGINNING AND FLUENT READERS IN EXPERIMENT 3

	Reading level: Beginning readers		Response type: Fluent readers	
Cluster type	Poor	Medium	Letter	Phoneme
Single	979 (108)	863 (128)	438 (36)	468 (70)
Double	1068 (142)	927 (166)	431 (34)	481 (66)
Mixed	1076 (162)	946 (164)	451 (42)	499 (66)

Note. SD in parentheses.

were removed for naming errors (children, 2.0%; adults, 1.0%), voice-key failure (children, 4.5%; adults, .8%), extremely long responses (more than 3 *SD* above the mean; children, 1.3%; adults, .9%), and extremely short responses (less than 100 ms, children, 0%; adults, .2%).

Beginning readers. Means for subjects and items were calculated for the three levels of the variable "cluster:" single, double, and mixed. A 2 (reading level: medium vs poor) by 3 (cluster) analysis of variance on the means of the subjects and the items showed significant main effects, but no interaction ($F < 1$ in both cases). The main effect of reading level showed that medium readers (912 ms) were faster in naming the initial phoneme than poor readers (1041 ms; $F_1(1, 39) = 8.91$, $p < .01$; $F_2(1, 57) = 145.83$, $p < .001$). The main effect of cluster ($F_1(2, 78) = 26.19$, $p < .001$; $F_2(2, 57) = 15.81$, $p < .001$) revealed that the initial letter of single-cluster stimuli was named faster than of double-cluster and mixed-cluster stimuli ($p < .01$ in both cases on a Newman–Keuls; the difference between double and mixed clusters was not significant). In other words, responding was fastest in the congruent condition. The results are shown in Table 4.

A further analysis of variance was performed on the means of the subjects, with non-verbal intelligence as an additional between-subjects factor (high vs low). The purpose of this analysis was to test for the possibility that non-verbal intelligence was responsible for the difference between poor and medium readers. The main effect of intelligence ($F < 1$) and the interaction effect did not reach significance, but the main effect of cluster again did, $F_1(2, 78) = 25.93$, $p < .001$. Because this effect was already discussed, it will not be commented upon any further.

Fluent readers. An error analysis on the data of the fluent readers indicated that subjects instructed to respond with phonemes made more errors (.95, $SD = 1.1$) than those who responded with letter names (.20, $SD = .41$), $F_1(1, 38) = 8.17$, $p < .01$.

A 2 (response type: letter vs phoneme) by 3 (cluster: single vs double vs mixed) analysis of variance was performed on the mean naming times of the fluent readers. All main and interaction effects were significant on both the subject and item analysis. The main effect of response type indicated that subjects in the phoneme condition were significantly slower (483 ms) than subjects in the letter condition (440 ms), $F_1(1, 38) = 6.43$, $p < .05$; $F_2(1, 57) = 289.12$, $p < .001$. The main effect of cluster ($F_1(2, 76) = 22.45$, $p < .001$; $F_2(2, 57) = 22.78$, $p < .001$) revealed that mixed-cluster stimuli (475 ms; $SD = 60$) were named slower than single-cluster (453 ms; $SD = 57$) and double-cluster (456 ms; $SD = 58$) stimuli, Newman–Keuls, $p < .01$. The important interaction between response type and cluster ($F_1(2, 76) = 5.19$, $p < .01$; $F_2(2, 57) = 6.93$, $p < .01$) showed that all means were significantly different from each other (Newman–Keuls, $p < .05$), except the one between single-cluster stimuli and double-cluster stimuli in the letter name condition. The results are presented in Table 4. A planned contrast between the single-cluster and double-cluster conditions in the letter condition showed a marginally significant effect, naming the first letter of double-cluster stimuli being faster than of single-cluster stimuli, $F_1(1, 19) = 3.31$, $.05 < p < .10$.

Discussion

The results indicated clearly that beginning and fluent readers are faster in naming the first letter (i.e., a vowel) of a pronounceable nonword when the response is congruent with the common pronunciation of this vowel in the stimulus where it is part of than when it is incongruent with this pronunciation. For the children, who used phonemes to specify their responses, the single-cluster stimuli resulted in the shortest response times. The critical characteristic of these stimuli is that their first phoneme is, in fact, the response to be produced by the subjects. There is no such congruence between the first phoneme of the stimulus and the required response in the case of double-cluster and mixed-cluster stimuli. The effect occurred for both poor and medium beginning readers. The only difference between these subject groups was that the overall response time was shorter for the medium readers than for the poor readers.

With adult subjects, the double-cluster stimuli resulted in the shortest response times and smallest number of errors when their task was to produce letter names as responses. Again, what seems critical is the congruence between the response to be produced and the first phoneme of the stimulus as a whole. With letter naming as the subjects' task, the double-cluster stimuli, not the single-cluster stimuli, provide this congruence. In contrast, when the subjects' task was to produce phonemes as responses, the single-cluster stimuli resulted in the fastest responses, as they did with beginning readers as subjects. In other words, response times were again shortest in the congruent condition. All in all, the general pattern of results is very consistent. The main determinant of performance appears to be whether or not the response is congruent with the pronunciation of the first phoneme in the stimulus.

The results of Experiment 3 clearly support the response-competition account of the first-letter effect. Furthermore, Experiment 3 (and Experiment 2) reveal the nature of the process that competes with the letter-name task: the competitor is a process by which the pronunciation is generated of the stimulus that carries the to-be-named letter. This pronunciation process appears to operate automatically, because the first-letter task per se does not require generating the pronunciation of the complete stimulus, and the subjects are in fact asked to ignore the context of the first letter. A further relevant feature of this pronunciation process to stress is that it operates on nonwords (all stimuli in Experiment 3 were of this type), that is, on letter strings that are not represented lexically. The pronunciation of these stimuli can thus not be directly addressed, but has to be assembled (see also Van Orden, Johnston, & Hale, 1988). In sum, the competitor process, at least for nonword stimuli, appears to be a pronunciation-assembly process that is enacted automatically.

But if the conclusion that the assembly process is automatic is correct, it will inevitably also be at work when *words* are encountered, either in an experimental setting or under more natural circumstances. A theoretical possibility that we consider in more detail under General Discussion is that the pronunciation of words is both assembled and addressed directly. Anticipating the outcome of that discussion, and in accordance with a number of other recent publications (see Introduction): the data in the present study all seem compatible with the view that word pronunciations are only derived via the assembly process.

A final point to stress here is that, as in Experiments 1 and 2, beginning and fluent readers showed similar data patterns in corresponding conditions. Furthermore it was shown that differences in reading-decoding ability of beginning readers did not lead to differences in the relevant effects on the first-letter task. Poor readers were only generally slower than medium readers in naming the first letter. These results suggest that it is the same pronunciation-assembly process that underlies performance across the various subject populations.

GENERAL DISCUSSION

One of the purposes of this research was to find out whether word recognition of beginning readers differed from that of more experienced readers. The first-letter-naming task as developed by Rossmeissl and Theios (1982) was applied to investigate the issue. The data of the adult subjects (fluent readers) in the letter-naming condition of our Experiment 1 replicated the results of Rossmeissl and Theios: naming the first letter of words and legal nonwords was faster than naming the first letter of illegal nonwords. However, the results were different for the fluent readers who specified the first letter by its phoneme (and also for the group of fluent readers as a whole): naming the first phoneme of words was faster than of legal nonwords which in turn was faster than naming the first phoneme of illegal nonwords. The beginning readers, who always used phonemes to specify their responses, showed the same pattern as the total group of fluent readers. Therefore we assumed that the difference between processing words and legal nonwords is a real one. We attributed the absence of the difference between processing words and legal nonwords in the adult letter-naming condition to a ceiling in performance.

Rossmeissl and Theios attributed their effect to a facilitatory influence of a word (or legal nonword) context on the identification of the stimulus' first letter. Instead, we suggested the possibility that response competition underlies the effects, and, consequently, that the effects in fact reflect inhibitory rather than facilitatory processing. The congruence effect in Experiment 3 provides particularly strong support for this interpretation, because the effects were all related to whether or not the pronunciation of the stimulus as a whole was congruent with the to-be-produced response: Response times were always shortest in the case of congruence, that is, under circumstances of the least response competition. By showing the relevance of congruence in *pronunciation,* Experiment 3 revealed the nature of the competitor process, after Experiment 2 had done the same from a different line of approach. A relevant conclusion to be drawn from both these experiments is that the competitor process entails assembling the pronunciation of letter strings. The fact that this process operates under the strict instructions to the subjects to ignore the context of the target letter, leads to the further conclusion that this process comes about automatically whenever a letter string, legal or illegal, is encountered. Finally, the finding that all subject groups participating in this study, children as well as adults, child readers with poor as well as medium skills, generally showed the same results, constitutes a strong indication that this process operates independently of individual differences between readers in terms of age, experience and skill. To rephrase these conclusions in the terminology used in the introduction to this study: it appears that phonologic mediation is a mandatory process in all readers.

The results of this study thus clearly suggest that phonologic recoding is a primary process in word recognition of all readers. On the basis of this conclusion we can at least reject the suggestion of Humphreys and Evett (1985) that word recognition *always* comes about lexically (see introduction). It seems that we are also in a position to reject the view, held by proponents of the dual-route model, that fluent readers *mainly* employ the lexical route to identify words. The present data even evoke the question whether we could not do without the lexical route altogether, as proposed in a number of recent studies (e.g., Van Orden, 1987, 1991; Van Orden, Pennington, & Stone, 1990). The data of Experiment 2 indeed suggest we can. In this experiment response times did not differ statistically for words and legal pseudohomophones. Had addressed phonology played a role, we might have expected shorter RTs for words than for legal pseudohomophones, because only in the case of words (being represented lexically, unlike pseudohomophones) both lexical and nonlexical reading may be operating. It may be expected that, on average, it would take longer for a process operating on its own to finish than it would take one out of two simultaneously ongoing processes to finish. The null effect of lexicality in Experiment 2 thus seems to speak against the use of a lexical route.

However, in Experiment 1 a difference in response time for words and legal nonwords *did* appear, a finding which seems to suggest a role of lexical reading after all. But this conclusion is not at all inevitable. The skill of assembling the phonology of a letter string is likely to improve with practice. The words presented in Experiment 1 had been encountered before both by the adults and the children (recall that these words were taken from the children's reading curriculum) whereas, of course, the legal nonwords were new to them. The difference between response times for words and nonwords may thus have come about because assembling the phonology of the words took less time than of the nonwords. Consequently, the subjects were ready to attend to the main task, first-letter naming, relatively soon in the case when a word stimulus was presented. Thus, a lexicality effect does not necessarily falsify the hypothesis that phonologic mediation is the sole process via which pronunciation is assigned to words. All in all, a "one-route" model provides the most parsimonious interpretation of the data of this study.

APPENDIX A

Stimuli Used in Experiment 1 (Translations in Parentheses)

	Nonwords	
Words	Legal	Illegal
boog (bow)	beeg	bgoo
boek (book)	biek	bkoe
doos (box)	dees	dsoo
deur (door)	doer	dseu
hout (wood)	heut	htou
haas (hare)	huus	hsaa
koek (cake)	keuk	kkoe
kees (= Christian name)	kuus	ksee
loop (walk)	laap	lpoo
lief (sweet)	leuf	lfie
maan (moon)	moen	mnaa

APPENDIX A — *Continued*

Words	Nonwords: Legal	Nonwords: Illegal
miep (= Christian name)	maap	mpie
noot (nut)	noet	ntoo
neus (nose)	nees	nseu
poes (cat)	peus	psoe
paal (post/pole)	puul	pkaa
raam (window)	reem	rmaa
reus (giant)	ries	rseu
voet (foot)	voot	vtoe
vuur (fire)	veur	vsuu
wieg (cradle)	woeg	wgie
weeg (weigh)	wuug	wgee
zout (salt)	zuut	ztou
zeef (sieve)	zief	zfee

APPENDIX B

Stimuli Used in Experiment 2 (Translations in Parentheses)

Training Word	Leg PsH	Ill PsH	Leg NonW	Ill NonW	Known W
brief (letter)	broot	briev	blark	bdral	boek (book)
brood (bread)	draat	dichd	droos	dkril	doos (box)
dicht (closed)	fluid	fietz	fliem	ftsie	fik (dog's name)
draad (thread)	gelt	grijz	glap	gsla	gaat (goes)
fiets (bike)	hont	huiz	harf	hdem	hoort (hears)
fluit (flute)	klij	kalv	karp	krti	kook (cook)
geld (money)	lant	leech	lons	lmsi	loopt (walks)
grijs (grey)	mont	menz	murg	mstu	maan (moon)
hond (dog)	naalt	nachd	nielt	ntlei	niest (sneezes)
huis (house)	pland	paarz	pralk	prkli	paal (post/pole)
kalf (calf)	rant	rupz	rems	rmsa	rookt (smokes)
klei (clay)	stoud	slurv	stril	sklri	soep (soup)
land (land)	vrei	vijv	vom	vme	veegt (sweeps)
leeg (empty)	zant	zalv	zulf	zfli	zeeft (sieves)
mens (person)					
mond (mouth)					
naald (needle)					
nacht (night)					
paars (purple)					
plant (plant)					
rand (edge/rim)					
rups (caterpillar)					
slurf (trunk)					
stout (naughty)					

APPENDIX B — *Continued*

Training Word	Leg PsH	Ill PsH	Leg NonW	Ill NonW	Known W
vijf (five)					
vrij (free)					
zalf (salve)					
zand (sand)					

APPENDIX C

Stimuli Used in Experiment 3

Single	Double	Mixed
ant	aab	auf
arg	aat	aul
ast	aaf	aud
arp	aam	aup
asp	aad	auk
elg	eeb	eum
ers	eep	euf
eps	eek	eul
erp	ees	eug
est	eeg	euk
ost	oos	out
orp	oob	ouf
olf	oop	ouk
org	oof	oup
orf	ool	oul
uls	uuf	uik
urp	uum	uip
ust	uud	uis
urg	uun	uif
urm	uut	uid

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